

SCME RELATIONSHIPS BETWEEN PERSONALITY,
AROUSAL AND THE STRENGTH OF THE EXCITATORY PROCESS.

by

Sunjai Gupta

Thesis submitted
for a Ph.D. at
Bedford College, London
February, 1981



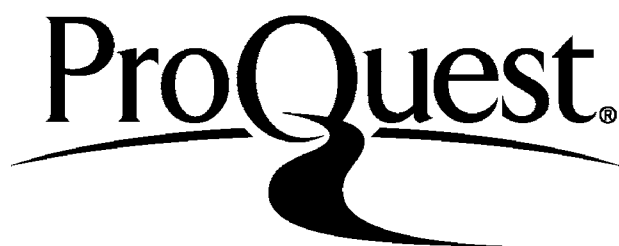
ProQuest Number: 10098406

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



ProQuest 10098406

Published by ProQuest LLC(2016). Copyright of the Dissertation is held by the Author.

All rights reserved.

This work is protected against unauthorized copying under Title 17, United States Code.
Microform Edition © ProQuest LLC.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

ABSTRACT

The primary object of the present investigation was to test the inverted 'U' model developed by investigators of 'arousal' in the West and of the 'strength of the excitatory process' in the Soviet Union to explain the relationship between a variety of factors and measures of behavioural, subjective and physiological response. In the present project adult human subjects took part in four experiments. The following factors were investigated in one or more of them: introversion, neuroticism, 'strength of the excitatory process', stimulus intensity, stimulus duration, signal frequency, signal probability, accessory stimulation, time on task, task repetition and time of day. Measures of psychoticism were also taken. The response indices included: gustatory measures, reaction time, signal detection theory measures, vigilance scores, autonomic indices and measures of subjective state.

Support for the model emerged most strongly in the form of certain lower order interactions between the factors, for example between introversion and neuroticism for simple auditory reaction time, and between neuroticism and time of day for the speed of response to signals in a vigilance task. Support from higher order interactions was less forthcoming.

Compared to low N subjects, high N subjects scored relatively low on the 'strength of the excitatory process' as measured by Nebylitsyn's index of the slope of the simple visual reaction time / stimulus intensity function. It was suggested, furthermore, that previously discrepant findings with respect to introversion using this measure may have been due to response bias effects, though experimental test of this idea yielded non-significant results.

Though only partial support for the model was obtained it was considered to remain a useful conceptual tool, and possible practical implications were discussed.

CONTENTS

	<u>Page</u>
Abstract	2
List of Tables	18
List of Figures	29
List of Graphs	33
Acknowledgements	39
Part one. Theoretical and methodological issues	42
Chapter One. The Inverted 'U' Hypothesis	43
1. The origins of the concept	43
2. The Russian and the Western models compared	46
3. The criterion of parsimony	49
4. The predictions of the hypothesis	51
i) The conjoint action of the determinants	51
ii) The problem of falsifiability	52
iii) Different forms of interaction	60
iv) The problem of intermediate groups	67
v) Multifactorial experiments	73
vi) A proposed modification	81
vii) Summary	91
5. The hypothesis under attack	93
i) Discrepancies between the determinants	93
a) Dual-system theories	93
b) The autonomic nervous system	94
c) The cortical system and the phenomenon of 'partial properties'	96
ii) Discrepancies between the determinants	99
iii) A statement of intent	101
iv) Physiological measures	103

	<u>Page</u>
Chapter Two. The Determinants and Determinates	110
1. The determinants	110
i) Stimulus intensity and associated factors	111
ii) Drugs	114
iii) Accessory stimulation of a non-relevant sensory modality	115
iv) Drive	116
v) Novelty	118
vi) Fatigue	120
vii) Individual differences	122
a) Individual differences as a determinant of the 'excitatory process'	122
b) Individual differences as a determinant of 'arousal'	124
c) The relationship between personality and 'strength' of the nervous system: a theoretical appraisal	127
d) Classical indices of 'strength'	133
e) Simple reaction time and the synthesis of the Western and Russian approaches to individual differences	137
2. The determinates	145
i) General considerations	145
ii) The choice of determinates	146
iii) Strength of inhibition	151
iv) Other 'properties' of the nervous system within the Russian theoretical framework and other dimensions of personality	157
v) Other ^{Western} dimensions of personality	160

	<u>Page</u>
Chapter Three. General Methodological Considerations	163
1. Issues in the overall design of the project	163
i) Implications of the use of the simple reaction time index	163
ii) The question of sample	165
iii) Temperament as a fixed characteristic of the individual	168
2. The design of individual studies	170
i) Multifactorial experiments and multi-level factors	170
ii) Between and within-subject designs	172
Part II: Experimental Evidence.	174
Chapter Four. Gustatory Indices: Review of the Literature.	175
1. Salivation	175
i) Stimulus intensity	175
ii) Drugs	176
iii) Accessory sensory stimulation	177
iv) Drive	177
v) Fatigue	178
vi) Novelty	178
vii) Individual differences	180
a) Western measures	180
b) Russian measures	190
2. Magnitude Estimation	191
i) Stimulus intensity	191
ii) Drugs	195
iii) Accessory sensory stimulation	195
iv) Drive	195

	<u>Page</u>
v) Fatigue	195
vi) Novelty	196
vii) Individual differences	197
a) Western measures	197
b) Russian measures	198
3. Hedonic Tone	200
i) Stimulus intensity	202
ii) Drugs	202
iii) Accessory sensory stimulation	202
iv) Drive	202
v) Fatigue	203
vi) Novelty	203
vii) Individual differences	204
a) Western measures	204
b) Russian measures	207
4. The Sensory Threshold	210
i) Stimulus intensity	211
ii) Drugs	214
iii) Accessory sensory stimulation	215
iv) Drive	218
v) Fatigue	220
vi) Novelty	220
vii) Individual differences	222
a) Western measures	222
b) Russian measures	227

	<u>Page</u>
Chapter Five. Gustatory Indices: The Design and Execution of a Study	230
1. The choice of factors	231
2. Predictions	232
3. Additional measures	235
i) Physiological indices	235
ii) State measures	239
4. Method	240
i) Factors governing the choice of method	240
ii) Subjects	248
iii) Materials	261
iv) General design	265
v) Procedure	270
a) Preliminaries	270
b) Measurement	274
Chapter Six. Gustatory Indices: Results and Discussion.	293
1. Results	294
i) Main indices	296
ii) Physiological measures	302
iii) State measures	309
2. Discussion	314
i) Main indices	314
ii) Physiological measures	357
iii) State measures	373
3. Summary	382
i) Main indices	382
ii) Physiological and state measures	384

	<u>Page</u>
Chapter Seven. Reaction Time: A Review of the Literature	386
1. Some associated measures and theoretical issues	386
i) Brebner and Cooper's model	386
ii) The tapping task	392
iii) Reactive inhibition	397
iv) The pursuit rotor	401
2. Simple Reaction Time: The Determinants	403
i) Stimulus intensity	403
ii) Drugs	405
iii) Accessory stimulation	405
iv) Drive	406
v) Fatigue	406
vi) Novelty	407
vii) Individual differences	408
a) Western measures	408
b) Russian measures	421
Chapter Eight. The Nature of Simple Reaction Time.	422
1. Brebner and Flavel's study	422
i) A hedonic tone model	422
ii) The criterion model of simple reaction time	423
iii) Implications of signal detection theory	428
iv) A possible difficulty	436
2. The slope of the reaction time/intensity curve	439
i) A new theory	439
ii) The role of response sets	445

	<u>Page</u>
iii) The joint effect of criterial and sensory factors	449
iv) Implications for the hypothesis that introverts have 'weak' nervous systems	452
v) Implications for Soviet work on 'strength' and for experimental design	454
3. The criterion as a possible determinate	456
i) Cheng's study	456
ii) The criterion model and the determinants	458
a) Stimulus intensity	459
b) Drugs	462
c) Accessory stimulation	462
d) Drive	462
e) Fatigue	462
f) Novelty	462
g) Russian measures	463
iii) A resumé	464
iv) A reassessment of the criterion model as applied to Mangar and Farmer's study	466
v) The criterion model, hedonic tone and the optimisation of performance	468
vi) Welford's theory and a reinterpretation of the criterion model	469
vii) Implications for simple reaction time	476
4. A proposed experimental test	479
i) Summary of analysis of simple reaction time	479
ii) A problem	479
iii) A possible solution	480
iv) Outline of a joint study	482
v) The choice of factors	482

	<u>Page</u>
Chapter Nine. A Preliminary Study: Simple Auditory Reaction Time.	488
1. Introduction	488
2. Method	491
i) Design	491
ii) Subjects	491
iii) Materials	492
iv) Procedure	492
v) Results	495
vi) Discussion	498
Chapter Ten. Reaction Time and Signal Detection Theory: The Design and Execution of a Joint Study.	503
1. Overall design	503
2. Predictions	507
1) Simple reaction time task	507
a) General predictions	507
b) Transmarginal inhibition	507
ii) Signal detection task	510
a) General background	510
b) Detailed predictions	515
1) The criterion	516
2) The discrimination index	520
3) An adjustment to allow for transmarginal inhibition effects	529
4) Summary of predictions for signal detection indices	532
5) The probability of a hit and the probability of a false alarm	533
6) Disjunctive reaction time	534
iii) The relationship between the simple reaction time and signal detection tasks	536
3. Method	540
i) Subjects	540
ii) Design	540
iii) Materials	543
iv) Procedure	545

	<u>Page</u>
Chapter Eleven. Reaction time and signal detection theory: results and discussion	554
1. E.P.I. analyses	555
i) The signal detection task	555
a) Results	555
b) Discussion	564
ii) The simple visual reaction time task	590
a) Results	590
b) Discussion of results of simple visual reaction time task	597
c) Results for latency measures from signal detection task	627
d) Discussion of latency measures from signal detection task	627
iii) The relationship between the signal detection and simple visual reaction time tasks	629
2. E.P.Q. analyses	640
i) The signal detection task	640
a) Results	640
b) Discussion (excluding latency measures)	645
ii) The simple visual reaction time task	649
a) Results	650
b) Discussion of results of simple visual reaction time task	653
c) Results for latency measures from signal detection task	659
d) Discussion of latency measures from signal detection task	660
iii) Summary of E.P.Q. analysis	
3. Psychoticism analyses	661
i) The signal detection task	661
a) Results	661

	<u>Page</u>
b) Discussion	663
ii) The simple visual reaction time task	665
a) Results	665
b) Discussion	666
4. Overall summary	667
i) Signal detection task	667
ii) Latency measures from signal detection and simple visual reaction time tasks.	669
Chapter Twelve. Vigilance: A Review of Literature	672
1. Theoretical background	672
i) Stimulus duration and frequency in a vigilance context	672
ii) The nature of vigilance tasks	673
iii) Theories of vigilance	675
a) The inhibition theory	675
b) Reinforcement theory	677
c) Expectancy theory	678
d) Attention theory	679
e) Signal detection theory	680
f) The arousal theory	683
2. The Determinants and Vigilance	684
i) Stimulus intensity	684
ii) Drugs	687
iii) Accessory sensory stimulation	689
iv) Drive	692
v) Fatigue	693
vi) Novelty	694
vii) Individual differences	696
a) Western measures	696

	<u>Page</u>
b) Russian measures	723
3. Analysis	726
i) Theories of vigilance and the determinants	726
ii) The problem of time on task	728
iii) Results and discussion of simple visual reaction time effects involving time on task	733
a) Results (E.P.I)	733
b) Discussion (E.P.I.)	737
c) Results (E.P.Q.)	752
d) Discussion (E.P.Q.)	753
e) Results (psychoticism)	754
f) Discussion (psychoticism)	754
4. Outline of a vigilance study	755
i) The choice of factors	755
ii) A partial solution to the problem of time on task	756
iii) Signal frequency and stimulus probability	761
iv) Signal frequency and stimulus frequency	762
v) Predictions for the overall level of performance	767
Chapter Thirteen. Vigilance: The design and execution of a study	782
1. Issues in the design of the study	783
i) Pretask training	783
ii) The choice of signal frequencies	799
2. Method	302
i) Subjects	302
ii) Design	305
iii) Materials	809

	<u>Page</u>
iv) Procedure	811
Chapter Fourteen. Vigilance: Results and Discussion	820
1. E.P.I. analyses	821
i) State and physiological measures	821
a) Results	821
b) Discussion	833
ii) Behavioural measures	857
a) Results relating to overall performance	862
b) Discussion of overall performance	873
c) Results involving time on task	888
d) Discussion of effect of time on task	898
2. E.P.Q. analyses	929
i) State and physiological measures	932
a) Results	932
b) Discussion	936
ii) Behavioural measures	939
a) Results relating to overall performance	939
b) Discussion of overall performance	941
c) Results involving time on task	944
d) Discussion of effect of time on task	944
3. Psychoticism analyses	956
i) State and physiological measures: results	956
ii) Behavioural measures: results	956
iii) Discussion	959

	<u>Page</u>
4. Summaries	960
Chapter Fifteen. The Operational Measure of 'Strength'.	963
1. The taste experiment	964
i) Main indices	964
a) Results	964
b) Discussion	968
ii) State and physiological measures	975
a) Results	975
b) Discussion	978
2. The signal detection task	980
i) Results	980
ii) Discussion	980
3. The vigilance task	982
i) State and physiological measures	984
a) Results	984
b) Discussion	989
ii) Behavioural measures (overall performance)	994
a) Results	994
b) Discussion	999
iii) Behavioural measures (time on task)	1004
a) Results	1004
b) Discussion	1010
Chapter Sixteen. Summary and concluding comments	1022
A) Summary	1023
i) Summary of aims of the project	1023
ii) Summary of experimental procedures and findings	1028
1) Overview of the project	1028

	<u>Page</u>
2) Discussion of the individual groups of experiments	1030
a) The gustatory study	1030
b) The simple auditory reaction time task	1035
c) Simple reaction time and signal detection theory	1036
d) The vigilance task	1042
e) The operational measure of 'strength'	1047
B. Concluding comments	1049
i) Theoretical implications	1049
1) Individual differences	1049
2) Time of day	1051
3) Stimulus associated factors	105-
4) The inverted 'U' and the normal distribution curve	1056
ii) Clinical implications	1059
Bibliography	1070
Appendices	

LIST OF TABLESPageTaste experiment.

A1	The main effect for stimulus intensity (SAL)	296
A2	The interaction of stimulus intensity and neuroticism (SAL)	296
A3	The main effect for stimulus intensity (LME 1)	297
A4	The interaction of noise and introversion (LME 1)	297
A5	The main effect for stimulus intensity (LME 2)	298
A6	The interaction of noise, stimulus intensity and introversion (LME 2)	298
A7	The main effect for stimulus intensity (HED 1)	298
A8	The interaction of stimulus intensity, introversion and neuroticism (HED 1)	299
A9	The interaction of stimulus intensity and neuroticism (HED 1)	299
A10	The main effect for stimulus intensity (HED 2)	300
A11	The interaction of noise and stimulus intensity (HED 2)	300
A12	The main effect for neuroticism (acidity of solution at discrimination threshold)	301
A13	The main effect for stimulus intensity (HR 1)	302
A14	The main effect for stimulus duration (HR 1)	303
A15	The main effect for noise (HR 2)	303
A16	The main effect for stimulus duration (HR 2)	303
A17	The interaction of stimulus duration, introversion and neuroticism (HR 2)	304
A18	The main effect for time (TEMP)	305
A19	The interaction of time and introversion (TEMP)	305
A20	The main effect for session (TEMP)	306

	<u>Page</u>
A21 The interaction of session and introversion (MNPUP)	308
A22 The interaction of noise and neuroticism (state anxiety)	309
A23 The main effect for introversion (CCNC)	310
A24 The main effect for neuroticism (DEACT)	311
A25 The main effect for session (DEACT)	311
A26 The main effect for session (ANX)	311
A27 The interaction of session and neuroticism (ANX)	312
A28 The interaction of noise and neuroticism (PLEAS)	312

Simple auditory reaction time task

X1	The interaction of introversion and neuroticism (LSCORE)	495
X2	The interaction of introversion and time of day (LSCORE)	496
X3	The main effect for introversion (LSCORE)	497
X4	The main effect for stimulus intensity (LSCORE)	497

	<u>Page</u>
<u>Signal detection task</u>	
B1	The main effect for neuroticism (TBE) 559
B2	The interaction of neuroticism and time of day (DY) 559
B3	The interaction of session and time of day (DY) 560
B4	The interaction of noise, session and introversion (DY) 560
B5	The interaction of noise, session and time of day (PH) 561
B6	The main effect for neuroticism (PF) 562
B7	The interaction of noise and introversion (PF) 562
B8	The interaction of noise, session and time of day (PF) 562
B9	The main effect for stimulus intensity (LSCORE) 591
B10	The interaction of stimulus intensity and neuroticism (LSCORE) 592
B11	The interaction of stimulus intensity and session (LSCORE) 592
B12	The interaction of stimulus intensity, session and neuroticism (LSCORE) 593
B13	The interaction of noise, neuroticism and time of day (LSCORE) 593
B14	The interaction of stimulus intensity, session and introversion (LSCORE) 594
B15	The interaction of noise, stimulus intensity and session (LSCORE) 595
B16	The interaction of noise, session and time of day (LSCORE) 595
B17	The main effect for neuroticism (SIGMA) 596
B18	The interaction of neuroticism (EPQ) and time of day (TBE) 641
B19	The interaction of session, neuroticism (EPQ) and time of day (DY) 642

		<u>Page</u>
B20	The interaction of neuroticism (EPQ) and stimulus intensity (LSCORE)	650
B21	The interaction of stimulus intensity, session and neuroticism (EPQ) - (LSCORE)	651
B22	The main effect for introversion (EPQ) - (LSCORE)	651
B23	The main effect for neuroticism (EPQ) - (SIGMA)	652
B24	The interaction of noise and neuroticism (EPQ) - (SIG)	658
B25	The interaction of noise, psychoticism and time of day (TBE)	661
B26	The interaction of noise, psychoticism and time of day (SIG)	662
B27	The interaction of stimulus intensity and psychoticism (LSCORE)	665
B28	The main effect for block (LSCORE)	733
B29	The interaction of block, stimulus intensity and session (LSCORE)	733
B30	The interaction of block and stimulus intensity (LSCORE)	735

	<u>Page</u>
<u>Vigilance task</u>	
C1 The main effect for position (TAROUSAL)	822
C2 The interaction of position and frequency (TAROUSAL)	823
C3 The interaction of noise position and introversion (TAROUSAL)	823
C4 The interaction of neuroticism and frequency (TAROUSAL)	824
C5 The interaction of introversion and frequency (TAROUSAL)	824
C6 The interaction of noise and neuroticism (TAROUSAL)	825
C7 The interaction of introversion, neuroticism, time of day and frequency (TAROUSAL)	825
C8 The main effect for neuroticism (TAROUSAL)	825
C9 The main effect for position (TSTRESS)	826
C10 The interaction of neuroticism and frequency (TSTRESS)	826
C11 The interaction of noise and introversion (TSTRESS)	827
C12 The interaction of noise and neuroticism (TSTRESS)	827
C13 The interaction of introversion and neuroticism (TSTRESS)	828
C 14 The interaction of noise, introversion and frequency (TSTRESS)	828
C 15 The interaction of noise and time of day (TSTRESS)	829
C 16 The main effect for position (ANX)	830
C 17 The interaction of neuroticism and frequency (ANX)	830

	<u>Page</u>
C18	The main effect for position (TEMP) 831
C19	The interaction of noise, introversion and time of day (TEMP) 831
C20	The interaction of neuroticism and frequency (TBE) 862
C21	The interaction of neuroticism and time of day (TBE) 862
C22	The interaction of introversion, neuroticism and frequency (TBE) 863
C23	The interaction of neuroticism and frequency (TDY) 864
C24	The main effect for neuroticism (TDY) 865
C25	The interaction of introversion and frequency (SPR) 866
C26	The interaction of introversion and neuroticism (SPR) 866
C27	The interaction of neuroticism and frequency (TPH) 868
C28	The main effect for noise (TPH) 868
C29	The interaction of neuroticism and time of day (TPF) 869
C30	The interaction of introversion, neuroticism and frequency (TPF) 870
C31	The interaction of neuroticism and time of day (LSIG) 871
C32	The interaction of noise and introversion 871
C33	The main effect for frequency (LSIG) 872
C34	The main effect for time of day (LSIG) 872
C35	The main effect for block (TBE) 888
C36	The interaction of noise and block (TBE) 888
C37	The interaction of block, introversion, neuroticism, and time of day (TBE) 889
C38	The interaction of block, introversion, neuroticism and frequency (TBE) 889
C39	The main effect for block (TDY) 890

	<u>Page</u>
C40	The interaction of noise and block (TDY) 890
C41	The interaction of noise, block and neuroticism (TDY) 891
C42	The main effect for block (TPH) 893
C43	The interaction of noise and block (TPH) 893
C44	The main effect for block (TPF) 894
C45	The interaction of block, introversion and frequency (TPF) 895
C46	The interaction of noise, block and introversion (TPF) 895
C47	The main effect for block (LSIG) 896
C48	The interaction of introversion (EPQ) and frequency (TAROUSAL) 933
C49	The main effect for neuroticism (EPQ) - (TSTRESS) 933
C50	The interaction of noise and introversion (EPQ) - (ANX) 934
C51	The interaction of neuroticism (EPQ) and frequency (TEMP) 934
C52	The main effect for introversion (EPQ) - (TEMP) 935
C53	The main effect for neuroticism (EPQ) - (TDY) 939
C54	The interaction of neuroticism (EPQ) and time of day (LSIG) 940
C55	The interaction of block, introversion (EPQ) and time of day (TBE) 944
C56	The interaction of block and neuroticism (EPQ) - (TDY) 945
C57	The interaction of noise, block and neuroticism (EPQ) - (TDY) 945
C58	The interaction of block and introversion (EPQ) - (TPH) 947
C59	The interaction of block and psychoticism (TDY) 956
C60	The interaction of block and psychoticism (SPR) 957
C61	The interaction of block and psychoticism (TPF) 958
C62	The interaction of block and psychoticism (LSIG) 958

List of tables for results involving 'strength'

D1	The interaction of noise, stimulus intensity and 'strength' (LME1)	965
D2	The interaction of stimulus intensity and 'strength' (LME2)	966
D3	The interaction of stimulus intensity and 'strength' (HED1)	966
D4	The interaction of stimulus intensity and 'strength' (HED2)	966
D5	The interaction of noise and 'strength' (Activation)	976
D6	The interaction of session and 'strength' (Startle)	977
D7	The interaction of noise and 'strength' (SIG)	980
D8	The interaction of noise, 'strength' and frequency (TAROUSAL)	984
D9	The main effect for 'strength' (TAROUSAL)	984
D10	The interaction of 'strength' and time of day (TEMP)	985
D11	The interaction of position, 'strength' and time of day (TAROUSAL)	987
D12	The interaction of session and 'strength' (SPR)	995
D13	The interaction of 'strength' and frequency (TPH)	996
D14	The interaction of session, 'strength' and frequency (LSIG)	998
D15	The interaction of block and 'strength' (TBE)	1004
D16	The interaction of block, 'strength' and frequency (TBE)	1005
D17	The interaction of block, 'strength' and frequency (TPH)	1007
D18	The interaction of block and 'strength' (TPF)	1008

LIST OF FIGURES

Part One

Fig 1	Empirical relationship between a determinant and a determinate	44
Fig 2a	Hypothetical relationship between the determinant and the 'excitatory process'	44
Fig 2b	Hypothetical relationship between the 'excitatory process' and the determinate	44
Fig 3a	Hypothetical relationship between the determinant and 'arousal'	44
Fig 3b	Hypothetical relationship between 'arousal' and the determinate	44
Fig 4	The Russian explanation of the conjoint effects of the determinants	52
Fig 5	The Western explanation of the conjoint effects of the determinants	52
Fig 6	The conjoint action of determinants A and B	53
Fig 7	An alternative representation	53
Fig 8	An interaction based on the size of differences	55
Fig 9	An alternative representation of the T.T.I.	57
Fig 10	A 'partial' interaction	62
Fig 11	An alternative representation of the positions of the intermediate groups	67
Fig 12	The inverted 'U' and the main effect of a factor	73
Fig 13	Diagrammatic representation of possible outcomes explicable by the inverted 'U' in its original form	75
Fig 14	An interaction opposite to the empirical result corresponding to 13a.	77
Fig 15	A triple interaction which the inverted 'U' cannot accommodate	80
Fig 16	A triple interaction which the inverted 'U' can accommodate	81

	<u>Page</u>	
Fig 17	The empirical relationship between determinant and a determinate	82
Fig 18	A modified inverted 'U' curve	83
Fig 19a	An interaction based on the size of differences for portion A	87
Fig 19b	An interaction based on the size of differences for portion D	87
Fig 20	An interaction between two factors that the model cannot adequately explain	89
Fig 21	An interaction between three factors for the modified inverted 'U' curve	90
Fig 22	An interaction due to the effect of determinants two factors which move subjects in opposite directions along the 'X' axis of the inverted 'U' curve	131
Fig 23	'Strength of excitation' and 'strength' of inhibition	152

	<u>Page</u>
Part Two	
Fig 24	Photocopy of Wardell's results 182
Fig 25	The inverted 'U' and the absolute sensory threshold 212
Fig 26	The gradient of the inverted 'U' and the sensory threshold 219
Fig 27	Summary of interactions explicable by the modified inverted 'U' 233
Fig 28	Predictions for the forced choice discrimination threshold 235
Fig 29	Overall design of the taste experiment 267
Fig 30	The counting model of simple reaction time 425
Fig 31	A signal detection model of Brebner and Flavel's study 429
Fig 32	A combined counting and signal detection model 432
Fig 33	The counting model and introversion 434
Fig 34	A criterion interpretation of Mangan and Farmer's study 439
Fig 35	A sensory interpretation of Mangan and Farmer's study 442
Fig 36	Cheng's study, the inverted 'U' and the 'tendency to respond' 458
Fig 37	Stimulus intensity and the slope of the sensory growth function 460
Fig 38	The counting model of simple reaction time 464
Fig 39	The postulates of signal detection theory 470
Fig 40	Conflicting predictions relating to the 'tendency to respond' 472
Fig 41	The Western model 473
Fig 42	The Russian model 473
Fig 43	The inverted 'U' hypothesis 511
Fig 44	The postulates of signal detection theory 511
Fig 45	Predictions for the discrimination index 523

- *
 Fig. 59. The inverted 'U', the Western and the Russian models.
- Fig. 46. The inverted 'U' hypothesis 768
- Fig. 47. The postulates of signal detection theory 768
- Fig. 48. Predictions for the discrimination index 770
- Fig. 49. Signal frequency and the postulates of signal detection theory 772
- Fig. 50. The inverted 'U' and Kishimoto's study: percentage of signals detected 775
- Fig. 51. The inverted 'U' and Kishimoto's study: total number of signals detected. 775
- Fig. 52. An alternative explanation for the interaction between frequency and position in the subjective 'arousal' measure 837
- Fig. 53. Hypothesised relationship between signal frequency and time on task for subjective 'arousal' 841
- Fig. 54. Neuroticism, frequency and subjective 'arousal' 845
- Fig. 55. Neuroticism, frequency and subjective 'stress'. 845
- Fig. 56. The predictions of the general model for the tendency to respond and discrimination ability 1023
- Fig. 57. Furneaux' theory of personality and hypnotic susceptibility 1043
- Fig. 58. A new theory of the relationship between personality and hypnotic susceptibility 1045
- *

List of Graphs for taste experiment

A1	The interaction of stimulus intensity and neuroticism in salivation	315
A2	The main effect of stimulus intensity on salivation	317
A3	The main effect of stimulus intensity on magnitude estimation (Session 1)	325
A4	The main effect of stimulus intensity on magnitude estimation (Session 2)	326
A5	The interaction of noise, stimulus intensity and introversion in magnitude estimation (Session 2)	331
A6	The main effect of stimulus intensity on magnitude estimation (Session 2) without transformation and with an ordinary scale for stimulus intensity	336
A7	The main effect of stimulus intensity on hedonic tone (Session 1)	338
A8	The main effect of stimulus intensity on hedonic tone (Session 2)	339
A9	The interaction of stimulus intensity, introversion and neuroticism in hedonic tone (Session 1)	345
A10	The interaction of noise and stimulus intensity in hedonic tone (Session 2).	349
A11	The interaction of stimulus intensity and neuroticism in hedonic tone (Session 1)	350
A12	The main effect for stimulus intensity on heart rate (Session 1)	359
A13	The main effect for stimulus duration on heart rate (Session 1)	361
A14	The main effect for stimulus duration on heart rate (Session 2)	362
A15	The interaction between stimulus duration, introversion and neuroticism on heart rate (Session 2).	365

List of graphs for joint signal detection/simple
visual reaction time task

B1	The interaction of noise, session and introversion (DY)	570
B2	The interaction of introversion, neuroticism and time of day (DY)	572
B3	The interaction of noise, session and time of day (PH)	574
B4a	The interaction of group, noise and time of day (PH)	576
B4b	The interaction of group, session and time of day (PH)	577
B5	The interaction of noise, session and time of day (PF)	588
B6	The interaction of stimulus intensity and neuroticism (LSCORE)	598
B7	The interaction of stimulus intensity and session (LSCORE)	608
B8	The interaction of stimulus intensity, session and neuroticism (LSCORE)	610
B9	The interaction of noise, neuroticism and time of day (LSCORE)	613
B10	The interaction of stimulus intensity, session and introversion (LSCORE)	621
B11	The interaction of noise, stimulus intensity and session (LSCORE)	623
B12	The interaction of noise, session and time of day (LSCORE)	625
B13	The interaction of session, neuroticism (EPQ) and time of day (DY)	647
B14	The interaction of neuroticism (EPQ) and stimulus intensity	654
B15	The interaction of session, stimulus intensity and neuroticism (EPQ) - (LSCORE)	656
B16	The interaction of noise neuroticism (EPQ) and time of day (LSCORE)	657

	<u>Page</u>
B17 The interaction of block, stimulus intensity and session (LSCORE)	745
B18 The interaction of block and stimulus inter- sity (LSCORE)	750

	<u>Page</u>
<u>List of Graphs for Vigilance Task</u>	
C1 The interaction of position and frequency (TAROUSAL)	834
C2 The interaction of noise, position and introversion (TAROUSAL)	839
C 3 The interaction of noise, introversion and frequency (TSTRESS)	849
C 4 The interaction of noise, introversion and time of day (TEMP)	855
C 5 The interaction of introversion, neuroticism and frequency (TBE)	883
C 6 The main effect for block (TBE)	899
C 7 The interaction of noise and block (TBE)	904
C 8 The interaction of block, introversion, neuroticism and time of day (TBE)	905
C 9 The interaction of block, introversion, neuroticism and frequency (TBE)	910
C10 The main effect for block (TDY)	914
C11 The interaction of noise and block (TDY)	915
C12 The interaction of noise, block and neuroticism (TDY)	917
C13 The main effect for block (TPH)	920
C14 The interaction of noise and block (TPH)	921
C15 The main effect for block (TPF)	923
C16 The interaction of block, introversion and frequency. (TPF)	924
C17 The interaction of noise, block and introversion (TPF)	925
C18 The main effect for block (SIG)	928

	<i>Page</i>
C19 The interaction of block, introversion (EPQ) and time of day (TBE)	950
C20 The interaction of block and neuroticism (EPQ) - (TDY)	952
C21 The interaction of block and introversion (EPQ) - (TPH)	954

List of graphs depicting results involving 'strength'

D1	The interaction of noise, stimulus intensity and 'strength' (LME1)	969
D2	The interaction of stimulus intensity and 'strength' (LME2)	971
D3	The interaction of stimulus intensity and 'strength' (HED1)	973
D4	The interaction of stimulus intensity and 'strength' (HED2)	974
D5	The interaction of noise, 'strength' and frequency (TAROUSAL)	990
D6	The interaction of position, 'strength' and time of day (TAROUSAL)	993
D7	The interaction of session, 'strength' and frequency (SIG)	1003
D8	The interaction of block and 'strength' (TBE)	1011
D9	The interaction of block, 'strength' and frequency (TBE)	1012
D10	The interaction of block, 'strength' and frequency (TPH)	1015
D11	The interaction of block and 'strength' (TPF)	1017

ACKNOWLEDGEMENTS

My thanks go first and foremost to my supervisor, John Nicholson, without whose help, advice and encouragement none of the present project would have been possible. In addition, I would like to apologise to him for having rewarded him for his pains with an almost illegible manuscript which he nevertheless, somehow, managed to read.

I also owe a considerable debt of gratitude to Professor Brian Foss within whose department I worked and to whom I frequently turned for help. Furthermore, I am indebted to Professor M.J. Christie for her interest in the project and my concerns in general, and for her helpful advice on a number of specific issues, particularly those related to the psychophysiological area.

Rosemary Westley, the Chief Technician of the Psychology Department at Bedford deserves a medal for her patience with my demands, as do all of the technicians under her supervision. Particular thanks go to Dave Buckwell and Dave Finn for their advice on electronic and photographic matters, and to Audrey Tanner for her help in the weighing of the salivary samples in the first experiment. I would also like to acknowledge the advice of Beecham's Company on matters relating to the storage of lemon juice in the latter.

My task was lightened immeasurably by the opportunity to use the computer facilities at Bedford and I would like to thank Ray Matthews, Chris. McManus and all the programmers and operators in the computer unit for their

help in the writing and the execution of the necessary programs.

I am also grateful to John Valentine for his advice on statistical matters and to Dr. John Wilding for his helpful comments on a number of my ideas, particularly those related to reaction time.

Cathy Metzenthin, our departmental secretary, has been extremely helpful at all times for which I would like to express my appreciation, which should also be extended to Valerie Allport of the Library staff.

During the later stages of the project, in particular, I have been touched by the number of offers of help that have been made to me. I would especially like to mention Denise Rose, Angela Bird, Sarah Chapman, Valerie White, Amanda Brown, my cousin Sandhya Dass and my father, who were all involved in the typing of the thesis.

I would, moreover, like to thank Marie Stewart for her practical assistance and also for holding my hand, metaphorically speaking, as deadlines approached in the later stages of writing-up.

There are a number of people who at various times have corresponded with me over specific points connected with the project and it would be impossible to mention them all by name. I would, however, like to acknowledge the assistance of Professor Jan Strelau of the Institute of Psychology in Warsaw, Poland, who gave me permission to use his 'temperament' questionnaire and whose advice on matters relating to psychological research in Eastern Europe were most helpful. I would also like to thank Tony Debski for translating the 'temperament' questionnaire for me.

I must also express my gratitude to St. Thomas' Hospital Medical School for permitting me to temporarily suspend my medical studies so that the present project could be undertaken, and for their loan of various pieces of equipment which were needed in the initial stages.

My thanks also go to the Science Research Council who funded the project.

Last, but not least, I would like to say a very special thank you to my parents who have had to live with me during the past three years and who have provided both moral and practical support throughout.

PART ONE

THEORETICAL AND
METHODOLOGICAL ISSUES

CHAPTER ONE - THE INVERTED 'U' HYPOTHESIS

1. THE ORIGINS OF THE CONCEPT

It has been proposed by Gray (1964) that there is a great deal of concordance between the hypothetical constructs of 'excitatory process' and 'arousal' studied in the Soviet Union and the West, respectively. In both cases an inverted 'U' relationship has been observed between certain experimental factors and certain response indices and the above two constructs have been postulated in order to explain this relationship. The experimental factors are assumed to be determinants and the response indices the determinates of the appropriate hypothetical construct. One difference is that in the West a positive, monotonic relationship is usually proposed to exist between 'arousal' and its determinants and a curvilinear one between 'arousal' and its determinates. The converse is thought in the Soviet Union to apply to the 'excitatory process's' relationship with its determinants and determinates. These relationships are depicted in figures 1-3.

Figure 1 shows the empirical relationship which is thought to exist between the level of a given determinant and the determinate in question. As the level of the determinant rises, the level of the determinate also rises until the peak of the curve is reached, after which further increases in the determinant produce a fall in the level of the determinate. In fact this relationship

Fig. 1 Empirical relationship between a determinant and a determinate

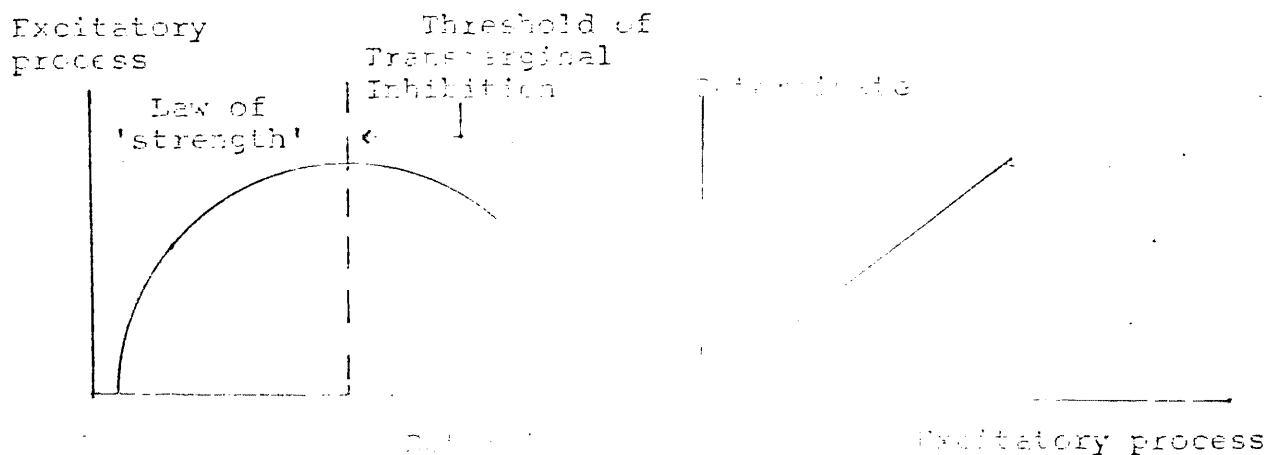
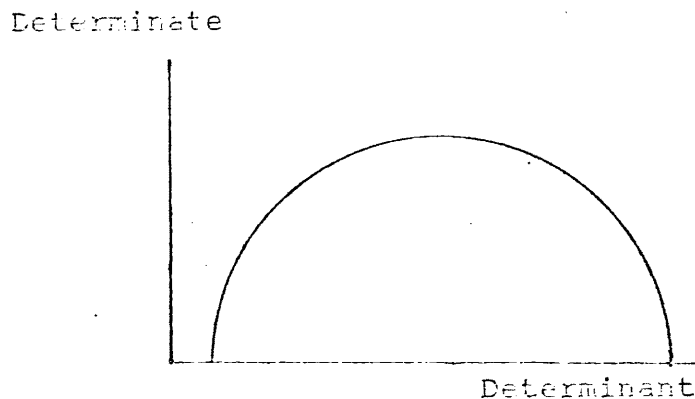


Fig. 2a. Hypothetical relationship between the determinant and the 'excitatory process'

Fig. 2b. Hypothetical relationship between the 'excitatory process' and the determinant

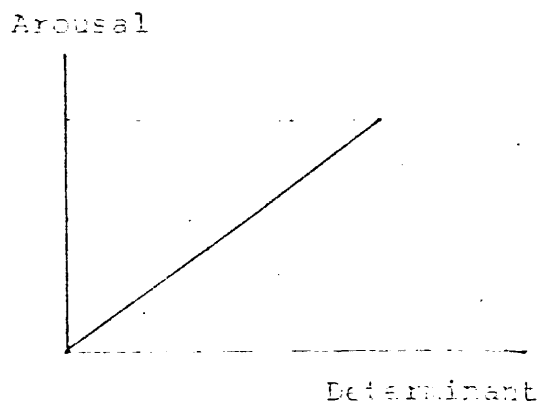


Fig. 3a. Hypothetical relationship between the determinant and 'arousal'

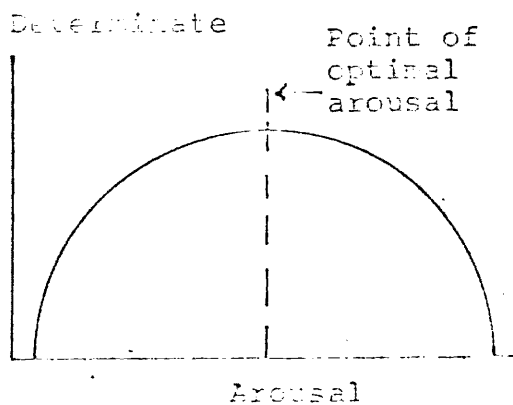


Fig. 3b. Hypothetical relationship between 'arousal' and the determinant

is only sometimes revealed in its entirety through the action of a single determinant. Instead the above function is sometimes inferred from the conjoint action of more than one determinant. This is a point to which we will return below. For the present the thing to note is that even when the relationship is shown separately for several different determinants, the tendency has been to try to explain the results by reference to a single intervening variable or construct, such as the 'excitatory process' or 'arousal'.

Such intervening variables are unpopular with certain schools of thought within psychology. The behaviourist tradition in its purest form (as exemplified by Skinner and his followers) prefers to simply investigate the relationship between 'input' (in this case the 'determinant') and 'output' (in this case the 'determinate') and not to speculate about the actual mechanism mediating between the two. This is the celebrated 'black box' approach, in which the organism which receives the input and which produces the output is regarded as an inscrutable entity, the nature of which can only be inferred, but not investigated directly. Since such inferences are unacceptable to strict behaviourists, they choose not to employ them at all.

However, Skinner and his associates are nevertheless keen to establish general laws governing the relationship between input and output. To have one law describing the way determinate A varies as a function of determinant A; and a separate law describing the way determinate B varies

as a function of determinant B (not to mention the way determinate A varies as a function of determinant B etc.) would be most cumbersome. One of the principle criteria for a good theory is thought to be parsimony - i.e. that it embodies the minimum number of postulates necessary to explain the empirical findings. So, in the interests of parsimony the behaviourists have tried to establish fairly general laws to embrace the action of the numerous determinants and determinates and their various permutations.

Soviet and Western workers who have described the kind of relationship depicted in figure 1 have also been concerned to produce parsimonious theories, but they have been willing to go one stage further than the behaviourists by developing what Hebb (1955) has called a 'conceptual nervous system' - i.e. a schematic, abstract model of the way the nervous system behaves to try to explain the observed relationships between 'input' and 'output' - i.e. between determinants and determinates. Figures 2a and 2b depict part of the Russian theorists' conceptual nervous system. Figures 3a and 3b depict part of the Western theorists' conceptual nervous system. Let us consider each more closely.

2. THE RUSSIAN AND THE WESTERN MODELS COMPARED

As Figure 2a shows, the Russian workers have proposed that as the level of a given determinant is increased, the level of their construct, the 'excitatory process', also increases in a positive, monotonic fashion up to a

certain point: the threshold of transmarginal inhibition (T.T.I.). This relationship is known as the 'law of strength'. However, once the T.T.I. has been reached, further increases in the level of the determinant produce a fall in the level of the 'excitatory process'. To be precise, the Russian theorists state that transmarginal inhibition replaces the 'excitatory process' at the T.T.I.

It is the present author's opinion that if one wishes to invoke the concept of inhibition, one could alternatively suggest that the level of inhibition in fact may be non-zero even before the T.T.I. is reached, but that this threshold simply represents the point at which the rates of increase of the 'excitatory' and 'inhibitory' processes become equal to each other. After it has been passed, the latter becomes greater than the former. On this view the 'Y' axis in Figure 2a would be equal to the sum of excitation and inhibition (with excitation having a positive sign and inhibition a negative sign). Whether such an interpretation is more intuitively reasonable than the Russian theorists' view that the inhibition mechanism is suddenly triggered at the T.T.I., is debatable. Gray (personal communication) has certainly agreed that it is a plausible alternative.

In fact, at the level of the conceptual nervous system at least, it is not necessary to invoke the concept of inhibition at all. One need only assume that the level of the 'excitatory process' falls at the T.T.I. (as shown in Figure 2a) and we will work on this basis.

The other postulate of the Russian model is depicted in Figure 2b - i.e. that an essentially positive and monotonic relationship exists between the level of the 'excitatory process' and the level of the determinate (i.e. the response index in question). The two diagrams (Figures 2a and 2b), which are both hypothetical, together predict the function depicted in Figure 1, which is basically empirical.

The Western model is, in fact, the obverse of the Russian one and is depicted in Figures 3a and 3b. As Figure 3a shows, an essentially positive monotonic relationship is thought to exist between the level of the determinant and the level of the Western intervening construct - i.e. 'arousal'. Figure 3b shows that an inverted 'U' relationship exists between the level of 'arousal' and the level of the determinate. The peak of the curve is known as the point of 'optimal arousal'. Again, Figures 3a and 3b, which are both hypothetical, predict the relationship depicted in Figure 1.

Thus, in terms of their ability to explain the empirical data, there is nothing to choose between the two models (so far at least). The differences between them at the level of the 'conceptual nervous system' are largely academic, and rest mainly on the fact that (as Gray (1964) has pointed out) in the Russian model the intervening construct ('excitatory process') is thought to be related in a positive, monotonic function to the determinate, whereas in the West the intervening construct ('arousal') is thought to be related in a positive,

monotonic fashion to the determinant. We shall see below that when one tries to match the conceptual nervous system onto the 'real' nervous system, the differences between the two models become more than just semantic and academic. Before we do this, however, let us consider another factor which is common to the two formulations.

3. THE CRITERION OF PARSIMONY

Both models represent two alternative, but equally parsimonious explanations of the function depicted in Figure 1. Furthermore, assuming that we are going to introduce an intervening construct at all, they are not only equally parsimonious, but they are also maximally parsimonious. They are the most simple form of explanation, in terms of an intervening variable, that is possible. If one wanted to, of course, one could invent an infinite number of possible hypothetical solutions to the problem posed by Figure 1. Furthermore, each of these could consist of as many diagrams as one wished, each one having as its X axis the Y axis variable from the previous one, and an additional construct for its own Y axis (finally ending up with 'determinate'). Furthermore, each of these diagrams on its own could be as complex as one wished. Clearly though our parsimony criterion would go out of the window in such a madcap 'cascade' process.

There is another way in which the models are parsimonious. It is one which has been referred to already, but it is not obvious from the diagrams as shown.

We pointed out earlier that we do not have just one determinant and one determinate, but several. One could simply state that wherever we have a determinate varying as a function of a determinant, in a manner described by Figure 1, an explanation in terms of the Russian or Western model would apply. This would be parsimonious in one sense, since we would have only one set of laws. But would it not on its own imply the existence of several different 'excitatory process' constructs or several different 'arousal' constructs, one for each of the possible permutations between the determinates and the determinants? Could we not introduce an even greater degree of parsimony if we assumed that in each case the same intervening construct is involved, whether we call it the 'excitatory process' or 'arousal, and whether we adopt the Russian or the Western model?

This is precisely what the earliest formulations of the Russian and the Western theorists have assumed. As Gray (1964, op. cit.) has described, the Russian workers do talk in terms of the 'excitatory process' within different 'analysers' (e.g. a visual 'analyser' for visual determinates and an auditory 'analyser' for auditory determinates). To this extent, then, they could be considered to have different intervening constructs. However, as we shall see below, when we consider individual differences, it was assumed in the early stages of the formulation of the 'theory of strength' (which is embodied in Figures 2a and 2b) that the level of the 'excitatory process', under standard conditions, in these different

analysers correlates very highly across individuals. In the West this has been taken further, for instance, by Duffy (1962) who proposes the existence of a single 'arousal' or 'activation' continuum.

The great virtue of such an approach is, of course, that, if it works, it brings together a whole mass of disparate data involving different stimulus and response measures into a single framework. However, we shall argue that its greatest strength is also in some ways its greatest weakness, since this particular aspect of the model(s) has proved to be something of an Achilles heel.

Let us first consider in more detail though, what the attempts to achieve such a high degree of parsimony imply. We have seen already that in the West, at least, the assumption has been made by some workers that the levels of different determinates can be predicted (in accordance with Figure 3b) from the position the subject occupies on a single 'arousal' continuum, and that this position is itself predictable from a function such as the one depicted in Figure 3(a). We will discuss this again below. But what of the other assumption - namely that for a given determinate, the level can be predicted from the value of a single construct ('arousal' or the 'excitatory' process) which is itself dependent on the levels of several different determinants? We will consider this now.

4. THE PREDICTIONS OF THE HYPOTHESIS

i) The conjoint action of the determinants

The way in which several determinants are thought to act together is most clearly illustrated by reference

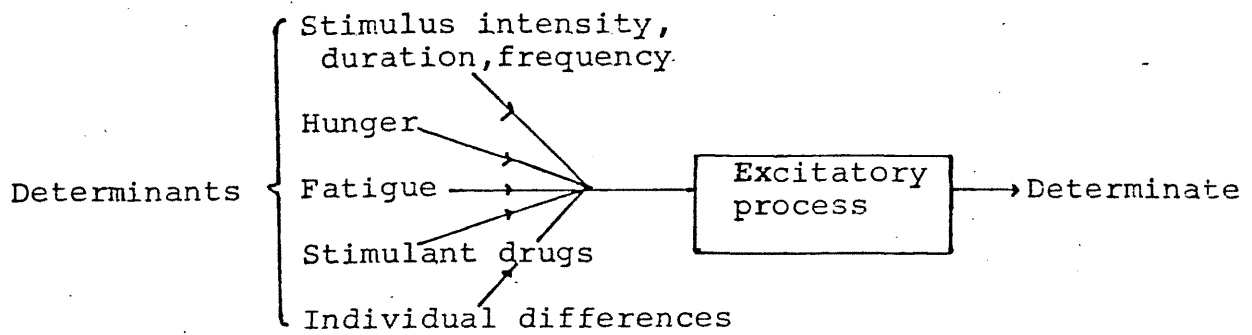


Fig.4 The Russian explanation of the conjoint effects of the determinants

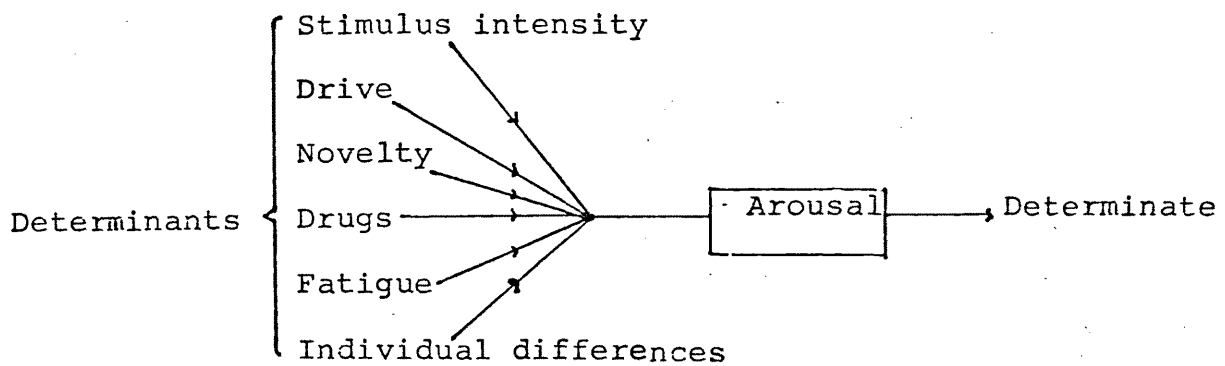


Fig. 5. The Western explanation of the conjoint effects of the determinants

to Gray's comparison of the Russian and Western models (1964). We have attempted to represent these in Figures 4 and 5.

The similarities and differences between the Russian and Western list of determinants (and also determinates - we have not listed them in the figures, in fact) will be considered later. For the present, the important point to notice is that in each case, the various determinants are thought to feed into a single box -i.e. to jointly determine the actual level of the 'excitatory process' or 'arousal'. What this means is that instead of the single curve shown in Figure 2a and in Figure 3a (page 44) we in fact have a family of curves. Let us illustrate this by using the Russian model and considering two determinants, which we will call A and B.

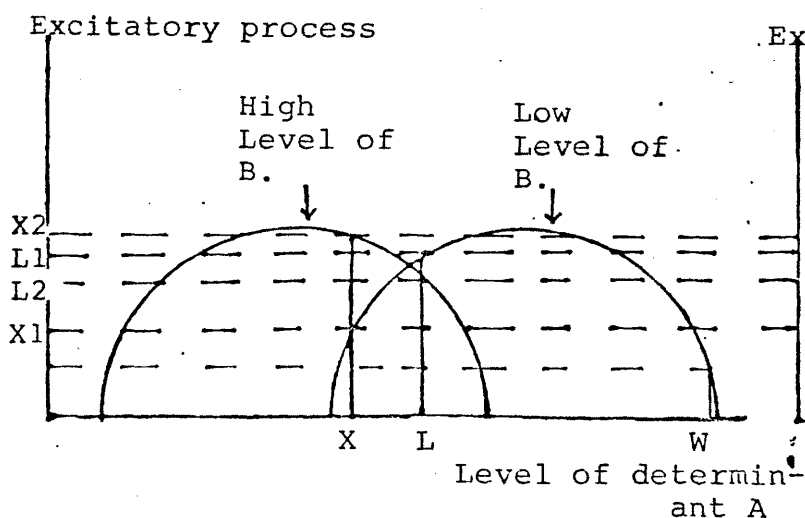


Fig.6 .The conjoint action of determinants A and B.

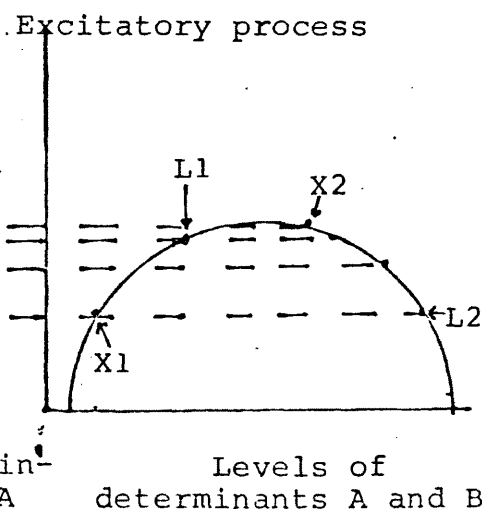


Fig.7 .An alternative representation.

Consider Figure 6 (ignoring Figure 7 for the present). This shows a hypothetical relationship between the level of the determinant A and the level of the 'excitatory process', for two different levels of the determinant B. We see that the curve for the low level of determinant B is shifted to the right relative to that for the high level of determinant B. Consider the situation when the level of determinant A is equal to the value X. If the level of determinant B is relatively low, the value of the 'excitatory process' will be X1. More importantly, if the level of determinant A is increased by a small amount, the level of the 'excitatory process' will increase, since we are operating on the left-hand side of the appropriate curve. If, on the other hand, the level of determinant A is X, but the level of determinant B is high, the value of the 'excitatory process' will be X2. Moreover, this time if the level of the determinant A is increased by a small amount, the value of the 'excitatory process' will fall, since we are operating on the right-hand portion of the appropriate curve. Since Figure 2b (page 44) shows that an essentially positive and monotonic relationship is presumed to exist in the Russian model, between the level of the 'excitatory process' and the level of the determinate, what is true of the former will also be true of the latter. In other words, the relationships depicted in Figure 6 would predict an interaction between determinants A and B, when the levels of these two determinants are manipulated in a single experiment, and the level of a determinate is measured. So when the level

of determinant B is relatively low, a small increase in the level of determinant A will produce an increase in the level of the determinate. However, if the level of determinant B is relatively high, a corresponding increase in the level of determinant A will produce a decrease in the level of the determinate.

We have used the term a 'small increase' because if it had been a large one, the effect of such an increase might have produced a fall in the level of the 'excitatory process' (and the determinate) even when the level of B was relatively low (as illustrated by point W). Similarly , we have used the terms 'relatively low' and 'relatively high', but if the difference between these two values was not sufficiently great, then an interaction of this kind might not appear.

This is since the two curves would be closer together and we might be operating on the left-hand side of both curves, as shown in Figure 8 below (larger scale for clarity).

Fig.8 .An interaction based on the size of differences.

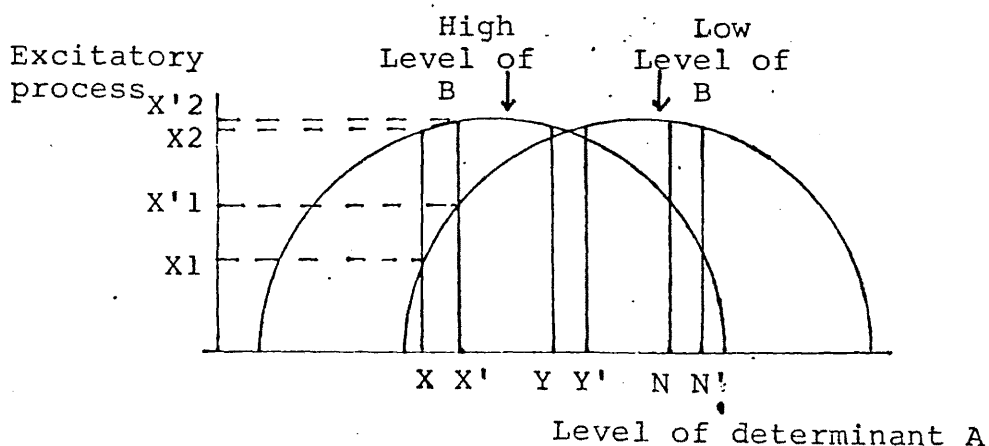


Figure 8 shows that a small increase in determinant A from X to X' will produce an increase in the level of the 'excitatory process' (and a corresponding increase in the determinate) from X₁ to X'₁, if the level of determinant B is relatively low. If the level of determinant B is relatively high, an increase in A from X to X' will also produce an increase in the 'excitatory process' from X₂ to X'₂. However, it should be clear that the difference between X₁ and X'₁, on the one hand, is much greater than the difference between X₂ and X'₂ on the other. Therefore, we might still get an interaction between A and B, but it would be of a different kind from the earlier interaction, since it would be based on a difference in the size of the change rather than a difference in the direction of change of the 'excitatory process', (and determinate). Nevertheless, it is equally predictable from our functions, so long as we assume that as we move to the right along the 'X' axis of figure 8 the gradient of the curves decreases, which it does as we have drawn it. Clearly it is necessarily the case that on the left of the curve (i.e. to the left of its peak) the gradient at some point decreases as we move from left to right, since the law of 'strength' (see Figure 2a, page 44.) predicts that the function rises, but also that it flattens off completely at the peak (the T.T.I.).

We could incorporate both these assumptions and yet reject the assumption that the gradient decreases in a smooth fashion if we assume that the peak is a sharp one, as in Figure 9.

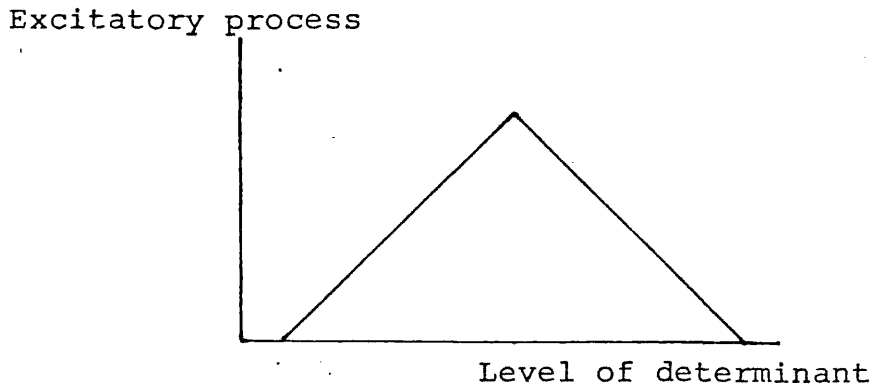


Fig.9 .An alternative representation
of the T.T.I.

This is, however, not only counterintuitive, but, more importantly, it is not in line with empirical findings. Data in this area, based either on the effect of manipulation of a single determinant, or on the joint manipulation of several of them, suggest that the curve is a smooth one (though there are grounds for suggesting a different modification to the curve and we will discuss this below). As we will see, interactions based on the size of the change in the level of the determinate do occur as well as interactions based on the direction of the change.

Nevertheless, the above analysis illustrates that factors such as the size of the increase in determinant A and the size of the difference between the two levels of determinant B, do affect the kind of interaction that we will get. Furthermore, the absolute values also matter. In Figure 8, if we had considered points Y and Y', instead of X and X', we would have got an interaction based on the direction of change of the 'excitatory process', despite the fact that the difference between the two levels of B is meant to be less than in Figure 6 (page 53).

ii) The Problem of falsifiability

We seem, therefore, to have a difficulty. All these various scenarios are explicable on the basis of the hypothetical model, but it is difficult to know beforehand which one will occur, since terms such as a 'small increase' and 'relatively greater' are difficult to tie down in operational terms. The curves shown are hypothetical ones - we have inferred them from empirical data, but since we cannot observe them directly it is not easy to say what particular operational values of the determinants would lead to which particular kind of interaction. The theory seems better able to explain than to predict.

On this basis, it might seem that the reluctance of the strict behaviourist school to indulge in such theorising is justified. However, let us see how serious the flaws in the theory's predictive powers really are.

Popper (1968) has argued that one criterion of a good theory is the degree to which it is 'falsifiable'. In other words, the degree to which a given empirical result can be unambiguously interpreted, either as supportive or as inimical to the theory. It could be argued that, the larger the proportion of the total possible experimental outcomes which a theory is capable of accommodating, the less 'falsifiable' it is. In the extreme we would have a theory which was capable of accommodating all possible outcomes and which, therefore, would be unfalsifiable. Popper would argue that such a theory is scientifically useless, (although it should be pointed out that a theory

which could account for, say, 99% of all possible outcomes - i.e. virtually all the possible outcomes - is still in principle falsifiable).

However, falsifiability is only one criterion of a good theory. The other main criterion is that it should be able to explain the facts. Clearly there is something of a trade off between the falsifiability of a theory and its ability to account for experimental data. The greater the proportion of all possible outcomes that a theory can account for, the less likely it is to be falsified and vice versa. Furthermore, since parsimony was one of the main reasons for the construction of the model in its present form, the clash between these two aspects of scientific value would seem to be even more apparent. This is one of the reasons why we said that the theory's greatest strength could also be regarded as one of its greatest weaknesses.

Obviously, if we accept this argument, we must try to strike some sort of a balance between the need to have a theory which is empirically testable or 'falsifiable' and the need to have a theory which can account for as wide a range of facts as possible. We have shown, and will show further, that the theory performs the latter function fairly adequately. But what of its degree of falsifiability? Above we stated that this could be defined as being inversely related to the proportion of possible outcomes which it can account for.

By corollary, it is directly related to the proportion of experimental outcomes which it cannot account for. So

far we have considered two interactions which the theory can account for. For each of these, though, there is a corresponding interaction which it is unable to explain. If the effect of an increase in A was to produce an increase in the determinate when the level of B was relatively high, but a decrease when the level of B was relatively low, this would clearly be quite contrary to the theory. It would be consistent with the view that the functions in Figure 6 (page 53) and Figure 8 (page 55) were 'U' shaped rather than inverted 'U's . Alternatively, we could suppose that the functions were inverted 'U's, but that the effect of an increase in the level of B was to shift the curve to the right rather than to the left.

Similarly, if the effect of an increase in A was to produce a greater increase in the determinate when the level of B was relatively high rather than relatively low, again this would contradict the theory , but would be consonant with the view that the curve corresponding to the high level of B was to the right of the curve, corresponding to the low level of B.

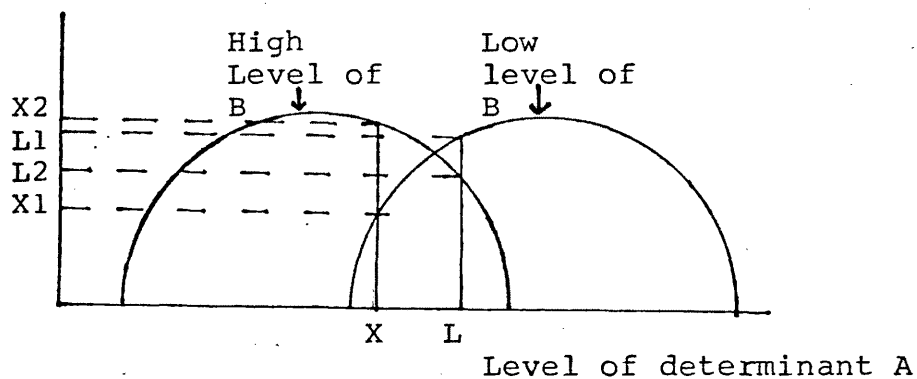
iii) Different forms of interaction.

It should also be pointed out that if in Figure 8 (page 55) we had chosen the points N and N' to represent our increase in A, we would have got an interaction due to differences in size of the change in the determinate (not its direction), but this time the change would have been in the downward direction. Again though, there would be a corresponding interaction which would be inimical to our theory.

Also, in the situation depicted in Figure 6, the interaction works both ways. For convenience we will reproduce Figure 6 below.

Fig. 6. The conjoint action of determinants A and B.

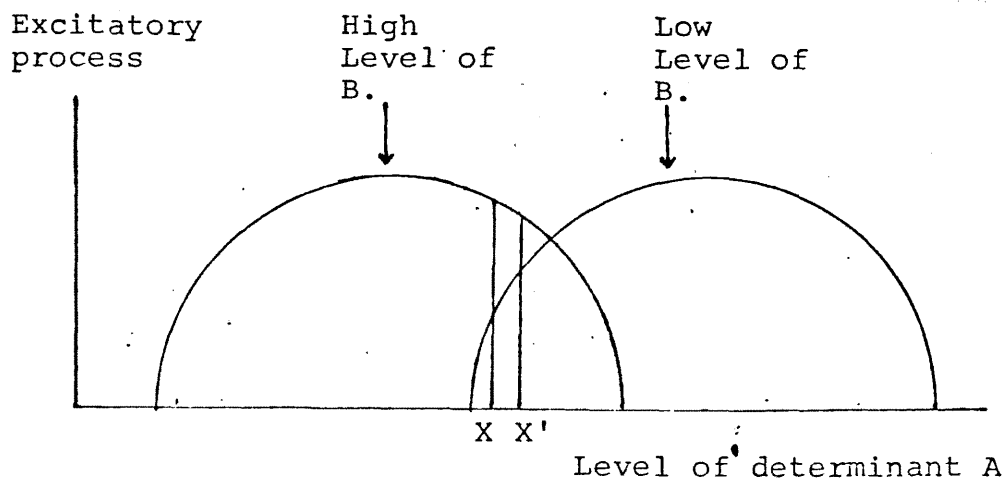
Excitatory process



So far we have considered the effect of an increase in A at two levels of B. Let us now consider the effect of an increase in B at two levels of A. At point X, an increase in B is equivalent to a shift from the right hand to the left hand curve, resulting in an increase in the level of the 'excitatory process' from X1 to X2, since the height of the left hand curve (high B) is greater than the height of the right hand curve (low B) at point X. At point L, however, (i.e. at a higher value of A), the reverse

is true. The height of the high B curve is less than the height of the low B curve, so an increase in the level of B would result in a decrease in the level of the 'excitatory process' at point L. We will call this kind of interaction, which works in both directions, a 'double interaction'. We have seen already that if it had turned out in the opposite sense for the first direction, it would have contradicted our theory. If so, then it would also have turned out in the opposite sense for the second direction (i.e. there would have been a decrease in the 'excitatory process' when B was increased at a low level of A, but an increase in the 'excitatory process' when B was increased at a high level of A). Consider now Figure 10.

Fig.10 .A 'partial' interaction.





b.



d.



a.



c.

direction, in which case it would have contradicted the theory.

At this point it is worth considering a slight change to the formulation of the theory, which does not alter its substance, but makes it easier to explain. Consider again Figure 6 (page 53). We have used this diagram to show how the effect of one determinant may depend on the level of another determinant. We have done this by drawing two curves for the two levels of determinant B. We could actually have drawn it the other way round and put determinant B on the X axis and used two curves to represent the two levels of determinant A. The two representations would have been equally valid, since A and B are in this context equivalent (and that is why we used letters to represent them and not concrete examples).

However, this equivalence is masked by the use of the X axis to represent the level of one determinant and separate curves to represent the level of the other. Also, if we were considering more than two levels of one or both determinants and/or the conjoint effect of three or more determinants, the use of this sort of representation would prove very cumbersome. It would be very difficult to get all the curves on one diagram without causing confusion, and separate diagrams would make comparison difficult.

There is, fortunately, an alternative way of representing the situation, and this is depicted in Figure 7. For convenience we will reproduce both figures below.

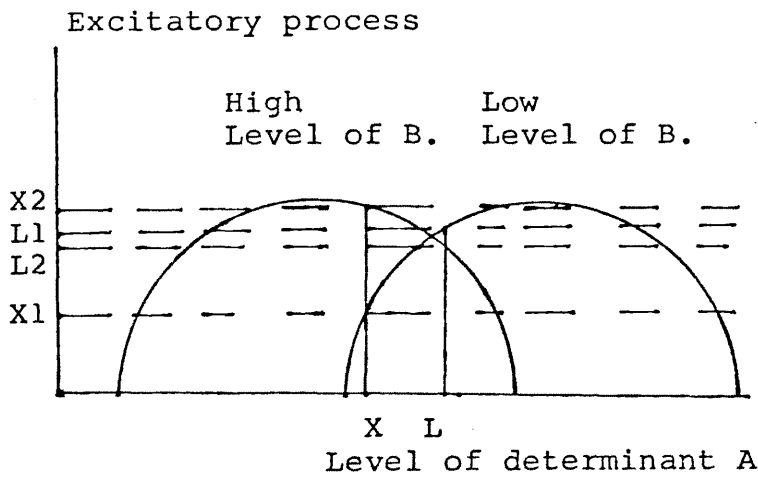


Fig.6. The conjoint action of determinants A and B.

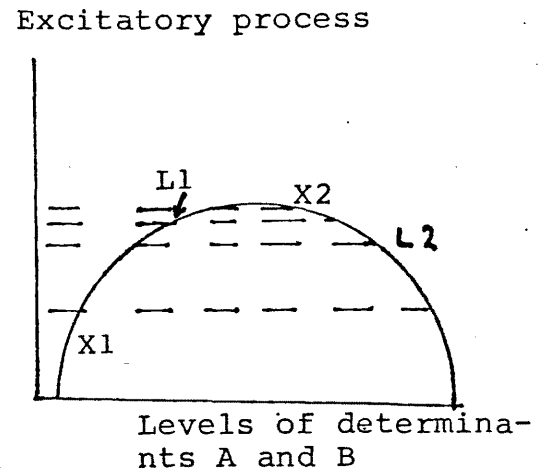


Fig.7. An alternative representation.

Instead of using the X axis to represent the level of one determinant and separate curves to represent the levels of the other determinants, it uses a single curve and uses the same X axis to represent the levels of all the determinants under consideration. This may seem an arbitrary procedure, but if we look back to Figures 4 and 5 (page 52), we see that they imply exactly this. In other words, the level of the 'excitatory process' (or 'arousal') depends on some composite measure of the levels of the determinants. It is this composite measure that would be represented along the X axis of Figure 7. As an example of how this model would work, consider the effect of an increase in the level of A from X to L. We have already seen that this will produce an interaction.

It will be a 'double' interaction, since the 'excitatory process' increases from X1 to L1 when the level of B is low, but decreases from X2 to L2 when the level of B is high. Also, if the level of B increases from low to high, the 'excitatory process' will increase from X1 to X2, if the level of A is X, whereas if the level of A is L, the 'excitatory process' will decrease from L1 to L2, if the level of B increases.

The horizontal dotted lines show the effect of projecting these values of the 'excitatory process' onto the curve in Figure 7. The first thing to notice is that each of the lines cuts the curve at two points. It should be made clear that when deciding which of these two points is the 'correct' one, we are at perfect liberty to choose either one, depending on which one conforms to the situation depicted in Figure 6 more closely. This is because at present our concern is to show that there is an alternative way of representing this situation. We are constructing a model, we are not as yet testing a hypothesis.

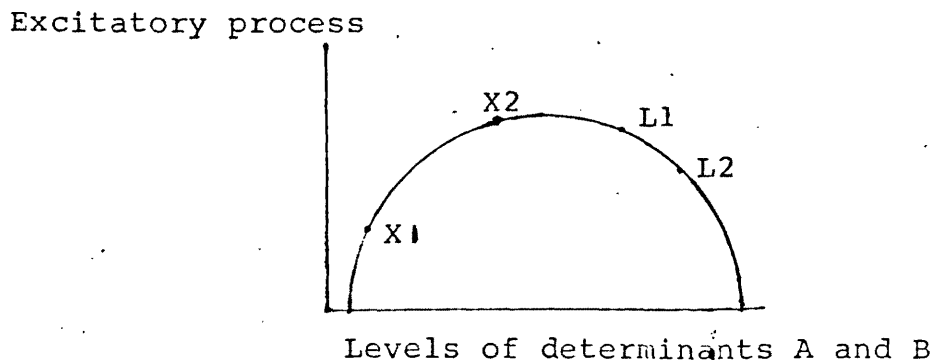
The symbols X1, X2, L1, L2 on Figure 7 represent our choice on this basis. X1 and L1 lie on the left hand side of the curve, since they lie on the left hand side of their respective curve in Figure 6. Similarly, X2 and L2 lie on the right hand side of the curve, since they lie on the right hand side of their respective curve in Figure 6. This correspondence is necessary since an alteration in the level of A (e.g. a small increase either from an initial level of X or L) would have

differential effects depending on whether the points were on the left or right hand side of the curve and we wish figures 6 and 7 to predict the same thing, and we see that we have achieved this aim. One difficulty remains, however.

(iv) The problem of intermediate groups

We have seen that using our alternative representation in Figure 7, we have our 'double' interaction. However, we argued earlier that the form of the interaction depended very much on the way we draw Figure 6 and that all of the different effects this would produce would be interactions, but of different kinds. Let us use our new technique embodied in Figure 7 to show another example of this. Consider Figure 11 below.

Fig.11 .An alternative representation of the positions of the intermediate groups.



This is identical to Figure 7 except that the relative positions of the points L1 and X2 on the X axis have been swapped round. The positions of X1 and L2 on the X axis and the positions of all the points on the 'Y' axis (i.e. the 'excitatory process') are the same. It should be clear that we still have our double interaction and it is exactly the same empirically as the one depicted in Figure 6 and Figure 7. The author could use exactly the same words to describe it (as on page 54) and it would correspond to the description in every respect. The reason is that the description was of the empirical results that would be obtained if such a hypothetical situation were to be reflected in the data of an experiment. It should also be noted that the new positions of X2 and L1 are the points of intersection of the corresponding horizontal lines with the curve in Figure 7, which were rejected earlier. The reason that they were rejected was because they would not have led to an accurate representation of Figure 6. If, however, we move the low B level curve in Figure 6 to the left and the high B level curve in Figure 6 to the right, by appropriate distances, we could get a situation in which the picture in Figure 11 was a more accurate representation. Such movements would bring the two curves closer together, and the sort of interaction depicted in Figure 11 is what one would get if one compared points X and N in Figure 8 (page 55) (which, it will be remembered, was an attempt to show what would happen if the curves were closer together).

The important point is that, as we have already stated, how we draw Figure 6 on an a priori basis is a matter of choice. But it can lead to different forms of empirical interaction. Here we have the opposite situation where the same empirical interaction could be predicted equally well by two alternative hypothetical models.

Another reason why the kind of representation in Figure 7 is preferable to that in Figure 6 (which is the more commonly used one) is that it makes this indeterminate nature of the model easier to see. The type of diagram shown in Figure 6 is more likely to give us the false impression that we know exactly where all the various pieces in the jigsaw lie.

However, this indeterminacy only applies to the two intermediate groups. It is easy to see why this should be so. The X axis in Figure 7 is meant to be a composite sum of the levels of the determinants A and B. But these are measured in totally different units - for instance A might be stimulus intensity measured in terms of dB, whilst B might be the dosage of a stimulant drug measured in units of mg./100 mls. of blood!

How can it possibly be valid to try to combine the two?

Consider what would happen if we do try to combine A and B, when both have two levels. This leads to 4 combinations:

Low A
High B

Low A
Low B

High A
High B

High A
Low B

What we can say for sure is that if there was a basis for combining them, the low A , low B combination would produce the lowest level of the composite measure and the high A, high B combination would produce the highest level. We cannot say which of the two intermediate groups would be higher, (i.e. further to the right along the X axis of Figure 7) since each one is high on one determinant, but low on the other. However, the fact that these two determinants interact at all - i.e. (to use the behaviourist terminology) the fact that they both go into the organism as different forms of 'input', but come out as the same form of 'output' (i.e. as the determinate in question) indicates that the organism is capable of combining them in some way. The question is how? Is there some way we can determine the equation which the organism's nervous system uses to establish what

value the composite measure has for given values of A and B? If we knew this equation, we could predict the relative positions of the intermediate groups, as well as the extreme groups, on the X axis of figure 7 (page 53).

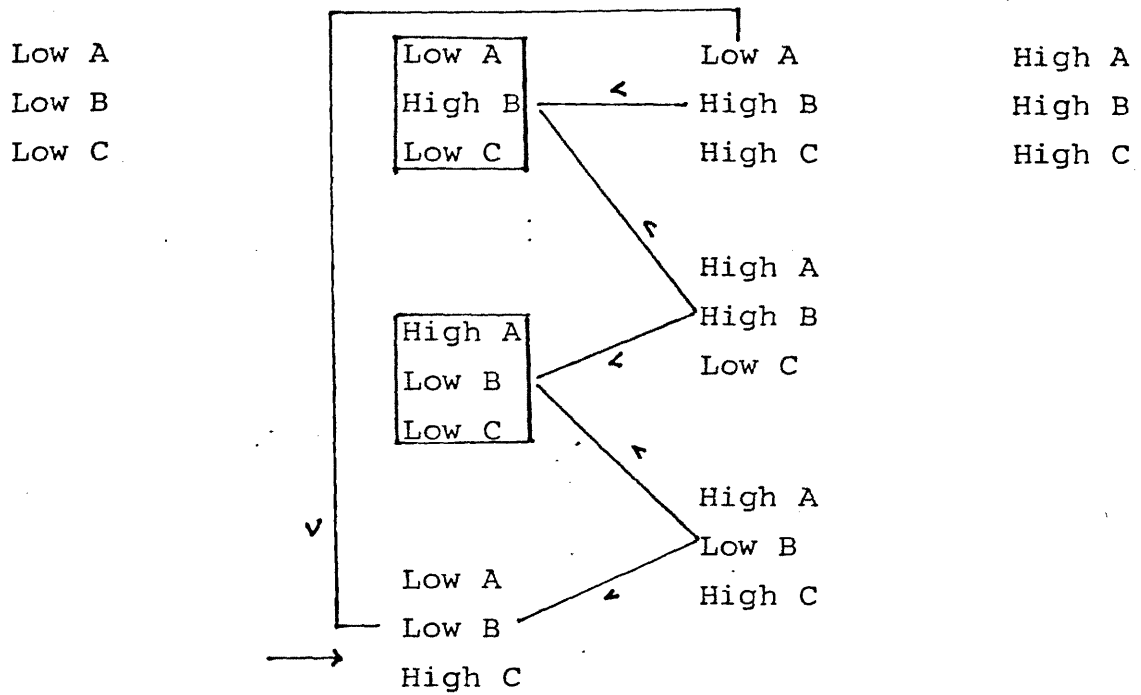
But we have already stated that the positions of the points in Figure 7 were chosen because if they had been

different the effect of a small increase in the level of A, from an initial value of X or L, would be different to that predicted by Figure 6. One way, therefore, to test whether the formulation in Figures 6 and 7, or the formulation in Figure 11 (page 67) was correct, would be to use more than two levels of determinant A. If Figures 6 and 7 are correct, a small increase in A would produce a decrease in the 'excitatory process' in the group corresponding to X2 (low A, high B), but an increase in the group corresponding to L1 (high A, low B).

If Figure 11 was correct, on the other hand, a small increase in the level of A would produce the reverse effect.

Another way of distinguishing the intermediate groups would be to include a third factor ('C'). Since an increase in its level would add to the value of the composite measure, it would move one to the right along the 'X' axis of Figures 7 and 11. It would, therefore, produce an increase in the 'excitatory process' in the group which was operating on the left hand side of the curve, but a decrease in the group which was operating on the right hand side of the curve.

We cannot, however, eliminate the element of indeterminacy in position of intermediate groups altogether:



The combinations shown in the boxes can be considered to be equivalent to our previous 2 intermediate groups. We now have other groups to compare them with and in each case we know which group must be further along the X axis than the other (as indicated by the symbol '>'), since they differ only in the level of one factor or determinant. We have, however, created another intermediate group as indicated by the arrow. For this group (low A, low B, high C) we do have appropriate comparison groups, i.e. the High A, low B, high C group and the low A, high B, high C group. But we do not know whether the low A, low B, high C group is greater than the two boxed groups, which also have a high level of only one factor. Also, we can compare the high A, high B, low C group with the high A, high B, high C group, but we cannot compare it with the two groups which are also

high on two determinants.

We could introduce a fourth factor, but by a similar argument we could not eliminate the element of indeterminacy completely and the same applies for the technique of including more than two levels of the same factor.

(v) Multifactorial experiments

We have gone into this in some detail to show that even a posteriori we cannot be absolutely sure what particular picture to draw to depict our results. There will always be alternatives. However, each of these alternatives will be consistent with the overall-theory, and we have seen that where more than two levels of a factor are involved, or where there are more than two factors, we can make deductions about the positions of some of the intermediate groups. This is one reason why multifactorial experiments are preferable to ones in which only two (or even one factor) are used. Clearly, when only one factor is used we do have a situation in which the theory is able to account for all possible alternatives and is, therefore, unfalsifiable.

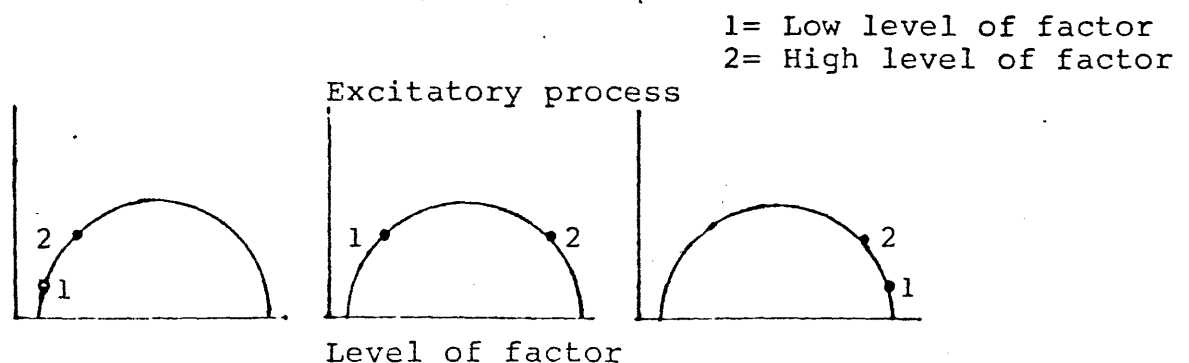


Fig. 12 . The inverted 'U' and the main effect of a factor.

As figure 12 shows, the results of an experiment which employs two levels of just one determinant can be explained by the inverted 'U' , whether they show a positive, insignificant or negative effect of the determinant . For this reason, even in an analysis of variance involving many determinants, main effects are not particularly informative on their own.

As Corcoran (1965) has pointed out, the use of two determinants can overcome this problem , since the inverted 'U' would predict certain specific kinds of interaction between them, as we have seen.

We have now suggested that there are grounds for including more than two determinants. However, as we shall see, there are reasons for doing this . other than simply to elucidate the positions of the intermediate groups (which we have seen it cannot do completely anyway).

At the beginning of our analysis we pointed out that the inverted 'U' function, shown in Figure 1, was not only produced by altering the level of a single determinant over a wide range, but also by looking at the joint effect of more than one determinant. We have considered at some length the possible joint effects of two determinants, and we will summarise these below, using our alternative method of representation - i.e. using the 'X' axis to represent a composite sum of the determinants involved.

DIAGRAMATIC REPRESENTATION OF POSSIBLE OUTCOMES
EXPLICABLE BY THE INVERTED 'U' IN ITS ORIGINAL FORM

Figures 13a and 13b show interactions based on differences in the size of the change in the determinate.

Figures 13c to show interactions based on differences in the direction of the change in the determinate.

Figure 13c shows a 'double' interaction (i.e. one which works both ways).

Figures 13d to g show 'partial' interactions (i.e. ones which work in only one way).

See pages 66-67 for further clarification.

- 1 = low level of determinant
- 2 = high level of determinant

Fig 13a

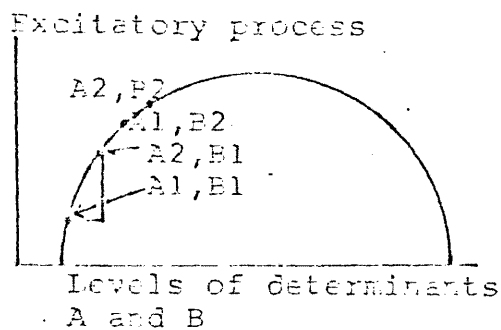


Fig 13b

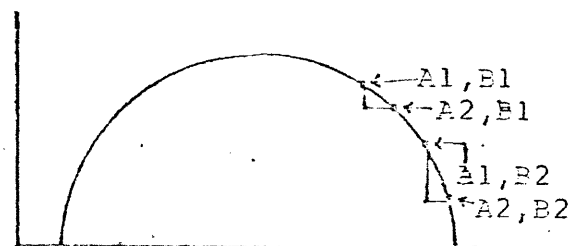
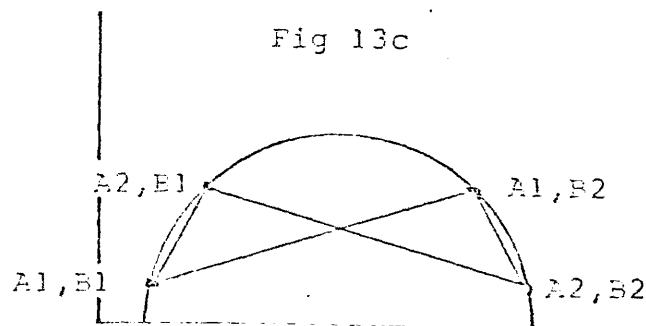


Fig 13c



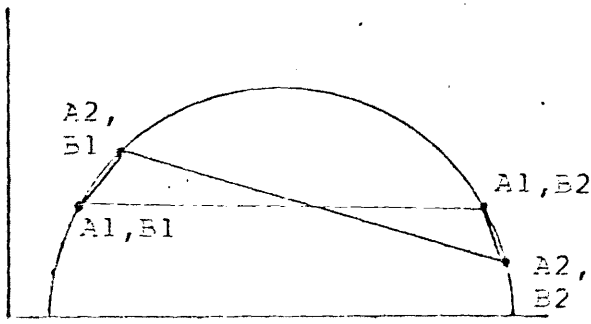


Fig. 13d

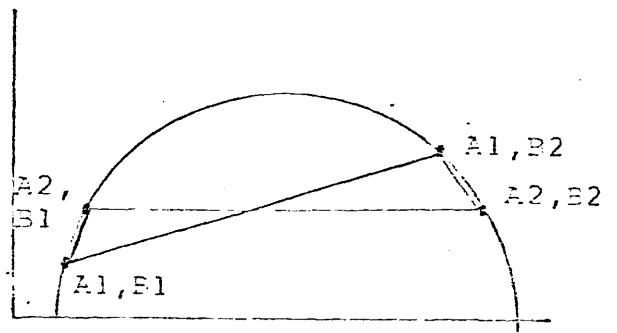


Fig. 13e

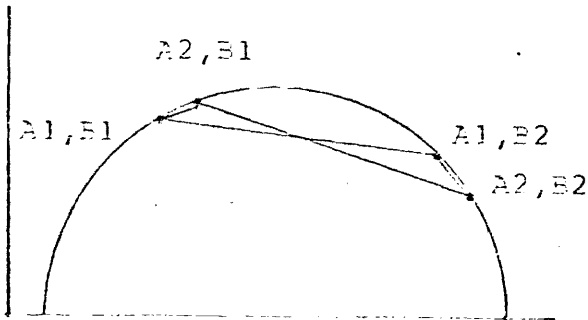


Fig. 13f

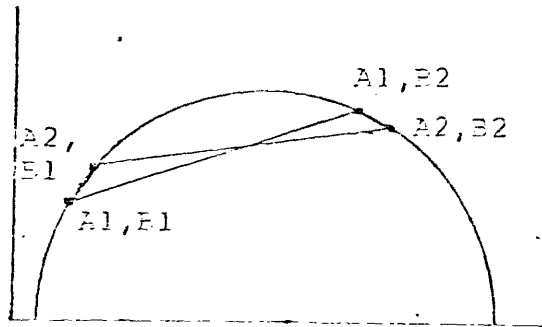
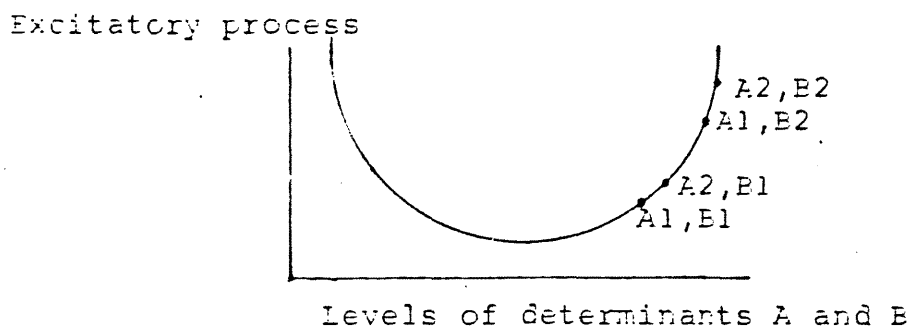


Fig. 13g

Let us return now to the question^{of} whether our theory is sufficiently falsifiable to meet Popper's criterion. We have depicted seven possible outcomes which might lead to a significant interaction between determinants A and B and which, therefore, we would regard as supportive of the theory. However, we have also argued that in each case there is a corresponding interaction in the opposite direction, which could have occurred and which would have directly contradicted the theory. For example, consider Figure 14 below.

Fig. 14. An interaction opposite to the empirical result corresponding to Figure 13a.



Empirically such a relationship would produce an interaction exactly opposite to that predicted by Figure 13a, so we would have to reject the theory and propose an alternative such as the 'U' relationship depicted above.

Let us now consider the more usual situation one encounters when, for instance, conducting an experiment to test the effect of a single factor on a given response

index. Two possible outcomes could give a significant result. One in which an increase in the level of the factor produced an increase in the value of the response index, and the other in which the increase in the level of the factor produced a decrease in the value of the response index. On an a priori basis these would be equally likely to occur by chance.

If we had a hypothesis that the increase in the level of the factor would produce a change in the response index in a certain specified direction, then one outcome would support the hypothesis, and the other would negate it. (Furthermore, we would be entitled to use a one-tailed test, since we had predicted the direction of the outcome).

The inverted 'U' hypothesis produces an equivalent situation. It is not the total number of outcomes that would support the hypothesis that is important, but the proportion of outcomes that would so do, since this would determine the probability of obtaining an outcome which supports the hypothesis purely by chance. In both situations, the proportion of significant outcomes which would support the hypothesis is one half, so although the total number of such supportive outcomes is greater, the probability of obtaining a spurious supportive outcome is no greater.

Let us now consider the situation where we have three factors involved. The inverted 'U' is essentially a second order function - i.e. a quadratic with a negative value for the quadratic coefficient. It should be clear that it can only accommodate the kind of interaction

which is based on differences in the directions of changes (and which works for more than one factor) when no more than two factors are involved.

The diagrams in Figures 13c - g are examples of such interactions in which the effect of at least one factor on the determinate is opposite in direction at the two levels of the other factor. It might be thought that the same applied to interactions which depend on differences in the size of the change in the determinate (rather than its direction) such as the ones portrayed in Figure 13a and 13b, and as the inverted 'U' stands this is true. We will see later that with a modification the inverted 'U' can accommodate interactions of this nature (i.e. based on size, but not direction) which involve 3 factors. Also we will see that when we are considering determinates which depend on the gradient of the inverted 'U' , and not its absolute height, the inverted 'U' can even account for the interaction of three factors where the interaction is based on the direction of changes, rather than the size.

However, these exceptions do not alter to any substantial extent the argument that is being developed here. If we have three factors (ignoring the above exceptions) , or if we have more than three factors (whether we ignore them or not), there are no crossovers which work for more than one factor that the inverted 'U' can explain. To show what we mean by this, consider Figure 15 overleaf. (It should be noted that we are using the term 'factor' , here, essentially synonymously with the term 'determinant')

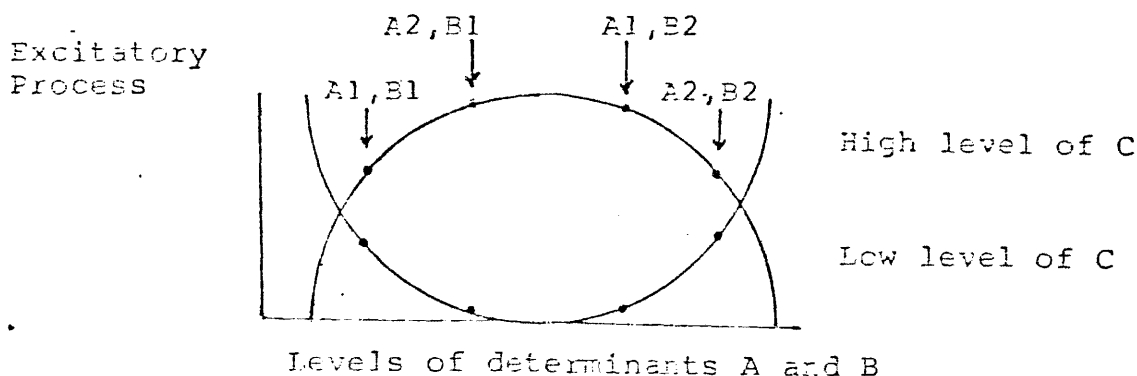


Fig. 15 .A triple interaction which the inverted 'U' cannot accommodate.

This shows a triple interaction between three factors (A, B and C) in which the interaction works for more than one factor. If we consider the joint effect of A and B for each of the two levels of C, we find that we have an interaction of the 'double' kind in each one. Also, the nature of this interaction is opposite at the two levels of C - hence the triple interaction. Clearly the inverted 'U' cannot explain this. We could also have drawn several alternatives involving partial crossover at one or both levels of the factor C, and the inverted 'U' would have been equally unable to account for these. The only form of triple interaction which (in its present form) it can accommodate, is the kind in which the effect of a factor reverses in sign, depending on the levels of the other factors, but where there are no other reversals when these levels are considered separately. An example is shown in Figure 16 overleaf.

Excitatory process

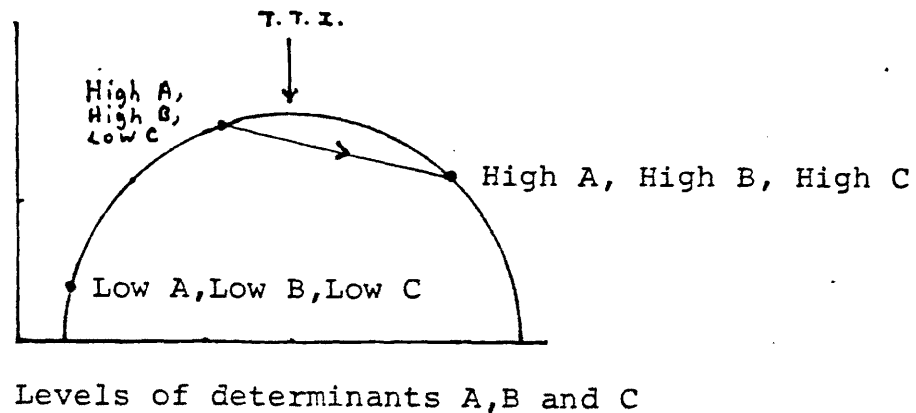


Fig. 16 Atriple interaction which the inverted 'U' can accomodate

Furthermore, even with this sort of interaction the inverted 'U' is very specific about the sort of interaction it will allow. For instance, the interaction must indicate that the group which is expected to be furthest to the right along the 'X' axis (i.e. the group with the highest levels of all three factors) has passed the T.T.I. (as in Figure 16).

It should be clear, though, that where we have three factors (and especially where we have more), there are a great many possible interactions that would not conform in this way to the inverted 'U' hypothesis. So we see that multifactorial experiments provide a very stringent test of the hypothesis and certainly meet Popper's criterion of falsifiability.

(vi) A proposed modification

Above , we mentioned a modification to the theory. Let us now consider this in detail.

Figure 17, below, simply reproduces Figure 1 shown earlier.

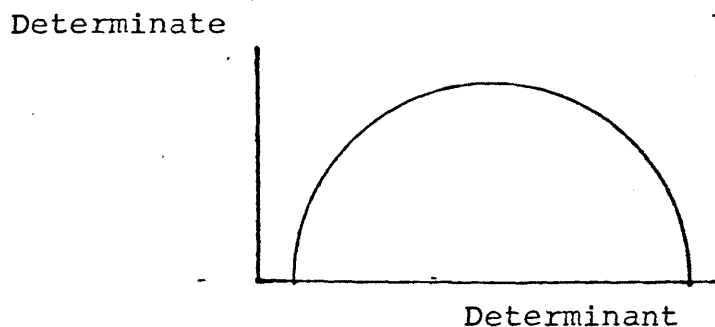


Fig. 17. The empirical relationship between a determinant and a determinate

In such a curve, the gradient progressively decreases as one moves along the X axis until the threshold of transmarginal inhibition (T.T.I.) is reached after which it becomes progressively more and more negative. However, as Gray (1964) points out, this is just an idealised representation and it is very difficult to know the exact form of the curve, since no definitive study has been carried out which varied a single determinant over a sufficiently wide range and measured the determinate directly. The curve as shown is to a large extent an inference from more indirect data. It should be pointed out, therefore, that there is evidence to support an alternative representation (at least over the portion of the curve to the left of the T.T.I.) as follows:

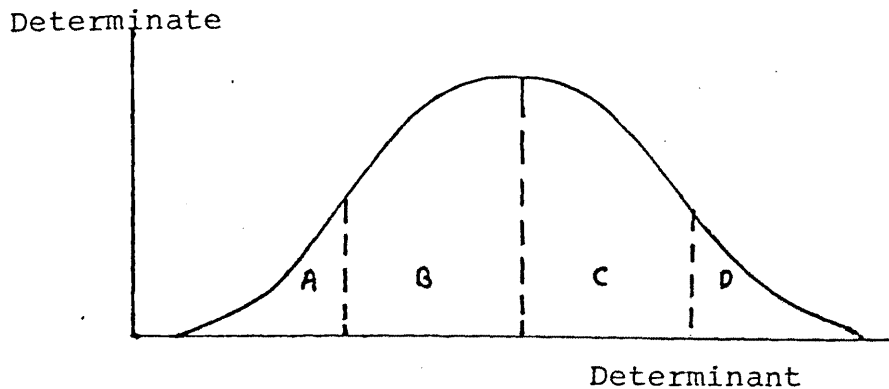


Fig 18 . A modified inverted 'U' curve

The difference is that at both extreme ends of the curve the gradient flattens off instead of steepening. This representation embodies two concepts very familiar to psychologists - namely 'floor' and 'ceiling' effects. The 'floor' effect would operate in portions A and D of the curve and the ceiling effect in portions B and C. The earlier representation would only incorporate the 'ceiling' effect, not the 'floor' effect. (That the former may well be relevant to our present considerations will be illustrated later (for instance, when we come to consider the relationship between the salivary response and level of introversion. See page 188)).

The left hand portion of the revised model is also the sort of 'sigmoid' curve that is used to describe the psychophysical function relating subjective and objective intensity in experiments on the 'just-noticeable-difference'. It, therefore, corresponds closely to the Weber-Fechner law (Wilding, personal communication)

The right hand portion of the curve is more indeterminate, since there are less data relevant to it.

However, the flattening off that occurs at both ends is more intuitively plausible than the earlier formulation. Figure 18 would imply that the level of the determinate suddenly jumps from a zero to a non-zero value, since its slope is steepest at the point at which it cuts the 'X' axis. Equally, at the other end, it implies that it suddenly alters from a non-zero to a zero value. In fact, these extremes are difficult to imagine anyway. We have amongst our lists of determinants factors such as individual differences and drive, and it is difficult to envisage a situation where their value is so low that it results in a zero level of the 'excitatory process', which is, itself, thought to be positively and monotonically related to the level of the determinate. If the determinate assumes a zero value, we could also assume that the 'excitatory process' had become zero. This is, in fact, not logically necessary. We could suppose that in Figure 2b (page 44) the function intersects the 'X' axis at a non-zero value of the 'excitatory process'. If we did this we could also suppose that the curve in Figure 18 did not intersect the 'X' axis, but suddenly came to a stop at a point slightly above it, despite the fact that it is steepest (either positively or negatively) at this point. But it is intuitively more plausible to adopt the revised model in Figure 18 (page 83). This also would have to 'float' above the 'X' axis, somewhat, but the flattening off at both ends would make the overall picture a more realistic one. This is not unimportant, since we shall see that attempts have been made to map the conceptual nervous

system onto the real nervous system.

Finally, the curve shown in Figure 18 conforms more closely to the analysis presented by Heilizer (1975), in which he attempts to show how the Pavlovian concepts of 'excitation' and 'inhibition' and the Western concept of introversion are related to the 'law of initial values' (which, itself, was formulated to explain 'ceiling' and 'floor' effects). The reader is referred to Heilizer's paper for a more detailed account. For our present purposes, the upshot of his analysis is that we should adopt the representation in Figure 18 rather than the one in Figure 17 (page 82).

It is worth pointing out at this juncture that such a modification does not violate the sanctity of the inverted 'U' in any way. The curves shown in Figures 1-3 (page 44) and subsequently, are only idealised representations, in any case. Some of them are based on representations proved by other workers - for instance Figure 2a is based on a similar curve drawn by Gray (1964, page 162), though its right hand half has been extended downwards. Some of the others are less often depicted explicitly in pictorial fashion. They are logical constructs based on empirical data or on theoretical formulations, and the author acknowledges his debt in this area to other researchers, such as Gray (1964, *op. cit.*), Corcoran (1965, *op. cit.*) and Eysenck (1967).

Another modification that one could suggest is that in Figure 3a, which shows the relationship between the level of a determinant and the construct 'arousal', the function might be better depicted as flattening off at

both ends. Again this would be more realistic for reasons we have already stated, but it would not alter the model to any substantial extent, particularly over the middle range, where most of the data are likely to be collected.

A final point that should be made is that we have employed the Russian model so far in our analysis largely as a matter of convenience. We could easily have provided a formulation in terms of the Western model, since the two are conceptually equivalent.

To summarise, the proposed modification to the hypothesis (depicted in Figure 18, page 83) is intuitively more reasonable than the original formulation (depicted in Figure 17, page 82). It also receives theoretical support from the 'law of initial values' and empirical support from a number of experimental outcomes, a point which will become clearer later.

Let us now see what implications the modification has. Portions B and C of the revised curve - i.e. the intermediate portions - are essentially the same as in the original formulation. We can, therefore, retain our previous list of possible outcomes (see Figures 13 and 16, pages 75 and 81). To these we must add, however, the outcomes which would be predicted if we were operating on portions A and D of the new curve - i.e. the appended, flattened extremities.

Consider Figures 13a and 13b (page 75). Here we depicted two possible interactions based on the size of the change in the determinate for portion B and portion C,

respectively. Now consider Figures 19a and 19b below.

Fig 19a. An interaction based on the size of differences for portion 'A'.

Excitatory process

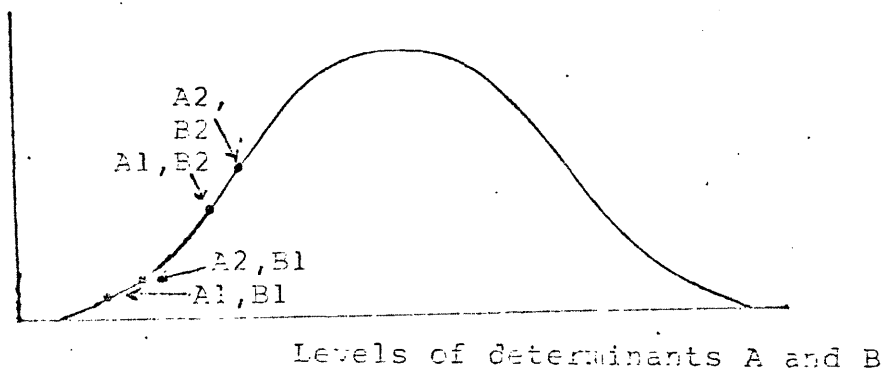
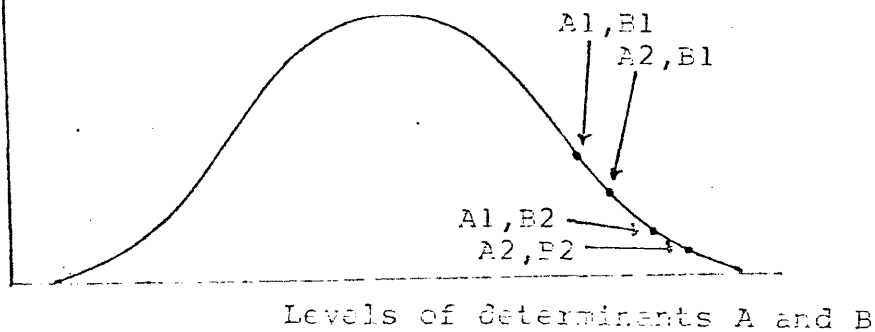


Fig 19b. An interaction based on the size of differences for portion 'D'.

Excitatory process



These represent interactions based on the size of the change in the determinate, but this time for portions A and D, respectively.

It could be argued that these are the opposites of the interactions for portions B and C, respectively. For

instance, in figure 13a, the increase in the value of the determinate is greater in the group placed relatively to the left than in the group placed relatively to the right. The exact reverse would appear to be true of Figure 20a. In this situation, the increase in the value of the determinate is less in the group placed relatively to the left, than in the group placed relatively to the right. This reversal stems from the fact that the curve in portion A is concave upwards, whereas the curve in portion B is convex upwards.

At first glance this would appear to have very serious consequences. Here we seem to have two interactions, both based on the size of the change in the determinate (in both the direction of change is upwards), but which are exactly opposite. Yet both seem to be equally possible on the basis of our revised theory! The latter would now indeed seem to be capable of accommodating all possible outcomes (since a similar argument applies to a comparison between Figures 13b and 20b - i.e. portions C and D) and would, therefore, be derided by Popper as being 'unfalsifiable'. However, we have ignored one vital factor - namely the absolute heights of the curves. The portion B curve is higher than the curve in portion A. This means that in Figure 13a the group on the right not only shows less of an increase than the group on the left, but also is higher than the latter. We could have an alternative interaction in which the relative differences in the size of the increase was the same, but the relative heights were reversed.

Excitatory process

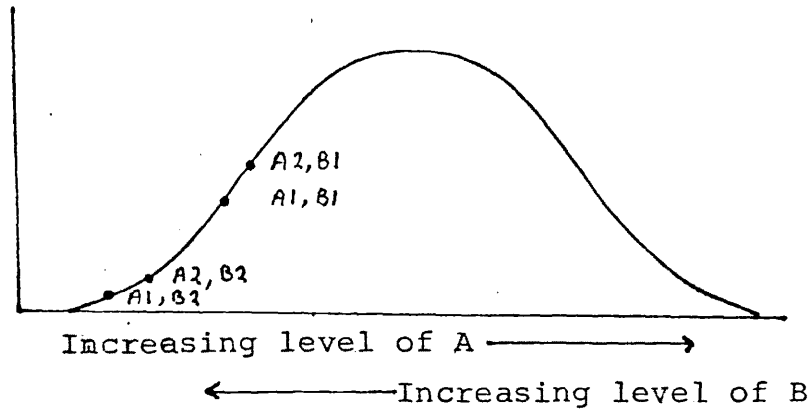


Fig. 20. An interaction between two factors that the model cannot adequately explain

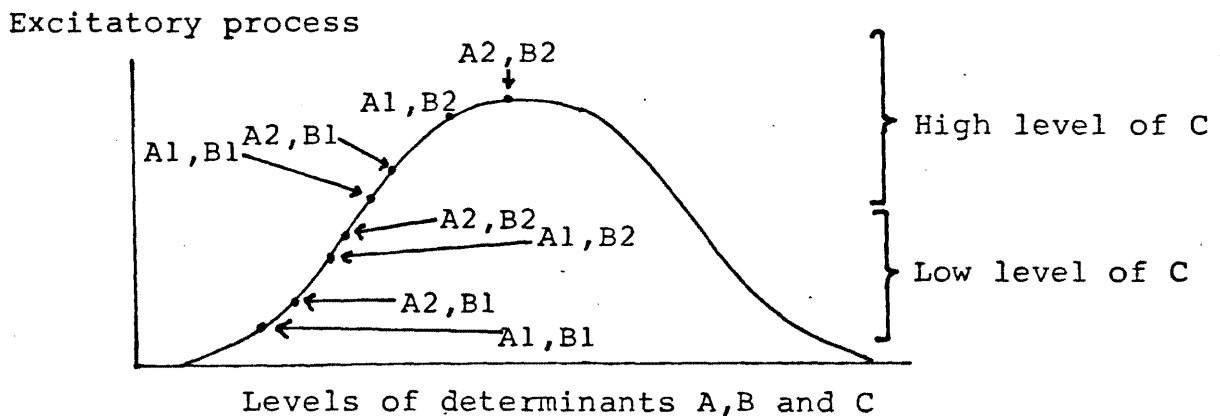
Figure 20 shows an example of such an interaction.

In Figure 19a, though the relative sizes of the differences are reversed compared to Figure 13a, the relative heights are not. For this interaction, there is also a corresponding interaction in which the relative sizes of the differences are the same, but the heights are reversed. We, therefore, have not violated the criterion of falsifiability any more than we did before (and as we saw, then, the degree of falsifiability was equivalent to that of a more usual psychological experiment, in which only one factor is employed).

We do have one problem though. When we considered the earlier formulation of the model we suggested that the interaction depicted in Figure 14 (page 77) was the obverse of that in Figure 13a. We now see that it is identical to that in Figure 19a. So although only half of the total number of possible interactions which we could draw (involving two factors) are consistent with the theory, our revised model shows that some of these are also consistent

with other models. This is not surprising, since with any model (even our earlier formulation of the present model) one could draw alternatives. The important thing is that in this case the alternative (Figure 14) is equally parsimonious. What this shows is that our revised model makes the use of more than two factors even more imperative than before. Consider Figure 21 below:

Fig. 21. An interaction between three factors for the modified inverted 'U' curve



This shows what would happen if we had three factors and both portion A and portion B were involved. We could get a triple interaction based on the size of the change in the determinate. (A similar triple interaction would exist for portions C and D considered together on the other side of the curve). However, if we extended Figure 14 suitably, we could still explain the above triple interaction equally parsimoniously, since the right hand

half of Figure 14 would be identical to the left hand half of our revised model and vice versa. In order to distinguish the two, we need to have an interaction based not on the sizes of differences , but on the direction of differences since the inverted 'U' and the 'U' function in Figure 14 cannot both accommodate these. The former would predict that the group operating on the right would show a decrease, whilst the group operating on the left would show an increase. The latter would predict the reverse. Such an interaction based on the direction of the differences can be obtained, as we have seen, by using only two factors. But it is more likely to occur the more factors we have, since if we ensure that the difference between the two levels of each factor is fairly wide, the effective separation of the highest combination and lowest combination group on the X axis is greater when a large number of factors is involved. Therefore, there will be a greater likelihood that, as a whole, the experiment will straddle both sides of the peak of the curve (or the trough in the case of Figure 14) and that an interaction based on the direction of differences will occur.

(vii) Summary

To summarise, we have argued that the Russian and Western models predict certain types of interaction between various factors and determinates, and we have tried to show what form such interactions would take (and also what form such interactions which would not be consonant with the theories would take). We have suggested a modification to the models involving the addition of two relatively flat

portions at either end of the inverted 'U', and we have argued that this effective prolongation of the parts of the curve which do not encompass its peak, both increases the number of possible outcomes which the theory could predict (without lowering its degree of falsifiability), and also increases the need to employ several factors so that alternative, and equally parsimonious, models can be excluded.

5. THE HYPOTHESIS UNDER ATTACK

We have stated before that there are several considerations, not just one, which make multifactorial experiments desirable. Let us consider some more of these.

In their most general form the Russian and Western models predict that one can explain the effects of various determinants on various determinates by reference to a single intervening construct (though in the case of the Russian model, this is slightly qualified by the postulate of separate 'analysers'; see page 50). This has the great virtue of parsimony. But it is also the point at which the theories have, in recent years, come under the greatest assault. Let us consider first the view that different determinates can be explained by a single intervening construct.

(i) Discrepancies between the determinates

(a) Dual-system theories

We have discussed already Duffy's (1962, op. cit.) concept of a single continuum of 'activation'. Eysenck (1967, op. cit.), in a major reformulation of ideas in this area, criticised this concept and suggested an alternative bimodal theory based on the cortex /ascending reticular activating system and the autonomic nervous system. These two systems are not totally independent and are thought by Eysenck to interact under certain

circumstances. For instance, under conditions of 'strong emotion', Eysenck suggests that activity in the autonomic nervous system may 'spill over' into the cortical system, so that in these circumstances there may be a high degree of concordance between the level of activity in each.

Nevertheless, Eysenck does regard the two systems as being essentially distinct and even suggests that they provide the physiological bases of two independent personality dimensions: introversion (cortical system) and neuroticism (autonomic system). Other workers have also put forward dual-system theories, for instance Claridge (1967) and Routhenberg (1968). We shall consider some of these in more detail later.

For the present, the point to note is that they all reject the notion of a single 'arousal' or 'activation' continuum. We have seen that the two systems which they postulate as an alternative, may, at times, work in the same direction, as in the case of Eysenck's theory.

There is evidence, though, that in certain circumstances, the level of activity in the cortex and autonomic nervous system may actually go in opposite directions

Lacey and Lacey, 1958). Even if we consider the two systems separately, we have further evidence of dissociation or 'fractionation' of different indices within each one. Let us consider the autonomic nervous system first.

(b) The autonomic nervous system

Lacey (1958), for instance, has found evidence for fractionation effects using different autonomic indices. Sternbach (1966) has also described two phenomena in this area which are

also inimical to the concept of a general factor of autonomic activation.

The first of these is 'individual response stereotypy' (I.R.S.) , which refers to the fact that the pattern of activity in the autonomic nervous system in response to a given stimulus configuration depends on the individual subject being tested. Some subjects, for example, show their maximum response in heart rate measures, others in skin conductance measures, etc. We will see that both the Russian and the Western models do incorporate individual differences, but the degree of specificity and idiosyncrasy embodied in the concept of I.R.S. , is far greater than such models can accommodate , since they are based on broad dimensions of individual differences, not patterns specific to given individuals. The phenomenon, of course, has the unfortunate consequence, therefore, that attempts to test such theories using only one or two physiological measures may produce widely differing results, depending on both the measures and the subjects chosen. Fowles et al (1977) have, for example, reviewed the highly conflicting findings relating introversion to skin conductance measures. This is one reason why, by and large, we have not attempted to use physiological measures in the present project and where we have used them our interpretation of the results has been tempered by our awareness of the above phenomenon.

This caution is further enhanced by a consideration of the second feature described by Sternbach - namely 'stimulus-response specificity' (S.R.S.). This means that

the pattern of response shown by an individual is not only dependent on the I.R.S. factor, but also on the particular stimulus configuration to which he is subjected. This at first glance seems fairly plausible, intuitively, and not necessarily inimical to our models. It is not always appreciated fully that models which incorporate an inverted 'U' function do, by their very nature, involve a certain element of situation specificity, since the effect of any one factor (such as an individual difference parameter - e.g. introversion: see later) will depend on which part of the inverted 'U' one is operating on. This follows from our idea that the various determinants can all be represented along the X axis of a single inverted 'U' curve - i.e. that the position on this axis depends on some composite measure of the levels of the various determinants. So the effect of any one determinant will depend on the levels of the ^{other} determinants.

However, the sort of situational specificity that is embodied in the concept of autonomic stimulus-response specificity (and also in the theories of men like Mischel, 1968) is far greater than the models, in their present form, can handle.

(c) The cortical system and the phenomenon of 'partial properties'.

If we now consider the cortical system, we find similar effects. Evidence for this has come partly from Western work on personality.

We will see when we come to discuss studies relating personality to sensory threshold, for instance, that the picture is a very mixed one, with the correlations with personality measures varying in size (and sign often) from one study to another. It could be argued that this is due to the large number of factors which also vary from study to study e.g. modality, method used to measure threshold, method used to assess personality, sex, plus other unknown factors. Certainly, as we have seen, the inverted 'U' does predict that the effect of a given variable (such as introversion) will depend on which portion of the curve one is operating on and this in turn will depend on the levels of other determinants.

It is not impossible that some of the variables mentioned above (e.g. modality) may indeed be determinants of the level of 'arousal' or the 'excitatory process'. But if so it would have important implications, since it contradicts the view that a given individual can be said to have a single level of the 'excitatory process' or 'arousal' if other factors (e.g. stimulus intensity) are kept constant. Certainly this is what the ideas of 'arousal' theorists who postulate a single central 'arousal' mechanism such as the A.R.A.S., would imply. Also, Russian theorists do recognise that there are separate cortical sensory 'analysers' , but until recently the degree of 'strength' of one was thought to correlate with that of another. However, increasingly the

phenomenon of 'partial properties' - i.e. the failure of a given index of strength to correlate significantly between sensory modalities - is being recognised. For instance, Nebylitsyn (1957) found that there was an insignificant correlation between the sensory threshold in vision and audition (see Gray, 1964, for a complete review). Nebylitsyn argues that the phenomenon only appears in a minority of subjects and Gray (1964) has suggested that it may be an artefact due to the chance distribution of successes and failure on response measures, exhibited by individuals of intermediate degree of 'strength'. However, Strelau (1972) is of the opinion that the phenomenon of partial properties is a real one which cannot be ignored. He does, however, propose that it is not necessarily incompatible with the idea of a general level of 'strength' - i.e. the notion that we can ascribe to each individual a single number which will represent the level of the individual differences determinant, though we may also have to postulate the existence of more specific 'strength' factors. His model is in many ways analogous to the hierarchical models of intelligence (see Butcher 1963) derived in the West from factor analytic methods and involving a general ability factor as well as individual ability factors which load on it. Perhaps factor analytic studies of the sensory threshold could help resolve the issue.

Certainly the results could be explained if one assumed that there may be a central level of cortical

'arousal' or 'excitatory process' but that this is determined by the input from the individual peripheral sensory organs whose sensitivity may vary independently and not correlate with each other. Individual differences in sensitivity may arise at a central level also, although it is worth mentioning at this stage a study carried out by Pfaffman (1971). This showed, firstly that the fall off in subjective sensation due to a taste stimulus, paralleled the fall off in the discharge in the peripheral chorda tympani nerve. But it also showed that the exponent of the function relating the concentration of the stimulus to the 'magnitude estimate' (see pp. 191-2) was the same as the exponent of the function relating stimulus concentration to the neural peripheral response and that this response varied linearly with the amplitude of the post synaptic potential evoked in the cerebral cortex. Pfaffman concluded that there was no need to assume that central mechanisms seriously alter the input.

All of these findings, taken together, make essential a serious reappraisal of the view that the effect of a given set of determinants or several different determinants can be predicted by assuming the existence of a single intervening construct.

(ii) Discrepancies between the determinants

Let us now consider the other side of the coin - namely, the view that one can predict the level of a given determinate by assuming that it is dependent on the conjoint action of several determinants in accordance with

the functions depicted earlier. In other words, that the level of a given determinate depends on the position one occupies on the X axis of a single inverted 'U' curve, which itself depends on some composite sum of the levels of several determinants. Up to now we have presented and manipulated this idea and tried to show what it would imply. But we have not criticised it seriously, except insofar as it sometimes makes it difficult to know exactly what picture to draw to represent a given set of results (for instance, due to the indeterminacy of the position of some intermediate groups). This, however, did not prove that the theory was wrong, simply that there were several interpretations of it, all of which were equally consistent with the empirical findings.

We also were at pains to point out that there were several alternative empirical outcomes which would be at odds with the theory. At that time we took this as an argument in favour of the theory, since it made it falsifiable. However, it is, of course, a two-edged sword and, as we shall see, there are many examples of cases in which a given set of determinants have failed to produce the predicted interaction effect on a given determinate, either because the results were non-significant, or, more seriously, because the interaction was in the opposite direction to that predicted.

(iii) A statement of intent

Our main purpose in the present project will be to take some of these recalcitrant indices, which have posed such problems for the models in their general form, and in each case to suggest possible reasons why this might be so, and to conduct experiments to test these ideas. Our basic plan is to test the theory at the points where it seems to be weakest. The rationale for this is that, to the extent that it is possible to provide support for a theory, one would serve this cause best by showing that the evidence which seems most damaging to it is perhaps amenable to an alternative interpretation which is still consonant with the theory, if not in its exact original form, in a revised form. On the other hand, one could look at it from the standpoint of someone who wishes to disprove the theory. If Popper is right and theories can never be verified, only falsified, then this would be perhaps the only position to take. Again, though, to concentrate on the weakest points of the theory would be the best approach.

However, one qualification should be added. Although the theory in its original form is a general one, it has no pretensions to being able to encompass the entire universe of facts. Such a claim would be absurd. It is assured to operate within a certain circumscribed area (which we will attempt to define when we come to consider the list of determinates and determinants). The fact that this area is nevertheless a large one is the basis for the statement that the theory is a general one.

However, we have not tried to test it in areas where its competence to deal with the facts has never been claimed, or where the evidence is overwhelmingly against it. We would regard such an exercise as both perverse and a waste of limited time and resources. Equally, we would regard it as inefficient and unproductive to test the theory in areas where its competence to deal with the facts has never been questioned. This is not to decry the need for such replication under other circumstances. However, as we have tried to show already (and will show further), the theory is in urgent need of re-assessment and we regard this need as more pressing than the need to consolidate its hold on undisputed territory or extend its dominion over, as yet, unexplored terrain.

We have, therefore, chosen measures for which the existing data are encouraging enough to suggest that the theory may be salvagable, but which are also sufficiently at odds with the theory to make this by no means a foregone conclusion.

The same arguments have dictated our decision to look at the aspect of the theory which predicts the conjoint influence of several determinants on individual determinates. The other aspect which predicts that the influence of a given set of determinants, will be similar using different determinates, is one^{to} which we hope to be able to address ourselves at various points along the way. But we have not designed the project with the aim of providing a rigorous test of it. Indirectly, of course, we will inevitably touch on it, since we are going to look at more than one determinate, so that how the theory

fares in each , individually, will give some indication of the tenability of this aspect of it. However, we have not attempted to, for instance, look at the inter-correlations between several autonomic indices. This is because we regard the case against the theory in areas such as this as largely proven already. In its original 'pure form', at least, it is unlikely to be able to accommodate the associated findings. However, such failure has not led to a total abandonment of all the principles on which the theory is based. Instead we have had a regrouping of the determinates. We described earlier how some theorists separated them into cortical and autonomic camps, though as we have seen further categorisation within each of these may be necessary.

It is likely that if the theory , in its original form, fails to account adequately for the conjoint effects of several determinants on individual determinates, a similar regrouping process may be necessary. This is perhaps the main reason why multifactorial experiments are so necessary - i.e. to show which particular sets of determinants (if any) act together in predictable ways. Furthermore, as with the regrouping of the determinates, the pattern of 'clustering' may give us clues as to the way in which the nervous system functions.

(iv) Physiological measures

It is at this point that we should, perhaps, consider the relationship between the conceptual and the actual nervous system. So far we have been concerned mainly

with the former, and as Gray (1972) has pointed out, it is not logically necessary that we should try to relate the two together. It is, however, desirable. Firstly, because there is a large body of results which relates specifically to physiological data, so that if we could combine it with other more behavioural data into a single framework, we would have a more parsimonious overall theory.

Secondly, we may wish not only to 'explain', but also to 'exploit'. We will, in the conclusion to this thesis, consider the implications it has for applied areas, such as clinical and occupational psychology. Clearly in such areas, particularly the former, one would like to know what the underlying physiological mechanisms are, since this will have implications for our attempts to control or modify them.

In some ways, however, the relationship between the conceptual and the physiological nervous system in this area is an uneasy one. Gray (1964) has pointed out that workers in the West have often taken autonomic indices (such as heart rate, skin conductance etc.) to be direct measures of 'arousal'. If we look back to Figures 1-3 (page 44) we see that both 'arousal' and the 'excitatory process' are hypothetical intervening variables. However, as Gray has argued, since the 'excitatory process' is presumed to be essentially positively and monotonically related to the level of the determinate, we can infer changes in its level directly from the latter.

'Arousal' is thought in the West to have an essentially positive and monotonic relationship with the levels of the determinants. However, the situation is not an entirely symmetrical one. This is because, in any one instance, we will have only one determinate to infer the level of the 'excitatory process' from, but we are likely to have several determinants from which the level of 'arousal' must be inferred. We have seen already that these determinants can be represented as some composite measure on the 'X' axis of Figure 2a (page 44). We also argued that a corresponding argument could apply to the Western model, so that we could also represent this composite measure on the 'X' axis of Figure 3a. However, we have seen that the exact value of this composite measure for different combinations of these determinants is, to some extent, indeterminate.

It is, perhaps, not surprising, therefore, that workers in the West have looked for direct indices of the level of 'arousal', and we have seen that they have generally turned to autonomic measures. But we also argued at some length that these measures do not always correlate with each other, and that the results which one gets, depends to a large extent on our choice of measures and our choice of subjects. The problem that has in fact bedevilled the whole area of 'arousal' is that there has been no agreement as to its definition and so much of the controversy in this field is essentially a semantic one. Because of the plethora of definitions, the 'arousal' area is also a vast one and

we have made no attempt to provide a comprehensive review of it. (See Gray , 1964, pages 290-296, for an analysis of the different uses to which the word 'arousal' has been put). Instead we have attempted to circumvent the problem raised by the ambiguity of the term, by returning to the basic motive which led to its being coined - i.e. the need to explain a large body of disparate data with reference to a relatively parsimonious model, embodying a minimum of postulates. We have tried to show the way in which both the Russian and Western models have attempted to meet this need, and our purpose here is to try to assess how successful they have been in one area in particular - i.e. in explaining the conjoint effect of various determinants on individual determinates.

The important thing is that nearly all the determinates we will be considering belong to the cortical 'camp' rather than the autonomic one (with a few exceptions). That is not to say that the autonomic nervous system cannot influence them, but since they are nearly all based on the subject's voluntary report of his perceptions (either through a verbal or behavioural response), one would expect their primary seat to be the cortex. If so, then the use of autonomic indices to provide a direct measure of 'arousal' is not really valid. Not only do these indices fail to correlate with each other, but they also often do not correlate with cortical measures, whether the latter are physiological (*Lacey and Lacey op.cit.*) or behavioural. One very good example of the latter kind is a study by Kishimoto (1978), which we will discuss in

detail in the section on vigilance. This found that the variables introversion and signal frequency interacted in a way that was predictable from the inverted 'U' , but that physiological measures of skin conductance did not correlate with performance. If one had on an a priori (and arbitrary) basis decided that skin conductance measures provided a definitive measure of 'arousal' , we might have been forced to reject the 'arousal' theory.

It could be argued that in this situation the best policy would be to use cortical physiological measures (for example E.E.G. and evoked potentials) rather than autonomic ones. This would certainly be a most useful exercise, for reasons we have already stated (i.e. the need to relate the conceptual and the physiological nervous systems to each other). However, there is another reason why such indices would be valuable. Subjective report depends not only on sensory factors, but also on certain response - related factors such as the subject's 'criterion' (Green and Swets, 1974). We shall devote considerable attention to this point and attempt to use non-physiological methods of getting round the problem. However, the use of E.E.G. or evoked potentials would certainly be another form of approach. Unfortunately, ^{practical} problems prevented the present author from employing them.

These problems aside, there is an important theoretical point to be made. To use such measures alongside our behavioural ones would have been interesting and important, but just as with the autonomic measures, if the model was confirmed at the behavioural level, but the measure failed to show predicted relationships with the

physiological indices, these would not be grounds for rejecting the theory at the level of the conceptual nervous system. We would have to revise our notions of the relationship between the latter and the physiological nervous system, but the fact that the various determinants did interact in a predictable way would be an important one in its own right. Equally, if the model failed at the behavioural level, but nevertheless the measures showed relationships with the physiological indices, we would still have to revise it at the conceptual level.

To conclude then, we regard the conceptual and physiological nervous systems as being logically distinct. It is highly desirable, nevertheless, to try to relate them and, wherever possible, we will do so.

However, due to practical problems which made the actual use of physiological measures, for the most part, impossible, such an endeavour will inevitably be only indirect.

CHAPTER TWO - THE DETERMINANTS AND DETERMINATES

Let us now consider the list of determinants and determinates in more detail.

1. THE DETERMINANTS

Table 1. The determinants of 'arousal' and the 'excitatory process'

<u>Arousal</u>	<u>Excitatory Process</u>
Stimulus Intensity	Stimulus intensity/duration/frequency
Drugs	Stimulant drugs
Accessory stimulation of a non-relevant sensory modality.	Accessory stimulation of a non-relevant sensory modality
Drive	Drive, hunger
Novelty	Fatigue
Fatigue	Individual differences
Individual differences	

The above table is based on Gray (1964), though similar lists have been provided by other workers - e.g. Haslam (1972). 'Accessory Stimulation of a non-relevant sensory modality' is a factor which was not included in Figures 4 and 5 earlier (page 52), but Gray has argued that it produces predictable effects (and we will see more evidence for this later), so it has been

included.

i) Stimulus intensity and associated factors

There are some differences between the list of the determinants of 'arousal' and the list of the determinants of the 'excitatory process'. For instance, stimulus duration and frequency are regarded within the Russian model as being functionally equivalent to stimulus intensity. The assumption is that the excitation produced by a prolonged stimulus is greater (initially at least - i.e. before the threshold of transmarginal inhibition, has been passed) than that produced by a shorter duration stimulus. This is thought to be analagous to the fact that the excitation produced by a high intensity stimulus is greater, initially, than that produced by a low intensity stimulus. Also, assuming that the inter-stimulus interval is short enough for the excitation from a stimulus to summate with the excitation from the preceding stimulus, before the latter has faded away (Gray 1964, page 165), stimulus frequency is also thought to act in an analagous way to stimulus intensity. The greater the stimulus frequency, the shorter the inter-stimulus interval and the more likely it is that such summations will occur. Also, if it does occur, the shorter the inter-stimulus interval the higher the level of excitation of the preceding stimulus when the next stimulus arrives (assuming that such excitation does indeed rise and then fall gradually with time) and, therefore, the greater the total excitation. However, when the stimulus is very prolonged

or stimulus frequency is very high, the threshold of trans-marginal inhibition is passed and a decrement in response occurs (as with high levels of stimulus intensity). In fact, due to the problems associated with the use of very strong stimuli, particularly in humans, many of the classical indices or 'strength' have employed stimulus duration or frequency, instead of stimulus intensity, to take the subject beyond the threshold of transmarginal inhibition (an example of this is the method of extinction with reinforcement of the photochemical reflex - see pages 134-5).

In the West, stimulus duration and frequency have not been related to stimulus intensity in such an explicit theoretical way, but we shall see that they have been used experimentally and the results have often been similar to those of studies which used stimulus intensity.

It should be pointed out that a certain ambiguity does exist in the terms 'stimulus duration' and 'stimulus frequency'. In the case of the latter, the phrase is sometimes used to refer to the pitch of an auditory stimulus and sometimes (as we have seen) to the number of stimuli presented per unit time. (It could also refer to the wavelength of a light stimulus, since this is inversely related to its frequency. Subjectively, of course, such differences manifest themselves as differences in colour - within the visual range at least. This factor has only rarely been studied in this context). Studies of the pitch of auditory stimuli have shown that it acts in an analagous fashion to stimulus intensity (see Stelmack and Campbell 1974). As we shall see when we discuss 'vigilance',

the other meaning of the term 'stimulus frequency' carries more problems with it. Firstly, in vigilance-type experiments there are often two types of stimuli : ones to which the subject has to respond ('signals') and ones to which the subject is instructed not to respond ('non-signals') . Independent manipulation of the frequencies of these two is not easy because both are related to another factor: i.e. the probability that a given stimulus will be a signal (see later). But, even where attempts to look at their separate effects have been made, often very differing results are found. This is possibly due in part to the fact that both signal and non-signal frequency (particularly the latter) are related to another determinant - i.e. novelty. The greater the frequency, the more quickly this factor decreases and, therefore, the faster the habituation rate. We will discuss this point in greater detail later.

A similar problem applies to the term 'stimulus duration'. Again this has two possible interpretations. It can refer to the duration of a single stimulus, and as with stimulus frequency, when used in this sense it has often produced analagous results to the stimulus intensity factor (e.g. Sanford 1972). However, it could also be construed as referring to 'time on task' - i.e. the length of time that has elapsed since the beginning of the task. Of course, there are many stimuli impinging on a subject in a psychological experiment, not just one, but there are many aspects of the total stimulus configuration which will remain relatively constant, so again stimulus duration, per se is confounded with the

novelty factor. This is not the only problem associated with this particular interpretation of 'stimulus duration', but we will consider it again in more detail under the heading of 'vigilance'.

ii) Drugs.

In the Soviet Union, stimulant drugs, such as caffeine, are the main ones that have been used. The results have often been interesting and we will refer to them as the occasion arises (e.g. in connection with reaction time). However, Gray has pointed out that there are certain theoretical difficulties associated with the use of caffeine in Russian studies -- the reader is referred to his account for more details (Gray, 1964).

In the West, caffeine is less widely used than in the Soviet Union, though there are exceptions (e.g. Revelle et al 1976).

Other stimulant drugs, such as amphetamine, are more commonly used in the West. In addition, depressant drugs such as barbiturates have figured in a number of studies, and their effects have been interpreted as evidence that they move the subject in the opposite direction, (compared to the stimulant drugs) along the 'X' axis of the inverted 'U'. Stimulant drugs are presumed to move subjects to the right, whilst depressant drugs are presumed to move them to the left (see Eysenck 1967 for a review of some of the studies).

For our present purposes, drugs, unfortunately, are not a practically viable proposition as their use is

governed by strict codes of practice requiring the attendance of suitably qualified practitioners and adequate recovery facilities for the subject. Neither of these were available to the present author and so our treatment of this particular determinant has had to be limited to the theoretical level.

iii) Accessory stimulation of a non-relevant sensory modality.

We have already considered accessory stimulation briefly. Its use, like that of certain other factors we have considered, is influenced by a certain degree of ambiguity. In addition to its 'arousing' effects, it is often considered to be a potentially distracting factor for the subject. In some cases authors have attempted to assess what the joint effects of these two aspects might be (e.g. Claridge 1967 in relation to the 'Stroop' task). Others have treated the performance decrement that can occur, due to the effect of accessory stimulation if it takes the subject beyond his T.T.I., as equivalent to 'distraction' (e.g. Siddle and Mangan 1971). In this case they are effectively trying to treat the two aspects ('arousal' and 'distraction') within the same framework (i.e. the inverted 'U'). Whether this is in fact possible is a point to which we will address ourselves later.

For the present, we would simply like to state that despite the possible ambiguity associated with the use of accessory stimulation, in this particular instance we regard its virtues as being sufficiently great as to warrant

its use. Such virtues arise partly out of its practicability (it is fairly simple to use requiring very little complicated equipment), and partly out of the fairly impressive body of experimental work associated with it. This has often (though not always) shown that it has effects which are predictable on the basis of the inverted 'U' and, in addition, it has a clear relevance to occupational settings in which subjects often perform in the presence of extraneous stimulation.

iv) Drive

Drive is a more problematic determinant. This is because the term has been used in many different contexts so that even if at the physiological level these all can be represented in terms of a unitary factor, one would expect the level of this factor to depend on a very large number of influences, some of which would be extrinsic to the organism and others intrinsic. Yet others would depend on the interaction of the two. Extrinsic factors would include any manipulation which might be expected to influence the level of 'motivation' (for example, the presence of feedback (Mackworth 1970), or performance - contingent rewards (Evans 1975)). However, feedback might be expected to have direct effects on performance, due to its informational aspect as well as effects mediated via an incentive mechanism (though in the field of vigilance, at least it appears that the latter may be the primary factor).

Also the effect of rewards would be expected to depend

on the nature of the reward and this might itself interact with organismic factors. Furthermore, performance in a task may be intrinsically rewarding and it would be very difficult to assess the importance of such an effect in different subjects , and also in relation to overt rewards that the experimenter might supply.

In addition, Gray (1971) has argued that susceptibility to reward (and also punishment) is a psychological dimension in its own right, and one which may be related to personality factors, such as introversion and neuroticism. We will see below that these are factors which can themselves be included in the list of determinants under the heading of 'individual differences'. So the 'drive' factor is inevitably confounded with the individual differences factor.

Another respect in which drive could be expected to depend on the interaction of extrinsic and intrinsic factors, is in relation to hunger. This might be expected to contribute to drive by providing internal stimuli (Miller 1959) , and it is, in fact, included with drive in the list of determinants of the 'excitatory process'. However, the level of hunger would be expected to depend not only on the recent feeding history of the subject, but also on his prior physiological state (e.g. the level of glycogen stores etc.).

We see then that the level of drive would be expected to depend on a multiplicity of factors, and since some of these would come under the heading of 'individual differences' , it is not - in some of its aspects, at least - distinct from other determinants.

As we have already seen, the attempt to combine several determinants on a single 'X' axis introduces a certain level of indeterminacy. We consider that attempts to manipulate drive using extrinsic factors such as feedback would add to this uncertainty, both because these would not be the only factors contributing to its level, but also because their effect might interact (in ways which would not be predictable from the inverted 'U' model) with intrinsic factors which would not be under the experimenter's control. For these reasons we decided against its use in the present project.

That is not to say that it does not influence the results, and its susceptibility to a wide variety of influences makes it a source of variance in a study such as this. The author has tried to minimise such variance by, for instance, not using performance - contingent reinforcement.

v) Novelty

Novelty is a factor which has been included under the list of determinants of 'arousal', but not the 'excitatory process'. This is because the above table is based on Gray's account and in the latter such a disparity exists. However, Gray himself argues that the novelty factor is implicit in the Soviet experimental work (Gray 1964, page 297). This is because the technique involved in testing for the appearance of

transmarginal inhibition in Russian studies involves not only an increase in stimulus intensity, but also a change in stimulus intensity.

However, even if the stimulus intensities are randomised, novelty is still, as we have seen, a factor which is confounded with stimulus duration and stimulus frequency, when these are interpreted as meaning 'time on task' and 'number of stimuli per unit time', respectively. It is also confounded with another factor which is not included in the list of determinants, but which might be expected to be important in some of the tasks which we will be considering. As time on task increases, novelty would decrease, but the time during which learning effects could have taken place would also increase.

In view of these problems, it might be thought that novelty would not be a good factor to employ. Actually in the present project it has been possible to look at the effect of novelty in many cases without introducing any extra manipulations, simply because the experimental design was amenable to this (for instance in some cases where more than one experimental session was employed). In other cases, we have considered its influence precisely because we felt that its relationship to some of the other determinants was partly at the root of the discrepancies that existed in the literature. An example of this is the area of vigilance.

vi) Fatigue

This is another determinant whose nature is difficult to assess. The reason for this is that the term could be included in the stimulus or the response category. If, for instance, we look at the effect of a factor such as sleep deprivation, we could assume that, all other things being equal, a high level of sleep deprivation is equivalent to a high level of 'fatigue'. This would involve including the term in the stimulus category and regarding it as a determinant.

On the other hand, we could interpret the decrement in the level of a determinate, which is consequent upon a high level of sleep deprivation, as an example of fatigue. If so, we would be including it in the response category and regarding it as a determinate.

Welford (1972) has also argued that it is a debatable question whether 'fatigue' effects are manifested at the left hand extreme or at the right hand extreme of the inverted 'U' X axis. Above we have assumed the former. However, we could regard transmarginal inhibition as involving fatigue. Again we could treat it as a determinant in which case it would not be a factor in its own right, but simply a label for one or more of the other factors operating at a sufficiently high level to produce transmarginal inhibition. Alternatively, we could include it in the response category (i.e. treat it as a determinate) and regard the phenomenon of transmarginal inhibition itself as an example of fatigue.

We thus have a very confused picture. Much of the confusion is due to semantics pure and simple: it is a question of definition. However, if we do wish to afford 'fatigue' a place in the list of determinants as a separate factor in its own right, the best approach would perhaps be to regard it as synonymous with the level of a factor such as sleep deprivation. It is this convention that will be adopted here, though we acknowledge that it is somewhat arbitrary. We have chosen it because it does avoid ambiguity and because sleep deprivation is a factor which is often employed in this area. Other possible candidates, such as the effect of preceding activity, are much less commonly employed - though, of course, as time on task increases the amount of preceding activity also increases.

However, this choice does not solve all our problems. As many workers (e.g. Hebb 1955; Kjellberg 1977) have pointed out, the effects of sleep deprivation cannot be incorporated into the inverted 'U' framework in a simple way - i.e. by assuming that it moves the subject to the left along the X axis. There is evidence, for instance, that sleep deprivation interacts with other factors (e.g. task complexity) in a way which is not predictable on this basis alone. For this reason, we have not attempted to manipulate it in the present experiment (it would have been difficult to do so on practical grounds as well).

vii) Individual differences

In Table 1, above, (page 110) this factor was common to the lists of the determinants of 'arousal' and the 'excitatory process'. However, the methods used to define these differences are not the same. Let us consider first the Russian work.

a) Individual differences as a determinant of the 'excitatory process'.

In the Soviet Union it is proposed that even if the levels of all other determinants are kept the same (e.g. stimulus intensity), the level of the 'excitatory process' (and therefore the level of the determinate which is positively and monotonically related to it) will differ. As a result of this, if one of these determinants is varied, the threshold of transmarginal inhibition (T.T.I.) will be reached sooner in some individuals than in others. This means that it is possible for certain individuals (defined as 'weak') to show larger response magnitudes than other individuals (defined as 'strong') when the levels of the determinants are relatively low. But also, as the levels of the determinants are increased, it is possible for the 'weak' individuals to pass the T.T.I. earlier than the 'strong' ones and thus exhibit lower response magnitudes than the latter. Such differences thus define a dimension of 'strength' of the nervous system.

A response index (e.g. the 'extinction with reinforcement of the photochemical reflex') which exhibits the characteristics of the curve described above is

then often used to divide individuals into a 'strong' and a 'weak' group and these individuals are then tested using a different response index (e.g. 'the induction method') to see if they will show similar behaviour relative to each other as they did on the first index.

This has frequently been found to be the case and ^zRohdestvenskaya (1960) conducted a factor analysis on a number of such indices and found good evidence for a unitary factor of 'strength' upon which the individual indices had loadings. This factor analysis has been criticised by Cattell (1972) on a number of grounds (e.g. because of the small number of subjects used), but its findings have been confirmed by a number of other workers (^yNeblitsyn 1963^a; Nebylitsyn et al. 1965; ⁴Turovskaya 1963).

One of the indices used in the factor analysis was the absolute sensory threshold measured by the method of limits. This has been interpreted as indicating that 'weak' individuals are more sensitive than 'strong' ones to weak intensity stimuli. Owing to the particular method used this interpretation will be questioned later, but for the present it is mentioned as an empirical discovery.

Finally, it should be noted that although most of the indices used in Russia and Eastern Europe have been experimental, a questionnaire measure of strength has recently been developed (Strelau 1972). Its use, however, up to now has not been widespread.

b) Individual differences as a determinant of 'arousal'.

In the West, unlike the Soviet Union, questionnaire measures are widely used, and a number of the resulting dimensions have been linked to 'arousal'. Principal amongst these is 'introversion/extraversion' (I), and Eysenck (1967) has presented a case for saying that at given levels of the determinants introverts are more highly 'aroused' than extraverts. In view of this Gray (1967) has proposed that introverts have 'weak' nervous systems and that extraverts have 'strong' ones. The rationale for this is that if introverts have a higher level of 'arousal' (i.e. are more 'arousable') they will be operating further to the right along the 'X' axis of Figure 3a (page 44), and this is regarded as functionally equivalent to the X axis of Figure 2a. If so then the T.T.I. of introverts will be lower than that of extraverts, and on the basis of our above definition, this would mean that introverts have 'weaker' nervous systems than extraverts.

There are a number of other personality dimensions which have also been proposed as determinants of 'arousal'. Principal amongst these is 'neuroticism-stability' (N), and compared to introversion-extraversion this has been largely ignored. There is, however, a growing body of evidence to suggest that it is involved. For instance, Woodhead (1969) has shown that the performance decrement, ^{at very high levels of accessory sensory stimulation,} which is characteristic of 'weak' and 'overaroused' individuals

(by definition), is exhibited by both introverts and high N subjects. Also, Gracz (1977) has shown that there is an inverted 'U' relationship between skin resistance before a race and performance during that race, and that skin resistance is related to neuroticism. In addition, Satinder (1976) has related 'strength' to ^oemotionality in rats and emotionality has itself frequently been linked to neuroticism (e.g. Eysenck, 1967).

It is possible that a certain amount of situation specificity may operate here. Keuss and Orlebeke (1977) have pointed out that a number of studies which have demonstrated 'overarousal' in the West (Malmo 1959; Standish and Champion 1960; Berry 1962) have involved an element of 'threat' and it may be in these situations that high N subjects behave like 'weak' individuals, who otherwise may be identified with introverts. Eysenck (1972) has also suggested that simple tests of sensory thresholds may correlate with introversion, whereas tests of distraction or tests involving 'overloading' of nerve cells may relate to neuroticism.

However, in a number of situations both introversion and neuroticism seem to be acting together and may often interact with each other and with other experimental variables. For instance, Broadbent and Gregory (*unpublished*) have shown that the direction of the correlation of performance with introversion under 'noise' conditions may reverse depending on the value of neuroticism (N). Also White et al. (1969) showed that 'weakness' of the nervous system was related to both introversion and

neuroticism. Their analysis was mainly correlational but an analysis of variance might have revealed an interaction. In a later study (White and Mangan 1972) the authors review a number of experiments showing that N is related to the level of the 'excitatory process', and they put forward a number of suggestions as to its relationship to 'strength'. For instance, the latter may be oblique to introversion and neuroticism.

This suggestion would fit in most elegantly with Gray (1970)'s hypothesis that a dimension of 'arousability' and 'anxiety' lies oblique to I and N. Spence and Spence (1966) have indeed shown that anxiety is related positively to the level of introversion and neuroticism (particularly the latter). Furthermore, at the physiological level anxiety is thought to be represented by the 'behavioural inhibition system' (Gray, 1976), part of which includes the ascending reticular activating system (A.R.A.S.) which a number of workers have related to cortical 'arousal' (see Eysenck 1967 for a review). In terms of physiology there are alternatives. Eysenck (1967) relates N to the level of activity in the autonomic nervous system (A.N.S.), and I to the level of activity in the A.R.A.S. However, he points out that both systems influence cortical arousal under conditions of emotional arousal, (see page 94). White and Mangan (1972) in fact suggest that in the latter instance it may be N which is responsible for determining the level of the 'excitatory process', (this fits in with some of the points made earlier), whereas at lower levels of emotional

'arousal' both I and N may play a part (although the authors confess that there is no evidence in their data to support this). Finally, they raise the possibility that the space relating 'strength' to introversion and neuroticism may be three dimensional and the relationships curvilinear.

In addition to the studies mentioned above there have been many others showing an interaction between I and N (e.g. Eysenck 1955; Costello 1957; Claridge 1960; Franks 1963; Rechtschaffen et al. 1960) and a number of authors who have suggested mechanisms for such an interaction (e.g. Claridge 1967).

Gray (1967.) did in fact mention the possibility that N might be related to 'strength' and though, since then, a number of studies have supported the hypothesis that 'introversion' = 'weakness' (e.g. Shigehisa, P.M. et al., 1973; Frigon 1976) the above review shows that N is a variable which can no longer be ignored.

c) The relationship between personality and 'strength' of the nervous system: a theoretical appraisal

We therefore have the hypothesis that introverts have 'weaker' nervous systems than extraverts and also the hypothesis that high N subjects have 'weaker' nervous systems than low N subjects.

In addition we have the possibility that both hypotheses may be true and we have a number of theories which can provide mechanisms to explain such relationships.

The evidence for the hypotheses comes mainly from the fact that both introversion and neuroticism have been found in many cases to interact with the other proposed determinants in a manner that is predictable from the inverted 'U' model (s). We must, however, note that there is an ambiguity in the Russian concept of 'strength' of the nervous system, just as we saw there was ambiguity in the Western concept of 'arousal' (see pages 105-6).

There are basically two ways to show that a given factor based on individual differences is related to the dimension of 'strength' of the nervous system. One way is to show that it interacts with the proposed determinants of the 'excitatory process' in a way that is predictable from the Russian model embodied in Figures 2a and 2b (page 44).

The other way is to show that the level of the factor correlates with certain classical indices of 'strength' such as 'extinction with reinforcement of the photochemical reflex'. Since the Russian model (ie. the 'theory of strength') was partly developed in order to explain the results obtained using such classical indices, the two methods are related; but they are not identical.

Firstly, even if there was only one classical index, an individual differences factor might produce the expected interactions with a given set of determinants using some other index, but it might fail to correlate in the predicted way with the classical index, or vice versa. One reason for this might be that the general model is wrong in its assumption that all of the determinants can be represented along the 'X' axis of the

inverted 'U' curve. It is possible that some of the determinants may not show the predicted effects (and it is the purpose of the present project to investigate indices where just such failures have been found). If this were true and if different sets of determinants were used in the two different investigations, this could help explain the discrepancy.

Another possible reason would be that the general model is wrong in its assumption that a given set of determinants produces its effects on different determinates by affecting the value of a single intervening construct. The phenomenon of 'partial properties' shows that the 'theory of strength' may be obeyed for each of two determinates considered separately, but yet these two determinates may fail to correlate with each other. If the general model is wrong on both counts, then it is possible that a factor such as introversion may interact in a predictable way with another proposed determinant, such as stimulus intensity, when one particular determinate is being considered, but it may fail to do so when considering another determinate such as a classical index of 'strength'.

We have argued that even if the general model is faulty, it is important to determine exactly in what way it is deficient so that the necessary revisions can be made. It is the author's opinion, therefore, that it is better to separate the two methods of determining whether or not a factor, such as introversion, is related to 'strength' of the nervous system, since it may pass the test using one method, but fail using another. If so, this would be important since the results of the two

methods have different implications.

The hypothesis which the first method tests can be formulated as follows (using introversion as an example).

"The proposed determinants of the 'excitatory process' and 'arousal' (including introversion) can be represented on the X axis of a single inverted 'U' curve. Furthermore, increasing the levels of these determinants results in movement along the X axis in the same direction, as evidenced by interactions of a specified kind."

This presents the hypothesis in its most general form. It should be noticed that we have not stated that the increase in the levels of the determinants produces movement to the right or to the left along the X axis. Up to now we have talked in terms of movements to the right as the levels of the determinants are increased. But this has been simply for convenience. Since the inverted 'U' , as we have drawn it, is sym^mmetrical, exactly the same interactions would have been produced if we had suggested that an increase in the levels of the determinants produced a movement to the left along the 'X' axis. The important thing is that they should produce movement in the same direction, since this will produce the sort of interactions which we described earlier, (see p. 75) If they produced movement in different directions , quite different interactions would be produced (in some cases these would be equally explicable if we assumed that they moved one in the same direction, but that the function was a 'U' and not an inverted 'U').

For instance, consider what would happen if determinant A resulted in movement to the right along the 'X' axis, but determinant B resulted in movement to the left as in Figure 21 below :

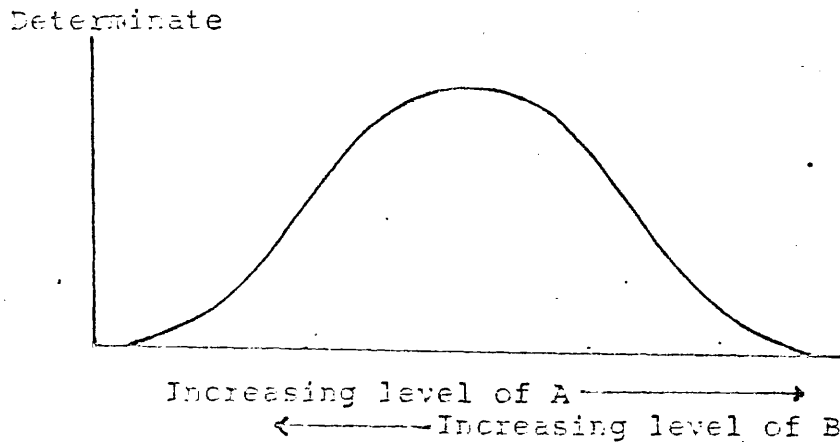


Fig 22. An interaction due to the effect of two factors which move subjects in opposite directions along the 'X' axis of the inverted 'U' curve

When the level of B is low, a small increase in A will result in a decrease in the level of the determinate, whereas when the level of B is high a small increase in the level of A will result in an increase in the level of the determinate. The interaction will also be apparent if one considered the effect of an increase in B separately at the two levels of A. The important point is that this 'double' interaction is exactly opposite to the one which would have been obtained if A and B had produced movement along the X axis in the same direction - e.g. to the right (see Figure 13c, page 75).

In absolute terms, therefore, the direction we choose is simply a convention. It is the relative directions of

movement (as evidenced by the direction of the interactions) produced by an increase in the levels of the various determinants that is important.

At this point, we should make clear that from now on when we state that such-and-such a factor 'is a determinant' this will mean that it interacts with other factors from the list of proposed determinants in a manner that is consistent with the above hypothesis. Which other factors are concerned will be clear from the context. Similarly, if we say that two or more factors 'are determinants', again it means that they interact with each other in a manner that is consistent with the above hypothesis. This may sound circular, but in fact it is simply a convenient form of shorthand which will save us having to write out the above hypothesis in full each time.

What we are doing here is in some ways similar to the technique of factor analysis. In the latter, we are generally testing how particular response indices (i.e. determinates) 'cluster' together. Here we are testing how particular proposed determinants 'cluster' together. In factor analysis the label we give to the factors that emerge is somewhat arbitrary, and their relationship to other indices (e.g. physiological ones) that were not included in the factor analysis can only be inferred indirectly. Similarly, here we are not really testing whether the various ^{factors} (stimulus intensity, accessory stimulation etc.) are determinants of 'arousal' or the 'excitatory process'. We are simply trying to assess their relationship to each other. It is helpful to explain this

relationship by reference to an intervening construct, but the label we give to this construct is unimportant. We have used the terms 'arousal' and the 'excitatory process', but we could call the construct 'X' if we wished to. It would not affect the validity of our hypothesis. As we have argued already, testing of such a hypothesis is worthwhile in its own right because its fate will, to a large extent, determine the shape of our 'conceptual nervous system'.

When we come to consider our second hypothesis, however, the definition of terms such as 'arousal', 'excitatory process', 'strength' etc., becomes more important. The second hypothesis can be formulated as follows (again using introversion as an example; neuroticism could also have been used): "The level of introversion is negatively related to 'strength' of the nervous system."

We suggest that the way to test this hypothesis is by looking at the relationship of introversion to a classical index of 'strength' - i.e. one which is widely accepted in the Soviet Union and Eastern Europe as being a valid index of this dimension.

d) Classical indices of 'strength'

There are a number of such indices available, but perhaps the two most widely cited (Gray 1964; Frigon 1976) are the methods of 'extinction with reinforcement of the photochemical reflex' and the 'induction method'. These have been described and discussed in detail by Gray (1964)

and we will not repeat his account here. To summarise, briefly, the former involves measuring the conditioned decrease in sensitivity of the visual system as the conditional stimulus (a light flash) is repeated several times over a short period. The greater the fall in the magnitude of the conditioned response between testings positioned before and after this repetition series, the lower the subject's threshold of transmarginal inhibition is presumed to be. The rationale behind this assumption is that the excitations produced by successive stimuli are thought to summate with each other in a manner described earlier (see page III) and result in the subject being taken beyond his threshold of transmarginal inhibition, as evidenced by the fall in the conditioned response. The lower the threshold, the greater the fall. Teplov (see Gray 1964, pp. 138-9) has pointed out that there are drawbacks to the use of this method. For instance, in order to test the magnitude of the conditioned response, it is necessary to present the conditioned stimulus without the unconditioned stimulus, but in doing so one interferes with the integrity of the conditioned reflex itself. Also it is extremely time consuming, requiring several months of work. Finally, in some individuals it is impossible to establish the conditioned response in the first place. For this reason, even in the Soviet Union its use is not widespread (Stralov, personal communication).

In the West it has hardly been used at all, though Frigon (1976) did employ an E.E.G. variant of it and found evidence that introverts do have relatively 'weak' nervous systems (though he found no relationship between 'strength', defined in this way, and neuroticism). However, we have already pointed out the difficulties associated with the use of measures such as E.E.G. (see also Gale (1977)).

The second technique we have mentioned is the 'induction method'. This is based on the finding that the sensitivity of the dark adapted eye to a point of light in peripheral vision is raised by the presence of an additional weak point of light, and lowered by the presence of an additional strong point of light. In the Soviet Union this has been explained largely in terms of two concepts, which we have not encountered so far - i.e. 'irradiation' and 'concentration of excitation'. We will not allow these to detain us here, because Gray (1964) has argued that these have not been satisfactorily integrated into the main body of the theory of 'strength', though the same writer has provided an alternative hypothesis accounting for them in terms of the orienting response (see Gray 1964 for a detailed account). The phenomena can also be explained in terms of the effect of accessory stimulation, but as Gray has pointed out, there are certain discrepancies here too. Finally, Strelok (personal communication) has informed the author that there are a number of practical problems associated with the use of this method.

These are not the only methods used to measure 'strength'; the reader is referred to Gray (1964) and Gray (1967) for a detailed account of the others, and we shall consider some of these, briefly, below. But they are mentioned because Frigon (1976) has argued that they are the two 'classical' methods, and the important point, here, is that they are considered to be valid indices of 'strength'.

They are not, however, the most widely used indices in practice, due to the problems associated with them. The most commonly used measure is the slope of the curve relating simple reaction time to stimulus intensity (Strelau - personal communication). Nebylitsyn (1960) measured this slope by means of the $\Sigma t/t_{min}$ index, defined as the sum of the ratios of the mean reaction time for each individual intensity, to the mean reaction time for the highest intensity. Another method is to calculate the coefficient of the line of best fit to the curve (e.g. Zhorov and Vermolayeva-Tomina 1972). Not only is the slope measure the most widely employed, but it has also been 'validated' or 'calibrated' against the classical indices of 'strength'. For instance, Nebylitsyn (1960) looked at the relationship between his $\Sigma t/t_{min}$ measure and 'strength' of the nervous system, as defined by the method of extinction with reinforcement of the photochemical reflex. He used two statistical techniques, one based on an analysis of variance, and the other based on a correlation coefficient between the $\Sigma t/t_{min}$ index and the classical index of 'strength'. Frigon (1976) has

pointed out that the analysis of variance was inappropriate to the design used. However, the same criticism does not apply to the correlation coefficient which was positive (0.61) and highly significant (1% level - see Gray 1964, page 236) and larger than any other correlation between this classical method and other indices in a factor analysis conducted by Rozhdestvenskaya et al. (1960), except for the correlation with one modified version of the classical index itself.

e) Simple reaction time and the synthesis of the Western and Russian approaches to individual differences.

We therefore propose to use the reaction time slope measure as an operational definition of 'strength' to test our second hypothesis, namely that individual difference parameters, such as introversion, are related negatively to 'strength'.

In fact, we do not need to limit ourselves to such parameters. It should already be apparent that to include individual differences amongst our list of determinants is a little strange, because, unlike the other determinants, they are to a large extent outside the control of the experimenter. However, even if we cannot for the most part control them, we can measure them and treat them as if they were experimental factors (or 'determinants'). This is less satisfactory than manipulating them directly, since it is basically a correlational approach. We cannot say that a particular difference in the level of a determinate which is associated, for instance, with a high level of introversion, was 'due' to the high level of

introversion. Nevertheless, the relationship between the level of the determinate and introversion may give us clues to the mechanisms underlying both.

We can, of course, also treat the individual differences parameter as a determinate, for instance the attempt to test whether drugs make a subject's behaviour more 'introverted' or 'extraverted' (see Eysenck 1967, for example). This approach, however, is relatively rare.

The important point is that individual differences can be included in both the stimulus and response categories, as a determinant or as a determinate. Just as introversion can be treated as a stimulus or a response factor, so 'strength' can be treated as a stimulus or a response factor; as a determinant or as a determinate. So far we have considered classical indices of 'strength' (or indices 'calibrated' against them, such as the reaction time slope) as determinates. We could also use them, like introversion, to divide subjects into two groups (a 'strong' and a 'weak' group) and use this 'strength' factor in an analysis of variance along with some of the other determinants, such as accessory stimulation. For example, we could look at possible interactions between 'strength' and accessory stimulation in a study on vigilance performance. It should be noted that in so doing we would be testing the relationship between the determinate, which is the object of the analysis of variance (e.g. vigilance score) and the index of 'strength'. We could do this by a straightforward correlation, but as with the other factors, the relationship may be a

non-linear one and it is possible that 'strength' defined in this manner interacts with the other determinants in a way that is predictable from the inverted 'U' hypothesis.

So by using the ^areaction time slope, we are actually killing two birds with one stone. Firstly, we are adding another factor - i.e. 'strength' - to the list embraced by the umbrella term 'individual differences' (the others being introversion and neuroticism). In doing this, we are still working within the framework of our first hypothesis (page 130) i.e. looking at the relationship between various proposed determinants (and we are, at the same time, looking at the relationship between various determinates and 'strength' of the nervous system). Secondly, we have pointed out that Western individual difference parameters can be treated as determinates as well as determinants, but we can look at their relationship to 'strength' more simply by investigating their effect (in conjunction with other proposed determinants) on the reaction time slope measure. In other words, in this case we will treat the Western individual difference parameters (e.g. introversion) as determinants, and the Russian measure of 'strength' (i.e. the reaction time slope) as a determinate. In so doing, we would be testing our second hypothesis (page 133) that the individual difference parameter is negatively related to 'strength'.

To summarise, we have distinguished two definitions of 'strength'. The first defines the dimension in terms of the 'theory of strength'. The second defines it in terms of operational definitions based on indices such as the reaction-time slope measure. By separating these two definitions we hope to avoid confusion and ambiguity which might arise if we treated them as identical (which they are not).

In the subsequent account we have not followed a totally consistent policy of using the terms 'strong' and 'weak' only when the second definition of 'strength' (i.e. in terms of the reaction time slope) is being referred to. This is partly because, on occasion, the two aspects do coincide. But more importantly, it is because other workers have not opted to make the separation, and in discussing their ideas and research the amount of circumlocution that would have been required to avoid using the terms would have been undesirable. It is hoped, though, that wherever the author has used them, he has made it clear which particular aspect of 'strength' is being considered.

As far as the second aspect is concerned - i.e. the operational definition in terms of the reaction time slope - a word or two more needs to be said. The reason why it is important to consider this measure is that one of the most interesting and exciting developments in recent years has been the possibility that the researchers in the West and in the East may have been investigating the same dimension(s) of 'personality', for want of a better

term, and this^{is} reflected in reviews provided by a number of Western and Russian workers (e.g. Gray 1964, 1967 ; Eysenck 1967; Nebylitsyn 1972; Nebylitsyn and Gray 1972; O'Connor 1961, 1966). Furthermore, this rapprochement has occurred despite the fact that they have carried out their research largely independently of each other and also from a somewhat different standpoint. Eysenck (1967) has suggested that an individual's 'personality phenotype' is reflected at a number of different levels. It is closest to the 'genotype' at the most basic physiological level, and this stratum is usually described in terms of a theoretical construct, such as 'excitation - inhibition' , 'arousal', the 'excitatory process' etc. Eysenck, in fact, regards personality dimensions such as introversion and neuroticism as being basically anchored at this level - i.e. he sees them as predispositions (determined by the genotype) which are reflected in particular characteristics of the nervous system (e.g. the ease of generation or dissipation of inhibition). At the next level up, we encounter laboratory phenomena, such as vigilance , conditioning, sensory thresholds etc. These are thought to be closely related to the individual's predispositions, but they are also thought to depend on the past history of the individual and on factors specific to the experimental paradigm employed.

Such differences in the laboratory are, further, thought to be mirrored in everyday life, and by interacting with environmental influences they result in differences at the final level of the phenotype model -

i.e. behaviour in 'real-life' situations. This is usually measured by questionnaires and yields dimensions such as introversion and neuroticism, in the case of theorists such as Eysenck who employ orthogonal factor analysis, or 'traits', in the case of theorists such as Cattell who employ oblique factor analysis.

The general approach in the West has been to start at this level and then to work backwards towards the level of the theoretical construct (such as 'arousal') via the mediating link of laboratory phenomena. For instance, Eysenck has suggested that differences in the level of introversion are associated with differences in conditionability which can be measured in the laboratory (e.g. Eysenck and Levey 1972), and which indicate that at the physiological level introverts are more 'aroused' than extraverts. We are not concerned here with the correctness or otherwise of such hypotheses, but rather with the general approach.

In the Soviet Union workers initially concentrated upon differences in the laboratory and have used indices which they regarded as fairly closely tied to the underlying nervous system characteristics or 'properties' (such as 'strength'). It is mainly in recent years, particularly in the work of Strelav (e.g. 1972) that we have seen a serious and concerted attempt to relate such differences to everyday behaviour through the use of observer ratings and questionnaires. Earlier theorists were more interested in 'temperament' than in 'character' - i.e. they were more concerned with the constellation of basic nervous system properties rather

than the way in which they manifested themselves in everyday life. 'Character' was thought to depend partly on 'temperament', but also on the influence of the environment. As Teplov puts it (see Gray 1964), the basic temperament of an individual is 'overgrown' during his lifetime by conditioned connections, and it is the amalgam of the two that is reflected in 'character'.

Nevertheless, despite this difference in approach the two sets of theorists may have been looking at the same dimension(s) of individual differences. The rapprochement has been most evident at the middle level of the personality phenotype model - i.e. in the area of laboratory phenomena. Though the indices used in the West and the East do differ in some respects, the determinants employed have often been very similar, as we have seen, and in many cases (as we will see below) the determinates have also been common to both groups. Simple reaction time measures are an example of this - they are used widely both in the West and in the East, and we have seen that the reaction time slope measure is accepted as an index of 'strength' in the latter.

This brings us back to our operational definition of the 'strength' dimension. If we can show that many indices which are commonly used in the West do show lawful relationships with an index that is widely used in the Soviet Union and Eastern Europe, and which has been invested with considerable theoretical significance, it would contribute to this rapprochement between the two separate bodies of research. This is a point which has also been made by Gray (1964, page 298), who argues that, in order to test the proposed equation of the Western and

Russian models, one needs to employ, side by side, indices which in the West are thought to depend on 'arousal', and indices which in the Soviet Union are thought to depend on 'strength'.

2. THE DETERMINATES

Let us now consider our list of determinates in more detail.

Arousal

Magnitude of Response
Alertness
Efficiency of Learning
Efficiency of Performance

Excitatory Process

Magnitude of Response

i) General Considerations

At first glance these two lists would seem to differ markedly , with the exception of 'magnitude of response' which is common to both. However, Gray (1964 pp. 298-9) has argued that, with the exception of 'efficiency of learning', the remaining determinates could be listed under the heading of 'excitatory process', as well as 'arousal'.

We will discuss the discrepancy with respect to 'efficiency of learning' later. All the remaining determinates will also be considered at some point during the course of the present project. For instance, 'magnitude of response' in connection with salivation, 'alertness' in connection with vigilance, and 'efficiency of performance' in connection with measures of discriminability.

These are only examples, and any one determinate is often involved in more than one response index or set of response indices. We have already discussed the phenomenon of 'partial properties', which indicates that for a given response index, insignificant correlations may be found when different sensory modalities are used. We will also come across instances in which treating a given response index as if it represented one particular determinate leads to quite different predictions than if it is treated as representing another. One example of this is the 'false alarm rate' in reaction time, signal detection and vigilance tasks. This could be included under the heading of 'magnitude of response' or 'efficiency of performance'. We will see that such an ambiguity is by no means academic.

ii) The choice of determinates

We have anticipated our later account by referring to some of the indices that were used in the present project. We must, however, say a little more about why they were chosen.

Two criteria have already been mentioned. Firstly, the index should be one which has provided enough evidence in favour of the inverted 'U' hypothesis to suggest that the latter is relevant to it, but enough discrepancies to make it worthwhile investigating it further. This^{is} especially so in cases where the author has felt that there is an explanation of these discrepancies which is compatible with the hypothesis.

The second criterion is practicability. However fruitful the investigation of a given index might be, if it posed intractable practical problems it was rejected. Fortunately, this particular criterion has necessitated the exclusion of very few indices, and nearly all of these belong to the physiological category. We have argued already that this is unfortunate, but not catastrophic, for an attempt to test the hypothesis at the conceptual level.

Gray (1967) has provided a comprehensive account of the broad areas within which Western work on 'arousal' and Russian work on 'strength' has come together. The reader is referred to his paper for more details, but the main headings are :

- 1) Sensory thresholds
- 2) The effects of distraction
- 3) Stimulus intensity and transmarginal inhibition
- 4) Flicker phenomena
- 5) Drug effects
- 6) Susceptibility to fatigue
- 7) Reactive inhibition
- 8) E.E.G. measures
- and 9) Speed of conditioning

Using the two criteria defined above, the present author isolated three main areas which he considered would be worthy of investigation.

- A) The Gustatory modality - specifically 4 indices:
 - i) The salivary response to an unconditioned stimulus
 - ii) Subjective intensity ('magnitude estimation')
 - iii) The level of 'hedonic tone'
 - iv) The sensory threshold
- B) Simple reaction time and signal detection theory.
- C) Vigilance.

All of these will, of course, be discussed in great detail in the ensuing pages and it is hoped that the reasons for their choice will become apparent at that time.

The above classification does not map directly onto the list provided by Gray, but this stems largely from the fact that the various terms used are different. We will not provide a lengthy account of how the two lists are related, but one or two examples will be helpful. For instance, the salivation measure was mentioned by Gray under his heading of 'stimulus intensity and transmarginal inhibition'. Also, when we come to discuss 'vigilance' we will need to consider the concepts of 'fatigue' and 'reactive inhibition', both of which figure in Gray's list. Reaction time indices were not mentioned to any significant extent by Gray, largely because the most salient studies were carried out later. However, he does mention the 'tapping task' and we will discuss similarities and dissimilarities between this index and reaction time measures.

We would also like to point out the areas which Gray has mentioned, but which we have not studied.

The first of these is 'Flicker phenomena'. Gray has argued that the 'critical frequency of flashing phosphene' (C.F.P.) is higher in 'weak' individuals than in 'strong' individuals, defined either in terms of the 'theory of strength' or in terms of a classical index (see pages 134-6). Firstly, C.F.P. varies positively with stimulus intensity, which we have seen is a determinant in the 'theory of strength'. Secondly, it correlates with established measures of 'strength'. If, therefore, it could be shown that introverts, for example, have a higher C.F.P. than extraverts, it would support the view that introversion and stimulus intensity are both determinants, and also the view that introverts have relatively 'weak' nervous systems. However, the C.F.P. method requires the experimenter to pass an electric current through the eye of the subject.

This is a procedure which would be unacceptable to many people and it was rejected on these grounds.

The other related phenomenon in this area is the critical frequency of flicker fusion (C.F.F.). This is easier to arrange experimentally, but there is already fairly good evidence in favour of the hypothesis that stimulus intensity and introversion are both determinants (e.g. Simonson and Brozek 1952; Frith 1967), though there is evidence that neuroticism may also be a relevant factor to C.F.F. measures (e.g. Ginsburg 1969).

We could have followed Gray's suggestion to test the hypothesis that introverts have 'weaker' nervous systems than extraverts by showing that the C.F.F. is related to our operational definition of 'strength' (the reaction time slope measure). However, we can test the hypothesis more directly by simply looking at the effect of introversion on simple reaction time.

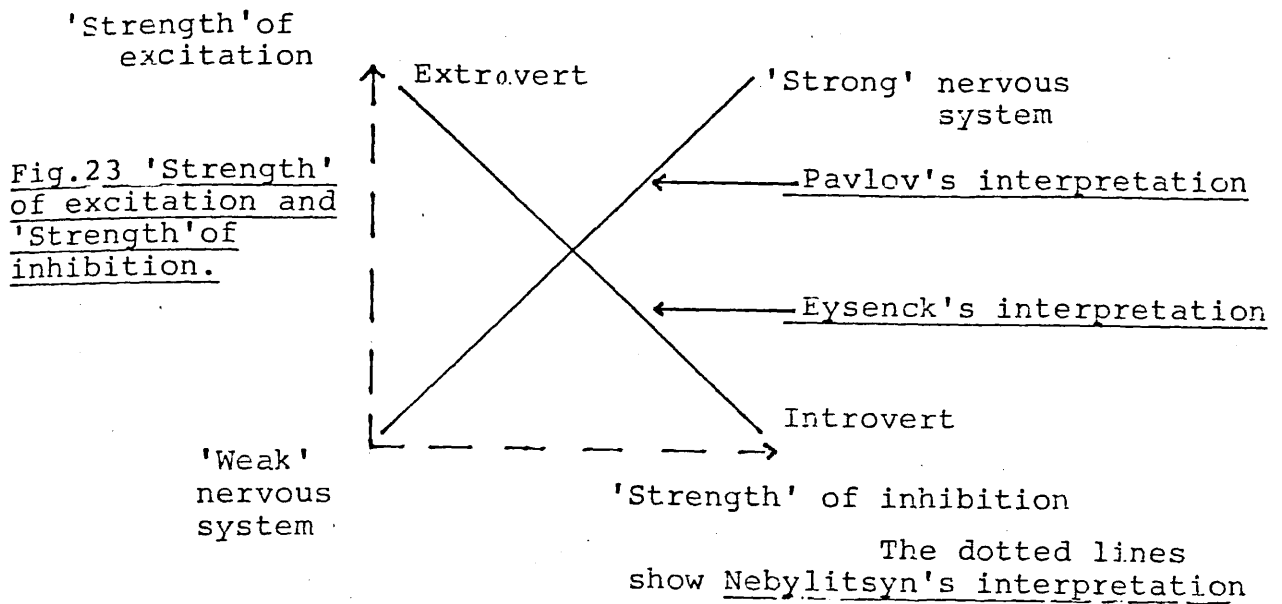
The second of Gray's categories that we have omitted, is related to the use of drugs. We have already mentioned other more recent work in this area (e.g. Revelle et al 1976). However, for practical reasons which have already been stated (page 114) , we do not intend to study the effects of drugs ourselves.

The same problem applies to the use of E.E.G. measures, but we will make one or two theoretical points here. Gray points out that although introverts have lower indices of 'alpha' activity than extraverts (e.g. Savage 1964), such indices are unrelated to established measures of 'strength' (Nebylitsyn 1963b, 1966). He suggests that this poses serious problems for the view that introverts have 'weak' nervous systems. The example illustrates very well the value of separating the two definitions of 'strength' . We will argue later that the study by Savage (op.cit.) and similar findings by other workers (e.g. Winter et al 1976) can be quite easily accommodated within the 'theory of strength', if we take into account the dimension of neuroticism. However, it is still possible (as the studies mentioned above would suggest) that E.E.G. indices may not show the expected relationships with classical indices of 'strength'.

The last area that we have chosen to omit is that of 'conditioning'. Aside from any practical considerations, there were theoretical reasons why it was excluded. The best way to introduce these, however, is to first discuss, briefly ^{a dimension} that we have also chosen to ignore - i.e. 'strength of inhibition'.

iii) 'Strength^t of inhibition'

Gray (1967) has pointed out that Eysenck's and Nebylitsyn's formulations differ in that the former regards the speed of generation, magnitude and speed of dissipation of excitation, on the one hand, and inhibition, on the other, as inversely related to each other. The latter sees them as independent. Eysenck maintains that at the cortical level there is a single dimension represented by strong excitation, weak inhibition and introversion at one end, and weak excitation, strong inhibition and extroversion at the other. The more recent Russian formulation suggests that excitation and inhibition can vary independently, so that not only may the absolute amounts vary from individual to individual, but also the relative amounts. The ratio between them determines the 'equilibrium' of the nervous system, with respect to the nervous system 'property' in question (e.g. 'strength'). In contrast, as Strelov (1970) has indicated, Pavlov believed excitation and inhibition to be positively related. These various formulations are summarised in Figure 23.



Gray (1964) has drawn attention to the ambiguity that exists in the Russian literature regarding the use of the terms 'strong' and 'weak'. These terms may refer to a basic typological characteristic of the nervous system. In this case the relative strength (i.e. the magnitude or level) of a given process, such as excitation, in different individuals, will depend on the levels of certain factors. We have seen already that the level of the 'excitatory process' is relatively greater in individuals who are 'strong' with respect to excitation when the levels of the determinants are relatively high, whereas the reverse is true when the levels of the determinants are relatively low. In other words, the relationship between 'strength' as a measure of a typological characteristic of the nervous system and the strength or level of a particular process (such as excitation) within the nervous system at a given moment in time, is a complex one. To avoid any ambiguity, we have used (and will continue to use) the terms 'strength'

of the nervous system and 'level' of a process. The terms used in Figure 23, therefore, refer to typological properties of the nervous system.

Strelau (op.cit.) has argued that the attempts to equate the dimension of extraversion-introversion with Pavlov's original conceptualisation of the dimension 'strength-weakness' is problematic. We can see why this is so by looking at Figure 23, itself. First of all, as the diagram is drawn, the two dimensions appear to be independent of each other, so that it cannot be stated that they are identical. Furthermore, as Eysenck has pointed out (1966), similarity does not imply identity. The diagram shows that with respect to 'strength of excitation', the extravert and the 'strong' nervous type do appear to be similar, as are the introvert and the 'weak' nervous system type. On the other hand, with respect to 'strength' of the inhibitory process, the reverse would appear to be true, the extravert is similar to the 'weak' type and the introvert to the 'strong' type.

Thus Strelau (op.cit.) concludes that there are grounds for equating the extravert with the 'strong' type and the introvert with the 'weak' type, if one considers 'strength' with respect to excitation, but not if one considers strength with respect to inhibition. He then goes on to discuss two sets of studies which have been used by Eysenck to develop his theory of introversion - extraversion: experiments on the speed of acquisition and extinction of the eyeblink conditional response and experiments on 'reminiscence'.

Subjects in both types of study are thought to be susceptible to forms of inhibition, and Strelav maintains that Eysenck's view that the same kind of inhibition is involved is fallacious. In the case of the eyeblink response, he argues that the extinction of the response can be regarded as due to Pavlovian 'conditioned inhibition'. He states that this form of inhibition is, in Pavlovian theory, "more efficient (quicker, more accurate)" in 'strong' than in 'weak' types," and we could take this as meaning that conditioned inhibition is generated more readily in the 'strong' type. But if this is what he means there is a risk of confusing the use of the word 'strength' as a designation of nervous system type and its use to describe the state of the nervous system at a given moment in time (see p. 152). Pavlovian theory, as described by Strelav earlier in his paper, regards 'strength' with respect to excitation and 'strength' with respect to inhibition as positively related to one another. We have seen that a high degree of 'strength' with respect to excitation means that the actual level of excitation (compared to subjects with a low degree of 'strength' with respect to excitation) is relatively high when the determinants are relatively high, but relatively low when the determinants are relatively low. By analogy, if we assume that a corresponding set of determinants exists for 'strength' with respect to inhibition, this would imply that the 'strong' type would have a higher level of inhibition only when the levels of these determinants were relatively high. Therefore, it follows, that Strelav's interpretation of Pavlovian theory, according to which conditioned inhibition would be relatively high

in the 'strong' type, would only apply if the levels of the determinants of the 'inhibitory process' were relatively high.

Nebylitsyn (1972) has recognised the implications of treating the concept of 'strength' of inhibition in the same way as the concept of 'strength' of excitation. One of these implications is that a threshold of transmarginal excitation exists for the 'inhibitory process' in the same way as a threshold of transmarginal inhibition exists for the 'excitatory process.' He points out that the theoretical underpinnings of the concept of 'strength' of inhibition and the operational measures of it are both relatively undeveloped compared to 'strength of excitation'.

For this reason, it is unclear whether in the extinction phase of a conditioned eyeblink experiment, the levels of the determinants of the 'inhibitory process' are relatively low or relatively high. If they are relatively low, then one would expect greater conditioned inhibition in individuals who are 'weak' with respect to inhibition. If this is the case then the finding (e.g. Franks 1956, 1957) that extraverts extinguish faster than introverts, would indicate a similarity between extraverts and the 'weak' nervous system type. On the other hand, if the levels of the determinants are relatively high, one would expect greater conditioned inhibition in the 'strong' nervous system type. If so, then this would indicate a similarity between the extravert and the 'strong' type.

Strelau seems to assume that the latter is true and argues as a result that the experiments on eyeblink

conditioning support the equation of the extravert with the 'strong' type. This, of course, conflicts with the diagram presented earlier. The reason for this contradiction is that Eysenck's formulation of the difference between introverts and extraverts is not sufficiently precise. Eysenck maintains that extraverts generate inhibition more easily than introverts, but he does not qualify this with reference to the prevailing experimental conditions. It is a fundamental tenet of the 'theory of strength' (and one which is implicit in the Western inverted 'U' model) that the relative behaviour of different groups of individuals depends on the levels of certain experimental factors and these must be specified before any predictions can be made. As Strelaw rightly points out, Eysenck assumes that the postulated greater level of inhibition generated in extraverts, due to the non-reinforcement of a conditioned response, is a result of a general characteristic of the extravert's nervous system. Furthermore, he also assumes that this characteristic manifests itself in a similar way in other situations where the experimental conditions are totally different.

One such manifestation is the phenomenon 'reminiscence' which we will consider later. However, before leaving the question of the extinction of conditioned responses, it should be pointed out that later Russian work has explained differences in the rate of extinction by reference to the nervous system property of 'dynamism' rather than 'strength of inhibition'. We have argued that the latter's role in determining the rate of extinction of conditioned

responses is not satisfactorily defined due to uncertainties inherent in the concept of 'strength of inhibition' itself. We see, now, that Soviet workers are possibly abandoning the idea that a relationship exists at all. Thus, a rather wide theoretical gap seems to have opened up at the Russian end between the concept of 'strength of excitation' (which is our primary concern) and the empirical data related to classical conditioning.

In the West, also, there has been a move away from attempting to explain individual differences in conditionability solely on the basis of the inverted 'U', especially since Gray (1970) pointed out that this function could not adequately explain differences in conditionability between introverts and extraverts. His later formulations have concentrated instead on the concepts of 'reward' and 'punishment' rather than the concept of 'arousal'. It is partly for these reasons that no attempt has been made to provide a comprehensive review of the literature on conditionability and the determinants of 'arousal' (e.g. introversion), and also why we have not included measures of conditioning in the present project.

iv) Other 'properties' of the nervous system

We have discussed 'strength of inhibition' at some length because it raised a number of theoretical issues which are relevant to a project primarily concerned with 'strength of excitation', as the present one is. There are other nervous system 'properties' which are part of the overall Russian model, but which we will not discuss in any detail (just as there are Western personality dimensions which we have not considered). Some of

these 'properties' should , however, be mentioned.

'Dynamism' is one which has already been discussed briefly and which has been proposed as a possible rival to 'strength of excitation' as the Russian equivalent of 'introversion'. Gray (1967) has reviewed a number of experiments which have indicated that introversion may be related to 'dynamism of excitation' (for example, E.E.G. studies: Savage (1964); Marton and Urban 1966). Mangan (1978a and b) has suggested that it may also be related to 'dynamism of inhibition', as evidenced by the speed of extinction of appetitive conditioned responses and the speed of habituation of orienting responses, for example.

Mangan (1978b) also suggests that introversion may be negatively related to 'mobility' - i.e. the speed with which excitation is replaced by inhibition and vice versa, as evidenced by the speed with which subjects adapt to a change in the nature of the imperative stimuli in a choice reaction time task (i.e. the stimuli to which a response is required).

We have already seen evidence that the critical frequency of flicker fusion (C.F.F.) is positively related to introversion (see p. 149). Furthermore, C.F.F. is taken to be a measure of the nervous system property of 'lability', so it is possible that introversion may be related to this dimension also.

No attempt has been made to give an exhaustive account here. We simply wish to make the point that although our main interest is the relationship of personality to 'strength of excitation', the possibility exists that the personality dimensions we consider are also connected

with other nervous system 'properties'. However, these may themselves not all be independent of each other. The discussion of C.F.P. and C.F.F. indicates that 'lability' and 'strength' may be related to each other, for example, as Gray (1967) has pointed out.

Other Western dimensions of personality:

Although introversion and neuroticism will be our main interest in the present project, it is salutary to consider certain other personality dimensions which may be worthy of investigation, though we do not propose to give an exhaustive account. We have already discussed Gray's suggestion that anxiety may underly an 'arousal' mechanism which itself may underpin the inverted 'U'.

The latter as we have seen is an integral part of the Russian 'theory of strength' and Cattell (1972) has suggested that this dimension may be related to one or more of the higher order factors derived from his 16P.F. questionnaire, such as 'cortertia'.

Finally, there is some evidence that the inverted 'U' relationship between the determinants and the determinates may be replaced by a 'U' shaped relationship in schizophrenics (Claridge 1972), and Claridge and Chappa (1973) and Claridge and Birchall (1978) have shown that the same may be true of non-psychiatric subjects scoring relatively highly on the dimension of 'psychoticism'. We will later discuss the theory that the inverted 'U' is partly a homeostatic mechanism, and Claridge (1972) has argued that the 'U' function found in schizophrenics is a derangement of this mechanism and may be related to their psychiatric disorders. If so, then it is possible that the psychoticism scale may be useful in identifying groups of 'normal' subjects who are at high risk of developing such disorders. This scale has been the subject of some controversy, (for example, Eysenck and Eysenck 1976; Bishop 1977; Block 1977; Eysenck 1977; Claridge and Birchall 1978), but the above results do suggest that it may be worthy

of investigation.

CHAPTER THREE - GENERAL METHODOLOGICAL CONSIDERATIONS

In the first two chapters we have developed a number of ideas and hypotheses. We must now consider how to put them to the test.

1. ISSUES IN THE OVERALL DESIGN OF THE PROJECT

It will be remembered that we have decided to investigate three main groups of indices:

1. Gustatory measures
2. Reaction time and signal detection measures
3. Vigilance measures

i) Implications of the use of the simple reaction time index

The second group has a particular significance since not only does it provide the opportunity to investigate simple reaction time in its own right, but also to derive our measure of the slope of the reaction time intensity curve (see p. 137). We could obtain values for this measure by employing separate groups of subjects for each of the three sets of indices listed above and by then giving each group a simple reaction time task in addition to the main task (in the case of (1) and (3)). Alternatively, we could use the same group of subjects throughout. We could derive the slope measure on one occasion and then use it as an individual differences factor in other experiments, in the manner described earlier

(see pp. 137-140).

There are problems with this latter approach. One such problem would be that since the project inevitably would stretch over a considerable period of time it would be more difficult to recruit subjects, since people would be less likely to commit themselves to remaining participant for such a long period. However, though the total length of time for which the project would run would be a long one, the actual length of time for which any individual subject would actually be in the experimental room would be negligible in comparison, and if split up into three separate occasions, less likely to prove a burden to the subject than if he was asked to spend a great deal of time in the experimental room over a more limited period. This would have been inevitable if the reaction time task had been included in each of the three sets of experiments.

We could still use this method if we reduced the amount of time spent in obtaining measures of any given index (for instance by reducing the number of reaction time trials), but this would have severely prejudiced the reliability of such an index. One could have reduced the number of indices actually investigated, but this would have emasculated the project and compromised its ability to test the hypotheses we have presented in any meaningful way.

For these reasons it was decided to use the same group of subjects throughout.

ii) The question of sample

University students are particularly suitable as subjects for a project like the present one, since they tend to be available over the period of their degree course. However, unforeseen circumstances can prevent a given subject from completing the whole series - e.g. expulsion from the University or a voluntary decision to leave. This may be more likely to occur in the case of certain types of subject. If so then such 'differential dropout' might result in a change in the overall composition of the sample with time. There are several reasons, however, why it was considered that this would not be serious.

Firstly, the present experiment is not a 'longitudinal' one in the usual sense of the word. We are not proposing to measure the same index several times over a prolonged period, comparing the results from each measurement to give an indication of change with time. Under such circumstances, differential drop out would be a very difficult problem, since changes in the composition of the group would be confounded with the effect of the passage of time. In our present project the aim is to investigate separate sets of indices. The only link between them is the fact that the reaction time index derived from the second set is to be used when analysing the results of the other sets (retroactively in the case of the first set).

Secondly, even if certain 'types' of subject did drop out, our concern is with particular dimensions of individual differences - i.e. introversion, neuroticism and 'strength' - not with the whole constellation

of possible differences between individuals. The hypothesised relationships between these dimensions and the various determinates in question is not dependent on the nature of the sample. The inverted 'U' hypothesis in its most general form does not include any qualifications which restrict its domain to any particular population.

That is not to say that such qualifications may not turn out to be necessary. The basic tenet of the individual differences approach to psychology (as described by Eysenck 1967) is that general laws may not in fact be as general as had been first imagined. It may be necessary to specify much more precisely the conditions under which a particular relationship is found. We have seen already that the general inverted 'U' model is threatened in just this sort of way. (See pp. 93-100). It may turn out that the nature of the sample which is under test will be a significant factor in determining whether the model is confirmed or not. However, it is not our present intention to provide a rigorous test of this. Our aim is to test the model within a particular sample, and to leave it to future investigation to show whether or not similar findings are obtained in other samples, should it be considered worthwhile. Of course, this is not to say that sampling effects are not important. The nature of the sample chosen is certainly very relevant since it determines the nature of the population to which the results may be generalised with validity, and we intend to define very clearly the nature of the sample we employ. But precision is the important thing, not the actual composition

of the sample itself.

This is a point which has also been made forcefully by Eysenck (1975) in his critique of workers, such as Cochran^e and Duffy (1974) who have argued that a failure to use 'random samples' has prejudiced the results of many psychological experiments - for instance those which have used college students. They maintain that such a population is special in many respects. Examples of this include its level of intelligence, its social class composition, etc. (the reader is referred to the original paper for a fuller account). However, Eysenck has pointed out that this does not in any way compromise the use of such a population to test a general theory which makes no reference to specific samples in any of its postulates. It is certainly true that the more narrowly defined a sample is, the less broad the population to which the results can be generalised to. However, if the individual differences philosophy, as propounded by Eysenck (1967), has any validity, then such generalisation must in any case be conducted with great caution. It is an interesting irony that this caveat has come from a theorist who has, himself, proposed one of the broadest and most general theories of personality. It should be noted, though, that the individual differences school is a very broad church, providing shelter for theorists, like Cattell, who define personality in terms of a very large number of traits, and Eysenck himself whose system is almost a typology in the tradition of Galen and Hippocrates.

We have gone into this question of the nature of the sample at some length, because it is an important one from a theoretical point of view. We see though that, at this level at least, it poses no serious problem for a project which attempts to follow one particular group of subjects over a long period of time. The 'dropout' that might be expected in such a situation may cause some practical problems, however, and we will describe later the attempts that were made to minimise these or to deal with them when they could not be circumvented.

To conclude, the decision to use the same group of subjects throughout is a defensible one. It has certain advantages which have been described, and its possible disadvantages are not considered to be serious ones. Furthermore, apart from the practical reasons already stated, there are serious theoretical objections to the use of the reaction time slope index separately in separate groups of subjects. These will be described later (see pp. 454-5), when we have considered, in more detail, the nature of simple reaction time itself.

iii) Temperament as a fixed characteristic of the individual

We have decided, then, that the reaction time slope index is to be derived from one set of experiments, but used in two other sets to analyse the results for indices derived from the latter. As a result, though, the separation in time of the measurement of the slope index and these other indices is likely to be considerable. It

could be argued, therefore, that this will reduce the likelihood of finding significant relationships between them. However, we pointed out earlier that the Russian theorists distinguish between 'temperament', which depends on basic, largely innate nervous system properties, and 'character', which is an amalgam of temperament and 'conditioned connections' acquired during the course of the individual's lifetime (see p. 142). Furthermore, we stated that the Russian workers had devised their laboratory indices with the aim of measuring 'temperament' rather than 'character'.

Simple reaction time is one of these indices. To the extent that the Russian theorists have been successful in developing 'pure' indices of temperament, and to the extent that this temperament is an essentially fixed, unchanging characteristic of an individual, one would still expect the simple reaction time slope index to be related to indices separated from it by a period of several months, (which is the order of magnitude of time relevant here).

In one sense, then, the proposed design provides a means of testing the above assumptions made by the Russian workers. It does not provide a rigorous test of them: to do this one would have to vary the separation in time as an experimental factor in itself. Also, there are other possible explanations for a failure to find a relationship between the reaction time slope and other measures: the phenomenon of partial properties may reduce the likelihood of obtaining significant results, since the reaction time and gustatory measures, for

instance, are to be conducted in different sensory modalities.

For this reason, we have sandwiched the reaction time experiment in between the other two sets to keep the maximum separation in time down. If there are factors militating against the discovery of a significant relationship, it is hoped that this procedure will help to reduce their influence.

2. THE DESIGN OF INDIVIDUAL STUDIES

We must now consider the design of the individual sets of experiments.

i) Multifactorial experiments and multilevel factors

A case has already been made for the use of several factors in studies in this area, and also for the desirability of having at least one factor which has several levels. In fact, ideally, one would like to have several levels of all the factors, since this would provide a much more detailed investigation of their interaction (Gray - personal communication - has criticised studies which have attempted to test the inverted 'U' hypothesis using only two levels of the factors). Unfortunately, on the practical level this would be inimical to the multi-factorial requirement. Whether one uses an independent groups design or a repeated-measures design, the greater the number of 'cells' the greater the practical problems. In the former case, one would require many more subjects. Or, for any given number of subjects, the greater the number of cells the smaller the number of

subjects per cell. This would be undesirable for a number of reasons - for instance, it would decrease the likelihood that random differences between subjects, in different cells, on non-relevant characteristics (age etc.) would cancel themselves out. Equally, in a repeated-measures design it would increase the total number of measurements and thus the total experimental time.

These problems would be apparent even if only two factors were multi-level. One advantage of employing several levels of a factor is that it provides the opportunity to look at trends - e.g. linear and quadratic trends. The latter are particularly relevant in the context of an inverted 'U' hypothesis. However, one can only investigate such trends in any meaningful way if one has four or five levels at least. If one had two factors which had four levels each, for example, this would by itself produce sixteen cells. With the addition of each extra factor this number would increase at a geometric rate. Clearly this would be an impossible situation on practical grounds.

For this reason, we have compromised between the need to have many factors and the need to have multi-level factors. Wherever possible we have tried to include at least one factor which has several levels. The choice of which one has been dictated by practical considerations and by the circumstances of the particular experiment. Generally speaking, stimulus intensity is a particularly easy factor to manipulate in this way. However, it is not always appropriate to use it, and other factors sometimes seem more suitable. For instance, in the

vigilance experiment, 'time on task' was the multi-level factor.

ii) Between and within-subject designs.

We come now to the choice between an independent measures and a repeated measures design. Some of the determinants are, by their very nature, between-subject factors - i.e. the individual difference factors: introversion, neuroticism and 'strength'. Also, repeated-measures designs do have certain disadvantages: for instance, the need to assume that sequential effects in a counterbalanced design are the same for subjects who perform the conditions in different orders. For this reason, it could be argued that it would be best to make all the other determinants between-subject factors also.

However, independent group designs have their disadvantages too. Unless large numbers of subjects are used, they are very susceptible to chance differences between subjects in different conditions on non-relevant variables (see above). Moreover, in the present instance there are also relevant between-subject variables (such as introversion and neuroticism) on which the different groups would have to be matched. Again this would have posed a problem unless large numbers of subjects were used. In the present project, this was not possible due to limitations of time and also the fact that recruitment of such large numbers of subjects would have been difficult. This is particularly the case when some of the experiments (e.g. vigilance) are by their very nature long ones.

It was, therefore, decided, again, to compromise and to employ mixed independent and repeated measures designs. Apart from the individual differences factors, it was decided to use one or the other method for a given factor on the basis of the merits of the particular case.

PART II: EXPERIMENTAL EVIDENCE

We will now consider in turn the three sets of indices mentioned before:

- 1) Gustatory indices
- 2) Reaction time and signal detection indices
- 3) Vigilance indices.

In each case we will first present an account of previous work relating the determinants to the measure in question, before considering any plans for our own experiments. With the exception of the factor of personality, for which a fairly comprehensive review will be provided, unless otherwise stated, we do not intend to give an exhaustive description of the literature, but rather an indication of the kinds of findings that have emerged. Also, where a study has investigated the joint effect of a determinant and personality, it will sometimes be considered under the heading of 'individual differences' only and not under the heading of the determinant (e.g. stimulus intensity).

It should also be mentioned that although we are essentially concerned with whether or not two or more determinants move subjects in the same direction along the 'X' axis of the inverted 'U' (see page 130), for convenience we will adopt the hypothesis that an increase in the levels of the determinants moves the subjects to the right along the 'X' axis. The choice of directions is simply a convention, though.

1. SALIVATION

The use of the salivary response to stimuli as an experimental index has a hallowed tradition dating back to Pavlov's studies of conditioning in dogs. It has, however, been used relatively little recently even amongst Russian workers in the 'strength of the nervous system' field. This is surprising since Teplov (1972) pointed out that involuntary measures (such as those involving the autonomic nervous system) were sorely needed because of the possibility that a subject might consciously or unconsciously distort his perceptions where voluntary indices were used.

Also, as Gray (1964) has noted, although it is response magnitude that is ostensibly under investigation in studies of 'strength', usually what is actually measured is a threshold (e.g. the absolute sensory threshold or the threshold of transmarginal inhibition) at which the relationship between stimulus intensity and response magnitude is presumed to alter. It is relatively rare for response magnitude per se to be measured directly over a wide range of stimulus intensities. The use of the salivary response, however, provides a good opportunity to do this.

i) Stimulus intensity

As previously stated the relationship between stimulus intensity and response magnitude is expected on the basis of both the theory of 'arousal' and the theory of 'strength' to be positively monotonic at low stimulus intensities, but also

curvilinear throughout its range to the extent that a point is actually reached (the threshold of transmarginal inhibition- T.T.I.) after which the relationship becomes negative and monotonic.

As far as the first half of the prediction (i.e. before the T.T.I.) is concerned, there is certainly supportive evidence available. Kerr (1961) and Davenport (1956) both report that the magnitude of the salivary response is proportional to the logarithm of the stimulus strength. Since such a relationship (known as a semi-log plot) is positive, monotonic and curvilinear, the picture conforms to the characteristics described by the first prediction and corresponds to portion B of the inverted 'U' curve (see page 83). Also Shannon and Feller (1970) have shown that the magnitude of the salivary response is proportional to the logarithm of the rate of application of the stimulus. It will be remembered that in the Russian theory of 'strength' stimulus frequency is considered to be analogous to stimulus intensity since it is assumed that the excitations produced by two stimuli separated by a sufficiently short interval will summate with each other.

A number of studies have also been carried out which have manipulated both stimulus intensity and personality factors, including one (Wardell 1974) which demonstrated what may have been transmarginal inhibition. Discussion of these studies will be deferred until the section on individual differences.

ii) Drugs

Frith (1968) showed that the difference between the resting level of salivary secretion and the response to a

stimulus of 'Jif' (lemon juice + sulphur dioxide preservative) was significantly greater when the drug nicotine was administered, as compared to a placebo condition.

Nicotine is normally classified as a stimulant in the West e.g. ^{by} Goodman and Gilman (1955), and would therefore be expected to move the subjects to the right along the 'X' axis of the inverted 'U'.

iii) Accessory Sensory Stimulation

Corcoran and Houston (1977) have demonstrated that an accessory white noise stimulus significantly increases the salivary response to a lemon juice stimulus. Accessory stimulation is one of our determinants and the authors themselves review a number of studies supporting this view with respect to 'white noise' specifically.

iv) Drive

An unpublished study by Nicholson and Gupta has shown that the increase in the salivary response to lemon juice following a cognitive task involving grammatical transformation is significantly greater than the increase following a monotonous task involving the sequential filling in of squares on a sheet of graph paper.

It should also be pointed out that in a study by Baddeley (1968) using the same grammatical transformation task, a significant interaction was found between noise and introversion. Introverts' performance was worsened by noise, extraverts were improved. This fits in neatly with the curvilinear functions described earlier. Thus performance on the task used would seem to be a determinate of 'arousal' level. It is not unreasonable to suppose that participation in such a task might also be a determinant of 'arousal' level -

i.e. one might expect participation to raise the level of 'arousal' if the subject was motivated to perform well.

v) Fatigue

Corcoran (1964) has found that sleep deprivation has no effect on the salivary response to citric acid solution.

vi) Novelty

Ramsay (1969) found no evidence of a significant 'order' effect in the salivary response to repeated acidic stimulation. It is possible that this is because a fairly long interstimulus interval was employed (3 minutes), thus preventing summation of excitation from successive stimuli. Equally the reduction in the novelty of the stimuli does not seem to have reduced the response. We will argue later that a long interstimulus interval will tend to counteract not only summation of excitation, but also any decrease in novelty (see page 729). However, in the present instance there may be another reason why novelty effects are not apparent. Although the stimuli were all acidic, they were derived from different fruits and were presented in a counterbalanced order. For any individual subject, therefore, successive stimuli would still retain a measure of novelty.

Frith (1968) found that the response to the second of two successive stimulations was greater than to the first. A relatively short interstimulus interval was employed, so it is likely that the reduction in novelty was more than outweighed by summation of the excitations.

Corcoran (1964), Eysenck and Eysenck (1967a) and Corcoran and Houston (1977) all looked at test-retest coefficients for successive testing. All found large significant

correlations ranging from 0.50 to 0.96. It would seem then that the reduction in the novelty of the stimulus has not, in these studies, produced any dramatic reversals in the relative positions of the various subjects, though Eysenck and Eysenck (who found the lower correlation values) do suggest that repetition may introduce new variables. They also argue that because of this, low reliability does not necessarily prejudice the validity of the salivation test.

vii) Individual Differences

a) Western measures

A number of studies have been carried out to investigate the relationship of Western personality dimensions (especially introversion) to the salivary response.

Corcoran (1964) found a significant positive relation between introversion and the salivary response to a lemon juice stimulus placed on the tongue. However, this relation disappeared when citric acid was used, which is surprising since citric acid is the main non-aqueous constituent of lemon juice.

Eysenck and Eysenck (1967a) have replicated Corcoran's finding for lemon juice using larger numbers of subjects with correlations of the same order of magnitude as the latter's (0.62 and 0.70 in two separate groups). They also found a very small, negative and completely insignificant correlation with neuroticism.

Eysenck, H.J. and Eysenck, S.B.G. (1967) have also found the correlations of individual items on the introversion scale of the E.P.I. with the salivary response to lemon juice were positively related to the size of the loadings of these items on the introversion factor. No such correspondence existed for the neuroticism scale.

In addition both Corcoran (op. Cit) and Eysenck and Eysenck (1967a) failed to find a significant correlation with introversion when Jif (lemon juice plus sulphur dioxide) was used.

Casey et al (1971) used lemon juice swabbed onto the sides and dorsum of the tongue and found a significant correlation between salivation and introversion in girls,

but not in boys. Medeiros and McManis (1974) failed to replicate this. In neither sex was there a significant difference between introverts and extroverts. Nor can such discrepancies be explained by the fact that children were employed rather than adults, since Eysenck and Eysenck (1969) have shown that the introversion trait stabilises by the age of seven, and the subjects in these studies were older than this.

Let us now consider studies which have manipulated introversion and one or more of the other determinants jointly, since cross study comparisons are less satisfactory than within-study comparisons.

Stimulus intensity: Eysenck and Eysenck (1967b) found that if the subjects were asked to swallow the lemon juice (which was accompanied by a much stronger subjective sensation than if it was simply placed on the tongue as before) the relationship with introversion was reversed with extroverts salivating significantly more. The authors suggest that this might be due to transmarginal inhibition in the introverts due to the stronger effective stimulus intensity. However, since no precise measure of the number of receptors stimulated was available, this interpretation was an interesting possibility and one which required further empirical investigation.

In an attempt to settle the matter, Wardell (1974) conducted an experiment in which he used a commercial analogue of lemon juice known as "Reallemon" (personal communication) at various levels of intensity (manipulated by the addition of acids and alkalis) and measured the salivary response in introverts, ambiverts and extroverts.

The author presented his results in the form of a graph, and a photocopy of this is attached.

The differences between conditions B and D for extraverts and between B and C for introverts are significant. The difference between C and D approaches significance for introverts ($p < 0.10$). Introverts salivate significantly more than extraverts only in condition C, where the pH level of the stimulus was lower than that of the stimuli used in previous studies showing such a difference. PH is, of course, an inverse measure of the acidity of a stimulus, and hence in this instance of its intensity.

If one assumed that progressing from the extravert end of the introversion/extraversion dimension through the ambivert to the introvert represented movement to the right along the 'X' axis of the inverted 'U', one might expect that if an appropriate range of stimulus intensities was chosen, extraverts would show an approximately monotonic, positive relation between stimulus intensity and response magnitude since they would be operating on the left hand limb of the inverted 'U'. Ambiverts might be expected to show a somewhat quadratic or at least slightly flatter relationship. Introverts might be expected to show at least the beginning of a negative monotonic relationship at the high stimulus intensities.

The results of Wardell's study show reasonable similarities to these predictions. However, there are certain discrepancies. Firstly, the very steep increase between B and C in introverts. Secondly, the rather high values in condition A (although the author attributed this to the incomplete counterbalanced design). Thirdly, the fact that

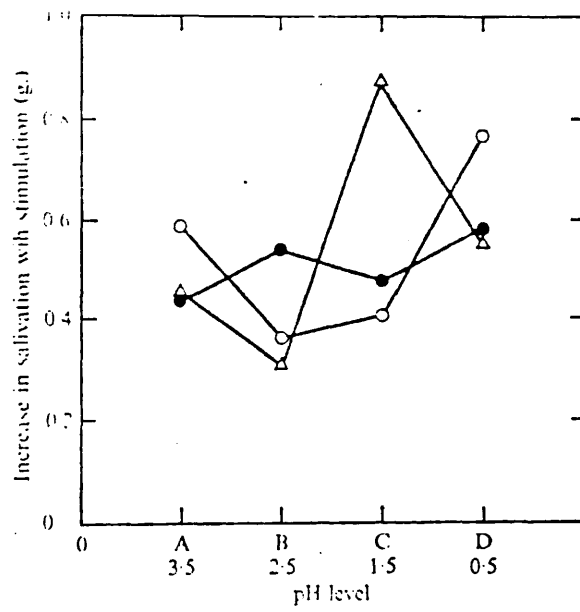


Fig. 1. Weight of saliva as a function of level of stimulation (pH). ○, extraverts ($n = 16$); ●, ambiverts ($n = 14$); △, introverts ($n = 15$).

an analysis of variance revealed no significant main effects for either introversion or stimulus intensity and more importantly, no significant effect for their interaction. Linear and quadratic trends were also non significant. The author concluded that the study provided only partial support for the equation of introversion with 'weakness' of the nervous system (defined in terms of the 'theory of strength') and for the identification of the decrement in salivation between C and D in introverts with transmarginal inhibition.

The above study did not report any measures of neuroticism. A study which did investigate the latter, however, as well as introversion was conducted by Ramsay (1969, op. cit.). In this the lemon juice stimulus was applied to the tongue of the subject using a standard sized gauze pad instead of a dropper which was used in the previous studies mentioned. There was no significant correlation between salivation and personality.

In the second part of the experiment, the original dropper method was used and a number of other acidic stimuli (e.g. apple juice, vinegar etc.) were also employed.

Once again there were no main effects for personality. However, the various substances used had different pH values (i.e. differing levels of acidity) and although no evidence of transmarginal inhibition at the high intensities was demonstrated (the upper limit of intensity was less than in Wardell's study), a significant interaction between neuroticism and stimulus intensity was found. This was due to the fact that the response magnitude of the high N subjects

remained almost level at strong levels of stimulation while the response magnitude of low N subjects continued to rise. This would fit quite well with the hypothesis that neuroticism is a determinant.

Howarth^{and Skinner} (1969) used the dropper technique and pure lemon juice and investigated the correlations between salivation and personality amongst a group of high and low N subjects combined (full matrix) and the group of low N subjects alone (reduced matrix). The correlations are presented below:

	Full matrix	Reduced matrix
Introversion	+0.34*	+0.46**
Neuroticism	-0.24	-0.14

* sig. at 5% level

** sig. at 1% level

The correlations with introversion are much lower than those reported by Eysenck and Eysenck (1967a) and Corcoran (1964).

If one supposed that both introversion and neuroticism are determinants, the lower correlation with the full matrix as compared to the reduced matrix would be explicable, since if one is operating on portion B of the inverted 'U' (see page 83) one would predict that the effect of variation in the level of any one determinant (e.g. introversion) will be greater if the levels of other determinants (e.g. neuroticism) are relatively low (as in the reduced matrix above). The relationship between stimulus intensity and salivation described earlier (see page 175) indicates that in some studies at least, subjects are operating on portion B.

The negative (though non-significant) relationship between neuroticism and salivation would seem to argue against the view that neuroticism is a determinant. However, it is possible that the various determinants of the level of 'arousal' and/or 'excitatory process' affect the levels of other intervening variables also. If so, and if one or more of these variables also affect a given response index which is assumed to be a determinate of 'arousal' and the 'excitatory process' alone, then the effect of such a determinant on the response index will be complex and may not conform to the predicted pattern. This suggestion applies to the present case in the following way. Corcoran (1964) assumed that the salivary response to lemon juice was a measure of cortical 'arousal'. If, as Eysenck (1967) suggests, neuroticism influences the level of activity in the autonomic nervous system in a positive, monotonic fashion, and if the latter can also influence the level of cortical 'arousal' in a similar fashion, then one would predict - following Corcoran - that increasing neuroticism would increase the salivary response by virtue of its effect on cortical 'arousal'. However, it must be remembered that the salivary response is itself an autonomic measure. Increases in the level of sympathetic activity will tend to decrease salivation. If increasing levels of neuroticism increase the level of sympathetic activity (and there is evidence for this - e.g. Rubin, 1962), then increasing levels of neuroticism would tend to decrease salivation by virtue of its direct effect on the autonomic nervous system.

These two opposing effects of neuroticism on salivation could explain the insignificant correlations between the two variables that have often been reported. In support of this interpretation it should be pointed out that the mean levels of salivation reported in the Howarth and Skinner (1969) study are lower than those reported in the Eysenck and Eysenck (1967a) and the Corcoran (1964) studies despite virtually identical methodologies. The authors suggested that this might be because in their study subjects were students rather than members of experimental panels (as in the other studies) and might have been more anxious. Anxiety is known to be positively related to neuroticism (Spence and Spence 1966), so this idea may fit in with our suggestion.

The above interpretation is speculative, but the question of the possible effect of the determinants of 'arousal' and 'excitatory process' on more than one variable will arise again.

Drugs: We have already mentioned the study by Frith (1968, op. cit.) which looked at the effect of nicotine on salivation to lemon juice. He also looked at the effect of introversion. The method employed involved squirting 'Jif' (i.e. lemon juice plus sulphur dioxide) into the mouth of the subject, and measuring the salivary response from the parotid gland alone by means of a 'Lashley disc' (unlike the sublingual swab method used in all previous studies) which draws off the saliva by suction and measures it by volume rather than weight. Frith makes no report of any interaction between the effect of nicotine and personality.

However, there are other features of his results that are worthy of mention. Though there was no relationship

between personality and the rate of increase in the response or the rate of decay of responses when measured on a moment to moment basis, like Eysenck and Eysenck (1967a) he did find that extraverts had a significantly lower resting level of secretion. For each subject two stimulus injections separated by 60 seconds were made. The difference between the response to the second of these and the resting level was significantly greater in extraverts, but the author points out that this was because all subjects had similar upper limits of response so that those with a lower resting level showed the greatest change. This is interesting since the inverted 'U' would predict such a relationship, if we assume that the subjects were operating on portion B. Eysenck and Eysenck (1967a)'s findings that the difference between the salivary response at rest and under stimulation from lemon juice is greater in introverts, as is the absolute level of response under both conditions, contradicts Frith's findings. It would be possible to accommodate both Eysenck and Eysenck's and Frith's results if one assumed that the former were operating on portion 'A' of the curve and the latter were operating on portion 'B'. Since different groups of subjects tested using non-identical stimuli and different methods are involved, it is difficult to substantiate such an assumption. Frith did use a larger volume of stimulus solution than Eysenck and Eysenck, but since the composition of the two solutions was not the same it is difficult to know whether this constitutes a greater effective stimulus intensity. A comparison of the absolute levels of salivary secretion would be helpful here, but unfortunately Frith does not quote any values.

He explains the fact that there was no significant correlation between introversion and the response to the first injection of lemon juice in terms of the unsatisfactory method of stimulus delivery employed. An alternative possibility is that the effect of a decrease in novelty and/or the summation of the two excitations was responsible. The fact that the response to the second injection was greater than to the first in absolute terms, suggests a summation effect. It is possible that this may have moved subjects from the border between portions A and B of the inverted 'U' where the curve is fairly linear (and interactions less likely) onto portion B. But this is very speculative.

No relation between salivation and N was found in Frith's study.

Accessory sensory stimulation: Although Corcoran and Houston (op. cit.) did look at the effect of white noise on the salivary response to lemon juice, they did not look at the effect of personality as well (personal communication).

Drive: Nicholson and Gupta (op. cit.) found no significant interaction between the effect of drive and introversion or neuroticism.

Fatigue: Corcoran (1964, op. cit.) reports no evidence of any interaction between the effect of sleep deprivation and introversion on the salivary response to lemon juice.

Novelty: The findings of Frith (1968, op. cit.) regarding the correlations between introversion and salivary response to two successive stimuli have already been discussed above.

One variable which we have not considered in its own right so far, since it is not included in the list of

determinants, is time of day. Horne and Ostberg (1975) have found, using a synthetic analogue of lemon juice, that there is a positive significant correlation between introversion and salivation (though again lower than in the earlier studies) in the morning, but that this correlation disappears in the afternoon. This would fit in with Blake's (1971) finding that introverts are advanced in phase compared to extraverts in respect of body temperature, showing a higher value in the morning, but not in the afternoon. Bent (personal communication to Corcoran and Houston, 1977 op. cit.) found that in absolute terms salivary output was greater in the afternoon than in the morning. Like Blake's temperature findings, this would be consistent with the view that time of day may be a determinant itself. However, Corcoran (1964, op. cit.) found no difference in the salivary response between morning and afternoon testing, nor does he report any interaction between personality and time of day.

b) Russian measures

To the present author's knowledge, ^{there are} no studies of the relationship between unconditioned salivation and established measures of 'strength'. Medeiros and McManis (1971), however, found no relation in children between salivation to lemon juice and performance on a vigilance task (the latter has been shown by some workers to be related to 'strength' (e.g. Pushkin 1972)).

2. MAGNITUDE ESTIMATION

The technique of magnitude estimation involves asking subjects to rate subjective level of intensity by assigning numbers to stimuli, and has been increasingly used recently to investigate the psychophysical function (i.e. the function relating objective and subjective stimulus intensity). Unlike the salivary response, it is not involuntary, and a number of workers (e.g. Ekman et al. 1967) have suggested that the results from it may depend not only on the true psychophysical function, but ^{on} independent factors relating to the way in which subjects handle numbers. However, it has the advantage of being relatively simple, requiring no elaborate equipment and providing a measure which is already quantified. In addition, like the salivary response, it has the advantage of providing a direct measure of response magnitude. Furthermore, it has a high test-retest reliability in both experienced (Stevens 1956) and naive subjects (Stevens and Poulton 1956).

There are also aspects of the quantitative nature of magnitude estimation which make it particularly attractive, and these are discussed below under the heading of stimulus intensity.

1) Stimulus intensity

Stevens (1956) has shown that the relationship between subjective stimulus intensity (as measured by the method of magnitude estimation) and objective stimulus intensity is best described by a power function of the form:

$$\text{Subjective intensity (S)} = \text{constant } (k) \times \text{objective intensity (O)}^n$$

$$\therefore \log S = n \log O + \log k$$

He and other workers have also shown that there are considerable individual differences in the value of 'n' (the exponent), the slope of the function relating log S and log O. Furthermore, it has been found (Jones and Marcus 1961; Rule 1966; Ekman et al. 1967; Reason 1968a) that the value of 'n' displays significant correlations between different sensory modalities.

The fact that the correlations are, however, not equal to one may represent different ways in which the nervous system transforms sensory inputs in these modalities. It is possible that differences in the value of 'n' between individuals may represent differences in the way these individuals transform incoming stimulation. Stephens (1970) has, in fact, suggested that 'n' may reflect one or more aspects of the personality of the subject. We will consider the findings of his study in the section on 'individual differences'. For the present let us see what relevance these ideas have for our general inverted 'U'.

The 'X' axis of the latter can be used to represent objective intensity and the 'Y' axis to represent subjective intensity (if the appropriate response index, e.g. magnitude estimation is used). As can be seen, the relationship between objective and subjective intensity is different in portions A, B, C and D of the curve.

The relationships are as follows:-

A	B
Positively monotonic and positively accelerated (i.e. increasingly steep)	Positively monotonic and negatively accelerated (i.e. decreasingly steep)
C	D
Negatively monotonic and positively accelerated	Negatively monotonic and negatively accelerated

The nature of the relationship between subjective intensity and objective intensity in a magnitude estimation study is reflected in the value of 'n'. If the relationship alters the value of 'n' will alter as follows:-

range of 'n'	$n > + 1$	$+ 1 > n > 0$
nature of relationship	Positively monotonic and positively accelerated	Positively monotonic and negatively accelerated
	$0 > n > - 1$	$- 1 > n$
	Negatively monotonic and positively accelerated	Negatively monotonic and negatively accelerated

It is tempting therefore to postulate that differences in the value of 'n' would result if one were operating on different parts of the inverted 'U'.

In fact it is not necessary to actually calculate the value of 'n', since the relationship between subjective and objective intensity can be deduced from the results of an analysis of variance, for instance, which includes stimulus intensity as a factor. The above analysis does indicate

though, that magnitude estimation could be used to test our inverted 'U' model. Let us see what other evidence there is relating stimulus intensity to magnitude estimation.

Verillo ^{et al} (1969) have shown that in the auditory modality, the slope of the magnitude estimation function is steeper closer to the threshold of the subject than at higher intensity levels. There was no evidence that at any point subjective magnitude decreased as objective stimulus intensity increased, therefore one is safe in assuming that one is not operating beyond the threshold of transmarginal inhibition but on portion 'B' of the curve (i.e. where a decrease in the range of stimulus intensities would result in a steepening of the curve). Whether a further decrease in the range of intensities used would bring one onto portion 'A' is questionable, since, of course, if one reaches sub-threshold stimulus intensities the method of magnitude estimation cannot be used, although the salivary index might still be usable. Pfaffman (1971) has shown that if the tongue is adapted to the stimulus solution there is both a decrease in subjective stimulus intensity and a steepening of the magnitude estimation slope. It is tempting to suggest that adaptation leads to the development of transmarginal inhibition, but once again there is no evidence that stronger stimulus intensities are rated as being less subjectively strong than weaker ones. Also, transmarginal inhibition is conceived of as a central phenomenon by Russian theorists, and Pfaffman states that the loss of subjective sensation with adaptation was directly paralleled by the loss of neural discharge in the peripheral chorda tympani nerve. Once again therefore one is safest to conclude that adaptation

represents a decrease in stimulus input to the central nervous system and that we are again operating on portion 'B' of the curve.

One more study should be mentioned and that is one which has already been considered in connection with salivation. Wardell (1974) asked his subjects to rate the stimuli for strength in subjective terms. He found that the subjective sensation followed the salivary response very closely (see pages 181-4). One significant point is that the decrease in salivary response in introverts between the second-strongest and the strongest stimulus was also accompanied by a decrease in subjective magnitude which possibly counts as evidence for transmarginal inhibition in the latter.

ii) Drugs: no studies known to the author.

iii) Accessory sensory stimulation: no studies known to the author.

iv) Drive: no studies known to the author.

v) Fatigue: the author knows of no studies which have looked at the effect of sleep deprivation itself on magnitude estimation. However, an interesting study by Le Vere et al. (1974) should be mentioned here. This showed that three auditory stimuli which differed in pitch, but which had been adjusted by the subjects in the waking state to produce equal subjective loudness, also produced equal degrees of cortical desynchronisation when presented during sleep characterised by NREM fast-wave E.E.G. activity. However, they produced different degrees of desynchronisation when presented during sleep characterised by slow-wave E.E.G. activity. In this case, the effect on the E.E.G. seemed to be more

related to objective sound pressure level than to subjective loudness.

vi) Novelty: Muller and Mauermann (1975) have found that repeated testing results in a reduction in the average group value of 'n' - i.e. the exponent of the function relating subjective to objective loudness (see page 191). The same effect appeared for individual subjects to a greater or lesser degree.

vii) Individual differences:

a) Western measures

The study by Stephens (1970) has already been mentioned. In this study the slope of the magnitude estimation function, 'n', was correlated with a number of personality measures including introversion, neuroticism and test anxiety. The correlations with the first two measures were non-significant, but the correlation with test anxiety was significant, with anxious subjects demonstrating a steeper slope than non-anxious subjects. As Wilding and Meddis (1972) have pointed out, the failure to obtain significant correlations with introversion and neuroticism may have been due to the use of the Heron inventory instead of the E.P.I.

The correlation with anxiety is interesting, however, since Spence and Spence (1966) have shown that the latter is positively correlated with both introversion and neuroticism, and Gray (1976) has suggested that the behavioural inhibition system (which includes the A.R.A.S.) may be the physiological substrate of anxiety. However, there is no evidence of transmarginal inhibition in Stephens' study and we may therefore assume that we are operating on either portion 'A' or portion 'B' of the inverted 'U'. If the former, then the results support the idea that anxiety (and its physiological counterpart) moves one to the right along the 'X' axis of the graph (i.e. acts in the same way as stimulus intensity etc). However, if we are operating on portion B of the inverted 'U' curve then the reverse is true - i.e. anxiety moves one to the left. Clearly, unless one has some other factor (e.g. accessory stimulation) manipulated within the same study alongside the personality

measures, to give some indication of whereabouts on the curve one is operating, interpretation of results is very difficult.

One more study should be mentioned in this connection. Reason (1967) found a significant correlation between the loudness slope and the spiral after effect which he defines as a measure of 'receptivity'. In his work, he equates receptivity with the ~~concept~~ of introversion. However, due to the very indirect nature of the measurement of the latter, his results cannot be considered an adequate test of our hypotheses.

b) Russian measures

As we have seen, the slope of the curve relating reaction time to stimulus intensity has been taken to be a measure of 'strength' of the nervous system in the Soviet Union and Eastern Europe (see pages 136-7). Those subjects with steep slopes are deemed to have 'stronger' nervous systems than those with shallower slopes. Reason (1968) and Sales^{and Throop} (1972) have both shown that there is a positive correlation between the slope of the reaction time/intensity function and the slope of the magnitude estimation function in the relevant modality. Furthermore, Aikin (1974) has shown that the ratio of the two slopes is almost exactly equal to one, indicating that the two functions are not only correlated but virtually identical. On the basis of these studies the correlation between 'n' and anxiety in Stephens (1970) seems to run counter to the suggestion that increasing anxiety is equivalent to increasing 'weakness' of the nervous system although the author himself seems to feel that

the correlation was due to the number-handling strategies of the anxious subjects rather than a reflection of their perceptual processes. Reason (1968) has argued that the relationship between the slope of the magnitude estimation function and the slope of the reaction time intensity curve indicates that the former is not dependent on such strategies, but is a reflection of sensory-perceptual factors. This may well be so, but reaction time studies can only be taken as proof of this if we assume that simple reaction time itself is not affected by such strategies or response biases. Later in this thesis we will attempt to show that this assumption is unfounded.

Another measure which has shown similar correlations with classical measures of the 'strength' of the nervous system is the absolute sensory threshold, measured using the 'method of limits' (see later). Sales^{and Throop} (1972) have found that the slope of the magnitude estimation function in the auditory modality is positively correlated with this threshold. Like the reaction time studies this supports the validity of the magnitude estimation slope as an index of nervous system 'strength'. However, Stephens (1970) failed to find such a relationship in subjects with normal hearing. One possible reason for this is that Sales used the 'method of limits' to measure sensory threshold which, like magnitude estimation, is influenced by response biases, whilst Stephens used a measure of the threshold which is independent of such effects (personal communication).

3. HEDONIC TONE

Hedonic tone refers to the degree of pleasantness experienced by the subject and it may, of course, have a negative value if the subject is in discomfort or experiences unpleasant sensations. Eysenck (1967) has suggested that the relationship between the determinants of 'arousal' and the degree of 'hedonic tone' is described by an inverted 'U'. If so, it ought to be possible to use this index to test the general model which is the subject of this thesis.

There are essentially two ways to measure hedonic tone. One is a direct measure - i.e. you expose a subject to a given stimulus situation which he cannot control or change and you ask him to rate his feelings of pleasantness or unpleasantness. This has the advantage that it is relatively easy to do, requiring little in the way of equipment to measure the subject's response. It has the disadvantage that it employs subjective ratings (e.g. 'pleasant', 'unpleasant') which may have different meanings to different subjects. In this respect it is similar to magnitude estimation. However, assuming that the ratings have a fairly stable meaning for a given subject (at least within a single experimental session) it can be used to investigate the effects of other determinants (e.g. stimulus intensity) and their interactions with individual differences.

The second, more indirect method, is based on the assumption that given the opportunity a subject will attempt to maximise his level of hedonic tone. This maximum level is assumed to occur at a certain 'optimal' level of 'arousal' which is the same for all subjects, but since, ex hypothesi,

the actual level of 'arousal' will differ from subject to subject in a given stimulus situation, the difference between the actual and the optimal level of 'arousal' will also differ. As a result the amount of extra stimulation the subject will need to acquire (or, if the subject is beyond the level of optimal 'arousal', the amount by which the stimulation will have to be reduced) in order to achieve an optimal level will vary in proportion. In turn the amount of effort a subject is willing to exert is assumed to be proportional to the degree of change in stimulation that the subject requires. Thus, by a somewhat tortuous path, this amount of effort is a measure of the subject's original level of hedonic tone before he was permitted to attempt any changes. Apart from its more indirect nature this method has the disadvantage that it often requires complex equipment to provide variable stimulation and to measure the subjects' responses. It has the advantage that it provides more objective measures and ones with perhaps 'lower visibility' - i.e. the subject is less likely to be aware of what the experimenter is actually trying to measure than using the rating method. However, since the subject will no doubt formulate his own hypotheses about this, it is still subject to experimenter effects.

Both methods have been very extensively used, especially in relation to personality. That hedonic tone (like magnitude estimation) may reflect a fairly stable characteristic of the subject (which may be related to personality) is suggested by McGuiness (1976), who showed that the comfortable intensity level (i.e. the intensity level which the subject described as 'comfortable') was positively and

significantly correlated between the auditory and visual modalities even though the experimental sessions were widely separated in time.

Let us now consider the relationship of the various determinants to hedonic tone.

i) Stimulus intensity

Pangborn^{et al} (1970) asked subjects to rate different concentrations of salt solution for their degree of pleasantness. They found that the relationship between stimulus intensity and hedonic tone took one of three forms depending on the subject:

- a) A positive monotonic relationship
- b) A quadratic relationship with both high and low intensities producing lower levels of hedonic tone than intermediate intensities
- c) A negative monotonic relationship.

It is very tempting to suggest that these three groups of subjects were operating on the left hand portion, intermediate portion and right hand portion of the inverted 'U', respectively. Unfortunately no other variables such as accessory stimulation or personality were employed.

ii) Drugs

We will consider the effects of drugs on hedonic tone in the section on individual differences since there are studies that have looked at the joint effect of these factors.

iii) Accessory sensory stimulation

We will consider this factor in the section on individual differences.

iv) Drive

Berlyne (1960) has suggested that 'arousal' is a drive

like any other and is subject to the same homeostatic principles as other drives. The notion of an optimal level of 'arousal' which subjects will exert effort to achieve is in line with this view, although in one sense this is treating drive as if it were the determinate and hedonic tone as if it were the determinant since the level and direction of the drive would depend on the level of hedonic tone and its sign (i.e. plus or minus). This difficulty stems essentially from the ambiguous nature of the term drive since it can be thought to depend on both intrinsic and extrinsic factors (see pages 116-8). Perhaps the best way to think of it is to assume that drive in this context is an intervening variable which is influenced by factors such as the level of external stimulation and which covaries with hedonic tone in the manner described on page

v) Fatigue

No studies known to the author.

vi) Novelty

Gray (1971) has proposed that moderate degrees of uncertainty as a result of novelty are pleasing and will encourage 'approach' behaviour, whereas high levels are aversive and will evoke 'avoidance' behaviour.

vii) Individual differences

a) Western measures

There are a great many studies which have looked at the relation between hedonic tone and personality. Only a few will be mentioned here - the reader is referred to reviews by Eysenck (1967), Ludvigh ^{and Happ} (1974) and Bartol (1975) amongst others for a fuller account.

Introversion/extraversion is the most widely studied dimension, and Pardes (1965) has shown that extraverts report more boredom than introverts in a monotonous task. Bowsher (1966) has found that introverts are significantly more annoyed than extraverts by noise (although Broadbent and Gregory - in an unpublished study - failed to find such a difference). These two studies thus represent differential behaviour at the different ends of the axis of the inverted 'U'.

McGuiness (1976) discovered that in women (but not men) there is a significant negative correlation between introversion and comfortable brightness level, and a significant negative correlation between the latter and neuroticism in men (but not women).

Stephens (1970) found a significant negative correlation between the uncomfortable loudness level and anxiety. This was replicated by Stephens and Anderson (1971) who also found a weak negative correlation with introversion (see Stephens' 1972 account for a more comprehensive review of personality and hedonic tone in the auditory modality).

A number of studies have also been carried out using Zuckerman's 'Sensation Seeking Scale', which is a

questionnaire designed to assess the degree to which subjects attempt to gain stimulation in everyday life.

Zuckerman and Link (1968) failed to find a significant negative correlation between sensation seeking and introversion, but a number of other workers have done so (Farley and Farley 1967; Bone and Montgomery 1970; Eysenck and Zuckerman 1978). These workers report no correlation with N.

In this connection it is worth mentioning that Hare (1970) identifies psychopathy with pathological stimulation-seeking. Also, unlike Eysenck (1967), he regards psychopaths as stable extraverts rather than neurotic extraverts since he reports that they have under-reactive autonomic nervous systems. If Hare is right this would support the hypothesis that introversion and neuroticism are determinants.

A number of other studies have studied hedonic tone using the second method described earlier - i.e. allowing the subject to respond in order to achieve an optimal level of arousal, but this time in the laboratory. Many of these have supported the idea that extraverts seek more stimulation than introverts (e.g. Gale 1969; Phillipps^{and Wilde} 1970; Hall 1975) at low levels of stimulation.

It is worth at this point considering some studies which have looked at the joint effect of personality and one of the other determinants.

Drugs: Bartol (1975) has investigated the effect of drugs and stimulus complexity on hedonic tone in introverts and extraverts.

We have already seen that drugs are a determinant, but it is possible that stimulus complexity may be one also.

The Western inverted 'U' model was in fact largely derived

from the Yerkes-Dodson law (1908) which states that the optimal level of 'arousal' is lower for complex tasks than for simple tasks. This would mean that the inverted 'U' curve was placed further to the left for a high level of complexity than for a low level and, as we saw, this is also the effect of an increase in the level of a determinant (see Fig 6 , page 53).

Bartol presented subjects with polygons of varying complexity and measured the resulting hedonic tone by both of the methods described earlier.

Method 1 - measured the pleasantness ratings ascribed to the polygons by the subjects ('divergent' paradigm)

Method 2 - measured the number of times the subjects allowed the polygons to be flashed on the screen. These methods were found to differentiate between introverts and extraverts in predictable ways in an earlier study (Bartol 1973).

The purpose of the later study (Bartol 1975) was to investigate the effects of a stimulant drug on extraverts and a depressant drug on introverts, the hypothesis being that in the drug condition subjects would display behaviour characteristic of the other personality group in the placebo condition.

Method 2 was found to reveal no such reversals of behaviour due to the drugs but the author points out that the method is relatively insensitive and inconsistent.

Method 1 showed that in the placebo condition extraverts rated all the polygons as equally pleasing whereas in introverts there was a negative monotonic relationship

between pleasantness and complexity. The interaction of extraversion and complexity was thus significant.

Furthermore introverts behaved like extraverts under the placebo condition when administered the depressant, but the behaviour of the extraverts was unaffected by the stimulant, (though the authors present a number of possible explanations for this).

The results of this study do, therefore, lend a certain limited amount of support to the hypotheses under consideration. It should be pointed out that only stable subjects were used.

Accessory stimulation: Weisen (1965) has shown that extraverts are more likely than introverts to respond in order to increase ambient sound and light intensity and less likely to respond in order to decrease it.

Also Ludvigh^{and Happ} (1974) found that the level of sound and light intensity required to produce an optimum level of hedonic tone was not significantly correlated with introversion, but the level required to produce a 'just uncomfortable' level of hedonic tone was significantly negatively correlated with introversion.

Time of day: Davies et al. (1969) have shown that extraverts preferred a higher level of auditory input than introverts at all times of the day.

b) Russian measures

A number of studies on the relation between the sensory threshold and hedonic tone have been carried out which pose problems for the hypotheses under consideration. For instance, Hood (1968) found a significant negative correlation between threshold and the uncomfortable loudness level. One

would have predicted a positive relationship. Also McGuinness (1976) has shown that there is no simple relation between threshold and the loudness level designated as 'too loud'. Finally Sales^{et al} (1974) have demonstrated that subjects classified as 'strong' on the grounds that they had relatively high sensory thresholds responded less frequently than 'weak' subjects in order to obtain a view of simple sensory stimuli. However, they also rated the experimental situation as more boring than 'weak' subjects. This latter finding is in line with expectation and it illustrates that the assumptions underlying the use of the second method to investigate hedonic tone may not always be valid. In this case the lower hedonic tone experienced by the 'strong' subjects made them less rather than more likely to respond in order to improve it. It is possible that they did not feel it was worth the effort. In a second experiment, however, where social rather than simple sensory stimuli were used, they did indicate that their need for stimulation was greater. Thus the particular kinds of stimuli employed may be an important factor.

A group of studies must now be reported which used Strelau's (1972) questionnaire to measure 'strength' of the nervous system. Elias (1972; 1973) and Strelau (1974) have shown that 'strong' subjects are willing to expend more effort to gain stimulation than 'weak' ones. Also, Kozlowski (1977) has found that 'strong' subjects prefer high risk situations to low risk situations, whereas the reverse is true for 'weak' subjects. This is also in line with predictions if we assume that a high risk situation involves more emotional stimulation than a low risk situation.

It is also interesting to note that in all of these questionnaire studies the EPI was also used and a significant negative relation was found in each case between stimulation-seeking and neuroticism. No mention of introversion is made.

4 . THE SENSORY THRESHOLD

The sensory threshold has been used widely as a laboratory index both in the West and the Soviet Union. The reason for this is that it is generally assumed that it provides a measure of the perceptual 'sensitivity' of the subject to external stimuli. In fact, in the Soviet Union the discovery (e.g. Nebylitsyn 1956; 1959) that subjects with relatively 'weak' nervous systems (as defined by a classical index of 'strength') have lower sensory thresholds than 'strong' subjects, had an important effect on the theory of 'strength'. Prior to this discovery, 'strength' of the nervous system was defined mainly in terms of the threshold of transmarginal inhibition: 'weak' subjects were defined as those which had lower relative response magnitudes at very high stimulus intensities. But the above finding showed that 'weak' individuals had greater relative response magnitudes at very low stimulus intensities. Both of these findings were incorporated in the inverted 'U' and in the theory that 'weak' individuals are in general more 'reactive'. The basis for the latter statement is the assumption that physiological changes in nerve cells are responsible for the behavioural changes observed when either the sensory threshold or the threshold of transmarginal inhibition (see Nebylitsyn 1972) are passed, and that these changes occur more readily in 'weak' individuals.

However, for the sensory threshold to provide useful information in this way it is essential that the processes involved in determining this kind of threshold are properly understood. In the case of the Russian work, the method

used to measure the sensory threshold was that of 'limits' - i.e. stimulus intensity is gradually increased until the subject reports its presence (ascending method) or gradually decreased until the subject reports its absence (descending method). The point of transition is taken to be the subject's threshold. However, many workers (e.g. Green and Swets 1974) have pointed out that such methods are highly dependent on the subject's 'criterion' - i.e. the subject's response strategy. Some subjects may be more inclined to report the presence of a signal (i.e. may have a lower criterion) than others and may therefore appear to have lower thresholds in the absence of a genuinely higher perceptual sensitivity. A pure measure of the latter can be obtained, however, using a 'forced choice' method or a 'signal detection' method (which also gives a measure of the subject's criterion). Details of these methods are given by Green and Swets (1974).

This possibility that a given response index may be dependent on more than one factor (in the above case the criterion and the perceptual sensitivity of the subject) has already been considered in relation to the effect of neuroticism on salivation (in the latter case both autonomic and cortical activity may have effects) and has important implications. The method used to measure the sensory threshold will therefore be taken into account when considering the use of the latter as a response index.

i) Stimulus intensity

Clearly, if one is using the 'method of limits' the threshold of the subject in a particular modality cannot

be said to depend on the intensity of the stimulus in that modality since it is itself measured in terms of stimulus intensity. However, one particular feature of the inverted 'U' should be noted:

Excitatory process

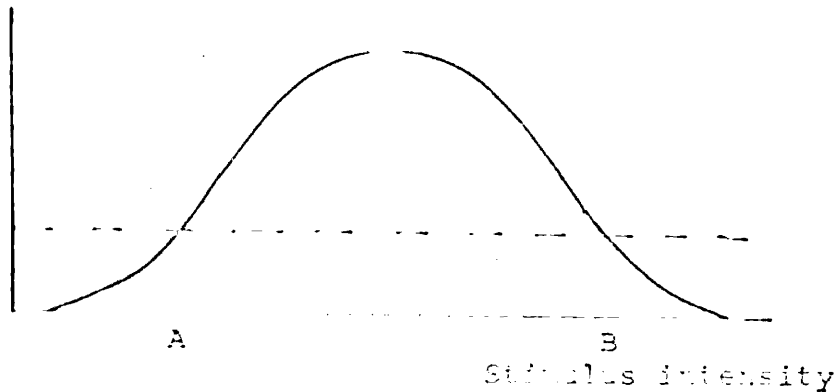


FIG. 10. The inverted 'U' curve and the absolute sensory threshold.

It will be remembered that in the Russian model response magnitude is thought to be positively and monotonically related to the level of the 'excitatory process' in the nerve cells of the relevant sensory 'analyser' (the term given by the Russians to the portion of the cortex responsible for the reception of the signal). If we assume that the value of the 'excitatory process' must lie above that defined by the dotted line for the subject to report the presence of a signal, then it follows that the subject has two thresholds not just one (i.e. A and B). The author knows of no study which has shown the existence of B, i.e. a stimulus intensity above which the stimulus is no longer reported by the subject. However, it should be pointed out that in the Russian theory of 'strength' an inverted 'U' relation is thought to hold not only between response magnitude and stimulus intensity but also ^{between} stimulus frequency and duration. In the case of the latter it should be remembered that a constant level of

stimulus may seem to disappear after a certain length of time (e.g. Gregory 1966), although whether one can call this 'transmarginal inhibition' is questionable, since the phenomenon is often attributed to peripheral retinal processes.

In the 'forced choice method', the subject is presented with a stimulus on every trial but he must decide within which observation interval it occurred or in which of a number of spatial positions. The subject's threshold can be measured either in terms of the stimulus intensity required to produce errorless performance or the number of errors made at a given stimulus intensity. In the former case the same considerations apply as to the method of limits. In the case of the latter, a rise in intensity is found to cause a decrease in errors (i.e. a fall in threshold) when the range of intensities is low (Green and Swets 1974). The author knows of no study which has shown an increase in errors with an increase in stimulus intensity when the range of intensities is high.

In the method of 'signal detection', the subject is randomly presented with a stimulus on some trials but not on others and is required to state on each trial whether or not a stimulus occurred. From an analysis of his responses, measures of his perceptual sensitivity (d') and of his criterion (β) are computed. As with the forced choice method (which yields a measure of perceptual sensitivity which is equivalent to d'), an increase in stimulus intensity over a low range leads to a rise in d' (Green and Swets 1974), and once again the author knows of no studies which have shown a fall in d' with a rise in stimulus

intensity over a high range (although an analogous effect using stimulus frequency and its interaction with personality has been demonstrated, and will be discussed under the heading of 'individual differences').

The author knows of no studies which show that stimulus intensity produces an inverted 'U' relationship with β .

In the account of the remaining determinants of 'arousal' and the 'excitatory process' and their effect on the sensory threshold that follows, the method of limits, the forced choice method, d' and β will all be considered. However, the forced choice method and the theory of signal detection are relatively recent developments and their use, especially in this area of research, is only just beginning, so there will be gaps in the account of the effect on them of certain variables.

ii) Drugs

Russian workers, and also Haslam (1972) and Diamond (1970) in the West have shown that sensory thresholds are lower under the stimulant drug caffeine than under placebo (see Gray 1964). However, American workers (Mandellbaum 1941; Granger 1960) have failed to confirm this. Both groups of workers used the method of limits.

Fischer et al. (1969) found that the taste threshold, measured by the forced choice method, is lowered by the stimulant drug Psilocybin. Furthermore, it has been demonstrated that the depressant drug Phenothiazine raises the taste threshold (Fischer et al. 1965; Fischer and Kaelbling 1967). It should be pointed out that these groups of workers did not use the absolute sensory threshold (i.e. signal present v. no signal present), but the 'j.n.d.'

threshold (i.e. 'just noticeable difference' threshold). It could be argued that the j.n.d. threshold is inversely proportional to the slope of the curve relating the 'excitatory process' (or response magnitude) to stimulus intensity, since a high slope would mean a greater difference in subjective intensity between the two stimuli and therefore a lower threshold. (The absolute sensory threshold is an indirect measure of the actual height of the curve for a given stimulus intensity. If the absolute threshold is passed when the 'excitatory process' reaches the level of the dotted line in Fig 25 (page 212) then an individual who reaches this level at a low stimulus intensity will, for a given stimulus intensity, have a greater height of curve than an individual who needs a higher stimulus intensity to reach this level, provided the T.T.I. has not been passed). If the just-noticeable-difference threshold is indeed a measure of the slope of the curve, the implication is that in the studies mentioned above, we are operating on portion 'A' of the inverted 'U' i.e. the portion over which an increase in 'arousal' leads to a steepening of the curve. However, Smith (1968) failed to find an effect of the stimulant drug nicotine on the absolute sensory threshold in the auditory modality using a forced choice method.

iii) Accessory stimulus intensity

Using the method of limits, Shigehisa and Symons (1973a) found a significant interaction between introversion and intensity of accessory visual stimulation on the auditory threshold. All intensities of accessory stimulation lowered the threshold in extroverts. However, in introverts the

threshold was lowered by weak and medium intensity accessory stimulation but raised by strong accessory stimulation. It will be readily apparent that these results could be explained by the inverted 'U' (though because of the method used the exact mechanism may not be as simple as it might at first seem; see page 461). Similar results using the effect of accessory auditory stimulation on the visual threshold were found by Shigehisa^{,P.M.} et al. (1975). Shigehisa and Symons (1973b) also found that in introverts only, the effects of accessory stimulation would persist for between thirty seconds and eight minutes, indicating that the excitation from such stimulation may take longer to 'fade away' in introverts than extraverts.

In none of these studies was neuroticism found to be a relevant variable. However, Siddle and Mangan (1971) found that subjects whose visual threshold was lowered by accessory auditory stimulation had lower N scores than subjects whose threshold was raised.

Ozbayday (1961) found that the auditory threshold is lower in light than in darkness, and both Gregg and Brogden (1952) and Thompson et al. (1958) found that visual stimulation lowered the auditory threshold provided the subject was instructed to attend to the auditory stimulus. An analogous effect was found by Semenovskaya (1947), using the visual threshold and accessory auditory stimulation. All these studies used the method of limits.

Using the forced choice method, a lowering of the sensory threshold due to accessory stimulation has been found in the auditory modality (Watkins 1966) and in the visual modality (Watkins and Fehrer 1965). However, Seif^{and Howard} (1975)

argue that these effects could be explained by special features of the design used, and in their own study of the auditory threshold they found that there was no consistent effect of absolute level of visual accessory stimulation. Although the discrimination index (d') was a positive function of change in level at this stimulation, this was not significant in Seif's study. However, a decrease in level of visual stimulation caused a significant increase in the subject's criterion. Zwosta and Zenhausern (1969) have found that low intensity auditory stimulation raises the value of d' . Kuechler ^{and Odwar} (1968) has also shown that electric shock increases d' in the auditory modality in normal subjects, but decreases it in neurotics and schizophrenics (who he argues are more highly 'aroused'). The shock also raised the criterion in all three groups, but the effect was not significant. Kuechler's neurotic subjects do, however, appear to have passed the T.T.I. with respect to d' . This in fact ties in with the finding that neurotics have higher visual thresholds than normals (Granger 1957). The method used was a forced-choice one which yields an index which is equivalent to d' . This finding was taken by Gray (1967) as evidence against the view that neuroticism is negatively related to 'strength'. However, Russian workers in this area have used the method of limits which is criterion-dependent and which we have already argued is also related to the absolute height of the inverted 'U' curve (see page 212). However, we will argue in the next section ('Drive') that d' is not only criterion-independent but also related to the slope of the inverted 'U'. Furthermore, we will suggest that apparent transmarginal effects

may be demonstrated for d' even though the true T.T.I. has not been passed. Kuechler's and Granger's results, therefore, are consistent with the view that neurotics are operating further to the right along the inverted 'U' than normals, and we do not even have to assume that they have surpassed their T.T.I.

However, we would also like to point out that studies employing hospitalised, psychiatric subjects must be treated with caution since such subjects differ from normals in many different ways (for instance, their performance may be influenced by long-term institutionalisation, the administration of drugs, etc.).

iv) Drive

Using the method of limits, Gershuni *et al.* (1960) and Sokolov (1963) have shown that reinforcement lowers the sensory threshold. Fischer (1967) has demonstrated that the forced choice taste threshold is raised by experimentally-induced anxiety. It is possible to incorporate this finding if one takes into account the fact that the measure d' in a forced choice or signal detection task is in fact analogous to a j.n.d. measurement. The reason for this is as follows. In the forced choice or signal detection task the subject must discriminate between the subjective sensation produced by a signal's presence and that produced by its absence. (Before the actual measurement takes place the subject is usually given a preview of the signal-present and signal-absent situations so that he will develop an idea of the nature of the two concomitant sensations and the difference between them). But the theory of signal detection postulates that in fact the background neural noise in the

subject's nervous system varies around a mean level, as does also the subjective sensation produced by a signal. The subject thus is really comparing two overlapping distributions of noise and signal plus noise. His ability to discriminate between them (and therefore his value of d') will be greater if the degree of overlap between them is low.

The degree of overlap depends on two factors. Firstly the difference between the means, and secondly the variance of the two distributions. The larger the difference between the means and the lower the variance, the less the overlap and the greater the value of d' . The difference between the means is proportional to the slope of the curve relating stimulus intensity to the level of the 'excitatory process'. Also, Green and Swets (1974) have suggested that the variance of the distributions increases as the absolute values of their means increase. Both these factors therefore predict that at least over the part of the inverted 'U' where the slope of the curve gets flatter as one moves along the 'X' axis to the right, the value of d' will decrease as one moves to the right.

Excitatory process

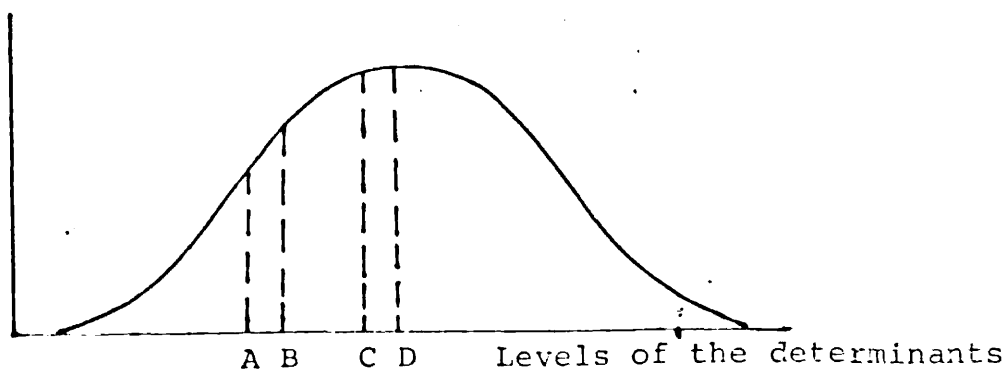


Fig.26. The gradient of the inverted 'U' and the sensory threshold.

Thus in the above graph the difference in the mean 'excitatory process' between C and D is less than between A and B, and the variance of the distributions will be greater. So, paradoxically, it is not even necessary to postulate that one had passed the threshold of transmarginal inhibition to explain Fischer's finding that the forced choice taste threshold is raised by an increase in experimentally-induced anxiety.

However, it should be equally clear that if one had been operating on the extreme left hand portion of the curve, the difference between the means, at least, of C and D, would have been greater than that between A and B, since over this part of the curve the slope increases as the level of a determinant (e.g. anxiety) increases. Since in a threshold measurement stimulus intensities are very low, it is perhaps more likely that this would be the case. If so, Fischer's results cannot be explained in the above fashion.

v) Fatigue

The author knows of no studies which have looked at the relationship between sleep deprivation itself and the sensory threshold. However, if it is possible to regard sleep deprivation as a continuum ranging from the normal waking state at one end to actual sleep at the other, then it is worth recording the common finding that sensory thresholds are raised during sleep (e.g. Oswald 1962).

vi) Novelty

Steklova (1958; 1959) and Sokolov (1963) have shown that the orienting reflex elicited by accessory auditory stimulation causes a lowering of the visual threshold as

measured by the method of limits. On Sokolov's model, the orienting reflex occurs in response to a novel stimulus which fails to match the neural models of past, familiar stimuli.

vii) Individual Differences

a) Western Measures

Method of limits: In the auditory modality, Shigehisa et al. (1973) found no relation between introversion and the sensory threshold under control conditions (i.e. in the absence of accessory stimulation). This lack of correlation was also found by McGuiness (1973) and by Stephens (1969), although the former used Cattell's 'exvia' and the latter the Heron inventory rather than the E.P.I. In the Stephens study, moreover, correlations were tested for a wide range of frequencies (250 - 2000 Hz).

In the visual modality, Shigehisa et al. (1975) found no correlation between the sensory threshold and extraversion in the absence of auditory accessory stimulation (see the section on 'accessory stimulation' for an account of the effects of this determinant on subjects differing in level of introversion; page 215).

However, Siddle et al. (1969) found that if high neuroticism scorers were excluded, there was a significant negative correlation between introversion and the absolute visual threshold ($r = -0.52$ and -0.57 in two separate groups). If the high N scores were included, the correlations were reduced and no longer significant ($r = -0.16$ and -0.33). This fits in with the prediction made earlier that where the slope of the curve steepens ^{when} we move to the left (portion 'B'), the effect of any one determinant (e.g. introversion) will be greater if the level of any other determinant (e.g. neuroticism) is low. However, as before, it is perhaps more likely that one is operating on portion 'A'. Also the criterion-dependent method used makes the exact nature of

the underlying processes difficult to elucidate.

The area of pain perception has also been studied. This cannot really be done using the forced choice or signal detection methods since they rely on being able to score the subject's responses as correct or incorrect on the basis of whether he was or was not presented with a signal. Clearly the question of whether a signal is painful or not is a purely subjective matter and the subject cannot be scored as right or wrong. The method of limits, therefore, has to be used. For this reason only a brief account will be given. Haslam (1972) has shown that introverts have lower thermal pain thresholds, but a study by Leon (1974) does not support this. Whalen (1966) found that amongst males, introverts had a significantly greater threshold than extraverts, but the reverse was true amongst females. Shiomi (1977) found that anxious and neurotic subjects had significantly lower pain thresholds for electric shock than normals. Introverts had a lower threshold than extraverts, but the difference was not significant. On the other hand, Hare (1970) found that psychopaths, who are thought to be 'neurotic extraverts' by Eysenck (1967) and stable extraverts by Hare, did not differ from normal subjects in their pain threshold for electric shock, nor in their electrodermal response - a more objective measure - to it.

The forced choice method: Stephens (1969; 1971) has found that, using the Heron inventory, there are no significant differences between the auditory thresholds of introverts and extraverts or high N and low N subjects over a wide range of frequencies. There was also no interaction

between personality and the effect of repeated testing. Extraverts did, however, demonstrate a greater fluctuation in sensitivity, and the author suggested that this might be due to a greater fluctuation in the efferent tonus to the peripheral auditory sense organs. Similar, though non-significant findings have been made in other studies (Reed 1961; Reed and Francis 1969; Farley and Kumar 1969). Stephens (1971), however, has pointed out that the methods used by these workers were rather crude and confounded the sensitivity of the subject with his criterion. Shigehisa and Symons (1973b) have also found that introverts show greater reliability in their thresholds than extraverts (although ambiverts showed the least reliability). Furthermore, this difference was true under varying levels of accessory stimulation. There is no mention of any role for neuroticism in this study as in the other studies by Shigehisa and his coworkers (see page 216), though again it should be noted that a criterion-dependent measure was employed. It is interesting in this connection to note that Stephens (1969 *op. cit.*) has reported indirect evidence that the fluctuation in the criterion may be greater in high N subjects than in low N subjects.

As already stated, in none of these studies was a significant relationship found between personality and the forced-choice auditory threshold. Similarly, in the visual modality McGuiness (1976) found no correlation between personality and threshold. Smith (1968), however, found that the correlation between introversion and auditory sensitivity was positive and significant at the 5% level if an adjusted method of limits procedure was used (the adjustment involving

a correction for the subject's criterion), and at the 10% level if a forced-choice method was used. In the taste modality, Fischer *et al.* (1965) discovered that introverts (as defined by the concept of 'internalisation-externalisation') had lower taste thresholds for quinine than extraverts. Also Corlis (1967) found that introverts (this time using a Jungian definition of the latter rather than an Eysenckian one) once again had lower taste thresholds than extraverts.

Finally, Fischer *et al.* (1969) found that schizophrenics had lower taste thresholds than normals and the authors stated that this was in line with prediction if one assumed that the former were more 'aroused' than the latter.

Koelega (1970) used a forced choice method to look at the relationship between olfactory sensitivity and personality. There was a significant positive correlation between introversion and threshold in males (0.23 with high N scorers included, 0.27 with them excluded). The correlations in females were insignificant. There was no significant correlation between N score and threshold in either extraverts or introverts. The author suggested that the direction of the correlation with introversion might have been due to the fact that testing was carried out in a noisy, sociable environment which might have favoured the extraverts (see Eysenck 1967). However, when tested in isolation it was found that although extraverts were no longer significantly more sensitive than introverts amongst males, they were amongst females. Unlike the Siddle *et al.* studies, Koelega found that inclusion of high N scores did not make a substantial difference to the correlation between olfactory sensitivity and introversion.

Signal detection method: In the auditory modality, Stelmack and Campbell (1974) have shown that using a 500 Hz stimulus, introverts have a significantly higher value of d' than extraverts (with ambiverts in between). However, if the frequency of the stimulus is raised to 6000 Hz, introverts show a reduction in d' (as do ambiverts) while extraverts show an increase, so that the difference between them is now in the reverse direction though non-significant. The fact that frequency may be analagous to stimulus intensity has been mentioned already, and receives experimental support, e.g. from Guildford (1954). It is therefore easy to incorporate these findings into our framework, since we have seen that d' depends on the slope of the inverted 'U' curve and that movement to the right (e.g. due to an increase in frequency) would increase the value of d' if one were operating on portion 'A', but decrease it if we were operating on portion 'B'. It is not unreasonable to suggest that this may describe the positions of extraverts and introverts, respectively, since portion B lies to the right of portion A (see page 83) and introversion is, ex hypothesi, thought to produce movement to the right.

Stelmack and Campbell used a variation of the normal signal detection procedure known as the 'rating' method (McNicol 1973) in which subjects are asked to express their degree of confidence in their responses. No values of the criterion were calculated since this method does not yield reliable measures of the latter (Stelmack - personal communication).

Milner^{et al.} (1971) found that obsessionals (often classified as 'neurotic introverts') did not differ from normals in their

values of d' or the criterion in the auditory modality.

In the visual modality, Harkins and Geen (1975) have shown that introverts have higher values of d' and the criterion measure than extraverts.

One last Western measure should be mentioned, and it is one which has not often been used in this context - the sedation threshold. It has been argued that subjects with a high level of 'arousal' will require a larger dose of a sedative drug to produce sleep than subjects with a low level of 'arousal' (e.g. Claridge 1967). On this basis the finding by Byrne (1976) that there is a significant curvilinear relationship between the sedation threshold and the number of correct detections in a signal detection task (with subjects with both a very low or a very high sedation threshold showing poor performance) and a significant linear positive relationship between sedation threshold and the number of false alarms, is interesting. Unfortunately, values for d' and the criterion were not calculated.

b) Russian measures

The fact that ^{the} sensory threshold (measured by the 'method of limits') correlates significantly and positively with established indices of 'strength' of the nervous system has already been pointed out. Gray (1964) has reviewed the earlier work, and this has been confirmed by later research using the slope of the reaction time/intensity curve as a measure of 'strength' (e.g. Siddle et al. 1969; Sales ^{and Thorpe} 1972).

It should also be pointed out that Yermolayeva-Tomina and other workers (see Gray 1964) have shown that accessory sensory stimulation lowers the sensory threshold in 'strong'

subjects, but raises it in 'weak' subjects. This could be considered analogous to Shigehisa et al 's findings (1973; 1975) in relation to extraverts and introverts. Siddle and Mangan (1971), however, found a relatively poor confirmation of Yaroslavskii-Tomina's result if 'strength' was defined in terms of the threshold index itself, measured in the absence of accessory stimulation.

Gray (1964) has also reviewed a number of studies which have looked at the effect of caffeine on sensory thresholds in 'strong' and 'weak' subjects. 'Strong' subjects tend to show very little change in threshold, whereas 'weak' subjects show a large increase in sensitivity or a fall. Gray points out that these findings have not been satisfactorily integrated into the 'theory of strength'.

CHAPTER FIVE - GUSTATORY INDICES: THE DESIGN AND EXECUTION
OF A STUDY

The review of the literature provided in Chapter 4 shows that for all four indices we appear to have a very mixed picture. Many studies provide confirmation of the inverted 'U' hypothesis, but many others have failed to do so. In most cases, however, this was because the results were non-significant rather than because they were significant but in the opposite direction to that predicted. Non-significant results can, of course, occur for many reasons (e.g. too few subjects, etc.) and this is a point which we will develop at greater length elsewhere. Also, where the results have seemed actually contradictory to the inverted 'U' hypothesis, we have often tried to suggest reasons why this might have been so in the individual study in question (particularly where measures of personality were involved). There is, of course, also considerable conflict apparent when we make comparisons across studies (as well as failures to confirm predictions within a given study). Such comparisons are, however, hazardous since studies differ in so many respects, and in an area such as the inverted 'U' hypothesis one would expect the results of a study to depend on a large number of factors. In connection with this point, perhaps the most general thing that can be said is that there seems to be a great dearth of studies which have looked at more than one proposed determinant conjointly. We have argued many times that such multifactorial studies are really the only way to test

whether the inverted 'U' model in its most general form has any validity or not.

We therefore propose to try to make good this omission by employing several factors in a single set of experiments combining all four indices. Clearly the gustatory modality (taste) provides an opportunity to do just this.

1) The choice of factors

The choice of proposed determinants is governed partly by the general points made when each of the individual determinants was discussed earlier (see pages 110-4). It will be remembered that at that time some of the determinants were looked upon in a less favourable light than others either because there was some form of theoretical ambiguity associated with them (e.g. drive) or because of practical problems (e.g. drugs). Also we must take into account more specific considerations arising out of the review which has just been provided.

Taken together, the following factors have been chosen:

Stimulus intensity: this is a factor which is easy to manipulate in taste research and which is an obvious candidate to fill the role of a multi-level factor which we argued was desirable. Furthermore, many of the previous findings in this area relating to stimulus intensity suggest that it would be promising. Examples include the study by Wardell (1974) on salivation and the study by Pangborn ^{et al} (1970) on hedonic tone (see pages 181 and 202 respectively). Also our theoretical analysis of the magnitude estimation measure indicated that stimulus intensity would be a worthwhile measure to use.

Accessory stimulation in the form of white noise is another factor which has been chosen, partly because of its practicability and partly because it has often shown predictable effects (e.g. Corcoran and Houston 1977: see page 177).

Introversion and neuroticism are of obvious theoretical interest here, so these were also included.

Of the others, novelty (in the form of a comparison between two sessions) is one which will also be given some consideration.

1) Predictions

As far as predictions are concerned, we have already gone into the kinds of results that would be expected on the basis of our model and these are applicable in general to experiments in this area. We will not repeat the arguments which led up to the predictions, but the various kinds of outcomes are summarised in Fig. 27.

We must, however, consider a little more closely predictions relating to the sensory threshold which we have already argued is related to the gradient of the inverted 'U' and not its absolute height.

Fig. 28, below, shows the way in which the gradient of the inverted 'U' changes as one moves to the right along the 'X' axis. We can, therefore, use this as a basis for prediction, but with the qualification that because we will be looking at very weak stimuli, we are most likely to be operating on the left hand portion of the curve (though it is not impossible that we will be operating further to the right with certain combinations of factors). This situation may change though if stimuli which are further above the absolute threshold are used. We will investigate such a

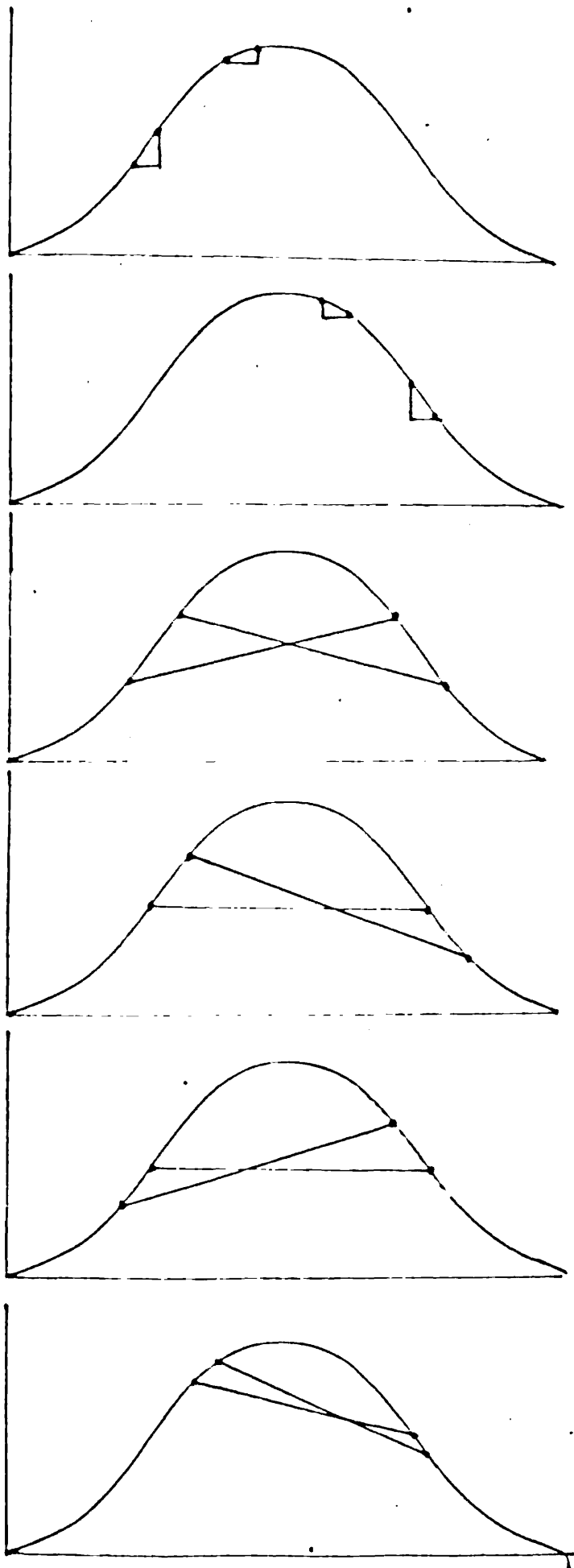
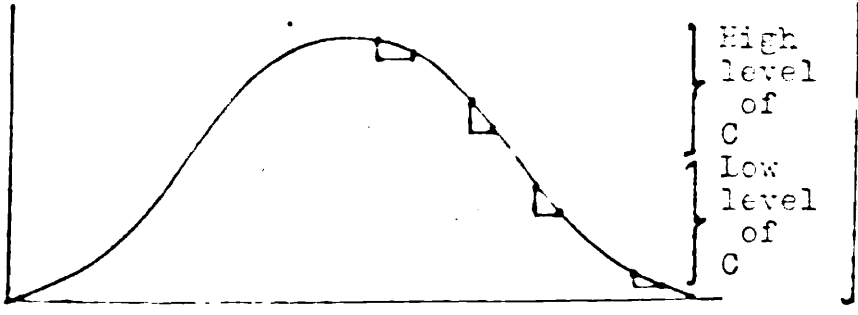
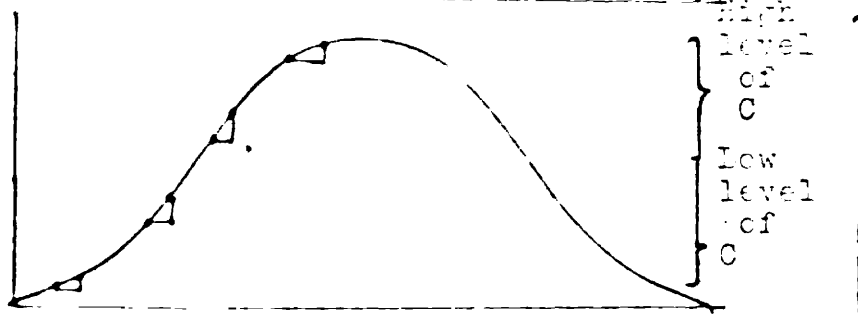
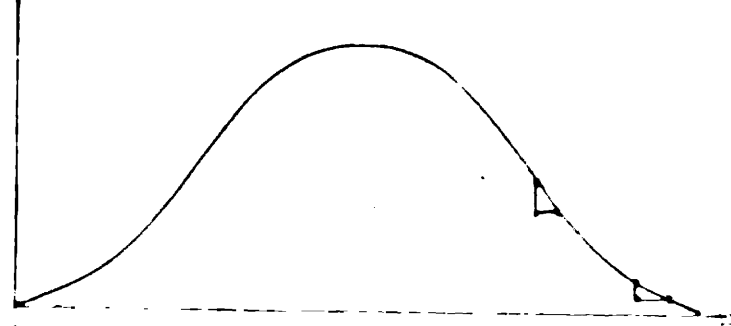
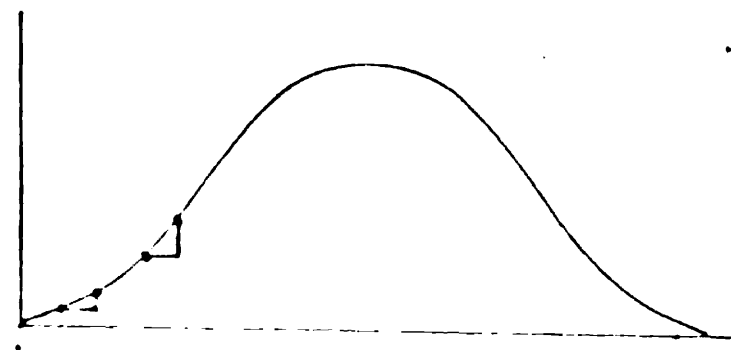
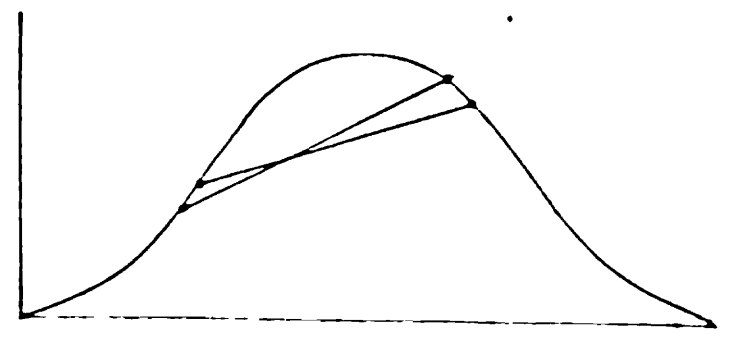


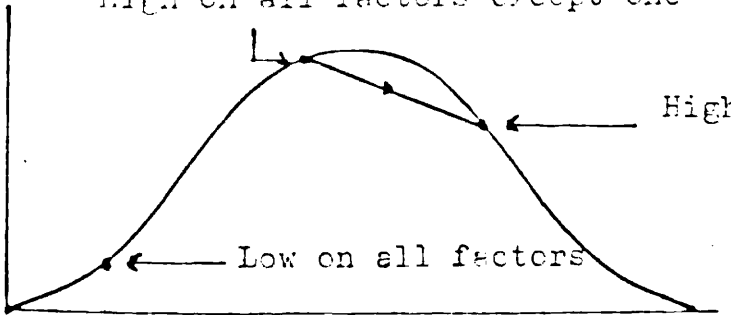
Fig. 27. The general categories of interactions which are consistent with the modified inverted 'U'.

With the exception of the last diagram, the order of the points along the 'X' axis of the curves is from left to right : Low A, Low B; High A, Low B; Low A, High B; High A, High B.



Triple interactions based on the size of differences

High on all factors except one



High on all factors

Low on all factors

A multiple interaction

possibility in the section on reaction time and signal detection theory, and we will discuss the curves depicted below and the relationship between them in greater detail at that time.

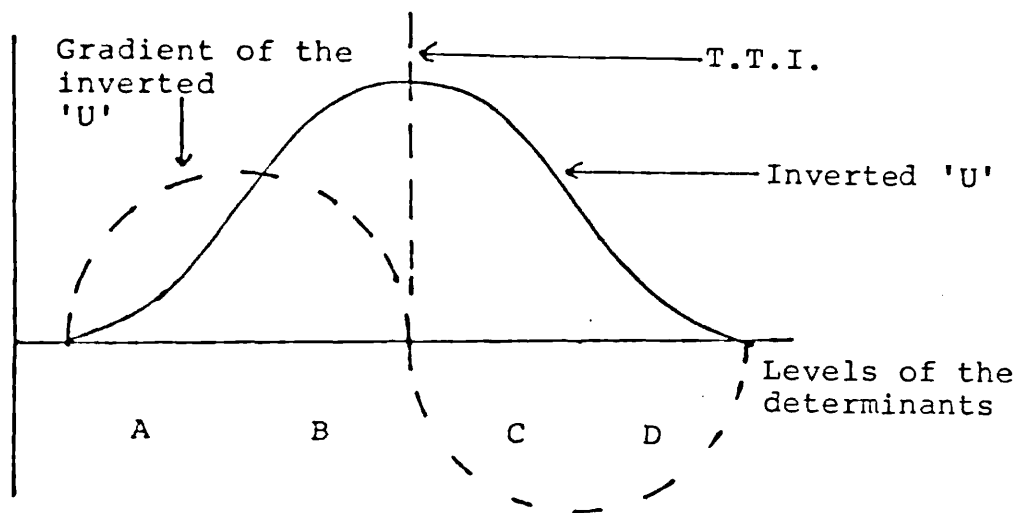


Fig.28. Predictions for the forced choice discrimination threshold.

.3) Additional measures

As well as the four main indices described above (i.e. salivation, magnitude estimation, hedonic tone and sensory threshold) there are two other groups of measures we are going to employ.

i) Physiological indices

It will be remembered that in the Western model of the inverted 'U', the hypothesised intervening construct is known as 'arousal'. Furthermore we described how Western workers have often assumed that autonomic indices are direct

measures of this construct. We criticised this view on a number of grounds, though we did point out that there were other reasons why physiological measures in general were a worthwhile inclusion in experiments in this area, particularly cortical indices such as E.E.G., but also to a lesser extent autonomic indices. One of our main indices - i.e. salivation - is itself an autonomic measure, so it is possible that it may show similar relationships with the determinants as ^{other} autonomic indices which we might include. For these reasons it was decided to employ four other autonomic measures - heart rate, body temperature, blood pressure and pupil diameter. The choice of them, rather than of other physiological measures (both autonomic and cortical), was made very largely on practical grounds since they were the only ones which required relatively little equipment and technical expertise. Even with these, the author acknowledges that the techniques used to measure them were somewhat crude (particularly in the case of the cardiovascular measures), especially in view of the great sophistication that has been achieved in the psychophysiological area (e.g. Venables and Christie 1974).

We also have some other reservations about them. For example, cardiovascular measures are known to be dependent (both in terms of tonic and phasic levels) on the degree of physical fitness of the subject. This is, therefore, likely to be a complicating factor, especially since there is some evidence that degree of physical fitness may be related to personality dimensions such as introversion and neuroticism (e.g. Christie, personal communication).

However, we have decided to include them since it is possible that they may help elucidate certain theoretical issues. One of these is whether or not autonomic indices can indeed be considered to be direct indices of 'arousal'. One could test this by looking at the effects of the determinants on the one hand upon our main indices and upon our autonomic measures on the other, and comparing the two sets of relationships. As Gray has pointed out (1964, *op. cit.*) if the Western model is correct and if Western workers are correct in assuming that autonomic measures do reflect 'arousal', one would expect a positive, monotonic relationship between the determinants and the autonomic measures (excluding salivation for which we have argued there is some evidence of a curvilinear relationship), but an inverted 'U' relationship between the determinants and our main indices (which we regard as proposed determinants).

On the other hand, if the Russian model is correct, and if autonomic measures reflect the Russian intervening construct ('excitatory process'), we would expect an inverted 'U' relationship between the determinants and both the main and autonomic indices. There is some evidence bearing on this point, already. For instance, Malmo (1966) and Malmo and Belanger (1967) have used heart rate and found evidence to support the Western view in rats. On the other hand, Fowles *et al.* (1977) found evidence to support the Russian view in humans using skin conductance. Other studies using E.E.G. have also supported the Russian view in humans - e.g. Savage 1964; Winter *et al.* 1976.

These autonomic measures also provide the opportunity to test two other hypotheses. The first is that neuroticism

is related to the level of activity in the autonomic nervous system (Eysenck 1967), and the second is that introversion is related to the balance between the sympathetic and parasympathetic halves of the autonomic nervous system (Gellhorn 1968, 1970; Wenger and ^{Cullen, 1972}). Lester (1974) has suggested that in introverts the parasympathetic nervous system may be dominant, whereas in extraverts the sympathetic nervous system may be dominant. The evidence for this is somewhat oblique, but if correct, it is the present author's contention that it could account for the findings relating a high level of introversion to a high level of salivary response, since the latter is increased by increased activity in the parasympathetic nervous system and decreased by increased activity in the sympathetic nervous system (Wright, 1964). However, Small (1973) failed to find any relationship between introversion and sympathetic dominance using a heart rate measure, so the issue is unresolved.

Finally Orlebeke (1973) has shown that extraverts and high N subjects show phasic heart rate deceleration to a neutral non-signal stimulus, whereas introverts showed phasic acceleration (stables hardly responded at all). Earlier work (Lacey and Lacey 1964 ; Graham and Clifton 1966) has suggested that heart rate deceleration in response to a stimulus may represent attention or 'intake', since it would result in de-inhibition of cortical activity via a reduction in the output of baroreceptors. On the other hand, heart rate acceleration may represent a 'defence reflex' or 'rejection' when the stimuli are very strong or painful. If so, then Orlebeke's findings with respect to introversion at least might make sense since the inverted 'U' model would

predict that introverts are likely to perceive a stimulus as painful at a lower intensity than extraverts. One might also have predicted the same, however, when comparing high N subjects to low N subjects, so Orlebeke's findings are much more equivocal with respect to this dimension. The inclusion of heart rate measures may provide an opportunity to clarify this issue.

(i) State measures

In connection with the search for direct indices of 'arousal' it should be pointed out that a possible rival to autonomic measures is a group of 'state' measures based on subjective report, and this is the second group of additional indices that we will employ.

Thayer (1967) has developed a checklist to measure the state of 'activation', which he equates with 'arousal'. This has been shown to vary in a predictable way with a number of the determinants of 'arousal' (e.g. drive as induced by an impending exam), and it has also been shown to correlate highly with physiological measures. Frequently, in fact, such correlations are higher than the correlations between the physiological measures themselves, possibly because of the phenomenon of 'individual response stereotypy' (Sternbach 1966), according to which the internal central changes induced by a given variable may manifest themselves more markedly in some physiological indices than in others, the pattern of response varying from individual to individual (see page 95). According to Thayer, this fact goes some way to meeting the objection that 'state' measures are too subjective in comparison with physiological measures.

At the time the present experiment was carried out, Thayer's checklist was not available to the author, but a similar checklist developed by Nowlis (1966) was available which includes an activation scale and which provided many of the adjectives for Thayer's own checklist.

In addition, a state measure of anxiety developed by Spielberger ^{et al.} (1970) was used. As has already been seen, trait anxiety is related to both neuroticism and introversion (Spence and Spence 1966), both of which have been postulated to be determinants of 'arousal'. Also trait anxiety has in its own right been postulated as a determinant of 'arousal' (e.g. Gray 1977), and Spielberger has shown that 'state' measures of anxiety and 'trait' measures are closely correlated, in addition to the fact that state measures are responsive to other determinants of 'arousal' (e.g. drive - Sachs and Diesenhau, 1969)

4) Method

i) Factors governing the choice of method

We need first to discuss certain methodological issues connected with some of our main indices, and to explain why a particular procedure was adopted in preference to another.

Salivation was measured using standard sized cotton wool rolls and swabs (details of which are given in Appendix A). The size of these was chosen so that they were as large as possible (to ensure maximum absorption of saliva) without being uncomfortable for the subjects and without making insertion and removal difficult. These factors were established during pilot experiments. There are two large pairs of salivary glands: parotids and the submandibular glands. The right and left parotids each open into the mouth

by a duct whose orifice is located on the inner cheek opposite the second molar upper tooth. The submandibular glands open into the mouth by orifices beneath the tongue as does a third, smaller gland - the sublingual gland (diagrams in Appendix A). In all of the studies investigating the relation of salivation to personality, except one, a single sublingual swab has been used to collect the saliva. Such a swab would be expected to absorb virtually all the saliva secreted by the submandibular and sublingual glands, but the degree to which it also absorbed the saliva secreted by the parotids would depend on the drainage of this saliva down from the parotid duct orifices and this in turn would be expected to be affected by factors such as the position of the head and tongue and mouth movements.

The one exception mentioned above is the study carried out by Frith (1968), in which a modified Lashley disc was used. This consists essentially of a double circular disc with an inner compartment from which leads a tube to drain off the saliva and an outer compartment from which leads a tube to provide suction. The capsule is positioned so that the opening of the parotid duct leads into the inner compartment. The capsule is held in place by the suction. The saliva is drawn off from the inner compartment and its volume is measured, usually by counting the number of drops that are obtained in a given length of time (i.e. by volume).

These are two of the three main methods to measure salivation discussed by White (1977) in an exhaustive review of such techniques to which the reader is referred. The third method is one which was adopted in the present experiment and involves the use of a sublingual swab positioned

beneath the tongue, but also a cotton wool roll placed over the opening of the parotid duct on each side.

The first method - i.e. the single sublingual swab - is not a very accurate way of collecting the secretion of the parotid gland. Conversely the second method (the Lashley capsule) does not measure the sublingual and sub-mandibular secretions at all, and unless two capsules are used it only measures the secretions from one of the parotid glands. This is a disadvantage since, as White (1977) has pointed out, there is evidence that some subjects may show gland dominance - i.e. that the secretion from the gland on one side is more copious than the secretion from the gland on the other side. Even when two capsules are used the correlation between the left and right gland secretions is lower than if two cotton wool rolls are used (the correlations are 0.69 and 0.90 respectively, under conditions of acid stimulation; under basal conditions - i.e. with no overt stimulus present - the correlations are 0.21 and 0.92 respectively). In addition, the method has the disadvantage that it requires complex equipment to collect and measure the quantity of saliva and it has also been found (M.J. Christie - Personal Communication) that the suction used to hold the capsule in place can sometimes cause mild tissue damage if its intensity is not very carefully controlled. Furthermore, it has been pointed out to the experimenter by Professor J. Garrett (Professor of oral physiology at King's College Hospital - whose help the author acknow-

ledges) that owing to the nature of the capsule it is more likely to cause discomfort and alarm in subjects (which, of course, could affect subjects with different personality profiles in different ways) than a small cotton wool roll.

Thus the single sublingual swab method and the Lashley capsule method both have major disadvantages. Principal amongst these is that neither accurately measures the total salivary secretion. This is particularly important since Kerr (1961) has shown that the relative contribution of the different glands to the total salivary secretion changes as stimulus intensity is changed.

Furthermore, White (1977) in his review argues that the method of the two cotton wool rolls plus the sublingual swab (known as the 'S.H.P.' test in honour of the experimenters - Strongin, Hinsie and Peck - who first developed it) has been shown to be more reliable than the single sublingual swab method. The reliability for the SHP test is in the region of 0.85 over a period ranging from twenty-four hours to a year. The reliability of the single sublingual swab method ranges from 0.78 to 0.50 for a period of twenty-four hours. The Lashley capsule does give reliable results - the correlation is 0.95 for a period of one week, but as has been seen it has other disadvantages and is in fact only required where precise second to second changes in salivation rate must be measured (for instance in studies on conditioning of the salivary response).

In view of all these factors it was decided to use the SHP test in the present study. Exact details of the procedure are given later.

MAGNITUDE ESTIMATION

This index is less of a problem since it requires virtually no equipment. It is, however, desirable to give the subjects some training in its use and later we will describe how this was done.

HEDONIC TONE

Hedonic tone can be measured in either of two ways, as already stated. The first - the direct method - is to get subjects to rate the degree of pleasantness or unpleasantness associated with particular stimuli or with the general experimental situation. The second - the indirect method - is to assess the responses which the subject emits, presumably in order to alter his level of hedonic tone. We have already discussed the relative merits of these two methods, and we will not repeat the account here. Suffice it to say that we chose to use the first method because it is more practicable (requiring no complex equipment), because it is more direct, and because the theory underlying its use is simpler, requiring fewer intervening steps.

One point that should be mentioned here is that a category scale (see Appendix A) rather than a numerical ratio scale was chosen since pilot experiments showed that subjects often get confused between the latter and the numerical ratio scale that was used for the magnitude estimation judgements.

THE SENSORY THRESHOLD

The method used to measure the sensory threshold needs to be considered in some detail. We have stated that there are three main groups of methods:

The method of limits: This may be 'ascending', 'descending' or both. In the ascending method the intensity of the stimulus is increased until the subject reports its presence. In the descending method the intensity of the stimulation is decreased (from an initially higher level than in the ascending method) until the subject reports its absence. In the ascending/descending method the two procedures are used alternately and an average measure is taken (since the ascending and descending methods do not always give the same results).

We have argued, however, that the subject's perceptual sensitivity and his criterion level are inextricably confounded in this method and it was, therefore, rejected for the present project.

Forced choice method, In this technique the subject is presented with a stimulus on every occasion. For instance, it may be presented in one of a number of different observation intervals and the subject's job is to state in which one the stimulus occurred. Alternatively it may be presented in one of a number of spatial positions and again the subject must select one of these as his response. Finally there may be several categories of stimulus and the subject must state which category a given stimulus on a given trial belongs to.

In the latter case the stimuli in the various categories may differ from each other in a number of ways, and stimulus intensity may be one of these. The threshold can be measured either in terms of the number of mistakes made at a given difference in intensity between the categories or in terms of the difference in intensity that is required before the subject makes no mistakes.

As Hake and Rodwan (1966) have pointed out, this forced choice technique does not measure the criterion but it controls for it, ensuring that the final threshold value obtained reflects the perceptual sensitivity of the subject and not his tendency to respond (since he, of course, makes a response on every trial).

Also, as Hake and Rodwan (op. cit.), Green and Swets (1974) and others have pointed out, it provides a measure which is equivalent to that of the discrimination index (d') derived from signal detection methods.

Signal detection procedures, This is the last category of techniques that we will consider. In this method, the subject has to decide on any one trial whether a signal occurred or did not occur. From the proportion of hits (i.e. the proportion of trials on which a signal was presented and the subject stated that a signal had occurred) and the proportion of false alarms (i.e. the proportion of trials on which a signal was not presented but the subject nevertheless reported that a signal had occurred), separate measures of his discrimination index (d') and his criterion (the reciprocal of his positive response bias or 'tendency to respond') are obtained.

Fergenson (1970),^{and} Green and Swets (op. cit.), have pointed out the impracticabilities of using signal detection methods in taste research. For this reason it was decided to use a forced choice technique in which the subject would have to discriminate between distilled water and a very dilute lemon juice solution (which the subjects were told was called 'fluid x').

This is, of course, a just-noticeable difference measurement and not an 'absolute' sensory threshold measurement. However, the basic thrust of signal detection theory is that the very concept of an absolute sensory threshold (as measured by the method of limits, for instance) is an invalid one. All thresholds involve discrimination. In the case of most signal detection and forced choice techniques it is discrimination between 'stimulus-present' ('signal') and 'stimulus absent' ('noise'). In the present instance to have used this method in the context of a forced choice procedure would have required the experimenter to present a taste stimulus either within one of a series of observation intervals or in one of a series of spatial positions on the subject's tongue. Neither of these seemed practicable. Instead, therefore, the subject would be required to discriminate between two stimuli which were both suprathreshold in the tactile sense, but which differed in their acidity. The discrimination task was therefore a gustatory one.

ii) Subjects

Since several indices were being investigated together, the duration of the experiment was fairly prolonged and therefore the number of subjects that could be tested reduced owing both to limitations of time and to some extent also to the unwillingness of subjects to commit themselves to lengthy experiments.

For this reason it was necessary to select subjects carefully to try to control for unwanted variables. It was therefore decided:

- i) To use only male subjects to control for possible effects of the menstrual cycle on the indices used (e.g. Diamond *et al.*, 1972)
- ii) To use only Caucasian subjects because of the differences between Caucasian and Negro subjects that have been demonstrated in some of the indices (e.g. Peck 1959 in relation to salivation)
- iii) To eliminate any subjects who admitted to taking drugs for hallucinogenic or medical reasons (other than ordinary aspirin)
- iv) To only use subjects who were either in the first or second year of their academic course since it was anticipated (correctly as it turned out) that the whole series of experiments could span up to two years and it was therefore essential that subjects should not leave the university in the meantime. (Reasons why the same subjects were used throughout have been given earlier. See pp. 163-4)

Also, prospective subjects were told that they would be asked to take part in more experiments at a later date and that they must commit themselves to this and not drop out half-way through.

Subjects who were acceptable on the basis of the above factors were told that the experimenter was not sure whether or not he would be calling on them to participate since he was not sure how much time he had available (which was true). He was also given a brief outline of the details of the experiment as follows:-

"The experiment will essentially involve placing a series of sterile gauzes soaked in harmless fluids on the tip of your tongue. During the course of the experiment I will be asking you at various times to make certain judgements about the taste of these fluids. I will also be measuring your salivation rate by placing sterile cotton swabs at various points inside your mouth. You will also be played noise at times through earphones but it will not be painful. Measurements will also be made of your heart rate, your blood pressure, your pupil diameter and your body temperature. I will also occasionally give you questionnaires to fill in. The entire experiment will take about two hours and will begin at 9.00am. There will be two sessions separated by exactly one week and these will be almost identical to each other except for the fact that I will not be measuring your salivation rate in the second session. You must not eat, drink, smoke, or brush your teeth on the morning before the experiment takes place."

The question of whether or not to tell the subjects about the purpose of the experiment was given long and careful consideration. In the end it was decided not to, since studies have shown that subjects are capable of consciously modifying even apparently involuntary indices such as salivation (Power and Thompson 1970). It was, of course, realised that subjects would formulate their own hypotheses about the purpose of the experiment but it was considered that this danger was a lesser one. For the same reasons it was decided not to use psychology students as subjects since they would be more likely to have prior knowledge of the hypotheses associated with experiments of this sort. It is possible that non-psychology students may have read about such hypotheses in popular books on psychology, but this factor was out of the author's control. The only thing he could limit was the information he himself provided.

Subjects were, therefore, simply told that it was an experiment to investigate the relationship of personality and perception since they would have certainly been able to deduce this anyway from the procedures which were adopted. They were, however, promised that they would be eventually fully briefed about the purpose of the research once the whole series of experiments was completed. They were also told that the results were confidential.

The subject was then given the Eysenck Personality Inventory (for this the subject was taken to a quiet portion of the library and he filled in the questionnaire

with the experimenter present - to ensure that the subject did not receive any distraction from other people - but the experimenter did not look over the subject's shoulder, but instead read a book).

It was explained to him that this was in order to find out a bit more about him and that he had nothing to lose by telling the truth since the results of the questionnaire, like the results of the experiment, were absolutely confidential.

The author then took details about dates on which the subject would be available to take part in the experiment and how he could be recontacted.

The subject's questionnaire was scored privately and any subjects with a lie score exceeding three were eliminated (as this is the cut-off point recommended by Eysenck).

Subjects with acceptable lie scores were recontacted one or two days prior to the experiment. Since pilot studies had shown that the method of magnitude estimation can sometimes cause a little confusion it was decided to train the subjects before the experiment using a procedure recommended by Stevens (1969).

The subject was told the following: "During the actual experiment I will at some stage be placing a series of gauzes on the tip of your tongue soaked in fluids of differing intensity. What I will ask you to do is to give the fluid on the first gauze any number you like between twenty and fifty. That is up to you. I then want you to give the fluid on the second gauze a

number by comparing its intensity to that of the first. So that if, for instance, the fluid on the second gauze tastes twice as intense as the fluid on the first gauze, give it a number twice as large as you gave the first one. If it tastes, for instance, half as intense as the first gauze, give it a number half as large as you gave the first. The restriction of twenty to fifty only applies to the first gauze, after that you can use any numbers you like, however small or large. You can use fractions or decimals, but not minus numbers please. I then want you to give the third gauze a number by comparing it to the second etc. In other words each time (except, of course, for the first gauze) give the gauze a number by comparing it to the previous one. Anything is possible. A gauze can taste the same, more intense or less intense than the one that went before. Just as a piece of training, I have here a series of cards and on each card is a line. I want you to give these lines numbers by comparing how long they seem to you relative to the one that went before. Give the first one any number you like between twenty and fifty. There is no right answer. I am interested in the length of the lines as they seem to you."

The subject was then shown a series of cards on each of which was a line of length 2 cms, 4 cms, 8 cms, 16 cms or 32 cms. For each length there were two cards and all the cards were presented in a random order. As the subject assigned the card a number the experimenter wrote it down on a slip of paper. The subject was allowed to see

the answer he had given to the preceding card but not any answers prior to that (this was to prevent subjects from trying to make comparisons with long-preceding stimuli which would have brought in the complicating factor of differential forgetting rates - although of course to a much smaller extent this might operate even in a comparison with the immediately preceding stimulus).

At the end he was told: "That was just to train you regarding the general method. The lengths of these lines do not necessarily bear any relation to the intensities of the gauzes I will give you during the actual experiment."

There was, of course, the danger that subjects might ignore the above statement but it was considered that dangers inherent in providing no training were greater.

Subjects were asked to compare the stimuli to the preceding one since in the method of magnitude estimation it is the slope of the function that is of interest:

$$\begin{aligned} \log \text{ subjective magnitude} &= \\ (n \times \log \text{ objective magnitude}) &+ \text{constant} \end{aligned}$$

The effect of experimental factors such as personality on the value of this slope (i.e. the value of 'n') would be reflected in the interaction between these factors and stimulus intensity.

For reasons stated earlier, the absolute values of the magnitude estimates are not readily interpretable across subjects. The absolute values are dependent on the value of the constant in the above equation which is

itself dependent on the scale 'modulus' used - i.e. the number assigned to the first stimulus. Since absolute values were not of interest it was possible to allow subjects a certain amount of latitude in choosing the number they assigned to the first stimulus. However complete freedom of choice was not given since pilot experiments showed that if subjects chose very small or very large numbers for the first stimulus they frequently got into difficulties when assigning numbers to later stimuli since of course the manipulation of such extreme numbers (e.g. .00001) is cumbersome. The range of twenty to fifty was chosen because pilot experiments showed that it yielded a scale range which subjects found to be manageable.

The above account described the various selection and training procedures that took place prior to the experiment. Gray (1964) has criticised the Russian experimenters for their failure to control variable such as sex, age, intake of drugs (such as caffeine), I.Q. etc. The first variable (sex), as has been seen, was controlled in the present experiment. An attempt was also made to match the various personality groups on age as far as possible (see Appendix A). Intake of hallucinogenic (including cannabis) and medicant drugs was controlled. An attempt was made initially to control for intake of coffee, tea, alcohol and nicotine (through cigarette smoking). However, it was found impossible to take into account the different caffeine, tannin, ethanol and nicotine contents of the various preparations consumed by the subjects.

In addition, many subjects stated that their intake of these substances was not regular but varied widely from day to day and week to week. As an alternative therefore it was decided to control for these factors by asking subjects to desist from consuming any food or drink for at least six hours prior to the experiment: a standard technique used, for instance, by Revelle *et al* (1976). This procedure was made automatically possible by the attempt to control for another relevant variable: i.e. the time of day. Experiments were conducted between 9.00am and 12 noon with subjects in a complete fasting condition (i.e. they were asked not to eat, drink or smoke anything on the morning of the experiment). This particular time of day was chosen partly for this reason and partly because Horne and Ostberg (1975) found that a relationship between introversion and salivation was most likely to reveal itself at this time. It could be argued that time of day could actually have been investigated in the present experiment by conducting tests later on in the day as well as in the morning. It was decided not to do this principally because this would have made it almost impossible to control for the intake of nutrients prior to the experiment. This may be a relevant variable even where apparently unrelated indices are used (Colquhoun 1971), but in an experiment on taste its effects could be extremely important. This fact taken in conjunction with the limited number of subjects available made the experimenter decide not to risk confounding the results of the experiment by this variable.

Intelligence quotient is another factor which the experimenter wished to control for. However, a large number of subjects refused to participate if I.Q. tests were administered (though they did not object to having their personalities assessed). However, as has been already seen, the experimenter did make strenuous attempts to train subjects in the one index used which could be described as complex - i.e. magnitude estimation. Furthermore, none of the results from the latter using the lines on the cards procedure indicated that subjects did not understand what was required of them (there are in fact no occasions when the relative size of the numbers assigned by subjects to two adjacent lines was the reverse of the actual objective relative length of the two lines). In addition, nearly all of the other indices were either simple (e.g. hedonic tone) or involuntary (e.g. salivation - although the results of the Power and Thompson (1970) experiment indicate that this may not be so in non-naive subjects).. Assuming, therefore, that subjects complied with instructions, differences in intelligence between the groups are unlikely to have exerted any major distorting effect on the results.

Subjects were tested as they became available though an attempt was made to ensure that there was no relation between personality and the order of testing. As will be seen, some subjects received the no noise condition first in session 1 (Group 1) and some subjects received the no noise condition second (Group 2). To ensure that the design was balanced it was necessary

that in each of the four personality groups ('stable introverts', 'neurotic introverts', 'stable extraverts', 'neurotic extraverts') there should be an equal number of subjects receiving the noise condition first as the number of subjects receiving the noise condition second. It was therefore essential that the total number of subjects tested be a multiple of the number eight. Taking this fact and the time available it was decided to aim at a final figure of 32 subjects (i.e. eight in each personality group). An attempt was made to isolate a pool of 32 subjects before any experiments at all were conducted, but this was not possible and so the experiments were initiated and an attempt made to recruit new subjects concurrently. Therefore, subjects were randomly allocated to Group 1 (no noise first in session 1) and Group 2 (no noise second in session 1) as they were tested until a total of eight subjects had been tested. At this point the personality scores (introversion and neuroticism) of these subjects were plotted on a sheet of graph paper and the subjects divided into four personality quadrants by means of two bimodal splits. In other words the dividing line between introverts and extraverts was chosen so that there were four introverts and four extraverts. Similarly the dividing line between 'neurotic' and 'stable' was chosen so that there were four 'neurotics' and four 'stable' subjects.

It was desirable that any two adjacent personality quadrants should differ on only one personality dimension (e.g. 'stable extraverts' and 'stable introverts' should differ only in their mean extraversion scores and not their mean neuroticism scores). For this reason the

mean personality scores for each quadrant were calculated at this point. Also the number of subjects in each of the two groups (Group 1 and 2) in each quadrant were calculated. In recruiting and testing further subjects (i.e. after the first eight) an additional factor was taken into account. It was determined firstly which quadrant the subject would fall into based on the dividing lines drawn up using the bimodal splits. It was then determined whether the inclusion of a subject would result in increasing the difference between the mean scores of two adjacent personality quadrants on the non-relevant dimension. For instance, if 'stable extraverts' had a higher mean neuroticism score than 'stable introverts' it was determined whether the inclusion of a particular subject would increase this difference. If this was the case the subject was not tested immediately but the experiment was delayed until such a time as his inclusion would not have such an effect (i.e. if in the mean time the inclusion of other subjects resulted in the elimination of or the reversal of the sign of the original difference in mean scores on the non-relevant dimension). In practice it had very little effect since very few subjects had to have their testing postponed for this reason.

Also, following the completion of eight subjects the allocation of subjects to Group 1 and Group 2 was random only if in the quadrant in question neither Group 1 nor Group 2 already contained four subjects (the maximum number permissible if 32 subjects were to be

tested and if a balanced design was to be achieved). If either of the two groups did contain four subjects, any subsequent subjects who fell in that quadrant were automatically assigned to the other group. This procedure was adopted following the completion of eight subjects since it was theoretically possible that following the two bimodal splits there would be four subjects in one quadrant and four subjects in the quadrant diagonally opposite (which could happen by chance or if the two personality dimensions were not in fact orthogonal to each other) and no subjects in the other two quadrants. This did not in fact happen, but it was possible. It would also have been possible in such a situation that all of the four subjects in one or both of the two quadrants which were not empty had been assigned to one of the two groups (Group 1 and 2) and none to the other. This too did not in fact happen, but if it had done it would still have been possible to achieve a balanced design by the appropriate allocation of subsequent subjects.

Once 32 subjects had been tested it was decided to test a further four subjects (one in each quadrant) in case some subjects were lost before the reaction time experiment (which was due to be carried out later) had been conducted. These four subjects were assigned randomly to group 1 and group 2. The effect of this was that in each of the four quadrants there were five subjects in one group and four subjects in another. One subject out of the group of five was randomly chosen and eliminated. The results that are to be presented are there-

fore from the remaining 32 subjects. The mean introversion and neuroticism scores of the subjects in the four personality groups (each containing eight subjects) are given in Appendix A.

ii) Materials

The experiment was carried out in a test room measuring approximately 10' x 10' x 10'. The room was not sound-proofed but it was located in a relatively quiet part of the building and during experiments signs requesting quiet were placed on the outside of the door and on the door controlling entry to the corridor which gave access to the room.

The temperature of the room was maintained at approximately 20°C. (This temperature was chosen because it was found to be reasonably comfortable for subjects in pilot work.) It was maintained by a convection heater controlled by a thermostat. This could, of course, only raise the temperature, it could not lower it. No cooling system was available to the experimenter. Because of this and because the room contained a water bath which was maintained at a temperature of 22°C (see below) the temperature of the room did tend to rise very slightly between the beginning and end of the experiment. This was, however, the same for all subjects.

Subjects were seated facing a table on which was placed a deep core body thermometer and a tape recorder containing a white noise tape and to which a pair of ear-phones was attached.

The subject had his back to the experimenter and to another table on which was placed a constant temperature water bath. The fluids used in the experiment were kept in jars which were placed in the water bath on a shelf whose height was adjusted so that the jars would not be

visible if the subject turned round. The temperature of the bath was maintained at 22°C (which is the temperature recommended for taste research by Fischer, 1971).

Since this temperature was higher than the room temperature, no cooling system was necessary and it was maintained with a high degree of accuracy. Behind the subject's chair was also another small chair upon which a pulse meter was placed as well as a burette, the purpose of which will be explained below.

The stimuli used in the experiment were based on pure lemon juice. It was decided to use this as some experiments have shown that the relationship between personality and salivation does not appear if synthetic analogues are used (e.g. Corcoran 1964). This of course raised the problem of how to standardise the stimuli since the content of lemon juice varies widely from lemon to lemon. It was decided therefore to extract a large volume of lemon juice prior to conducting any experiments and to homogenise this and then store it in sealed containers which could be opened just prior to the start of the experiment.

To do this the experimenter purchased 200 lemons, and during the course of a single day he extracted the juice from all of these and homogenised it and then divided it between a large number of sterile containers ensuring that no air gap was present once the juice had been placed in the container (to prevent oxidation of lemon juice constituents). The containers were sealed and stored in the ice compartment of the experimenter's home fridge. This

was a procedure recommended by Beecham's Company who stated that under these conditions no significant changes in the content of the lemon juice would take place even over a period of many months. It was nevertheless decided to check on this and so every month two of the containers were randomly chosen and the chloride concentration of the lemon juice was determined by the Biochemistry department of the experimenter's college. The choice of chloride was made on the advice of the chief technician of the Biochemistry department whose opinion it was that though any changes were extremely unlikely, if they occurred at all they were most likely to show up as changes in the chloride ion concentration. The results are given in Appendix A and they show that although the monthly values are not identical to each other (probably because of minor inaccuracies in the homogenisation procedure - details of which are also given in Appendix A) there is no overall trend with time.

Salivation was measured using the S.H.P. technique described in outline earlier (see p. 241). The heart rate of the subject was measured using a standard pulse meter (details in Appendix A). Equipment to measure and record the heart rate automatically was not available. Blood pressure was measured using a standard sphygmomanometer. Pupil diameter was measured using a special card in which are punched a series of pairs of holes arranged vertically (see Appendix A for diagram). The use of the card is described in the 'procedure' section below. Both the card and the sphygmomanometer were supplied by

the Physiology Department of St. Thomas' Hospital Medical School.

Body temperature was measured using a deep core body temperature thermometer consisting of a pad which is attached by tape to the trunk of the subject. It has the advantage over a clinical thermometer that it can be left in place to provide a continuous measure which can be recorded at appropriate intervals, at will. In addition it has been pointed out to the author (M.J. Christie - personal communication) that clinical thermometer readings are much more likely to be subject to local effects such as changes in oral blood flow (especially in an experiment involving taste stimuli) than a deep core body thermometer.

White noise was administered using a standard broad band white noise tape (details in Appendix A) whose noise level was set to 70 dB. This value was chosen on the basis of pilot experiments which showed that this was a level described by a majority of subjects as 'just uncomfortable' and very uncomfortable by none. Corcoran and Houston (1977) showed that a 'just uncomfortable' level of white noise significantly increased salivation to lemon juice although they allowed subjects to adjust the white noise level till it reached this subjective level of discomfort rather than equating the noise level for different subjects in objective terms. This point will be reconsidered in the discussion of the present experiment's results.

iv) General Design

The experiment consisted of two sessions each lasting approximately two hours and separated by exactly one week. Each subject participated in both sessions.

Each session began with a measurement of the subject's taste threshold. This was conducted under conditions of quiet.

Following the measurement of the taste threshold, five stimuli were presented in each of the noise conditions. These five stimuli consisted of pure lemon, pure diluted x 2, pure diluted x 4, pure diluted x 8 and pure diluted x 16. On the evening prior to each session two of the sealed containers were defrosted for exactly half an hour and from the 50 ml of pure lemon juice thus obtained a series of dilutions of pure lemon juice was obtained up to a dilution of x 1024. The details of the procedure are described in the Appendix A. Thus each dilution was half the concentration of the preceding one. The scale was therefore a logarithmic one, and this was chosen because for both magnitude estimation studies and the forced choice measure of taste threshold used by Fischer et al. (1966), logarithmic intervals were employed.

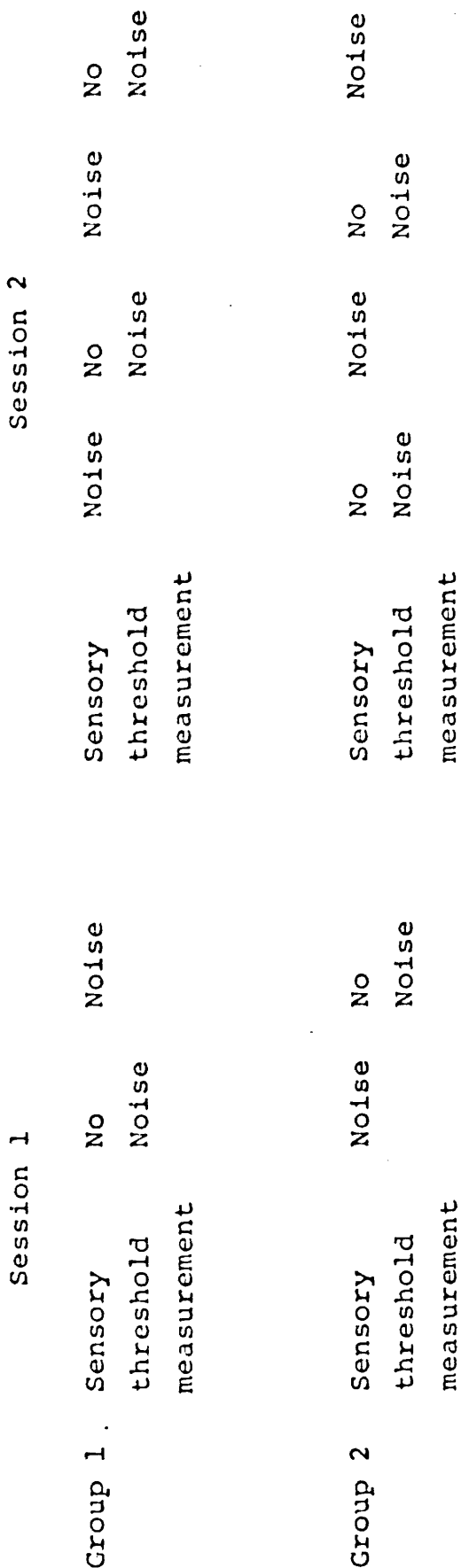
Pure lemon juice and the first four dilutions (x 2, x 4, x 8, x 16) were used in the measurement of salivation, subjective magnitude and hedonic tone whilst the higher order dilutions were used to measure the taste threshold (see later).

In session 1 each noise condition was presented once (i.e. quiet (50 dB) and noise (70 dB)). Which condition came first was determined as described earlier in the 'Subjects' section. In session 2 each noise condition was presented twice and the two noise conditions were alternated. Whichever noise condition was presented first in session 1 was presented second in session 2.

The overall design can be represented as shown in fig. 29.

The order of the five stimuli within each noise condition was determined randomly.

Each subject was asked to rate each stimulus for subjective magnitude and hedonic tone in both session 1 and session 2. Salivation, however, was measured only in session 1. The reason for this is that studies have shown that a relatively long interstimulus interval is required in order to allow salivation to return to basal levels between stimuli. Ramsay (1969) found, for instance, that this would occur if an interstimulus interval of three minutes was used. It was decided, therefore, to use an interval of approximately this length in session 1. However, since the magnitude estimation and hedonic tone measurements both involved making comparisons with the preceding stimulus it was considered desirable to use a short interstimulus interval in session 2 to minimise the possibility that differential forgetting rates between subjects might affect the results. The use of this shorter interval had the



During each noise condition five stimuli were presented (pure lemon juice, pure diluted x 2, pure diluted x 4, pure diluted x 8, pure diluted x 16).

Fig. 29 Overall design of the taste experiment

additional advantage that each noise condition could be presented twice in session 2. Thus each stimulus was presented twice under 'no noise' conditions and twice under 'noise' conditions. The results that are given later for session 2 are based on the means of these two values. This ensures greater reliability and Stevens (1939) in fact recommends that each stimulus should be presented twice under each condition employed (according to him presenting the stimuli more than twice does not yield a significantly greater amount of information).

Apart from the fact that the short interstimulus interval employed in session 2 would probably not allow sufficient time for a return to basal salivation levels, it would also not have been possible on practical grounds to prepare and insert the cotton wool rolls and the swab in the time available (an attempt was made to do this in pilot experiments but it was not found to be feasible). For this reason, salivation was not measured in session 2.

Results for magnitude estimation and hedonic tone in session 1 will be presented later but it is possible that these may not be as reliable as the results for session 2 since they are based on only one value for each stimulus intensity under each noise condition.

The Nowlis Mood Adjective Checklist, followed immediately by the Spielberger inventory of state anxiety, were administered just prior to the presentation of the first noise condition (i.e. after the sensory threshold measurement) and also just after the presentation of the

last noise condition. The condition under which they were administered (i.e. noise or no noise) was the same as that of the adjacent noise condition (e.g. they were given under conditions of 70 dB white noise if the condition that had just preceded them or that was to follow them was the 70 dB condition). They were administered in both session 1 and session 2. Just prior to their *first* administration a body temperature reading was taken. . . . Approximately fifteen minutes were required for the body temperature thermometer to equilibrate with the subject's body. Since the first reading was taken following the sensory threshold measurement, which invariably took a minimum of fifteen minutes to conduct, it was considered that sufficient time had been allowed for equilibration to take place.

Heart rate was measured during the actual presentation of the stimuli (though not during the sensory threshold measurement). Blood pressure and pupil diameter were measured after the second set of questionnaires had been administered.

v) Procedure

a) Preliminaries

Experiments were scheduled to begin at 9.00am and subjects were asked to avoid being late.

The experimenter arrived at approximately 8.45am and the following preparatory procedures were carried out:

- i) The thermostatically controlled room heater was switched on.
- ii) The jars containing the stimulus solution which had been kept overnight in the experimenter's fridge (though not in the ice compartment since defrosting time would have been considerably lengthened if they had) were placed in the water bath and the latter switched on. It was found that it took approximately ten minutes for the water bath to reach the required temperature (22°C), depending on the temperature of the room.
- iii) The deep core body temperature thermometer was switched on and placed on 'standby' which has the effect of keeping the thermometer pad at a steady temperature slightly below normal body temperature and this reduces the equilibration time when the thermometer pad is attached to the subject and switched to 'Read'.

On arrival the subject was asked to visit the lavatory (since the experiment was a long one).

He was also asked whether or not he had complied with the instructions not to eat, drink, smoke or brush

his teeth beforehand. All subjects stated that they had complied, though, of course, the experimenter had no way of checking on this.

If the subject did not arrive by 10.00am, (and this happened on a number of occasions, and in some cases the subject did not arrive at all) the experiment was abandoned for that day. If the session was the first for that subject, a fresh appointment was arranged. If it was the second session no new appointment was arranged and the subject was eliminated. This happened less frequently than the failure of subjects to arrive for the first session, probably because the experimenter emphasized on the previous session the importance of punctual arrival at the second session. He also said that failure to do so would result in the subject being eliminated and the forfeiture of the fee for participation which was not paid until both sessions had been completed. The reason why subjects who did not turn up for the appointed session 2 time were eliminated is that in order to standardise the experiment for all subjects, it was essential that the two sessions be separated by exactly the same interval of time.

If the subject arrived later than the appointed time 9.00am and if (as often happened) the subject had an appointment to keep at 11.00am (for instance a lecture), he was asked if he would be prepared to miss that appointment or arrive late should the experiment continue beyond 11.00am. If the subject agreed (as usually happened) the experiment was conducted, if not the experiment was postponed (if it was the first session).

It should be noted at this point that the experimenter at one time had considered giving the subjects water to drink prior to the start of the experiment to prevent them from suffering discomfort due to thirst. However, it was decided not to do this since a standard volume of water might nevertheless lead to different degrees of hydration of different subjects due, for instance, to differences in the volume of body fluids. In view of the findings relating body mass to personality (see Eysenck, 1960, for a review) and the argument presented by White (1977) that the degree of hydration of a subject can significantly affect his salivation rate, it was decided that this factor could confound the present study's results. It would, of course, have been possible to relate the volume of fluid given to the subject to his body weight, but the relation of the latter to the volume of the body fluid is not a perfect one and one might expect other factors (e.g. the rate of absorption of fluid from the gut) to affect the level of hydration also.

Once it was decided to conduct the experiment the subject was seated in his chair (which was situated as described earlier in the 'Materials' section). He was then asked to lift up his shirt on the right hand side, and the deep core body temperature pad was attached to the side of his trunk, with adhesive tape, just above the waist. Its position was thus standard for all subjects though the accompanying manual states that it can in fact be placed anywhere on the trunk. The

thermometer was then switched to the 'Read' position and left to equilibrate with the subject.

The experimenter then said:

"Please put these earphones on." The earphones were on the table in front of the subject. "You can adjust them until they are comfortable for you. Please keep them on at all times. Can you hear me clearly?" In all cases the subject stated that he could. The subject kept the earphones on throughout the experiment.

The experimenter then said:

"Later on at various times I will be playing you some noise which will sound like this." The white noise was then played to the subject for five seconds. "If at any time when I turn it on you can't hear it, let me know."

The lead from the pulse meter was then attached to the smallest finger of the subject's non-preferred hand and he was told:

"This is to measure your pulse rate."

The pulse meter itself was behind the subject so that he could not see the reading and the volume control was turned right down so that he could not hear it.

A paper cup was now placed on the table in front of the subject. This had a mark on the outside. 40 mls of fluid when poured into the cup just reached the level of this mark and this was visible from the outside since the cup was semi-transparent. A bottle containing approximately 1000 mls of distilled water was also placed on the table in front of the subject.

b) Measurement

The sensory threshold

The subject was then given the following instructions:

"The bottle on the table in front of you contains distilled water. Please could you pour some of the fluid into the cup until it reaches the level of the mark." The subject then did this and the experimenter checked the level of the fluid.

"Please now take all of the fluid in the cup into your mouth and swill it around thoroughly till I tell you to spit it out into the bucket." The bucket was placed beside the subject's chair. It was realised that this might be an unpleasant procedure for the subject but no means of draining the waste fluid away out of sight was available. At the moment the subject took the fluid into his mouth the experimenter noted the time on the stop clock placed on the experimenter's table (i.e. the one on which the water bath was placed) and he told the subject to spit when 15 seconds had elapsed.

This procedure was then carried out two further times. Thus the subject rinsed three times in all. The reason for this was to ensure that the subject's mouth was clean, especially his tongue. This organ, in particular, is often coated with mucus in the early morning. Such a coating is heavier during illness, and for this reason subjects were not tested if they were suffering from any illness including a mild cold. This rarely happened during the early experiments which were carried out in the summer term, but it was a cause of

delays and cancellations during the following Michaelmas term. It will be remembered that subjects had been asked not to brush their teeth on the morning of the experiment. This was because not only do such brushing procedures vary considerably from one person to another, but because many people do not brush their teeth at all. For this reason it was decided that it was better that the experimenter himself should standardise and supervise a cleaning procedure (as described above) immediately prior to the presentation of any stimuli.

The subject was then told the following:
"In a moment I'm going to ask you to stick out your tongue like this." The experimenter demonstrated by sticking out his tongue so that approximately $1\frac{1}{2}$ inches protruded from his mouth. The tongue was held as horizontal, still, and as flat as possible. "Could you try that." The experimenter then instructed the subject if the subject did not do it properly. All subjects managed to produce the desired shape of tongue reasonably well after a few tries, though the amount of practice did differ somewhat from subject to subject.

"In a minute I will ask you to rinse and then stick out your tongue exactly like that and then to shut your eyes till I tell you to open them. This is to help you concentrate. I'm going to then put a sterile cotton gauze on the tip of your tongue for five seconds. While the gauze is on your tongue please do

not withdraw the tongue back into the mouth and try to keep it as still as possible. The gauze will be soaked in a harmless fluid. I will then remove the gauze and you may then open your eyes, and then I will ask you to rinse your mouth with the distilled water until I tell you to spit. I will then place another gauze on the tip of your tongue for five seconds and then I will ask you to rinse again. The fluid on one of those two gauzes will be the same as the fluid you rinsed with - i.e. distilled water - the fluid on the other gauze will be something else, we'll call the fluid 'X'. I am not going to tell you which gauze is which till after the second rinse, but I want you to compare the taste of the fluid on each gauze with the taste of the following rinse because afterwards I will give you a series of gauzes each one followed by a rinse and I'll want you to tell me whether the fluid was distilled water or fluid X. So it will be important that you remember how the taste of these two gauzes compared with the taste of the distilled water rinse since I'm giving them to you so that you have some basis for comparison. When I come to ask you to make the judgements afterwards I want you to remember to keep your tongue still while the gauze is on your tongue, to rinse your mouth immediately I remove the gauze and then immediately to tell me whether it was distilled water (i.e. the same as the rinse) or fluid X (i.e. different from the rinse).

I also would like to emphasize that the chances of the fluid on the gauze being fluid X are exactly equal to the chances of the fluid on the gauze being distilled water. The probability is exactly the same. I want you to keep facing forwards at all times and I assure you that I have taken every possible precaution to make sure that you can't predict which fluid you are going to get before the gauze is actually placed on your tongue. Also, some of my subjects think that if they have had several gauzes of one fluid in a row that it is likely that there will be a change soon and so they make sure they do not give the same reply too many times in a row. But I assure you that they are mistaken, and that you will perform best if you just rely entirely on the taste of the fluid as it seems to you and that you ignore everything else. I will not be telling you whether you are right or wrong.

I will now summarise what is going to happen. I will first of all give you two gauzes in a row and I want you to shut your eyes while the gauze is on your tongue. Then rinse immediately after each gauze and compare the taste of the fluid on the gauze with the following rinse because the fluid on one of the two gauzes will be the same as the rinse while the other one will be fluid X and I will tell you which was which after the second rinse.

I will then give you a series of gauzes in exactly the same way and after each one I will ask you immediately to rinse and then immediately to tell me

whether it was distilled water or fluid X, relying entirely on the taste of the fluid and of the rinse. Do you understand?"

Any queries the subject had were then answered. The subject was then told to pour distilled water into the cup up to the level of the mark (the experimenter checked that this was done accurately) and asked to take it into his mouth and rinse. Five seconds after the fluid had been taken into the subject's mouth he was told to spit and then to replenish the cup and then shut his eyes. The experimenter then picked up a sterile cotton gauze measuring exactly 2.5 cms x 2.5 cms (see Appendix A) from a plate on the experimenter's table using two forceps, one gripping each of two adjacent corners. The gauze was then dipped for exactly five seconds into either the jar in the water bath containing the pure lemon juice diluted x 256 (i.e. which was one two hundred and fifty sixth of the concentration of lemon juice) or a jar containing distilled water (of exactly the same volume). This distilled water had been poured into the jar on the previous night from the bottle which contained the subject's rinse water. Both the bottle and the distilled water jar were kept in the experimenter's fridge along with the other jars containing the stimulus fluids. The bottle containing the distilled water was kept in the water bath along with the jars until the start of the experiment.

Which jar (i.e. pure lemon juice diluted x 1/256 or distilled water) the experimenter dipped the gauze in

was determined randomly. After five seconds the gauze was lifted out of the jar and held over it for a further five seconds (pilot experiments showed that exactly two drops of excess fluid fell off it in this space of time). The subject was then asked to stick out his tongue keeping his eyes closed and the gauze placed on it (while the gauze was being prepared the experimenter checked that the subject did not turn round to look at what he was doing) for exactly five seconds. The gauze was then removed with a pair of forceps and thrown in a bin placed under the experimenter's table. In placing the gauzes on the subject's tongue it was arranged that two adjacent corners were exactly touching the edges of the tongue (see Appendix A for diagram). In removing it, the experimenter took care that he lifted it cleanly off the subject's tongue and did not drag it over areas of the tongue not previously touched by it.

After removing the gauze the experimenter asked the subject to take the fluid from the cup into his mouth and rinse, reminding him to compare its taste with the taste of the fluid on the gauze. He was told to spit after five seconds and then to replenish the cup. The experimenter then prepared the second of the two gauzes (i.e. the distilled water if the first gauze had been lemon juice $\times 1/256$ and the latter if the first gauze had been distilled water).

The subject was then asked to shut his eyes and to stick out his tongue again, the gauze was placed on it, removed after five seconds and the subject told to rinse.

He was told to spit after five seconds and then to replenish the cup.

He was then told which gauze had the distilled water on it, and which had fluid X (i.e. pure lemon juice x 1/256). He was then told:

"That was to show you the difference between the distilled water and fluid X and to allow you to compare each with the distilled water rinse. I will now give you a series of gauzes and each time after it is removed, rinse till I tell you to spit, compare its taste with the rinse and then immediately tell me if it was distilled water or fluid X, remembering that there will be an equal chance of it being either."

The experimenter then presented the subject with eight gauzes in a row. Four of these were distilled water, four of these were pure lemon juice x 1/256. The order of these was determined randomly. Each time the gauze was placed on the subject's tongue for five seconds, the subject was then asked to rinse, told to spit after five seconds, asked to make a judgement immediately (if he was unsure he was asked to guess) and then to replenish the cup. The experimenter did not tell the subject if he was correct or incorrect.

The experimenter then checked if the subject had made any mistakes - i.e. if he had for any of the gauzes stated that the fluid was distilled water when it was in fact fluid X or vice versa. If he had not, the aim was to try the next most dilute stimulus (i.e. pure lemon juice diluted x 1/512) to see if the subject would make

any mistakes when randomly presented with four gauzes of this stimulus and four gauzes of distilled water.

If he did make one or more mistakes the aim was to try the next most concentrated stimulus (i.e. pure lemon juice diluted x 1/128).

The experimenter therefore told the subject:

"We are now going to repeat the entire procedure. Once again I will give you two gauzes in succession, each followed by a rinse. Again the fluid on one of the two gauzes will be distilled water, the other one will be something different and again we will call it fluid X although it may not taste the same as the fluid X you have just had. I want you to forget the series of gauzes you have just had and concentrate on the new series. After the initial two I will tell you which was distilled water and which one was fluid X and then I will give you a series of gauzes like I did before and I want you each time to tell me whether it was the fluid X you'd just had or distilled water after rinsing once. As before rely entirely on the taste since there is an equal chance of it being fluid X and distilled water."

The above procedure was then repeated exactly as before using Pure x 1/128 as fluid X if the subject had made a mistake on the previous series, and Pure x 1/512 if he had not. In the former case the procedure was repeated, each time ascending in concentration steps separated by a factor of two (i.e. Pure x 1/128, Pure x 1/64, Pure x 1/32 etc.) until a concentration was reached at which the subject made no mistakes - i.e., at which he perfectly discriminated

between four gauzes of fluid X, and four gauzes of distilled water presented randomly to him. At each step a gauze of fluid X and of distilled water was first presented to the subject (which one was presented first was determined randomly) and after the second the subject was told which was which. In each case the same instructions were repeated. In the latter case (i.e. if the subject made no mistake at Pure x 1/256) the procedure was repeated, each time descending in concentration steps separated by a factor of two (i.e. Pure x 1/512, Pure x 1/1024, etc.) until a concentration was reached at which the subject did make one or more mistakes.

In either case, a rough measure of the subject's threshold had now been obtained. However, in order to improve the resolution of the technique, the author decided to test the subject using a fluid X which was 0.75 as concentrated as the lowest concentration at which the subject made no mistakes - i.e. using a fluid X whose concentration lay exactly between the latter and the highest concentration at which the subject did make a mistake.

For instance if it was found that initially the subject made one or more mistakes at (Pure x 1/256) and following the ascending method that the lowest concentration at which he made no mistakes was (Pure x 1/64), the aim was to try him also at a concentration exactly midway between (Pure x 1/64) and (Pure x 1/128) - i.e. (Pure x 1/85).

Similarly if it was found that initially the subject

made no mistakes at (Pure x 1/256) and following the descending method the lowest concentration that he made no mistakes at was (Pure x 1/512), the aim was to try him at a concentration exactly between (Pure x 1/1024) and (Pure x 1/512) - i.e. (Pure x 1/683).

The experimenter, therefore, then told the subject: "You will have to bear with me for a few moments. Please sit quietly while you are waiting".

The experimenter then prepared the intermediate concentration using as a dilutant distilled water from a bottle which was placed in the water bath at the start of the experiment and was the same as the distilled water in the distilled water jar and the subject's rinse bottle. Between each series of gauzes, the distilled water jar was replenished from this bottle to ensure that it had the same quantity of fluid as the jar containing fluid X. (If at any stage the subject ran out of rinse fluid during the course of the threshold measurement, he was given a second rinse bottle. All the containers with distilled water in them were filled from a single larger bottle obtained the previous day from the Chemistry Department whose help the author would like to acknowledge.)

The details of the preparation of the intermediate concentration are given in Appendix A.

If the subject made no mistakes at this intermediate concentration, the latter was taken to be his taste threshold. If he made one or more mistakes, the threshold was taken as the next most concentrated step (e.g. Pure x 1/64

if the subject made a mistake at Pure x1/85) - i.e. the step which was the lowest concentration at which perfect performance was obtained.

A few words should be said at this point about one or two of the procedures employed in the experiment.

At the very low concentrations of the fluid X generally used, there was no difference in the colour of this fluid and the colour of the distilled water, that was perceptible to the experimenter. But just in case, the experimenter asked the subject to close his eyes before the gauze was put on and to keep them closed until after it was removed (the experimenter checked that the subject complied). This ensured that different subjects did not obtain different amounts of information from any visual cues that might have been present.

The reason that a standard size gauze was used to administer the stimuli is that it has been shown (e.g. Smith 1971) that responses to taste depend on the area of the tongue stimulated. Many workers in this field (e.g. those who have looked at the relationship of salivation to personality (see pp. 180-90)) have used a standard volume of fluid administered by a dropper. However, in the absence of proper control of the area stimulated this does not constitute standardisation.

THE MEASUREMENT OF THE REMAINING INDICES

The experimenter then said:

"Okay that's fine. Now in the next part of the experiment, at regular intervals, I am going to put swabs and two cotton wool rolls, in your mouth. For convenience, I'm

going to call them all 'swabs'. Each time I'll ask you to rinse, spit and then swallow, and then when I tell you, to lift up your tongue like this (the experimenter demonstrated) so that I can put one swab underneath it. I'll then put one swab on either side between your upper teeth and cheek. Then please face forwards again. I'll then ask you to stick out your tongue like you did before and I'll put a wet gauze on the end of it. Please close your eyes after sticking out your tongue.

I'll leave the swabs in for a while and then I'll take off the gauze and take out the swabs.

Please, whilst the swabs are in your mouth, keep your whole body as still as possible.

So let's just put the swabs in once to show you what it's like."

The experimenter then asked the subject to rinse, to spit after five seconds, to swallow and then to face him and lift up his tongue. He then placed the swabs in position (the swabs were kept in sealed containers on the experimenter's table) and asked the subject to stick out his tongue.

"Okay, that's fine. Now lift up your tongue." The experimenter then removed the swabs and threw them away.

"That was just a trial run. When we do it for real later, the swabs will be left in for longer and there'll also be a gauze on the tip of your tongue.

I'll also be asking you to judge how intense the taste of the fluid on the gauzes was by giving them numbers

proportional to their intensity exactly like you gave those lines numbers proportional to their length. I'll also be asking you to tell me how pleasant or unpleasant the taste of the fluid on the gauze was by giving each one a letter from this preference scale. I'll give you more detailed instructions later."

The subject was then shown the preference scale. A copy is given in Appendix A.

"First I'd like you to fill in two questionnaires for me. They are both to test how you are feeling right at this moment. There are no right or wrong answers. Please do them in the order in which I give them to you." The subject was then given a pencil and the Nowlis Mood Adjective Checklist followed by the Spielberger Inventory of State Anxiety. If the subject was to receive the noise condition first, the white noise tape was turned on while the subject was completing the questionnaires.

Once the questionnaires had been completed the subject was told the following:

"Now I'm going to put those swabs in at regular intervals, and each time after putting them in I'll put a gauze on the end of your tongue. The gauze will be soaked in a harmless fluid.

What I want you to do is to give each gauze a number proportional to the average intensity of the taste you feel while it is on your tongue.

Forget everything else, just concentrate on the taste and if the solution has more than one type of taste

judge the total intensity.

I want you to do this by giving the fluid on the first gauze any number you like between 20 and 50 and then give the fluid on the second gauze a number by comparing it with the first, though you no longer have to stick to numbers between 20 and 50. So that if, for instance, the fluid on the second gauze tastes twice as intense as the fluid on the first gauze give it a number twice as large as you gave to the first. If, say, one-third as intense, give it a number one-third as large as you gave the first gauze. These are just hypothetical examples. Anything is possible, a gauze can taste the same, more intense or less intense than the preceding one. There are no right or wrong answers. I'm interested purely in the taste as it seems to you. After the first gauze you can use numbers as large or as small as you like (except minus numbers)."

The subject was then given a pile of slips of paper.

"Remember to judge each gauze - except of course the first one - by comparing it to the preceding one. Please write the number you give the first gauze at the top of the first slip of paper, the number you give the second gauze at the top of the second slip, etc. You are allowed to look at the answer you gave to the previous gauze but I will take away the slips prior to that one. There will be ten gauzes in all."

The subject was told this because it was thought that some subjects might guess that following five stimuli under the first noise condition there would also be five stimuli under the second noise condition. It was, therefore,

considered wise, in this instance, to give all the subjects the relevant information.

"I also want you to judge how much you like or dislike the taste of the fluid on the gauze. Do that by selecting the most appropriate letter from this scale running from 'a - as unpleasant as it is possible to be' to 'y - as pleasant as it is possible to be'. As you can see there are various other statements at intervals to act as landmarks, but you don't have to stick to letters which have got statements by them."

"Again I want you to assign the gauzes letters by comparing each one to the preceding one. So that if a gauze tastes more unpleasant, for instance, than the preceding one, make sure that you give it a letter closer to 'a' than the preceding one. But I would like you also to relate your judgements to the landmark statements if you can. Please write the letter you give a gauze underneath the number you give it for its intensity. Do you understand?" Any queries were then answered.

The subject was then presented with five stimuli: Pure, Pure x $\frac{1}{2}$, Pure x $\frac{1}{4}$, Pure x $\frac{1}{8}$, and Pure x $\frac{1}{16}$, in a random order under each noise condition. The stimuli were presented in exactly the same fashion as the taste threshold stimuli had been. The swabs were placed in the subject's mouth as described above. After each stimulus the gauze and the swabs were removed and the subject was asked to rinse before writing down his answers. This was because different subjects took different lengths of time to write down their answers and any stimulus fluid left

in their mouths would, therefore, have differential effects on the adaptation state of the tongue receptors. The stimuli were presented in four minute cycles. In each cycle the subject was asked to rinse three times. Firstly at the beginning of each cycle (i.e. about one minute before the swabs were placed in his mouth). Secondly, 30 secs. before the swabs were placed in his mouth (to remove saliva whose acidity and, therefore, whose effect on the adaptation state of the tongue can vary from subject to subject). Thirdly, after the stimulus was presented. The exact sequence of events and the detailed time relations are given in Appendix A.

The experimenter noted (as far as possible without revealing this to the subject) the subject's heart rate immediately after the stimulus gauze was placed on the subject's tongue, 15 seconds after the gauze had been placed on his tongue, and just prior to the removal of the gauze.

The swabs, after removal from the subject's mouth, were replaced in their sealed containers. These containers had been weighed with the swabs in them prior to the experiment, and they were reweighed after the experiment, again with the swabs in them. The difference in the two weighings represents the weight of saliva secreted.

After the ten stimuli had been presented the subject was given the Nowlis Checklist and the Spielberger Inventory again under 'noise' or 'no noise' conditions depending on the preceding condition (e.g. under 'noise' if the previous five stimuli had been presented under 'noise').

The subject was told: "Once again I want you to answer according to how you feel right at this moment".

The blood pressure cuff was placed in position and the subject was then asked to sit quietly for a few moments. The subject's blood pressure was then measured (see Appendix A for details).

The subject then had the use of the pupil card explained to him (see Appendix A for details) and his pupil diameter was measured. The experimenter then noted the subject's temperature.

The procedures described above relate to session 1. The procedures were identical in session 2 except that no salivary measurements were made - i.e. no swabs were placed in the subject's mouth. He was informed of the difference after the threshold measurement and also told that there would be twenty stimuli separated by a shorter interval than in the previous session (see Appendix A for detailed time sequence), but that his instructions were the same. (See section entitled 'General Design' for further clarification of the difference between session 1 and session 2).

After both sessions had been completed, the subject was thanked and paid at the rate of 60p per hour. He was asked at the end of both sessions not to reveal the details of the experiment to anyone else.

It should also be noted that at the end of the first session, subjects were given Cattell's 16PF, Eysenck's Personality Questionnaire and Spielberger's Inventory of Trait Anxiety to take away and complete in their own time.

They were asked to return them to the experimenter on the occasion of the second session, but very few complied and very few of the remainder sent the questionnaires on to the experimenter afterwards despite repeated entreaties. For this reason the results that will now be presented relate only to the E.P.I. Questionnaire obtained prior to the experiment at initial recruitment.

CHAPTER SIX

GUSTATORY INDICES: RESULTS

and

DISCUSSION

1. Results of taste experiment

The following results are based on an analysis of variance carried out using a standard Genstat computer package. As already stated the results for hedonic tone and magnitude estimation are based on one value per intensity, per noise condition for session 1, but on the mean of 2 values for session 2. Salivation measures were only taken in session 1.

All of the other indices were measured under identical conditions in session 1 and session 2 and so session is included as a factor in the analysis of variance. In the case of the 'state' measures, the 'noise' factor is also included. In the case of the body temperature measure a 'time' factor is included: i.e. 'before' or 'after' the measurement of the other indices (magnitude estimation etc.).

The values for magnitude estimation were skewed and a logarithmic transformation (base 10) was, therefore, carried out prior to the analysis of variance (Meddis, 1973). The values for the Nowlis Wood Adjective Checklist were also skewed and so a square root transformation was employed (the logarithmic transformation could not be used since the values included zeros, and the logarithm of zero is indeterminate).

In the case of the taste threshold, the results were analysed not only using the concentration of the dilutest lemon juice solution at which the subject made no mistakes, but also using the pH of this solution which was measured afterwards. This was in case of slight inaccuracies in either the standardisation procedure or in the preparation

of the solutions which might have affected the results, since the threshold measurement was a very sensitive one. Because the results were identical (i.e. in no case was a result significant in one analysis but not in another) all the results using the pH measure will be presented.

As has already been stated the stimulus intensities were related to each other in a logarithmic fashion (base 2). For convenience the following code will be employed:

- 1= pure diluted $\times 16$
- 2= pure diluted $\times 8$
- 3= pure diluted $\times 4$
- 4= pure diluted $\times 2$
- 5= pure

For the sake of clarity, description of a particular significant effect and associated graphs will sometimes be presented in the discussion rather than in the results section.

The index to which a table refers will be given in brackets after its heading. The following abbreviations will be employed:

Salivation = SA

\log_{10} of magnitude estimate in session 1 = ME 1

Hedonic tone session 1 = HD 1

\log_{10} of magnitude estimate in session 2 = ME 2

Hedonic tone session 2 = HD 2

i) Main indices

Results for salivation

a) The main effect for intensity is significant at the 0.1% level (2 tail). The linear and quadratic components are also significant at the 0.1% and 2.5% levels (2 tail), respectively. As stimulus intensity increases, salivation also increases. The rate of increase increases slightly as stimulus intensity increases at the lower range, but is fairly constant afterwards.

Stimulus Intensity	1	2	3	4	5
Salivation (grams)	1.337	1.526	1.896	2.434	2.896

Table A1. The main effect for stimulus intensity (SAL).

b) The cubic component associated with the interaction between stimulus intensity and neuroticism is significant at the 5% level (2 tail). In low N subjects, the curve is initially concave upwards (i.e. at the lower intensities) and later convex upwards. In high N subjects, the curve is fairly linear for most of its range.

Stimulus Intensity	Low N	High N
1	1.291	1.383
2	1.342	1.710
3	1.900	1.993
4	2.541	2.326
5	2.917	2.875

Table A2. The interaction of stimulus intensity and neuroticism (SAL).

Results for magnitude estimation (session 1)

a) The main effect for stimulus intensity is significant at the 0.1% level (2 tail). The linear and quadratic components are also significant at the 0.1% level (2 tail) and 0.5% level (2 tail), respectively.

Stimulus Intensity	1	2	3	4	5
LME 1	1.1285	1.3585	1.5592	1.7492	1.8309

Table A3. The main effect for stimulus intensity (LME 1).

As stimulus intensity increases the logarithm of the magnitude estimate increases but the rate of increase decreases as stimulus intensity increases at the higher range (though it is fairly constant over the lower range).

b) The interaction of noise and introversion is significant at the 5% level (one tail). Amongst introverts subjects made larger estimates under 'no noise' than under 'noise', whereas the reverse was true amongst extraverts.

	Introverts	Extraverts
No Noise	1.4886	1.5243
Noise	1.4758	1.6121

Table A4. The interaction of noise and introversion (LME 1).

Results for magnitude estimation (session 2)

a) The main effect for stimulus intensity is significant at the 0.1% level (2 tail). The linear component is also significant at the 0.1% level (2 tail).

As stimulus intensity increases the logarithm of the magnitude estimate increases in a fairly linear fashion.

Stimulus Intensity	1	2	3	4	5
LME 2	1.0166	1.1756	1.3724	1.6010	1.7535

Table A5. The main effect for stimulus intensity (LME 2).

b) The quadratic component associated with the interaction between noise, stimulus intensity and introversion is significant at the 2.5% level (2 tail). See discussion.

Stimulus Intensity		1	2	3	4	5
No Noise	Introverts	0.9145	1.1307	1.3549	1.5644	1.7166
	Extroverts	1.1010	1.2316	1.4430	1.6414	1.8241
Noise	Introverts	0.9816	1.1183	1.2271	1.5621	1.7024
	Extroverts	1.0692	1.2220	1.4645	1.6359	1.7708

Table A6. The interaction of noise, stimulus intensity and introversion (LME 2).

Results for hedonic tone (session 1)

a) The main effect for stimulus intensity is significant at the 0.1% level (2 tail). The linear component is also significant at the 0.1% level (2 tail). As stimulus intensity increases, hedonic tone decreases.

Stimulus Intensity	1	2	3	4	5
HED 1	12.81	11.67	10.39	8.03	7.34

Table A7. The main effect for stimulus intensity (HED 1).

b) The linear component associated with the interaction of stimulus intensity, introversion and neuroticism is significant at the 0.5% level (2 tail). See discussion.

Stimulus Intensity		1	2	3	4	5
Introverts	Low N	13.19	13.38	10.31	7.56	7.00
	High N	12.13	10.50	10.06	8.55	7.25
Extraverts	Low N	11.88	11.05	10.25	7.87	7.94
	High N	14.06	11.75	10.94	8.13	7.19

Table A8. The interaction of stimulus intensity, introversion and neuroticism (HED 1).

c) The cubic component associated with the interaction of stimulus intensity and neuroticism is significant at the 5% level (2 tail). See discussion.

Stimulus Intensity	1	2	3	4	5
Low N	12.53	12.22	10.28	7.72	7.47
High N	13.09	11.13	10.50	8.34	7.22

Table A9. The interaction of stimulus intensity and neuroticism (HED 1).

Results for hedonic tone (session 2)

a) The main effect for stimulus intensity is significant at the 0.1% level (2 tail). The linear and quadratic components are also significant at the 0.1% level (2 tail).

Stimulus Intensity	1	2	3	4	5
HED 2	13.313	12.556	11.906	9.898	7.664

Table A10. The main effect for stimulus intensity (HED 2).

As stimulus intensity increases, hedonic tone decreases, but the rate of decrease also increases.

c) The quadratic component associated with the interaction between noise and stimulus intensity is significant at the 5% level (one tail). See discussion.

Stimulus Intensity	1	2	3	4	5
No Noise	13.453	12.644	12.234	10.063	7.547
Noise	13.172	12.328	11.578	9.734	7.781

Table A11. The interaction of noise and stimulus intensity (HED 2).

Results for the sensory threshold

The following results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels) and session (2 levels).

The main effect for neuroticism was significant at the 2.5% level (2 tail). Overall, high N subjects showed a higher level of discrimination ability than low N subjects.

Low N	High N
3.078	3.266

Table A11. The main effect for neuroticism (taste discriminability).

The figures shown in the table are the mean values of the pH of the lemon juice solution at which the subjects made no errors. A relatively high value, of course, indicates that this solution was relatively dilute and the level of discriminability was relatively high. As already stated, the results obtained using a measure of the dilution of the lemon juice were identical.

ii) Results for Physiological Measures

i) Heart Rate

The following results for heart rate are based on an analysis of variance involving introversion (two levels), neuroticism (2 levels), accessory stimulation - noise (2 levels), stimulus intensity (5 levels), and stimulus duration (3 levels).

The stimulus duration factor is based on the three measurements of heart rate: immediately following stimulus onset (zero seconds after stimulus onset), fifteen seconds after stimulus onset and immediately before stimulus removal (thirty seconds after stimulus onset).

Results for heart rate in session 1 (ER1):

a) The linear component associated with the main effect for stimulus intensity is significant at the 5% level (2 tail). The overall trend is for heart rate to increase as stimulus intensity increases.

Stimulus Intensity	1	2	3	4	5
Mean Heart Rate	68.27	68.85	68.61	68.95	69.76

Table A13. The main effect for stimulus intensity (ER1).

b) The main effect for stimulus duration is significant at the 5% level (2 tail). Following stimulus onset, heart rate first rises slightly and then falls.

Stimulus Duration (secs.)	0	15	30
Heart Rate	69.32	69.42	67.93

Table A14. The main effect for stimulus duration (HR1).

c) The quadratic component associated with the interaction between noise, stimulus intensity, stimulus duration and introversion is significant at the 1% level (2 tail).
See discussion.

Results for heart rate in session 2 (HR2):

a) The main effect for noise is significant at the 0.5% level (2 tail). Heart rate is higher under 'noise' than under 'no noise'.

No Noise	Noise
68.01	69.20

Table A15. The main effect for noise (HR2).

b) The main effect for stimulus duration is significant at the 1% level (2 tail). As time proceeds following stimulus onset, heart rate steadily falls.

Stimulus Duration (secs.)	0	15	30
Heart Rate	69.40	68.55	67.87

Table A16. The main effect for stimulus duration (HR2).

c) The interaction of stimulus duration, introversion and neuroticism is significant at the 5% level (2 tail). See discussion.

Stimulus Duration (secs)	Introverts		Extraverts	
	High N	Low N	High N	Low N
0	68.83	75.34	67.22	66.21
15	68.36	73.88	65.26	66.68
30	67.76	72.46	64.81	66.45

Table A17. The interaction of stimulus duration, introversion and neuroticism (HR2).

There were four other significant effects (see discussion).

d) The cubic component associated with the interaction between stimulus intensity, stimulus duration and neuroticism (1% 2 tail).

e) The cubic component associated with the interaction between stimulus intensity, stimulus duration and introversion (2.5% 2 tail).

f) The linear component associated with the interaction between stimulus intensity, stimulus duration, introversion and neuroticism (5% 2 tail).

g) The interaction between noise, stimulus intensity, stimulus duration and neuroticism (5% 2 tail) and its cubic component (5% 2 tail).

ii) Results for deep core body temperature (TEMP)

The following results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels), time (2 levels) and session (2 levels).

a) The main effect for time is significant at the 0.1% level (2 tail). Subjects overall had a higher body temperature later in the task compared to earlier.

Before	After
36.145	36.405

Table A18. The main effect for time (TEMP).

The terms 'before' and 'after' refer to the position of the temperature measurement in time relative to the other indices such as magnitude estimation.

b) The interaction of time and introversion is significant at the 2.5% level (2 tail). The overall level of body temperature is greater in extraverts than in introverts, but the former show a less steep rise than the latter as time proceeds.

	Introverts	Extraverts
Before	36.009	36.281
After	36.381	36.428

Table A19. The interaction of time and introversion (TEMP).

c) The main effect for session is significant at the 5% level (2 tail). Subjects overall have a lower body temperature in session 2 than in session 1.

Session 1	Session 2
36.372	36.118

Table A20. The main effect for session (TEMP).

iii) Results for blood pressure

The following results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels) and session (2 levels).

Systolic blood pressure

No significant effects.

Diastolic blood pressure

No significant effects.

iv) Results for pupil diameter

The following results are for mean pupil diameter (MPDP) measured in millimetres and based on the average of the values for the left and the right pupil.

The analysis of variance involved introversion (2 levels), neuroticism (2 levels) and session (2 levels).

The interaction of session and introversion is significant at the 5% level (one tail). Amongst introverts mean pupil diameter is greater in session 2 than in session 1, whereas the reverse is true amongst extraverts.

	Introverts	Extraverts
Session 1	5.516	5.328
Session 2	5.786	5.016

Table A21. The interaction of session and introversion (MPDP).

iii) Results for state measures

The following results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels), accessory stimulation - noise (2 levels) and session (2 levels).

Results for the Spielberger state anxiety measure:

The interaction of noise and neuroticism is significant at the 5% level (one tail). Amongst low N subjects, 'state anxiety' is higher under 'noise' than under 'no noise', whereas the reverse is true amongst high N subjects.

	Low N	High N
No Noise	36.75	41.66
Noise	38.50	40.69

Table A22. The interaction of noise and neuroticism ('state anxiety').

Results for the Nowlis Mood Adjective Checklist

This has 13 scales: 'aggression', 'concentration', 'deactivation', 'affiliation', 'anxiety', 'depression', 'egotism', 'pleasantness', 'activation', 'nonchalance', 'scepticism', 'startle' and 'worthlessness'.

The ones that seem most relevant here are 'concentration', 'deactivation', 'anxiety', 'activation' and 'pleasantness'. Inspection of the results shows that despite a square root transformation, some measure of skewedness remains. Meddis (1973), however, has argued that one can circumvent this problem by adopting a more stringent significance level. The qualification should, therefore, be made that some of the results presented below which are significant at the 5% or 10% level may be suspect due to the residual skewedness.

a) Concentration (CONC)

The main effect for introversion is significant at the 0.5% level (2 tail). Overall introverts report a higher level of 'concentration' than extraverts.

Introverts	Extraverts
2.598	2.238

Table A23. The main effect for introversion (CONC).

b) Deactivation (DEACT)

The main effect for neuroticism is significant at the 0.5% level (2 tail). Overall, high N subjects report a higher degree of 'deactivation' than low N subjects.

Low N	High N
1.415	2.196

Table A24. The main effect for neuroticism (DEACT).

b) The main effect for session is significant at the 0.5% level (2 tail). Overall, a higher degree of deactivation is reported in session 2 than in session 1.

Session 1	Session 2
1.606	2.006

Table A25. The main effect for session (DEACT).

c) Activation (ACT)

No significant effects.

d) Anxiety (ANX)

The main effect for session is significant at the 0.1% level (2 tail). Overall, subjects reported a higher level of 'anxiety' in session 1 than in session 2.

Session 1	Session 2
1.195	0.721

Table A26. The main effect for session (ANX).

The interaction of session and neuroticism is significant at the 5% level (two tail). This was due to the fact that in session 1, high N subjects reported a higher level of 'anxiety' than low N subjects, whereas the reverse was true in session 2.

	Low N	High N
Session 1	0.956	1.435
Session 2	0.754	0.689

Table A27. The interaction of session and neuroticism (ANX).

d) Pleasantness (PLEAS):

The interaction of noise and neuroticism is significant at the 2.5% level (2 tail). Amongst low N subjects a higher degree of 'pleasantness' is reported under 'no noise' than under 'noise', whereas the reverse is true amongst high N subjects. Also under 'no noise' a higher degree of 'pleasantness' is reported by low N subjects than by high N subjects, whereas the reverse is true under 'noise'.

	Low N	High N
No Noise	1.544	1.088
Noise	1.151	1.285

Table A28. The interaction of noise and neuroticism (PLEAS).

e) Other significant effects:

The only other significant effects derived from the Nowlis Checklist are:

1) A significant main effect for noise on the 'aggression' scale. Subjects report a higher level of 'aggression' under 'noise' than under 'no noise'.

2) A significant interaction between noise and neuroticism on the 'nonchalance' scale. Amongst low N subjects a higher level of 'nonchalance' is reported under 'no noise' than under 'noise', whereas the reverse is true amongst high N subjects. Also under 'no noise' a higher level of 'nonchalance' is reported amongst low N subjects than amongst high N subjects, whereas the reverse is true under 'noise'.

3) A significant main effect for session on the 'scepticism' scale. Subjects report a higher level of 'scepticism' in session 1 than in session 2.

No specific predictions were made for any of these scales so no attempt will be made to discuss these results.

2. DISCUSSION

i) Main indices

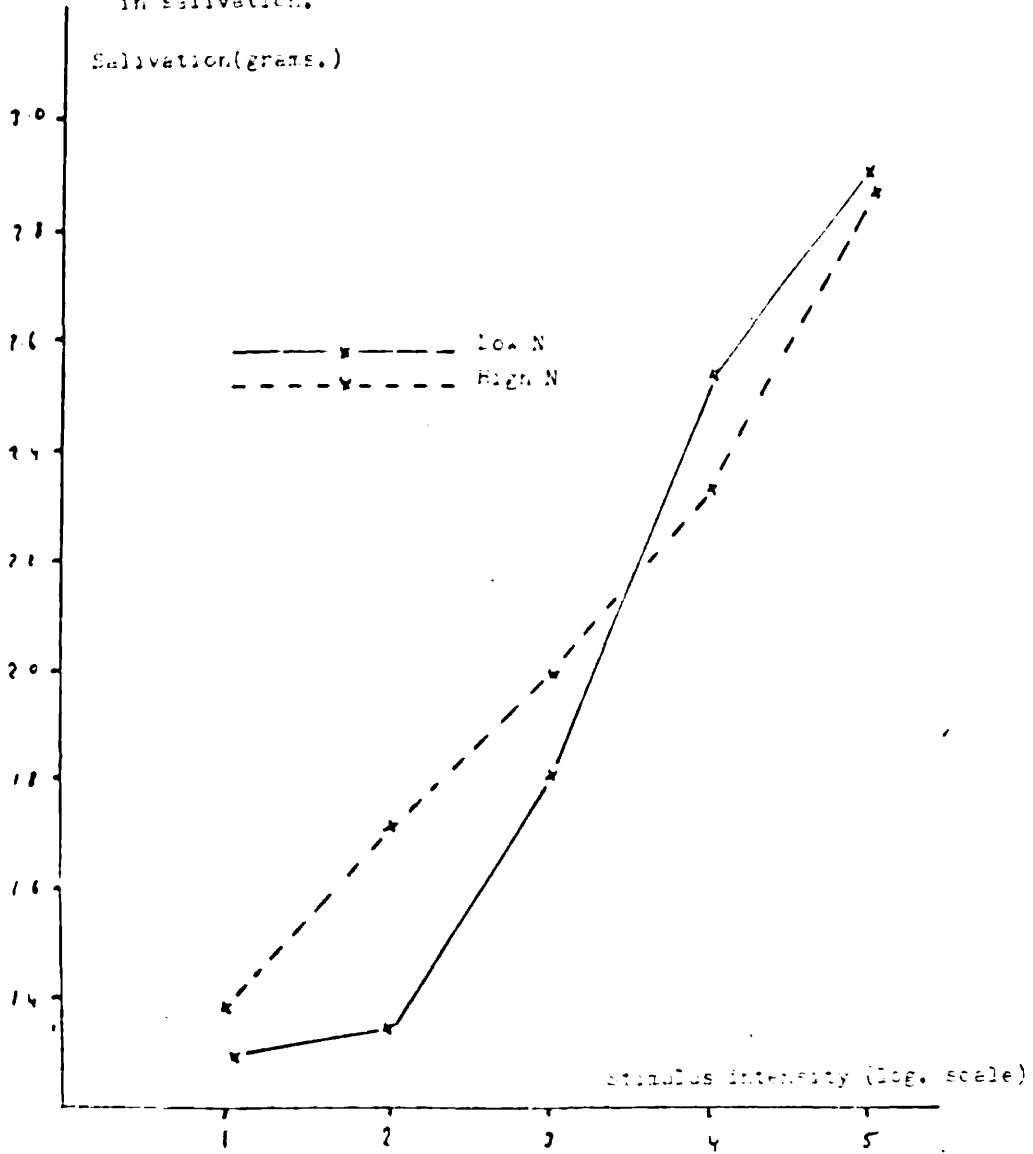
Salivation

As Graph A 1 shows, the curve relating salivation to stimulus intensity for low N subjects is initially concave upwards and later fairly linear (with slight evidence of convexity upwards at the higher intensities). On the other hand the curve for high N subjects is fairly linear through most of its range (salivation increasing as stimulus intensity increases) though its slope is less steep than the linear portion of the low N curve, and there is evidence of concavity upwards at the higher intensities. These differences are reflected in the significant cubic component associated with the interaction between stimulus intensity and neuroticism.

The differences in curvature between the two groups are certainly not far out of line with prediction. Portion A of the inverted 'U' is concave upwards and we would expect it to be more likely to show up in the low N group than in the high N group, since the former are, ex hypothesi, operating further to the left along the 'X' axis of the inverted 'U' than the latter. Also the portion of the curve lying on the border between 'A' and 'B' is fairly linear so it is not surprising that the high N curve overall and the low N curve over the higher range of intensities are fairly linear.

The convexity of the low N curve at high intensities is, perhaps, unexpected, but it is only slight. Also, the lower slope of the high N curve, compared to the low N curve over the lower range, is not unexpected assuming that

Graph A1. The interaction of stimulus intensity and neuroticism in salivation.

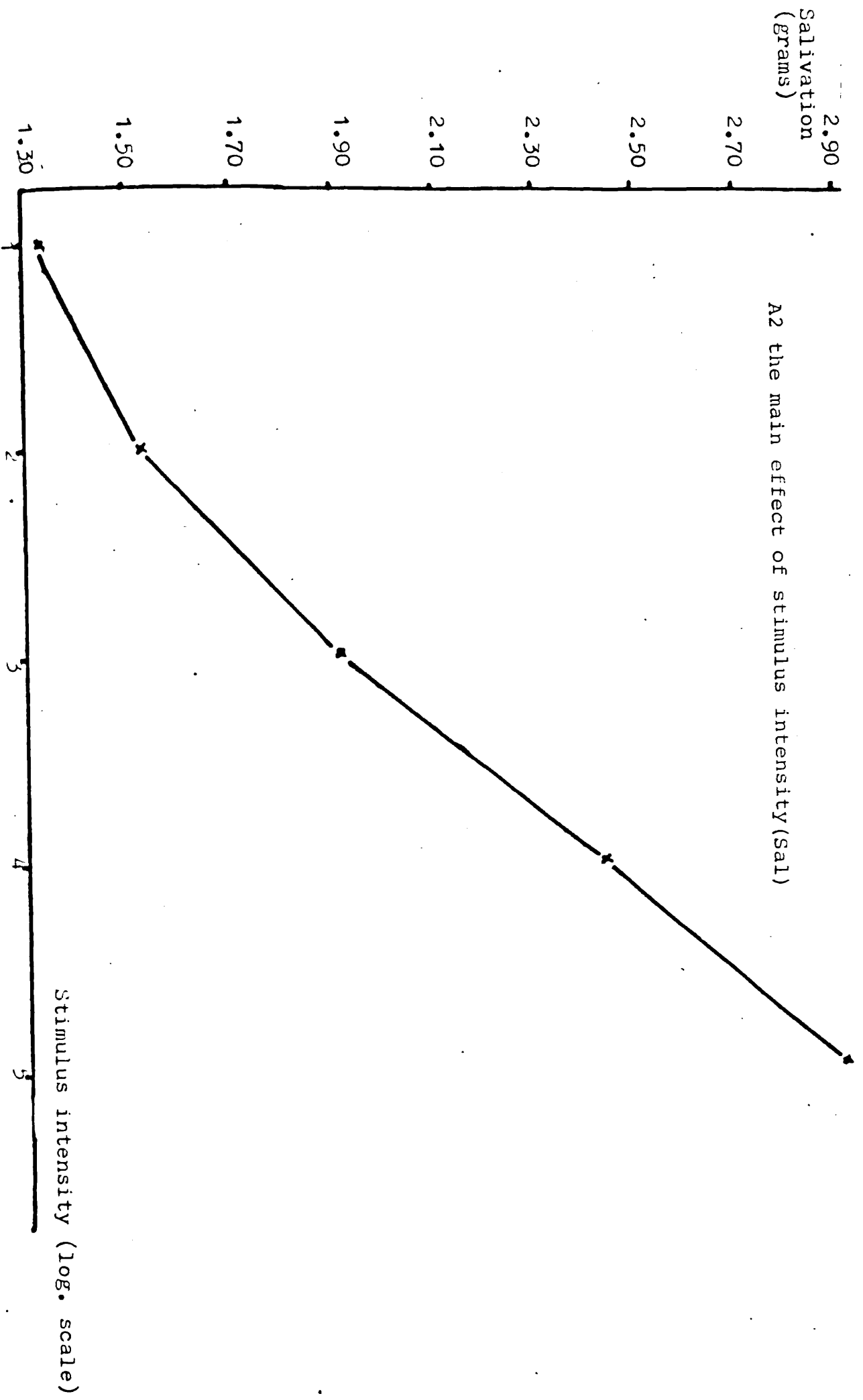


the high N subjects are operating further to the right, though one might have expected some evidence of convexity upwards at higher intensities, and it to some extent also runs counter to the view that they are operating between portions 'A' and 'B'.

The most surprising finding, though, on the basis of the inverted 'U' model alone is the fact that in absolute terms the high N subjects salivate more at low intensities (compared to the low N subjects), but the reverse is true at the high intensities. Though it is only the cubic component and not the interaction itself which is significant at the 5% level, this relationship deserves comment since it cannot be explained by transmarginal inhibition, since in both groups salivation continues to increase as stimulus intensity increases; it never falls. This is also reflected in the curve for all the subjects combined shown in Graph A2.

This failure to find transmarginal inhibition is not surprising since the highest intensity employed in the present study was that of pure lemon juice as subjects would not tolerate anything stronger. Furthermore, the failure to find any transmarginal inhibition due to accessory stimulation may be due to the fact that the difference between the noise levels was deliberately chosen to be fairly low to avoid spurious transmarginal inhibition effects due to direct action on the autonomic nervous system.

But, of course, this may be the explanation for the interaction between stimulus intensity and neuroticism.



The relative heights of the curves for the two groups may not conform strictly to the inverted 'U', but they are in line with what we suggested might happen when salivation was the measure in question (see p. 186). At the low intensities the high N subjects salivate more than the low N subjects, the inverted 'U' might predict. But at high intensities the direct inhibitory action on the autonomic nervous system may come into its own. Furthermore, we would expect high N subjects to be more susceptible to this following Eysenck (1967), who suggests that high N subjects have more 'labile' autonomic nervous systems than low N subjects.

It is possible that if the balance between the parasympathetic and sympathetic nervous systems shifts in favour of the latter as stimulus intensity rises and the stimuli become more unpleasant (as they did - see later), neuroticism may have a general 'boosting' effect so that it accentuates this process. This is very much the kind of role Eysenck conceives of for this personality dimension.

We see, then, that if we take into account the fact that salivation is an autonomic index we can explain the results. The rôle of the autonomic nervous system is hardly surprising since we are considering unconditioned salivation. Early Pavlovian work on salivation was concerned mainly with conditioned salivation, in which the role of the cortex would be expected to be greater. The original prediction that higher levels of cortical 'arousal' would be associated with greater unconditioned salivation (Corcoran 1964) is dependent on the effect of

the cortex upon the synapses involved in the salivary reflex arc (Christie, personal communication). Clearly, though, even if such cortical effects occur they may be counteracted under certain circumstances by more direct effects on the salivary response mediated via the autonomic nervous system. The present findings are in line with those of Ramsay (1969) who also found an interaction between stimulus intensity and neuroticism, due to the fact that salivation tended to level off as stimulus intensity increased in high N subjects, but continued to rise steeply in low N subjects. In our results the slope of the curve is less in the high N subjects than in the low N subjects (over the high range of intensities) and are, therefore, consonant with Ramsay's findings.

Another similarity between the present study and that of Ramsay is the failure to find any significant effects involving introversion. This applies both to the main effect and interactions. In the case of the former this is not surprising since we have already stated that the inverted 'U' model can accommodate positive, negative and non-significant results for the main effect associated with a given factor. This is reflected in the conflicting findings for introversion and salivation described in the introduction.

Furthermore, since the present experiment was completed, McManis et al (1978) have failed to show a relatively low salivary response in hyperactive children (whom Eysenck and Eysenck (1967) have shown to be relatively extraverted), whereas Rodriguez ^{and Mikulinski} (1977) have

found that extroverts have a greater salivary response than introverts (there was no significant effect for neuroticism or manifest anxiety). Rodriguez^{and Mikusinski} explain this on the basis of ethnic differences between samples, since their subjects were Spanish, whereas the subjects in most of the other studies on salivation and personality have been British. This is a possibility, but the inverted 'U' model can accommodate such apparently surprising findings without resort to such an explanation. The problem with main effects is that they produce results which may be consistent with the inverted 'U' , but which do not really provide an adequate test of it, and Rodriguez^{and Mikusinski} (like most of the other workers in this area) failed to look at interactions between several factors.

Wardell (1974) did vary stimulus intensity as well as introversion with reasonably predictable results (see introduction), as did Eysenck and Eysenck (1967c). However, Wardell used a synthetic substitute for lemon juice and both studies provided very poor control over the number of receptors in the mouth that were stimulated by the lemon juice (particularly the study by Eysenck and Eysenck in which subjects had to swallow the lemon juice in order to raise the stimulus intensity). Even in the study by Ramsay, the significant interaction between stimulus intensity and neuroticism was obtained using a dropper method which provides poor control over stimulus delivery.

The failure of introversion to interact with the other variables in the present study does require some mention. It is again, not out of line with other findings

(e.g. those of Ramsay) and in the case of some factors - e.g. noise - may be simply a consequence of the relatively small difference between the two levels employed (see below). Nevertheless, the failure of introversion to interact with other proposed determinants such as neuroticism and stimulus intensity is difficult to explain, especially since such great care was taken in the present experiment to optimise the conditions for the appearance of such effects if they exist.

For instance, pure lemon juice was used as opposed to citric acid (which produces a negative result - Corcoran 1964) , a highly reliable method was used to collect the saliva (White 1977) and to measure it. Also, in view of the fact that subjects can voluntarily alter the salivary response (Power and Thompson 1970), subjects were not told about the hypothesis that was under test in case they tried through their own efforts to confirm or refute it.

Time of day was another variable which was controlled, the experiments being carried out in the morning which has been shown by Horne and Ostberg (1975) to be the most propitious time for a relation with introversion to reveal itself.

Finally, a wide range of scores on both the introversion and neuroticism axes (in view of Howarth and Skinner (1970)'s findings - see introduction) was ensured.

Thus, in terms of design and procedure no real explanation for the lack of a significant result emerges. It is possible, simply, that the measure itself is not

sufficiently reliable or sensitive (as has been suggested by Claridge 1967) to adequately reflect the processes under consideration here. The wide variability of autonomic measures has often been noted (e.g. Power and Thompson 1970).

Let us now consider the failure of noise to produce any significant effects for the salivation measure.

'Noise' did increase salivation, but it failed to reach an accepted level of statistical reliability, possibly due to the rather low level (70 dB) chosen. The reasons for this choice were explained earlier. Corcoran and Houston (1977) did find a significant effect of noise on salivation, but since they were not interested in between-subjects comparisons they allowed the subject to adjust the level of noise till it was 'just uncomfortable'. They therefore equated the noise levels for all subjects in subjective terms, though in objective terms the levels were different. The problem that a fixed level of a given factor (e.g. white noise) may have different subjective or physiological effects in different subjects (e.g. due to different sensitivities of the auditory system) also arises in the area of drug research (e.g. Gray 1964; Eysenck 1967). It is possible that in the present study the noise level itself may have been too low overall and that the same objective level of noise may have had differential effects on different subjects (i.e. the same level of noise may have moved different subjects different distances along the 'X' axis of the inverted 'U'). If such differences were related to the level of one of the other factors (e.g. neuroticism, introversion, taste

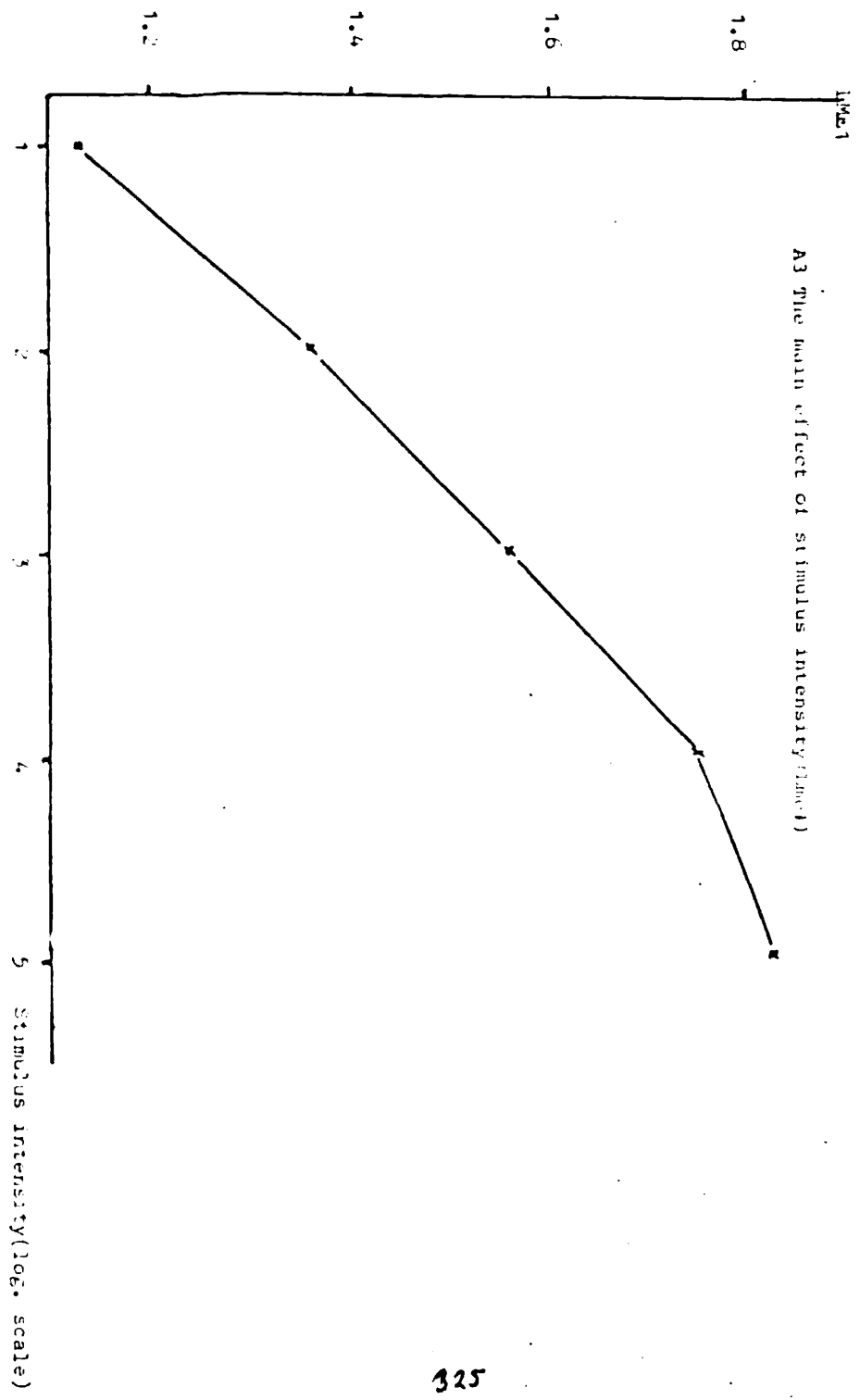
sensitivity etc.) then under some circumstances this could explain the lack of significant interactions between noise and these factors. This is very speculative, but the question of whether to equate accessory stimulation intensity in objective or subjective terms should be borne in mind. Labels such as 'just uncomfortable' may have different subjective meanings for different subjects, but it is worth noting that Guski (1975) found in a reaction time task that the subjective experience of noise was a better predictor of performance than its objective level.

b) Magnitude estimation

The most important finding using this measure is the significant interaction between noise and introversion in session 1. Amongst introverts subjects made larger estimates under 'no noise' than under 'noise', whereas the reverse was true amongst extraverts. This is in line with prediction, since one could suggest that introverts under 'noise' had passed their threshold of transmarginal inhibition and as a result produced lower magnitude estimates than under 'no noise'.

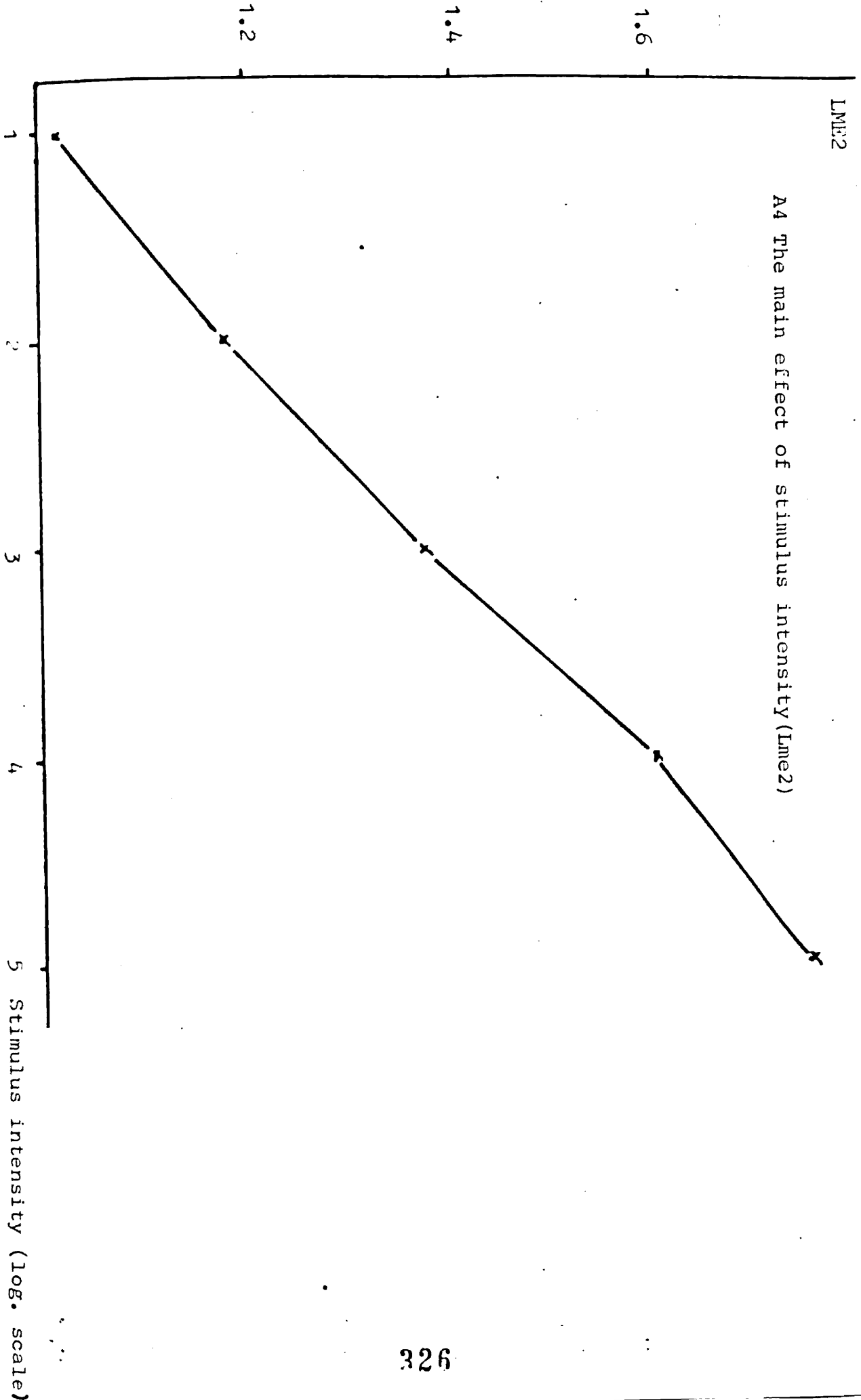
Furthermore, since the comparisons involved are all within-subject ones (since noise is a within-subject factor) they are more safely interpretable as due to actual differences in subjective magnitude than if the comparisons had been between-subject ones. It will be remembered that we suggested that between-subject comparisons were relatively suspect, since one could not be sure that a given number represented the same subjective intensity for different subjects, or even for the same subject when the estimates were obtained on two occasions widely separated in time. This was one reason why both stimulus intensity and noise were designed not only to be within-subject factors, but also to be presented at their various levels within the same experimental session.

However, the interaction raises a number of interesting theoretical issues. Firstly, Graph A3 shows that in session 1 magnitude estimates rise as stimulus intensity increases (the same applies to session 2 as shown in graph A4). Furthermore, it can be shown by inspection of the means that the same applies to the 'no noise' and 'noise'



LME2

A4 The main effect of stimulus intensity (Lme2)



conditions when considered separately for introverts and extraverts. Even if we only consider the introverts under 'noise', whom we suggested above might have passed their T.T.I., we find no evidence of a fall in magnitude estimate due to a rise in stimulus intensity.

Thus we have the first indication arising out of experiments which we ourselves have conducted that stimulus intensity may not interact with the other proposed determinants in a manner that the model in its most general form would predict. If the introverts under 'noise' have indeed passed their T.T.I. we would expect that at the highest intensity at least, subjective magnitude estimates would fall. They do not. As we will see later, when we consider simple reaction time, there is some evidence already in the literature for similar discrepancies, though at present it is slight and has not been remarked upon to the author's knowledge. We will also later provide more evidence to suggest that the discrepancy is a real one and not just due to a few solitary findings.

The second point of interest is that even though the interaction is consistent with the view that subjective intensity is a determinate, it is still possible that magnitude estimates may reflect the number-handling tendencies of the subjects, rather than their actual perception. But why the interaction, and why should it conform to our inverted 'U' model? There is nothing so far to suggest that number-handling tendencies or strategies should behave in this way. However, it will be remembered that the slope of the magnitude estimation/ stimulus intensity curve is known to be related both to the

slope of the reaction time/stimulus intensity curve and to the absolute sensory threshold (as measured by the method of limits), and that these two measures are also related to each other (e.g. Sales ^{and Throop} 1972; see p. 227).

What these latter two measures have in common is that they are both dependent on the subject's 'criterion', which is itself an inverse measure of the subject's positive response bias or 'tendency to respond'. We will discuss this in great detail under the heading of 'simple reaction time and signal detection theory', but it is worth anticipating at this point a hypothesis that we will develop and test in that section. The hypothesis states that there is an inverted 'U' relationship between the subject's 'tendency to respond' (i.e. the reciprocal of the criterion) and the levels of the determinants.

What the 'tendency to respond' and the number handling tendencies of the subject (which may be reflected in magnitude estimation) have in common is that they are both forms of response bias. So, although the relationships between magnitude estimation, simple reaction time and the absolute sensory threshold could be due to sensory-perceptual factors, they could also be due to the fact that all three measures are influenced by response bias. The crucial point is ^{that} the levels of the determinants may affect such response biases instead of, or in addition to, their effect on pure sensory mechanisms, as the above hypothesis would suggest.

If this hypothesis is correct, and there is an inverted 'U' relationship between the levels of the

determinants and the 'tendency to respond', then we can look at the interaction between noise and introversion in a somewhat different light. If the 'tendency to respond' is related positively to the tendency to assign large numbers to stimuli in magnitude estimation tasks, then the interaction could be explicable in these terms rather than in terms of actual differences in perceived subjective intensity. The introverts under 'noise' may not actually be perceiving the stimuli as less intense than under the 'no noise' condition. They may simply have suffered a reduction in their 'tendency to respond', reflected in this case in reduction in the size of the numbers which they assign to the stimuli.

This does not mean that the interaction is any less in line with the inverted 'U' hypothesis at the level of the conceptual nervous system. But it does mean that it may be manifesting itself through response biases rather than through sensory-perceptual mechanisms.

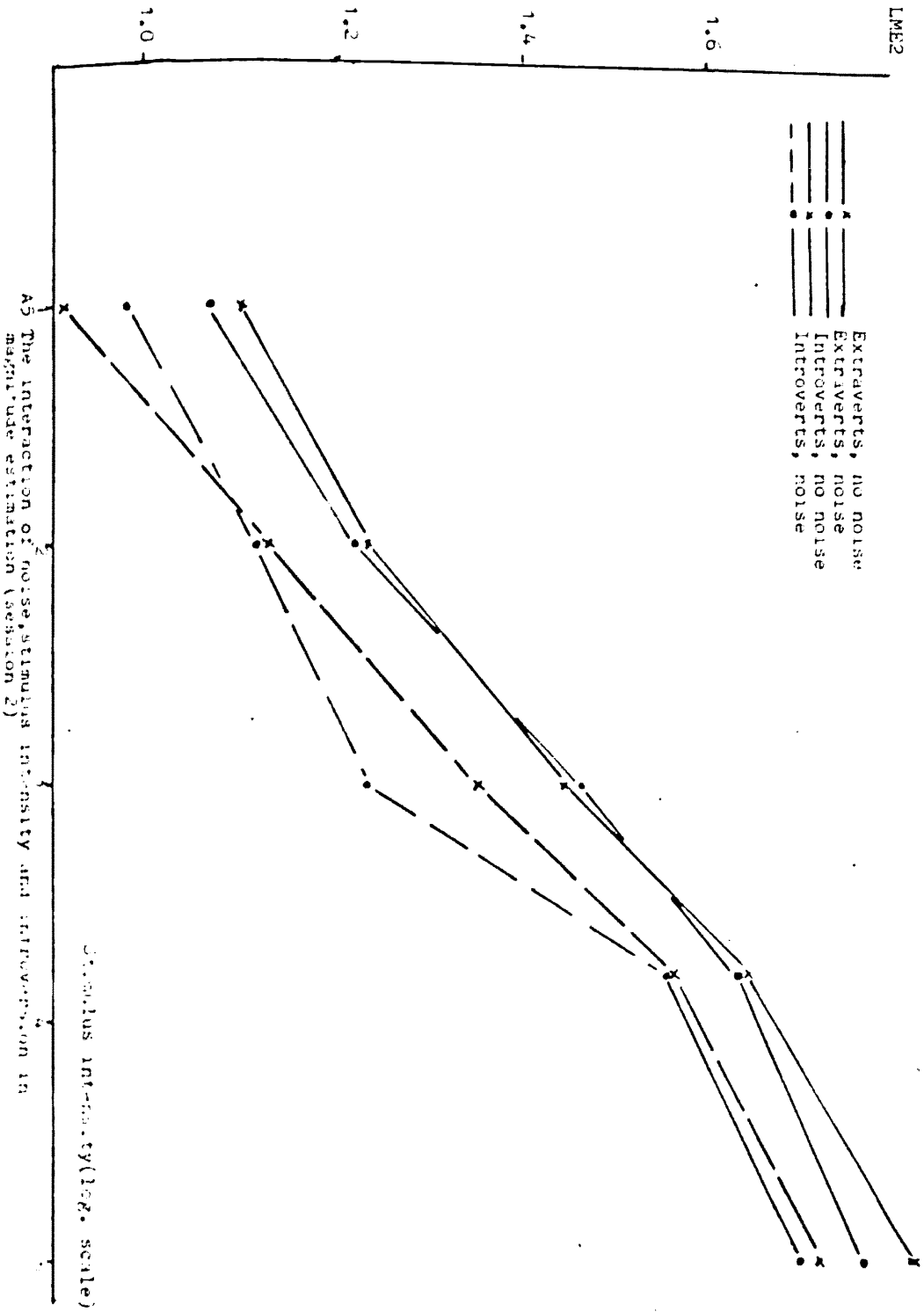
This view perhaps gains greater credibility from the fact that the present interaction is one of the few arising out of the present set of results which involves introversion and also one of the few that involves 'noise'. In most of the other measures employed, especially ones in which response biases either cannot have an effect (e.g. salivation) or in which their effect has been controlled for (e.g. the forced-choice sensory threshold measurement), introversion has rarely emerged as a relevant factor, whereas neuroticism has. The same applies to noise and it is not unreasonable to suggest that low level noise may be more likely to affect response biases

than sensory-perceptual mechanisms. There is, furthermore, evidence that introverts and extraverts do differ in response bias (Harkins and Geen 1975, op.cit.).

This is not to say that introverts and extraverts may not also differ in sensory-perceptual terms. The same study showed that they do. Furthermore, we will ourselves provide evidence later that under certain circumstances low and high N subjects may differ in response bias as well as sensory factors. The point we will develop is that which of these two factors emerges as the most relevant may depend very much on the conditions of the individual study. In the present study it is possible that differences between low and high N subjects are emerging mainly on measures which are free of response bias influences, whereas the reverse may be true for introverts and extraverts.

It should be noted that there was no interaction between noise and introversion in session 2. A possible reason for this is that due to the reduction in the novelty of the stimuli, subjects were operating further to the left along the 'X' axis of the inverted 'U' and so even the introverts under 'noise' may have failed to pass their T.T.I. .

The only other significant effect for magnitude estimation is the quadratic component associated with the interaction between noise, stimulus intensity and introversion in session 2. This is depicted in Graph A5. The change in magnitude estimates is fairly similar for all groups between the two highest intensities. Over the lower range of intensities, all groups show an essentially



linear trend except for the introverts under 'noise' who show evidence of concavity upwards. This is not in keeping with the predictions of the inverted 'U' model, and the author has no explanation for this effect.

At this point a word or two must be said about the choice of a logarithmic scale for stimulus intensity. The hypotheses that we are attempting to test in the present project have, of course, been postulated to explain the findings of researchers in the West and in the Soviet Union. Both groups of workers have tended to use logarithmic intervals to separate the different stimulus intensities which they have employed. To quote a specific example in the context of taste: Fischer et al (1965) used logarithmic steps in their measurement of taste threshold (upon which our own method was based) - see p.

There is in fact experimental evidence to support such a policy. The bulk of the data seems to suggest that the nervous system 'transforms' or 'transduces' the sensory input so that the relationship between objective intensity and the nervous system's response is a logarithmic one. Furthermore, there is evidence that this transduction takes place at a peripheral level. For instance, salivation has been shown to have a roughly logarithmic relationship with stimulus intensity and frequency (see p.175). The salivary response is, of course, essentially a peripheral reflex. This does not mean that it cannot be influenced by central factors, so that it may well reflect central differences between individual's differing on personality type (and this is why it was included). Nevertheless, the overall, basic relationship between salivation and stimulus intensity can be expected to depend on relatively peripheral factors.

Also Kocher (1969) has suggested that peripheral mechanisms may initially 'transform' stimulus intensity whilst the role of central mechanisms is to govern the relationship

between stimulus intensity and factors such as hedonic tone.

Nissen (1977) has reviewed evidence suggesting that in the visual modality (which will be the main one used in the rest of our project), the relationship between stimulus intensity and peripheral neural responses is an essentially non-linear, logarithmic one. We will return to the question of the location of neural responses to visual stimuli in the section on reaction time.

The important point to note here is that all this suggests that a logarithmic scale may provide a more accurate representation of the nature of the input to central structures in the nervous system than an ordinary scale. It is, of course, central mechanisms which have been thought to underly the inverted 'U' mechanism, both in the West and the East, particularly where the factor of personality is concerned.

In actual fact, the choice of such a logarithmic scale makes very little difference to our present hypotheses. We have argued already, that overall main effects for a factor such as stimulus intensity are not particularly important. It is the differences between the effects of the factor at different levels of other factors which is important - especially where such differences involve a reversal of the sign of the effect of the factor. It is such interactions that provide the most conclusive tests of our inverted 'U' model and they would be unaffected by the choice of the scale used to define the stimulus intensity factor.

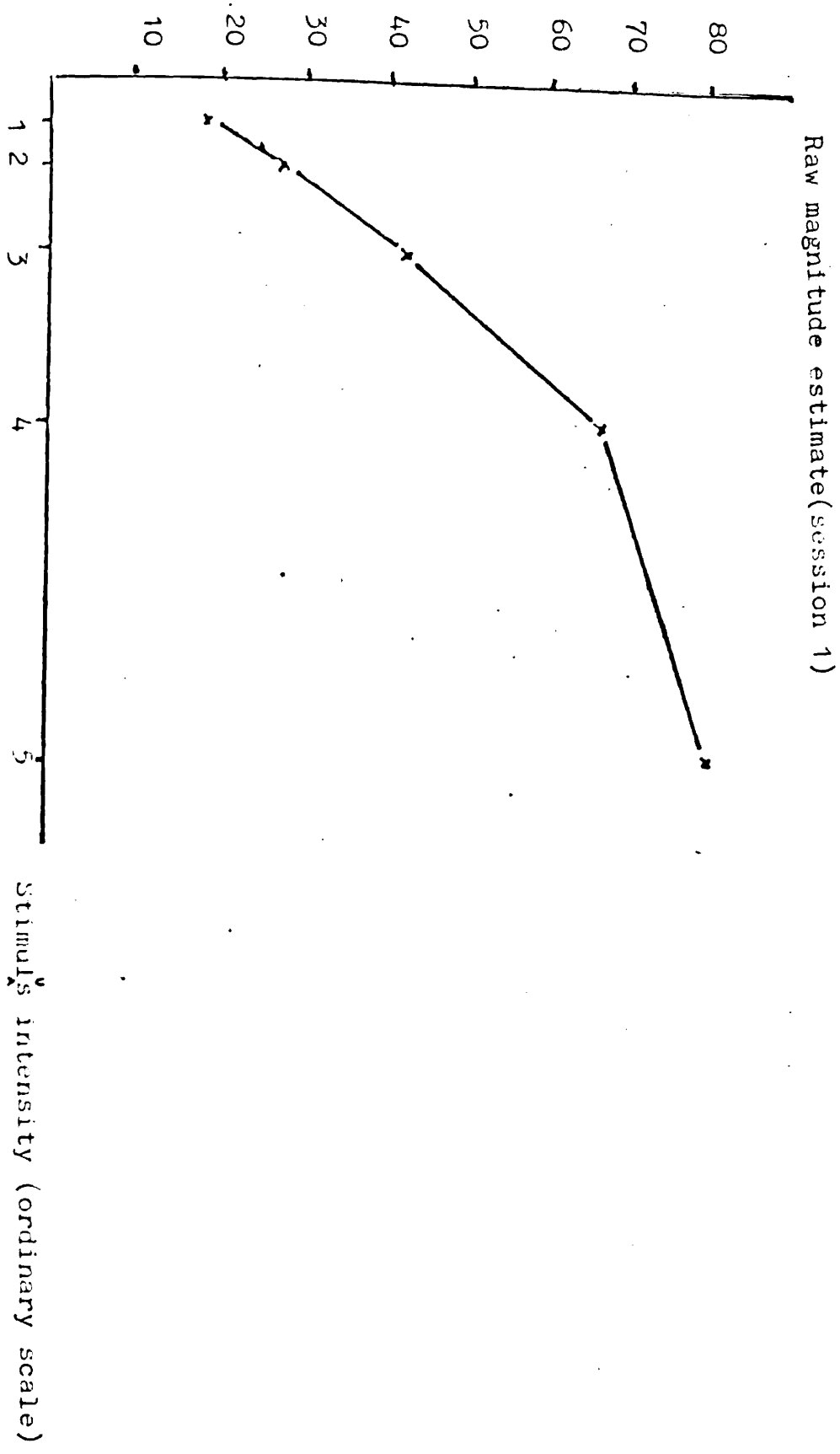
The same argument applies to the use of a transformation to correct the skewedness in the values of a response

index, (e.g. the magnitude estimates in the present study). As in the case of the use of a logarithmic scale for stimulus intensity, such transformation^s do not invalidate our attempt to test the inverted 'U' model since such attempts are based on the analysis of interactions not on absolute values.

Transformations and logarithmic scales may not even affect the function for a single factor considered on its own (let alone interactions). An example of this is shown in Graph A6 which depicts the effect of stimulus intensity, drawn on an ordinary, non-logarithmic scale, upon the raw, untransformed magnitude estimates for Session 1. We can see that the overall shape of the function is essentially the same as that in Graph A3.

There is, however, one point which arises out of what has been said above. We made the tentative suggestion earlier (see p. 193) that the relationship between subjective and objective intensity (raw and untransformed in any way) in a magnitude estimation experiment could be explained by the operation of central rather than peripheral mechanisms - i.e. by the inverted 'U'. Unfortunately there are no interactions involving stimulus intensity which provide evidence for this. The interaction between noise, stimulus intensity and introversion would not have supported this view even if redrawn using raw magnitude estimates and an ordinary scale for stimulus intensity. For example, it contains crossovers between the functions for different conditions which are inexplicable on the basis of the inverted 'U'.

A6 The main effect of stimulus intensity on magnitude estimation(session 1) without transformation and with an ordinary scale for stimulus intensity.

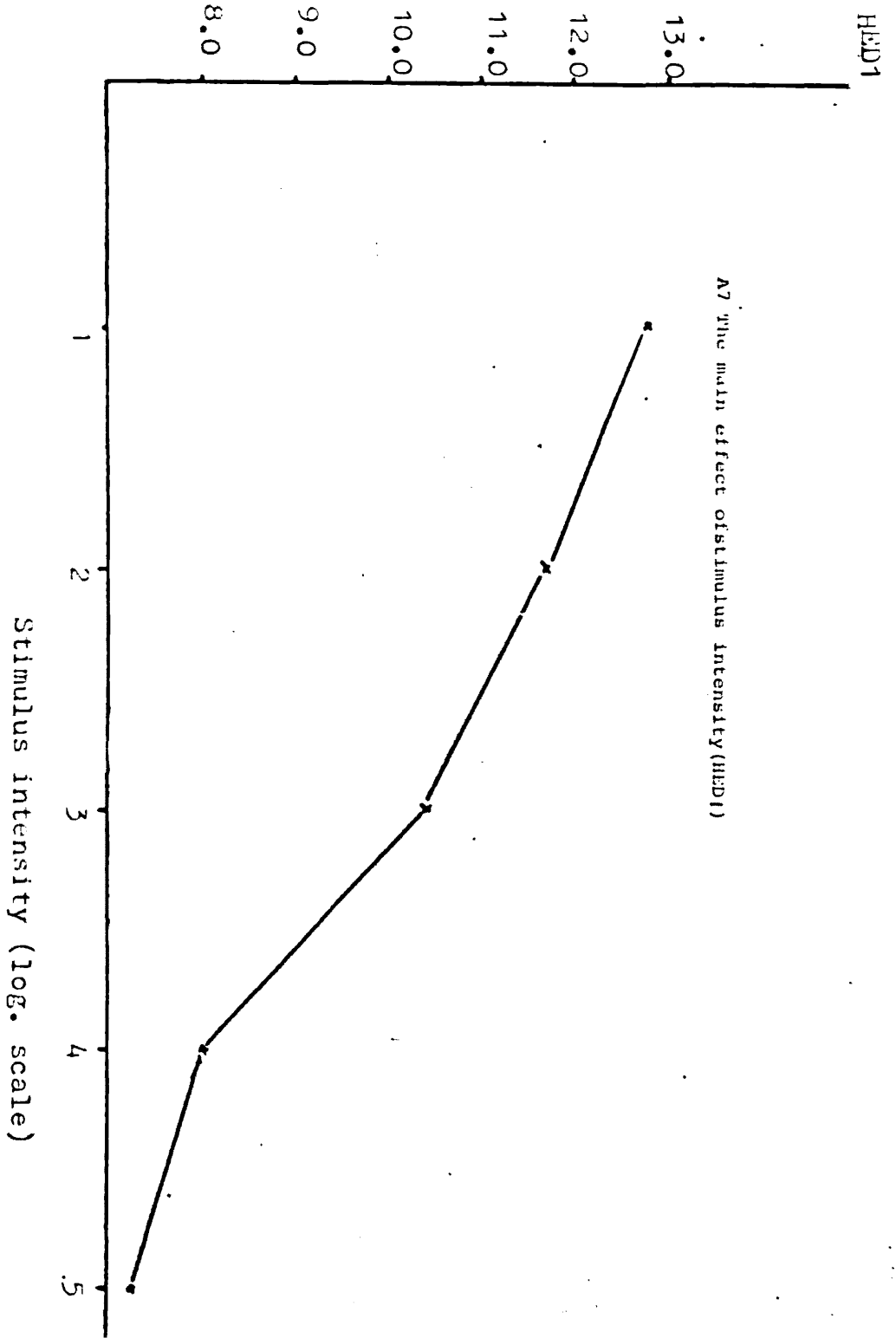


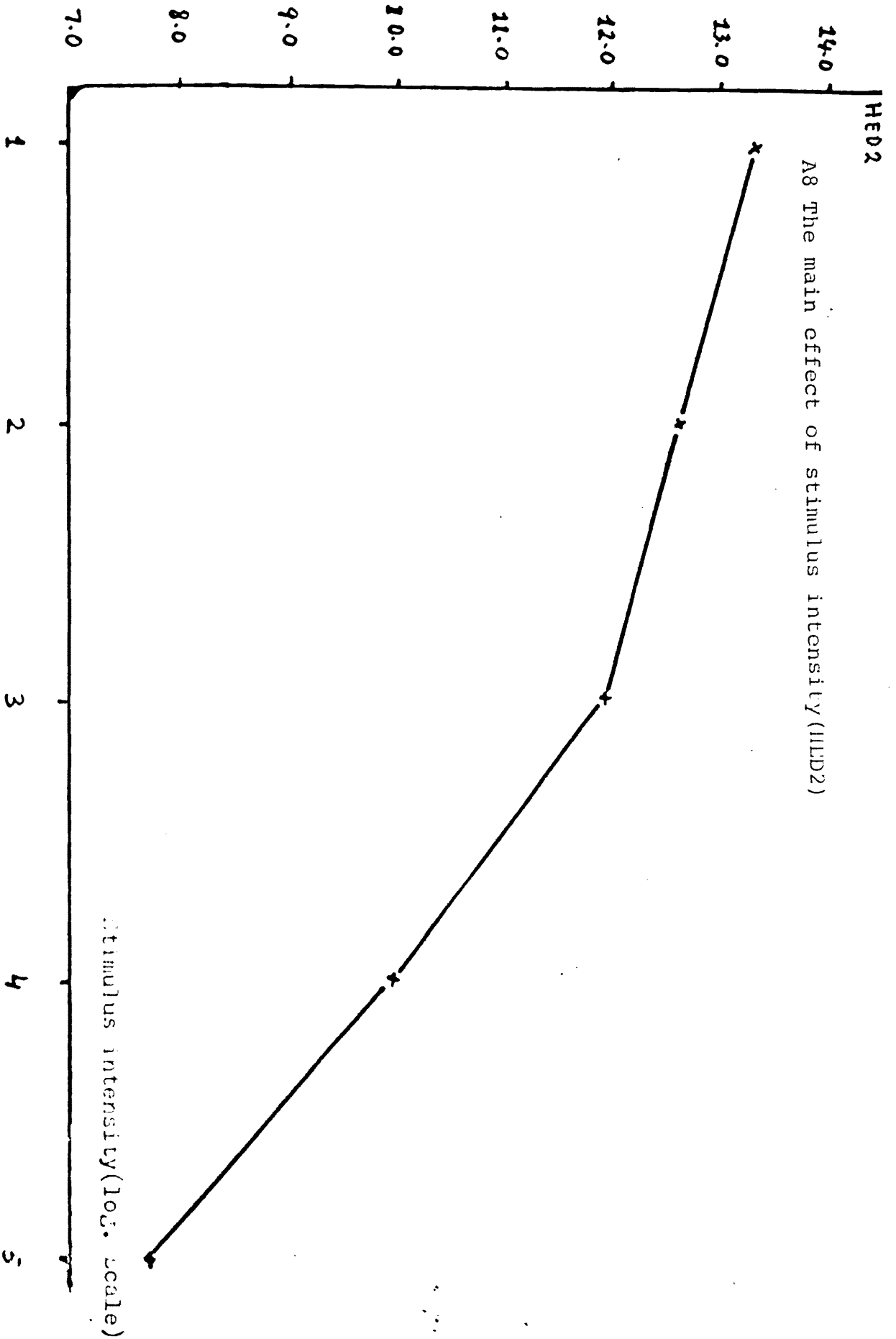
c) Hedonic Tone

As both Graphs A7 and A8 show (for session 1 and session 2 respectively), subjects found nearly all the stimuli to be unpleasant, since the figure of 13 on the hedonic tone 'Y' axis represents neutrality - i.e. the value at which subjects stated that they found the stimulus neither pleasant nor unpleasant. Furthermore, as stimulus intensity increases the level of hedonic tone steadily falls, which is in line with prediction, if we assume that they are operating beyond the T.T.I..

Also, the curve for session 1 is somewhat lower than that for session 2 and shows a less steep fall with evidence of initial convexity upwards and later concavity upwards (though the cubic component is not significant). This is also in line with prediction, although the session factor was not actually included in the analysis of variance itself. In session 1 the stimuli and the experimental situation as a whole are more novel than in session 2, and one would therefore expect subjects to be operating further to the right along the 'X' axis of the inverted 'U' in the initial session, than in the second session. Therefore, they are more likely to be operating on portion 'D' of the curve at the higher intensities at least - hence the portion of the curve which is concave upwards in session 1 over the higher intensity range.

Some caution must be exercised here since the scale employed is inevitably an arbitrary one, and one cannot be sure that successive points along it are really equally spaced in terms of some 'internal' subjective hedonic tone scale, if such a thing exists. What the scale provides is an operational measure of hedonic tone





and using it we can at least say that the results are consistent with the view that hedonic tone is a determinate, and that stimulus intensity and novelty are determinants of the intervening construct ('arousal' or the 'excitatory process').

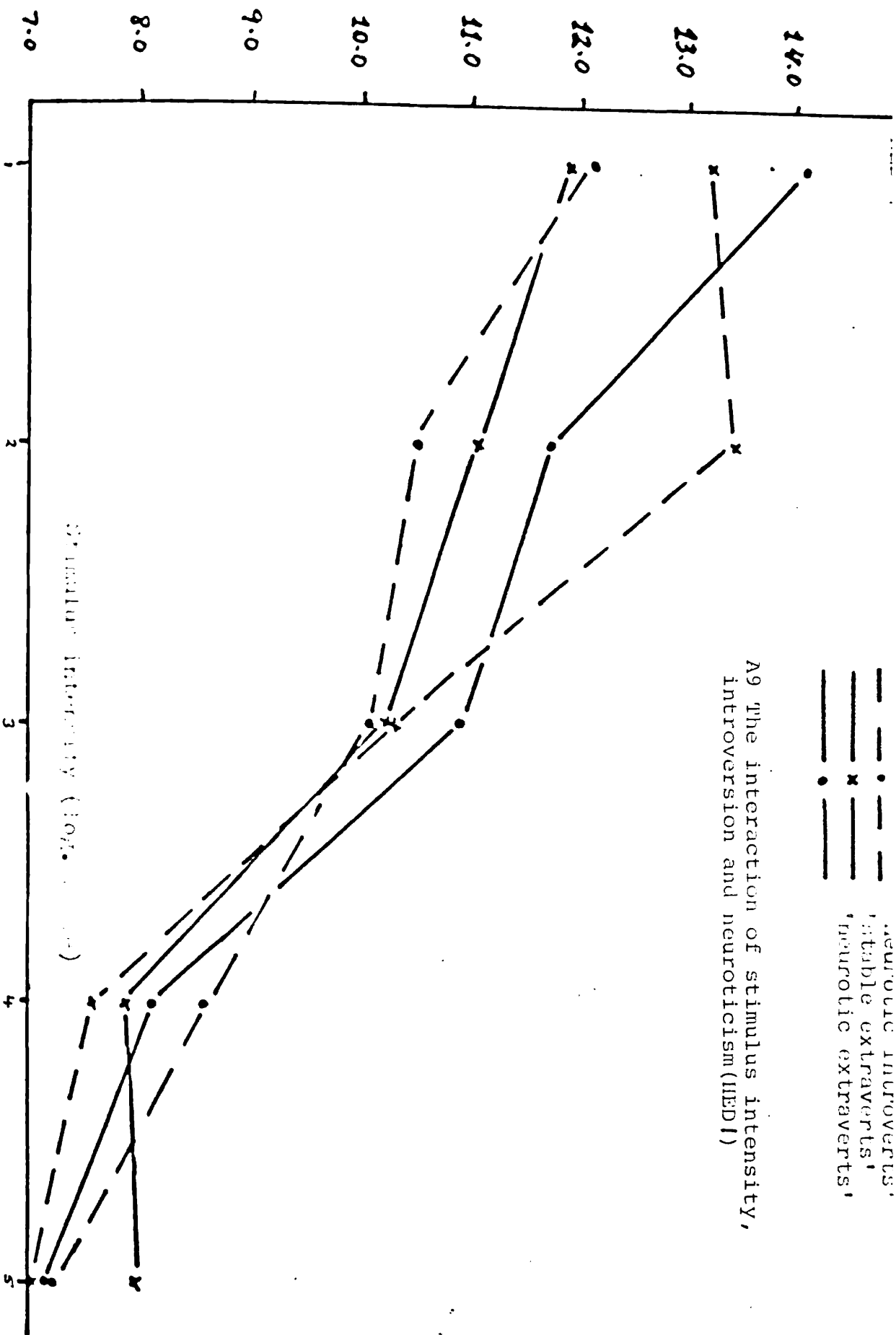
Furthermore, if we accept this view then the results are interesting because they provide a glimpse of the right-hand half of the inverted 'U' which is relatively unexplored territory. For instance, they are consistent with our suggestion that the inverted 'U' curve has a flattened portion at both its extreme ends and we have some evidence of portion D in the session 1 curve.

Another interesting point to note is that we appear to be operating beyond the threshold of transmarginal inhibition for hedonic tone, whereas the corresponding curves for salivation and magnitude estimation (i.e. the curves showing the effect of stimulus intensity) indicated that for these measures the T.T.I. had not been passed, at least in so far as stimulus intensity was concerned. This brings us to another area in which the inverted 'U' model in its most general form may require revision, since it would appear that the T.T.I. may be different for different determinates (assuming that the unconditioned salivary response, magnitude estimation and hedonic tone all fall into this category). If we look back to our list of determinates (see p. 145), we see that salivation and magnitude estimation could be included under the heading of magnitude or intensity of response. It is not clear, though, under which category hedonic tone should be placed. However, from a utilitarian or evolutionary point of view

it would make sense if the point of optimal hedonic tone coincided with the point of optimal efficiency of learning and performance. We have argued that under circumstances which permit, the individual may actually try to alter his level of hedonic tone to bring it closer to its optimal level, and if this did coincide with the point of optimal cognitive efficiency, he would also, in the process, move closer to the latter. Furthermore, we will suggest later that the fact that response magnitude, as indexed by magnitude estimates, for instance, continues to increase as stimulus intensity increases, despite the fact that hedonic tone shows a decline, may also have utility value for the organism.

It should be pointed out that although Wardell (1974) found some evidence of transmarginal inhibition, due to a rise in stimulus intensity, using measures which could be included in the category of magnitude of response (i.e. salivation and magnitude estimation), this was achieved at stimulus intensities which were far beyond those which subjects in the present study found either pleasurable or tolerable.

Another interaction that we must consider is that between stimulus intensity, introversion and neuroticism in session¹ for which the linear component is significant. This is depicted in Graph A9. Amongst introverts, low N subjects show a steeper fall in hedonic tone overall than high N subjects, whereas the reverse is true amongst extraverts. Also, amongst low N subjects, introverts show



A9 The interaction of stimulus intensity, introversion and neuroticism (I)

a steeper fall than extraverts, whereas the reverse is true amongst high N subjects.

In some ways the results might seem explicable on the basis of the inverted 'U'. Amongst introverts the low N subjects show some evidence of the peak of the curve at the lowest intensities, and the relatively shallow slope of the high N subjects would be explicable if we assumed that they were operating on portion 'D' of the inverted 'U'. However, the fact that the high N subjects show higher levels of hedonic tone than the low N subjects at the higher intensities is puzzling.

We remarked earlier, though, that as with magnitude estimation cross-subject comparisons are somewhat suspect with hedonic tone, since one cannot be sure that a given label (e.g. 'unpleasant') means the same thing in subjective terms to different subjects (though the problem is perhaps less serious than one is considering pure numbers as in magnitude estimation). Differences between subjects in the labels they ascribe to stimuli which are equivalent to all of the subjects in terms of 'true' hedonic tone do represent, of course, differences in response bias, which we have already suggested may be operating here. If so, then it is possible that a difference in response bias between low and high N subjects may have resulted in an upward shift in the curve of the high N subjects relative to that of the low N subjects, leaving the overall shape of the curve largely unchanged (and it will be remembered that it was the linear component of the interaction which was significant rather than the interaction itself). We have suggested that there is an inverted 'U' relationship

between the levels of the determinants and the degree of positive response bias, which in the present instance would be equivalent to a tendency to ascribe higher levels of hedonic tone to stimuli. The fact that high N subjects seem to show greater positive response bias than low N subjects (both in the introverts and in the extraverts) is not inconsistent with this view, but it also provides no real support for it, since we have repeatedly argued that main effects do not tell us much ^{in situations} where an inverted 'U' may be operating.

However, we have already seen some evidence for curvilinearity in the interaction between noise and neuroticism, and later when we come to consider signal detection theory we will encounter further evidence that under certain conditions at least high N subjects show more positive response bias overall than low N subjects.

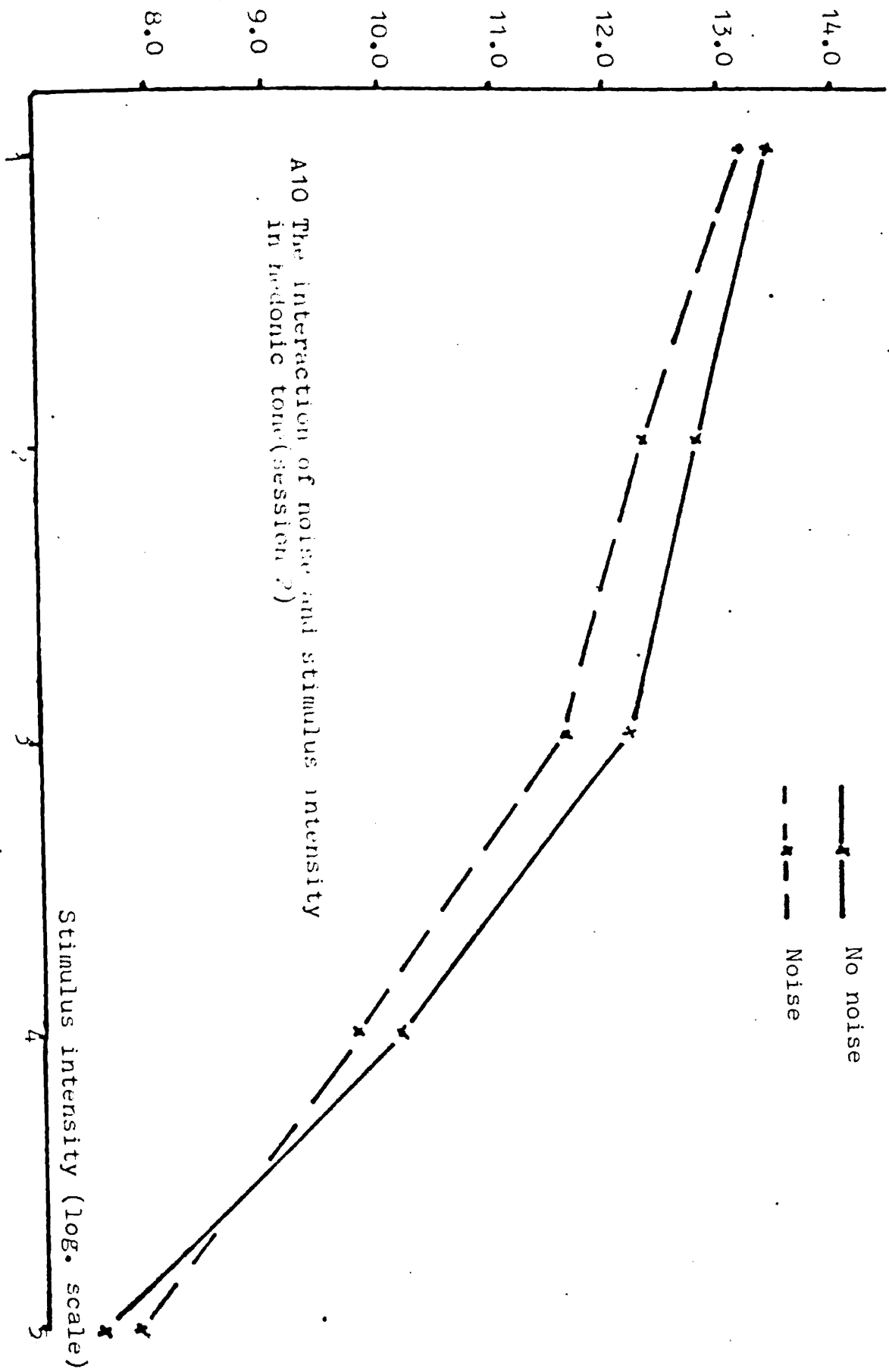
However, the suggestion that high N subjects show a high degree of positive response bias is a little surprising in view of what we have said about the relative susceptibility to punishment of low and high N subjects, since the stimuli in the present experiment were regarded as being mainly unpleasant. Furthermore we still have not considered the extraverts in Graph A9. These pose more of a problem since it is not simply the overall heights of the curves, but also their shapes, that do not conform to prediction. A greater overall fall in the high N group would be understandable if the groups were operating on portion 'C' of the inverted 'U' or on the borderline between portions 'C' and 'D', and there is some indication of this (i.e. the fairly linear fall in the high N group

and the initial convexity upwards in the low N group). A very shallow section of the curve between the two highest intensities might be expected also. But the fact that it occurs in the low N group and not the high N group is a mystery. It is possible that since it is the linear component of the interaction which is significant (which takes into account all the points not just individual ones) this may be just a chance effect, but we cannot regard the present interaction as more than partially supportive of the model.

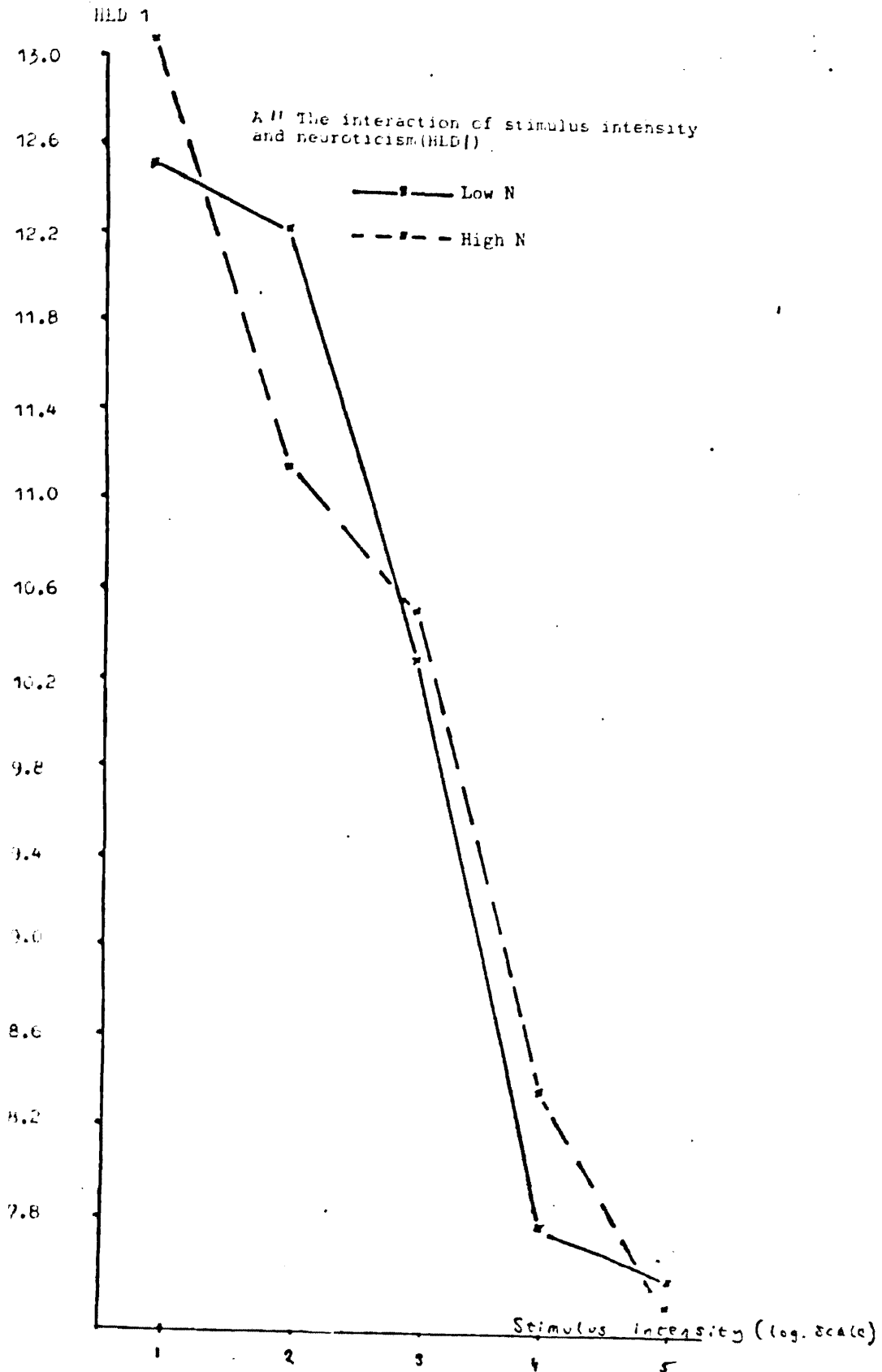
The interaction between noise and stimulus intensity for session 2 is depicted in Graph A10. The curve for 'noise' falls more steeply initially than that for 'no noise', but the reverse is true later on. This would be expected if we assume that under 'no noise' the subjects are operating on portion 'C' of the inverted 'U', but that under 'noise' we begin to move onto portion D. However, there is no evidence for actual concavity upwards in the 'noise' condition. Also the higher level of hedonic tone in this condition at the highest intensity (compared to the 'no noise' condition) is unexpected, though it may be due to some form of response bias altering the relative heights of the two curves.

The final interaction that we must consider is that between stimulus intensity and neuroticism for session 1, for which the cubic component is significant (see Graph A11). This is due to the fact that the curve for the high N subjects is reasonably linear throughout its range, whilst that for the low N subjects is initially convex and later concave. This is what we would predict, though

Hedonic tone
(session 2)



A10 The interaction of noise and stimulus intensity
in hedonic tone (session 2)



again an explanation of the overall heights of the curves may require recourse to a response bias interpretation, and the very shallow portion of the low N curve at the highest intensities is unexpected.

Before we leave hedonic tone we must consider the fact that for this index most of the effects which involve personality relate to neuroticism rather than to introversion. One possible reason may be related to the fact that the origins of the word 'emotion' lie in the field of evaluation of stimuli as 'good' or 'bad', 'pleasant' or 'unpleasant'. Gray, Eysenck and others all see the degree of emotionality as being reflected in the personality dimension of neuroticism. Nevertheless, introversion is also considered to be relevant here. Gray considers introverts to be more susceptible to punishment than extraverts, and since the stimuli were unpleasant in the present experiment, we might have expected to find more effects involving introversion than we actually did, though we noted in the introduction that non-significant results have been obtained in other studies.

It could be argued that the limited range of intensities employed (encompassing only the region beyond the T.T.I., by and large) may have reduced the likelihood of obtaining significant interactions involving introversion. However, Ludvigh and Happ (1974) have shown that the differences between introverts and extraverts are in fact enhanced over this range. They do suggest, though, that 'internal arousal' - i.e. differences between groups on the number of fantasies experienced etc. - may mitigate expected differences in hedonic tone. Even if this is

true, however, it would be very difficult to control for this factor, and it is not clear why a similar argument should not apply equally to high N and low N groups.

It is possible that the concept of hedonic tone itself may not be a unitary one. This is supported by the finding of Sales ^{and Throop} (1974) that the level of hedonic tone seems to be influenced by several features of the stimulus complex that the subject experiences. We have concentrated on the stimulus intensity aspect, ^{and} since the stimuli employed were very strong, differences in susceptibility to punishment (reflected more in neuroticism than introversion) may be more relevant than other factors.

However, though the stimuli were intense and therefore corresponded to a high level on one of the determinants, they were also simple and unchanging on parameters other than stimulus intensity. We have already seen that novelty is a determinant, and stimulus complexity may be one also. Bartol (1975) has provided evidence in favour of the view that introverts and extraverts differ in their response to stimulus complexity. Furthermore, Gale (1969) has shown that the introversion/hedonic tone relationship is linked more to changes in stimulation than to the absolute level of the latter.

It is possible that these factors may explain the relative paucity of findings with respect to introversion.

d) Sensory threshold

The results show that taste discriminability is positively related to neuroticism not introversion. This may seem out of line with the findings of Fischer et al (1966) and Corlis ^{et al} (1967) who showed a relationship to the latter. However, Fischer used a concept known as 'internalisation - externalisation' and he describes it as a dimension related to sociability. But, as Eysenck (1967) has pointed out, sociability is related negatively to both introversion and neuroticism. Corlis used introversion defined in a Jungian sense. Thus the discrepancy may be due to different definitions and measurements of introversion.

The result with respect to neuroticism is in line with predictions if we assume that we are operating on portion A of the curve, since taste sensitivity is a measure of the slope of the curve and over portion A a movement towards the right - e.g. due to a rise in neuroticism - results in an increase in slope. It is difficult to substantiate this in the absence of a significant interaction between neuroticism and another factor such as session or introversion, but since very weak stimuli were employed, it is not unreasonable to suggest that this may have been the case.

The failure to find any significant effect involving introversion is in line with similar failures in some other studies which have used the forced-choice technique - i.e. ones which have controlled for the effect of the subject's criterion (e.g. McGuiness 1976). It should also

be mentioned that subsequent to the completion of the present experiment the results of a study by Edman et al (1979) were published reporting a similar failure to find a main effect of introversion on sensory threshold. The authors used electrocutaneous stimulation and employed both a forced choice technique and the method of limits. The method used to measure threshold and the dimensions of introversion and neuroticism were included in a three way analysis of variance. As for introversion, there was no main effect for neuroticism, unlike the present study. However, since the results for the two methods were not analysed separately the two studies are not quite comparable.

Furthermore, the main effect for method was significant due to the fact that the thresholds using the method of limits were higher than those using the forced choice technique. Also, the difference between the two methods was greater for the high N subjects than for the low N subjects. These two facts taken together indicate that subjects tended to adopt high criteria and that this effect was most marked in high N subjects. Later we will discuss this fact in relation to Gray's theory of reward and punishment (e.g. 1971). For the present it may explain why there was no main effect for neuroticism, since if high N subjects adopt high criteria and the results for the two methods are lumped together, one might expect any superiority of high N subjects in sensory sensitivity to be masked.

Edman et al did also find an interaction between

introversion and neuroticism due to the fact that thresholds were lowest in 'neurotic introverts' and highest in 'neurotic extroverts'. However, again the failure to separate the two methods makes this result difficult to interpret and it was in any case only marginally significant (10% level).

Some studies, though, which have adequately separated criterial and sensory factors and which also used the E.P.I. (e.g. Harkins and Geen 1975) have found evidence of greater discrimination ability in introverts compared to extroverts, so the failure to do so in the present study is somewhat surprising. It is, though, consonant with the findings from the present experiment using the other indices. These have also revealed more significant and predictable effects involving neuroticism than involving introversion. One possible reason for this is that in an anxiety-provoking situation one would expect neuroticism to play a pre-eminent role, since it is more closely related to anxiety than is introversion (Spence and Spence 1966). Furthermore, as already stated, Gray's proposed physiological substrate for anxiety (the 'behavioural inhibition system') contains an 'arousal' system which could underpin many of the effects we have considered. Other workers (e.g. Keuss and Orlebeke 1977 and White and Manly 1972) have also suggested that neuroticism may be the important factor where some element of threat is involved. Every attempt was made to reassure the subjects beforehand, though it is possible that they nevertheless found the experimental situation threatening. It will be interesting to see if in later experiments the

relative importance of neuroticism diminishes as the subjects become more familiar with the experimenter (though the experimental situation itself will be different each time).

PHYSIOLOGICAL MEASURES

Heart Rate:

The first finding we should consider is the highly significant main effect for noise in Session 2, with subjects demonstrating a higher level of heart rate under 'noise' than under 'no noise'. In the absence of any other interactions indicating an inverted 'U' relationship between heart rate and the levels of the determinants, this result might seem to support the Western model of the inverted 'U'.

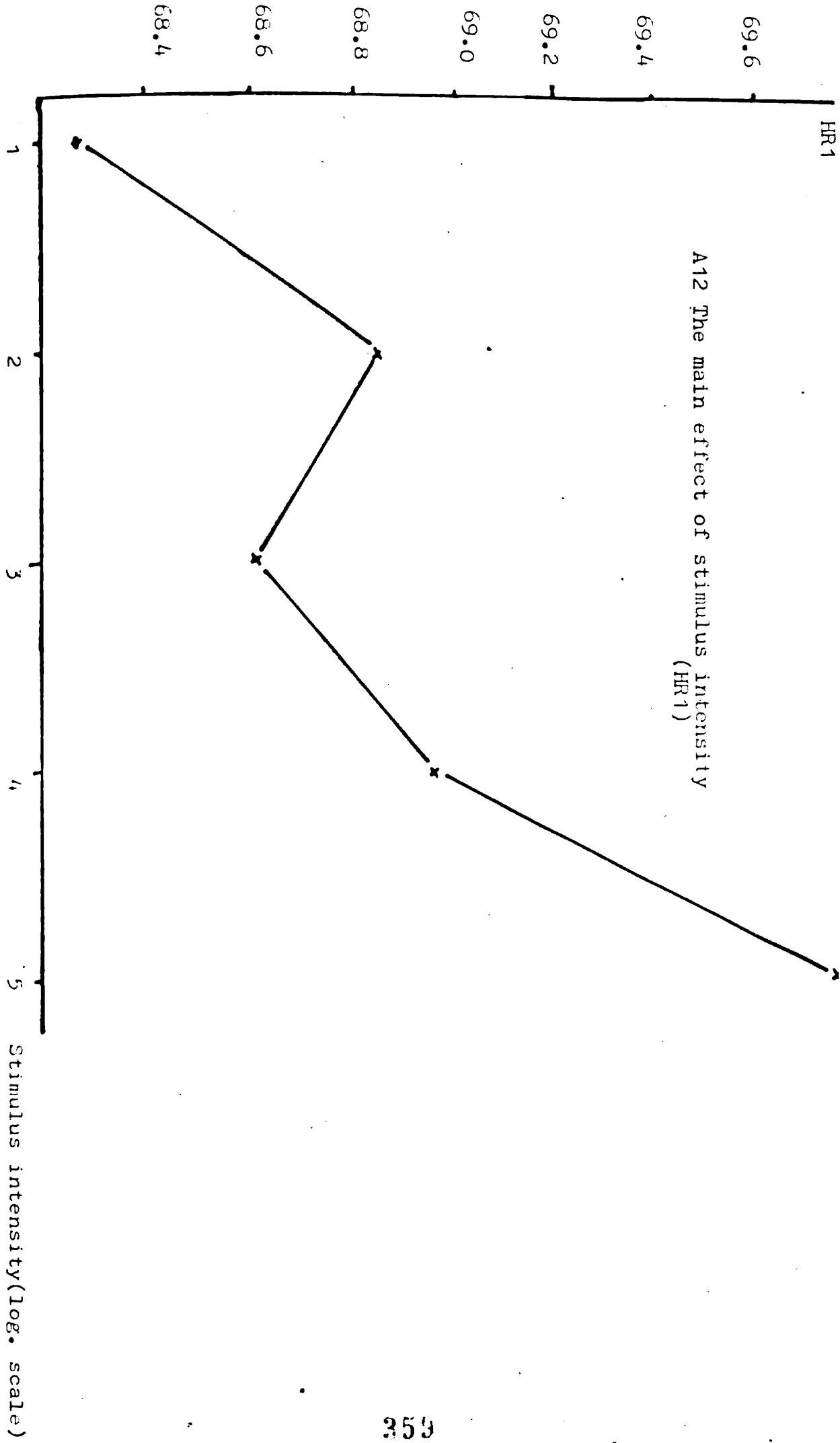
It will be remembered that this postulates an essentially positive, monotonic relationship between the levels of the determinants and the level of the intervening construct 'arousal'. The Russian model on the other hand postulates an inverted 'U' relationship between the levels of the determinants and the level of the corresponding intervening construct: 'excitatory process' (see figs. 2 and 3, p. 44). Western workers have often used autonomic measures as direct indices of 'arousal', but Gray (1964, op. cit.) has suggested that the difference between the Russian and Western models should be put to experimental test using physiological measures in general. To recap what has already been said earlier, support for the Russian model has come from E.E.G. (Savage 1964; Winter et al 1976) and skin conductance measures (Fowles et al 1977) in human subjects, whereas support for the Western model has come from heart rate measures in rats (e.g. Malmö 1966).

The present study used human subjects so, from one point of view, one might have expected the Russian model to have been confirmed. Furthermore, we will also argue later that

the Soviet theory has certain features which make it more plausible than the Western one (see pp. 473-5). For these reasons, the most parsimonious explanation of the findings overall is that it is the Russian model which is the correct one and that where discrepancies occur this has been due to the use of heart rate measures. Christie (personal communication) has argued that the cardiovascular system's vital role in maintaining the physiological integrity of the organism may undermine whatever validity it may have as an index of emotional states or intervening constructs. (This applies less to other measures such as skin conductance). It is not unreasonable to suggest that when the levels of the determinants are very high (e.g. when the level of stimulation to which the organism is subjected is very high), it would be maladaptive and inappropriate for a reduction in cardiovascular activity to take place. These are the conditions under which 'fight or flight' measures may be necessary and the cardiovascular system would play a vital part in any such emergency action.

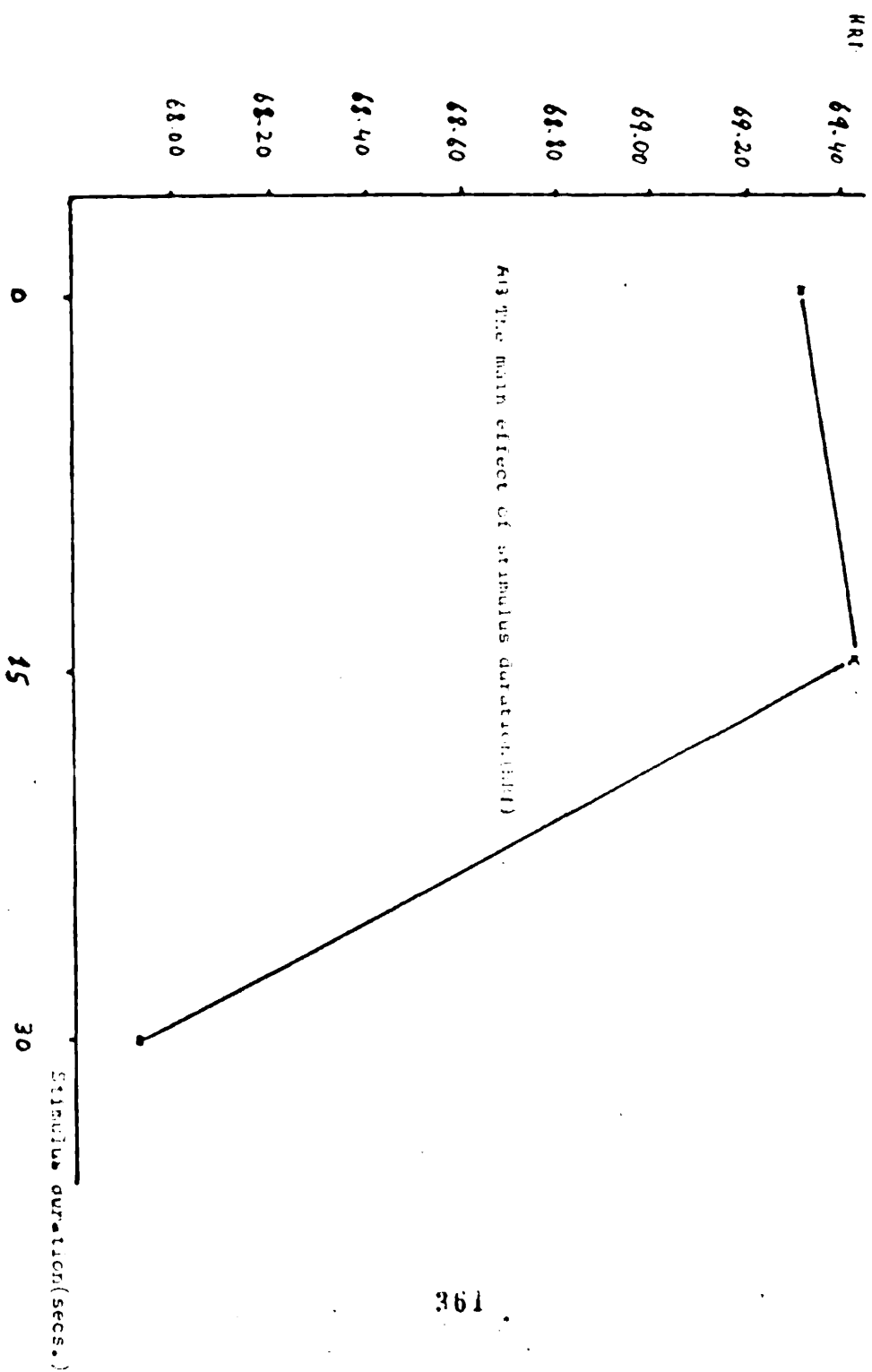
There is also a significant linear component associated with the main effect for stimulus intensity in Session 1 (see Graph A12), due to the fact that as stimulus intensity increases, heart rate increases overall. The irregularity in this increase over the low range of intensities is puzzling, but this may be a chance factor since it is only the linear component that is significant.

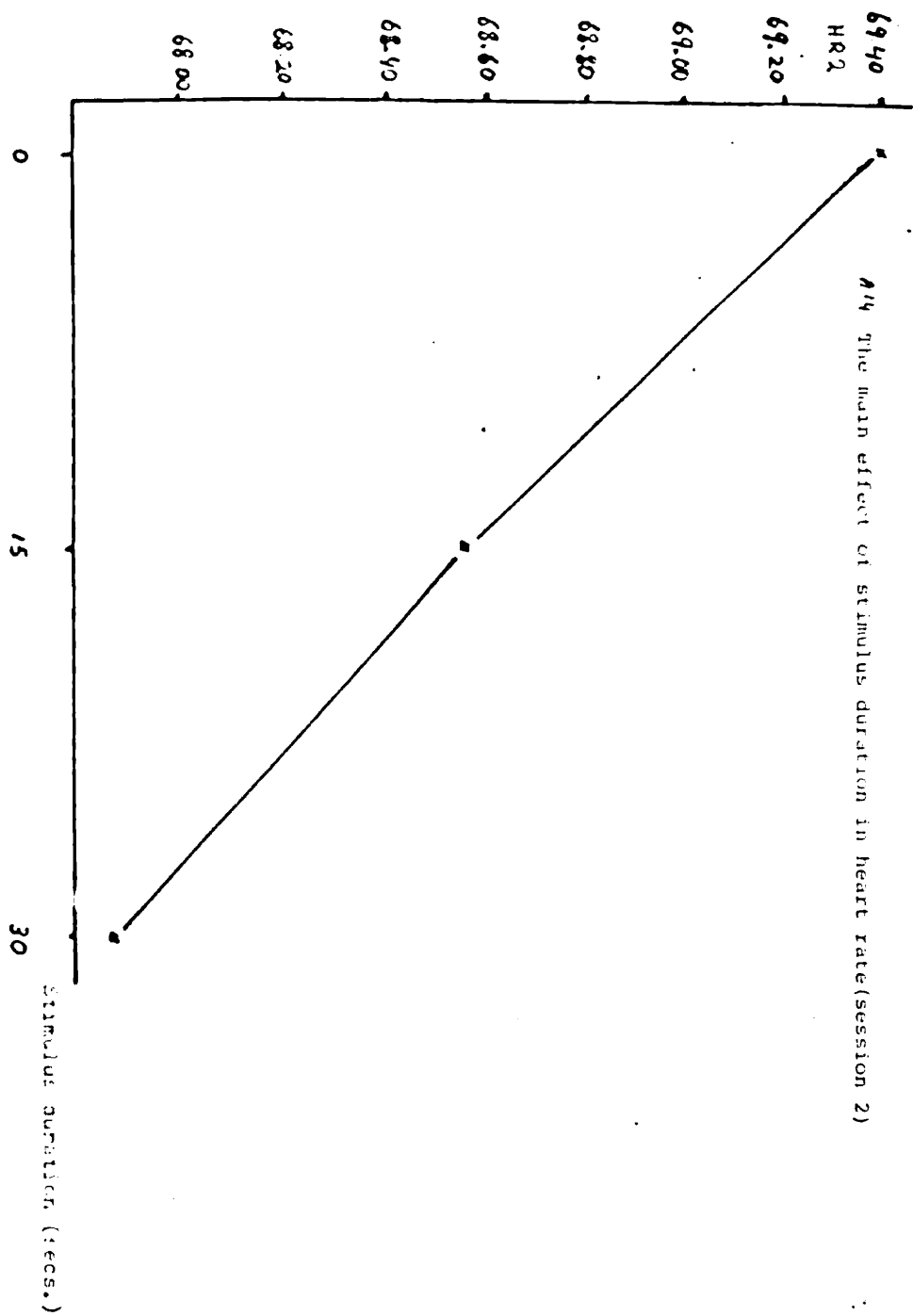
The fact that a similar effect is not found in Session 2 is, perhaps, explicable in terms of the fact that the novelty of the stimuli and the experimental situation as a



whole is less in Session 2 than in Session 1. It is possible, therefore, that the effect of an increase in stimulus intensity (which as we have seen produced a considerable reduction in hedonic tone and which subjects frequently reported as being very painful) no longer produces an adaptive cardiovascular response since the effects are no longer unexpected.

On the other hand, it is extremely puzzling that while the effect of an increase in the noise level was to produce a highly significant increase in heart rate in Session 2, it produced no significant effect in Session 1 when the subjects experienced the noise for the first time. Such discrepancies between main effects under different conditions can be accommodated within an inverted 'U' framework, but we have already argued that this may be inappropriate where heart rate measures are concerned. It is conceivable that in Session 1 subjects responded in a similar way to both levels of 'noise' since both were novel and fairly similar in intensity. By the time of the second session, however, the subjects may have habituated to the less intense stimulus ('no noise') but not the more intense stimulus ('noise'). This is a possibility, but it is very speculative and the author has no really satisfactory explanation for the discrepancy. As graphs A13 and A14 show, heart rate declines following the onset of the taste stimulus in both Session 1 and Session 2. However, in Session 1 there is evidence of a slight initial increase. Some care must be exercised in interpreting these results since for practical reasons the measuring instruments were somewhat crude and the time interval between successive





readings was a relatively long one (i.e. 15 seconds). Graham and Clifton (1966) have suggested that the changes in heart rate following stimulus onset are often complex and ideally require continuous monitoring.

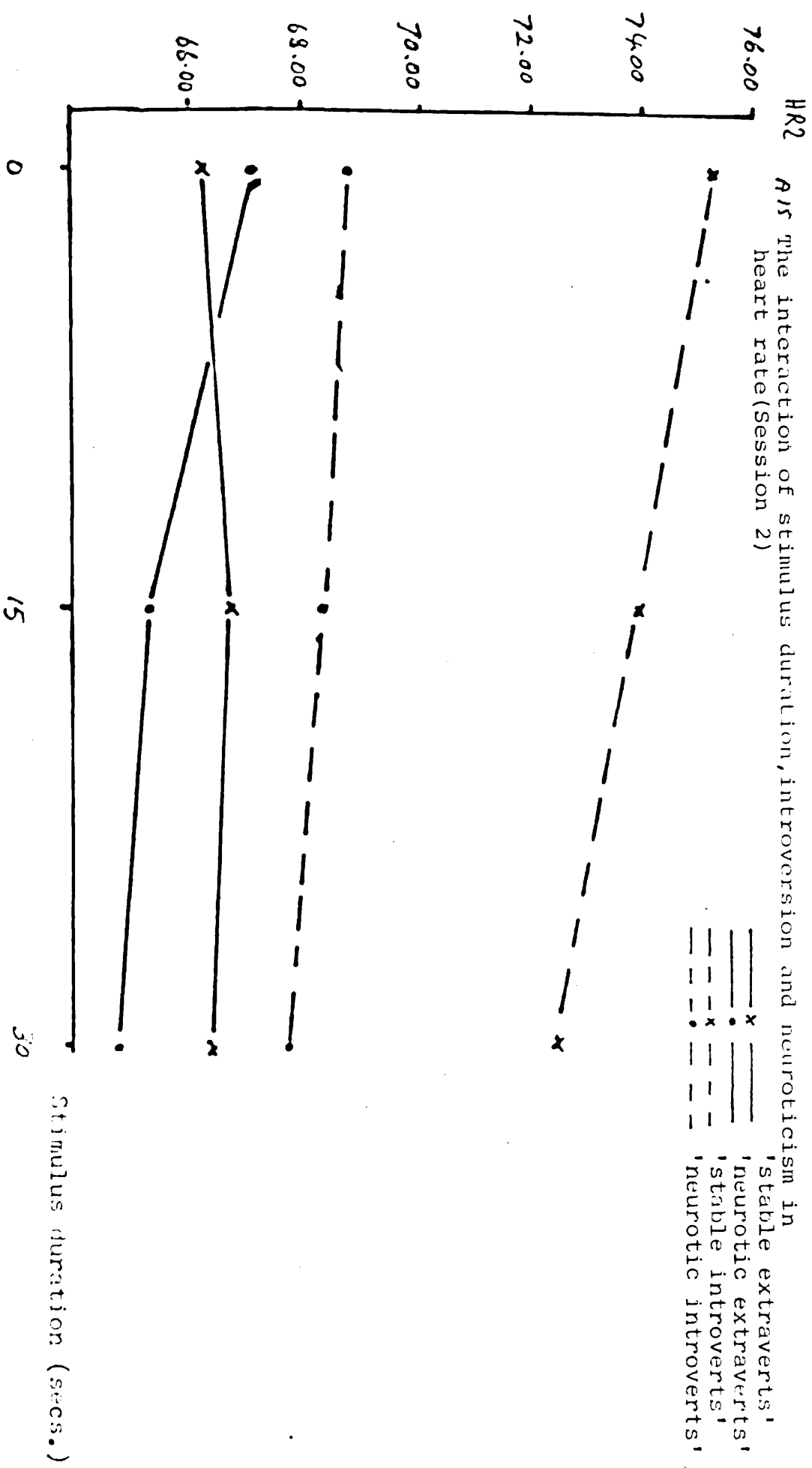
However, there are certain interesting similarities between their analysis and the present results. They suggest that a diphasic response (i.e. an initial acceleration followed by a deceleration) is characteristic of studies which have used intense, near-painful stimuli. Our present study clearly falls into this category. Furthermore, they suggest that the diphasic response may reflect an initial phasic aspect of the orienting response followed by a tonic component of the latter (they also argue that this distinction may map onto the one between 'local' and 'generalised' orienting reflexes). Alternatively, the initial acceleration may be a 'defense' reflex, whereas the orienting response may be reflected in the subsequent deceleration.

This latter suggestion would gain support if there were an interaction between stimulus intensity and time since stimulus onset (i.e. 'stimulation duration'), showing a greater acceleration to high intensity stimuli than to low intensity stimuli. Such an interaction was absent in the present study. This may be because the long interval between readings (15 seconds) made the experiment insensitive to such nuances. Another possibility is that the initial acceleration is a 'startle' reflex - again in line with a suggestion by Graham and Clifton. If so this may explain why it appears in Session 1 but not in Session 2, although one might still have expected a greater degree of startle to high

intensity stimuli than to low intensity stimuli. A 'defense reflex' interpretation would also be able to accommodate a difference between sessions since one might expect a certain degree of habituation to have taken place by the occasion of the second test.

We see then that the results may be explicable in terms of Graham and Clifton's analysis. They are, however, inconsistent with the view which treats time since stimulus onset (i.e. 'stimulus duration') as if it were a determinant. If the decline in heart rate in Session 2 (see Graph A 14) is due to transmarginal inhibition, it does not explain why the peak of the curve seems to appear in Session 1 when the level of novelty is higher in the latter and the subjects are presumably operating further to the right along the 'X' axis of the inverted 'U' (i.e. further from the T.T.I.).

It could be argued that stimulus duration must in fact be moving the subjects to the left along the 'X' axis (see pp. 113-4) due to habituation to an unchanging stimulus. However, the interactions involving the other proposed determinants do not support an inverted 'U' interpretation. For instance, consider the interaction between stimulus duration, introversion and neuroticism for Session 2 (depicted in Graph A 15). One might explain the relative positions of the low and high N subjects amongst introverts by assuming that both were operating beyond the T.T.I. and that stimulus duration moved them to the right. However, this does not explain why both extravert groups show an even lower absolute heart rate. If on the other hand we assume that stimulus duration moves subjects to the left. We cannot explain why



the 'neurotic introverts' have a lower heart rate level than the 'stable introverts'.

Nor are these findings in line with the earlier suggestion that both introverts and high N subjects are more likely to show heart rate acceleration due to 'rejection' of a noxious stimulus, than extraverts and low N subjects respectively. We pointed out in any case that the evidence for this was equivocal. Again it is possible that the crudity of our measuring equipment has masked nuances that exist between different groups. Also, we argued that physical fitness may complicate between-subject comparisons (although the 'neurotic introverts' would be expected to have the highest heart rate on this basis (Christie, personal communication)).

For these reasons we have not attempted to explain the other significant interactions found for heart rate - mostly involving personality - since these are not amenable to adequate explanation either. (It is possible that some of these may have occurred due to chance anyway. In a large analysis of variance one can expect some false positives.)

Our earlier analysis of the effect of stimulus duration by itself is, however, more sturdy since stimulus duration is a within-subjects factor, and we saw that the results tied in with one theoretical approach - though not the inverted 'U' model. The failure of the inverted 'U' here is not actually all that surprising. Gray (1964) has pointed out that the Pavlovian concepts of 'irradiation' and 'concentration' of excitation have not been satisfactorily integrated into the theory of 'strength'. Furthermore, his own explanation

of them is based on the orienting reflex, which as we saw was part of Graham and Clifton's explanation for the diphasic heart rate response to a stimulus. In addition, the orienting response comes into play when the organism is confronted with a novel stimulus which may be threatening and which certainly may require the organism to adapt in some way on a short term basis. The present results, therefore, seem to belong to a more general category - i.e. results obtained in situations where quick, short-term responses may be required of the organism. Under these conditions it is possible that the mechanisms underlying the inverted 'U' may be temporarily overridden.

This may also explain the failure to find any support for Lester's hypothesis that the autonomic nervous system of introverts is relatively dominated by the parasympathetic half, whereas the reverse may be true for extroverts. Conceived of in this way, autonomic 'balance' could be regarded as an essentially long term characteristic of the nervous system. On the other hand, in response to specific stimuli - particularly noxious ones - one might expect a shift towards sympathetic dominance in both introverts and extraverts, and this may obliterate differences between the two groups on phasic rather than tonic measures. This is all very speculative, but it should be remembered that Small (1973) also failed to find any evidence of differences in autonomic balance between introverts and extraverts using heart rate. Furthermore his study was specifically concerned with the effect of threatening stimuli on the two groups.

Deep Core Body Temperature

The most significant finding in this section is that extraverts have a higher overall body temperature than introverts, but show less of an increase as time proceeds. This is surprising, firstly, because if body temperature is an index of 'arousal' of the 'excitatory process', then the present results are at variance with the view that time of day may be a determinant. We have seen already that there is some evidence in favour of this view at the conceptual or behavioural level (see p.190), but on this basis one would have predicted that the introverts would have a higher overall level in the morning at least.

However, it has been shown that though body temperature may be synchronous with whatever internal construct (e.g. 'arousal') that controls the levels of the determinates, the relationship is not a causal one. The 'post-lunch dip' phenomenon illustrates this quite well. After a heavy meal, there is often a transient fall in performance, but the body temperature continues to rise. Such situations under which 'arousal' and body temperature become desynchronised illustrate the danger of using physiological measures to index intervening constructs whose origins lie in behavioural data. In the case of body temperature, we may have a situation which is somewhat analagous to that of the heart rate measure. Christie (personal communication) has argued that body temperature, like heart rate, is related to basic physiological mechanisms which are unlikely to be 'accurate indicators of the kinds of changes that underly precise behavioural

measures. She has furthermore criticised Duffy (1962) and workers in the applied field (e.g. Blake 1971) who have suggested that body temperature may provide the physiological underpinning for the concept of 'arousal'.

However, despite her strictures, the results of Blake in particular merit attention since in many ways they are strikingly similar to some of the phenomena we have already considered. His basic finding was that introverts seem to be advanced in phase compared to extraverts in terms of body temperature. Both groups showed a rise in temperature during the day followed by a fall in the evening. However, the curve for the introverts was shifted to the left relative to that of the extraverts resulting in an earlier peak time, a higher temperature in the morning compared to the extraverts and a lower temperature in the evening.

If we look back to Fig. 6 (p.53) we see that if we consider two determinants A and B and if we represent the level of A on the 'X' axis of the inverted 'U' curve, we can represent an increase in the level of B by a second curve shifted relatively to the left, resulting in a lower T.T.I., a higher level of the 'excitatory process' or determinate at low values of A, but a lower level at high values of A. It should be clear that if we equated determinant A with time of day, determinant B with introversion and the 'excitatory process' or determinate with body temperature our figure would bear a striking resemblance to Blake's findings. These, therefore, support the view that time of

day is a determinant. Furthermore, fairly similar results were obtained in a more recent study by Horne and Ostberg (1977).

If we now return to our interaction between introversion and time of day, however, we find little support for this view. Since the experiments were conducted in the morning, we would have expected almost the reverse if one goes by Blake's temperature curve - i.e. we would have expected the introverts to show a higher overall level, but a less steep rise with time, especially since Blake's curve shows some evidence of a slight early peak at around 10.00-12.00 hours.

Furthermore, the remaining significant results for body temperature are main effects: subjects showed an increase in body temperature as time wore on and a decrease between Session 1 and Session 2. The first result is consistent with the view that body temperature rises during the morning, and the second is perhaps explicable if we assume that anticipation of a novel event results in a rise in metabolic rate and hence a rise in body temperature (though a more long term rhythm in body temperature might also be conceivable). However, neither of these involve more than one factor so they cast little light on the relationship between time of day, body temperature and the inverted 'U'. We are left, therefore, with the persisting interaction between introversion and time of day.

The discrepancy between the present results and those of Blake could be due to some difference in the samples

employed, but it is difficult to see what this might be or how it could have influenced something as fundamental as body temperature. Another possibility is that the task which intervened between the two temperature readings in some way affected them and their relationship to introversion. But again, it is difficult to see how such an effect would be mediated. Finally, we have the possibility that the use of deep core temperature rather than oral temperature (as in Blake's study) may have affected the results. The two regions of the body concerned are separated geographically and we have already suggested that oral temperature would be more readily affected by changes in blood flow in the region of the mouth and head. Because of the similarity between Blake's curve and fig. 6, and because of the predictable relationships between cortical (rather than peripheral) physiological measures and proposed determinants such as introversion and neuroticism (e.g. Winter et al., op. cit.), one could suggest that physiological changes in the region of the central nervous system might be more likely to show predictable relationships to the determinants than changes which are more peripherally based. This is very speculative, but it is a possibility.

Blood pressure

There are no significant effects for systolic or diastolic blood pressure.

Mean pupil diameter

There is one significant interaction for this measure, namely an interaction between session and introversion. This is due to the fact that amongst introverts, mean pupil diameter was greater in session 2 than in session 1, whereas the reverse was true amongst extroverts. This is in line with prediction and supports the Russian model.

iii) Discussion of State Measures

State Anxiety

The only significant effect which appears for the 'State Anxiety' measure is the interaction between noise and neuroticism. This is due to the fact that amongst low N subjects 'state anxiety' is higher under 'noise' than under 'no noise', whereas the reverse is true amongst high N subjects.

The result for the high N subjects may seem surprising at first glance, but it will be remembered that state measures (such as Spillinger's state anxiety questionnaire) have been suggested as an alternative to physiological measures as direct indices of 'arousal' or the 'excitatory process' (see p. 229). The interaction supports this view and the Eysenck model of the inverted 'U'. Gray (1976) has suggested that the behavioural inhibition system (B.I.S.) is the physiological substrate for anxiety (both state and trait), and the ascending reticular activating system (A.R.A.S. is part of the B.I.S. Since the A.R.A.S. is often cited as a candidate for the physiological substrate of 'arousal', the tie-in between 'arousal' and 'state anxiety' is complete. However, to explain the above interaction one would have to suppose that 'arousal' is not in fact positively and monotonically related to the levels of the determinants, but instead shows a curvilinear relationship. Also one would have to postulate a reduction in the level of activity of the A.R.A.S when the levels of the determinants are high.

Nowlis Mood Adjective Checklist

As already stated, we are primarily interested in a limited number of the 13 scales derived from this particular checklist and we shall consider these first. The choice of them is based on face validity and is to some extent, therefore, subjective and arbitrary. We have pointed out already that this is one of the disadvantages of state measures. However, it has also been stated that we are concerned here to establish relationships between operational definitions of subjective states and the levels of the determinants. Whether such operational definitions will later be found by further investigation to correspond to the actual mechanisms mediating between determinants and determinates is a matter which cannot be decided on an a priori basis. In the case of the state anxiety measure we have seen that there is good supportive evidence both of a theoretical and experimental nature to suggest that it may well be an index of a relevant underlying variable. In the case of the Nowlis checklist the body of evidence as yet is relatively slim, but it is growing since the checklist has provided the seeds for later questionnaires (some of which we will consider further on). It is hoped that the present results may contribute to this body of work.

However, owing to the relatively small number of adjectives per scale in this particular checklist, or possibly because the adjectives (being largely American in origin) themselves are inappropriate to the cultural setting in which we have used them (Mackay et al 1978), many of the subjects scored zero on many of the scales. This makes the results

less informative than they might otherwise have been since it reduces the spread of individual differences. Also the resulting skewedness makes it necessary to adopt a more stringent level of statistical significance, and we will take this fact into account when considering the results.

The main effect for introversion on the 'concentration' scale is significant at the 0.5% level (two tail). Introverts overall report a higher degree of concentration than extraverts, and this is in line with other studies which have looked at behavioural measures of attention (e.g. Mohan et al 1974).

It will be remembered that 'alertness' is one of our list of determinates. Furthermore, Gray (1964) has suggested that the range of cue utilisation is the best measure of alertness. If this is true, and if the range of cue utilisation is an inverse measure of 'attention' or 'concentration' to task-relevant stimuli, this implies a 'U' shaped relationship between attention or concentration and the levels of the determinants. This is a somewhat surprising conclusion since it implies that attention to task relevant stimuli will be lowest at intermediate levels of the determinants which we normally associated with high performance. We, therefore, appear to have a discrepancy between predictions based on the concept of attention treated as an inverse measure of alertness, and the concept of attention, treated as a direct measure of performance.

The source of the discrepancy probably lies in the fact that alertness refers to the subject's receptivity to all stimuli including those which are not relevant to the task.

This would, however, impair the ability of the subject to attend specifically to task-relevant stimuli (Broadbent 1958). Thus there is an ambiguity in the concept of attention itself. Normally the two aspects would be expected to be inversely related to each other. However, under certain conditions both aspects of attention would be impaired - for example in sleep (when attention to both task-relevant and task-irrelevant stimuli would be reduced). It is this effect of 'de-arousal' under conditions of sleep that forms the basis for the left hand *half* of the proposed inverted 'U' relationship between alertness and the determinants (Gray, 1964).

Because of these complexities, it is difficult to predict what form the relationship between the 'concentration' scale and the levels of the determinants is likely to be. As a result we cannot assess the significance of the finding that introverts report a higher degree of 'concentration' than extraverts, other than to say that it is in accord with results using behavioural measures.

The next scale that we must consider is the 'de-activation' scale. If we regard 'de-activation' as an inverse measure of 'arousal' we would expect it to have a negative, monotonic relationship with the determinants. If we regard it as an inverse measure of the 'excitatory process' we would expect it to have 'U' shaped relationship with the determinants.

The only significant results for this scale are both main effects. Firstly, for neuroticism (0.5% two tail), indicating that high N subjects report a higher degree of

de-activation than low N subjects. The second is for Session (0.5% two tail), indicating that subjects report a higher degree of de-activation in Session 2 than in Session 1. This second effect is consistent with the view that de-activation may be an inverse measure of 'arousal', since the level of novelty is lower in Session 2 than in Session 1. The effect involving neuroticism is not consistent with this view, however - we would have predicted the reverse.

Both effects could be explained if we alternatively assumed that de-activation is an inverse measure of the 'arousal' process and that an inverted 'U' relationship exists between the latter and the determinants. However, since we are dealing with main effects, one cannot say that the results provide any great support for this view, though they are probably genuine effects and not due to chance, since both are significant at a stringent level.

When we consider the 'activation' scale, we see that the results are not the converse of the results for the 'de-activation' scale. This is not surprising since they were employed as separate scales because they did not seem to form a single bipolar factor (though workers who subsequently re-analysed data using many of the words from the checklist did find evidence for such a factor). It does, however, illustrate the problems associated with the use of state measures - i.e. that the names assigned to them can be misleading. If two separate factors do indeed exist, and if they both show lawful relationships with the determinants, then this might suggest that the processes underlying the

inverted 'U' are not unitary. There are, in fact, no significant effects for the 'activation' scale.

The anxiety scale is also of interest for reasons which were stated when we considered the Spielberger measure. However, the results from the two scales do not show agreement in the present instance.

Using the Moxlis Checklist we find that the main effect for session is significant at the 0.1% level, due to the fact that overall subjects reported a higher level of 'anxiety' in Session 1 than in Session 2. This is intuitively reasonable and is consistent with both the Western and the Russian titles. However, such an effect was not found using the Spielberger measure.

Also, there is a significant interaction between session and neuroticism using the Moxlis Checklist (which again was not found using the Spielberger test). *The interaction*

was due to the fact that in session 1, high N subjects reported a higher level of 'anxiety' than low N subjects, whereas the reverse was true in session 2. This is not in line with prediction, nor has the author any explanation for it. However, since the transformed data were still slightly skewed and since the result was only significant at the 5% level, too much importance should not be attached to it.

Furthermore, no such interaction was found for the Spielberger measure. Instead there was an interaction between noise and concentration which suggested that under 'noise' at least, the high N subjects might have passed their T.T.I.

Nevertheless, since a different factor was involved (i.e. noise rather than session), and since in any case we have accepted the possibility that different state measures may be measuring different things even though they have been given similar names, we will not allow this discrepancy to detain us any longer.

The final state we should consider is the 'pleasantness' measure. This could be regarded as a measure of overall

hedonic tone, but the results do not support this interpretation. The interaction of noise and neuroticism (significant at the 2.5% level) is in the opposite direction to prediction and the author has no explanation for this.

Summary

Main indices

The most interesting finding that emerges from the present set of results is an interaction between introversion and noise for magnitude estimation in session 1, which is consistent with the inverted 'U' model. However, we have suggested that it is possible that the interaction may have been due to response biases rather than sensory-perceptual factors, and that if so it might support the hypothesis that there is an inverted 'U' relationship between the determinants and the degree of positive response bias.

Another feature of this interaction is that even in subjects who appear to be operating on the right hand half of the inverted 'U', there is no evidence of a fall in magnitude estimates as stimulus intensity rises. This would suggest that the general model as presented may not be able to account for the effect of this factor. Furthermore, overall an increase in stimulus intensity produces a monotonic increase in unconditioned salivation and magnitude estimates, but a monotonic decrease in hedonic tone. This would indicate that the T.T.I. may be different for different determinates.

Finally, we have argued that the salivation index is susceptible to influences mediated directly via the autonomic nervous system and that the hedonic tone measure may not be unitary. In both cases this could explain apparent failures to confirm the inverted 'U' model.

ii) Summary of results for physiological and state
measures

Although the results for the heart rate measure do not conform to the predictions of the various hypotheses presented earlier, it is suggested that this may reflect

the special function this parameter has in the mobilisation of the organism's resources to meet an emergency. Similarly, the failure of stimulus duration to interact in predictable ways with the other determinants may reflect adaptations associated with the orienting response. None of the other physiological measures provides any coherent support for the present hypotheses, though there is a limited amount of support for the inverted U' from the state measures.

CHAPTER SEVEN - REACTION TIME: A REVIEW OF THE LITERATURE

1. SOME ASSOCIATED MEASURES AND THEORETICAL ISSUES

In the taste experiment we considered indices which were either largely involuntary (e.g. salivation) or in which the subject made a fairly passive response. We will now consider certain indices in which the subject is required to make a more active motor response and in which, therefore, he is in a better position to influence the total amount of stimulation he receives. First it is worth considering a model of introversion initially proposed by Brebner and Cooper (1974) and later developed further experimentally (Brebner and Flavel 1978; Brebner and Cooper 1978).

1) Brebner and Cooper's model

According to Brebner and Cooper, the central nervous processes of a subject can be in a state either of excitation or inhibition, due to the demands for organising stimuli into percepts or constructs (S - excitation or inhibition) or due to the demands for organising responses to these stimuli (R - excitation or inhibition). In either case, inhibition can be caused by the demands for stimulus or response organisation being too low or too high. Furthermore, Brebner and Cooper suggest that for a given level of stimulation the resulting S - excitation is greater in introverts than in extraverts, whereas the R - excitation is greater in extraverts than in introverts.

As regards the former suggestion, we can see that it is quite in line with our view that where the levels of the determinants are relatively low, at least, the level of the excitatory process is greater in introverts. The only difference is that Brebner and Cooper invoke the concept of inhibition to explain changes in performance at both extremes of the stimulus and response continua, whereas we have only had reference to it at the high end at which 'transmarginal inhibition' is presumed, on the Russian view, to replace excitation. In fact, at the level of the conceptual nervous system, at least, one needs only one construct - excitation or inhibition - to explain the findings, since a decrease in excitation is equivalent to an increase in inhibition and vice versa (see p. 47).

When one considers Brebner and Cooper's R - excitation postulate, however, the situation becomes a little more complex. The model states that the relatively greater S excitation of introverts is associated with a relatively greater tendency to 'inspect', whilst the relatively greater R excitation of extraverts is associated with a relatively greater tendency to respond. It is not entirely clear whether a given state of excitation is the cause or the effect of the associated tendency to inspect or respond (or both). Brebner and Cooper (1978) have shown that where the subject is himself able to control both the stimuli to which he is subjected and the responses which he makes, introverts tend to inspect stimuli for longer than extraverts, whereas extraverts tend to emit more responses than introverts.

If it is true, as our present model would suggest, that at relatively low levels of the determinants stimuli produce a greater degree of excitation in introverts than in extraverts, then it could be argued that the 'profit' associated with stimulus inspection would be greater in introverts than in extraverts. By analogy, can we infer that the 'profit' associated with responding is greater in extraverts than introverts? This may be true, but the exact underlying mechanism is of considerable theoretical importance.

There is nothing in our model to suggest that the amount of excitation produced by the organisation of a given response of a given intensity and of a given kind is greater in extraverts than in introverts. Brebner and Cooper distinguish between the excitatory effects produced by response organisation per se and the excitatory effects produced by the stimuli generated by the response. The former are included in the category of response-related effects, the latter in the category of stimulus-related effects. Such a distinction would seem to be somewhat arbitrary, since both effects are consequent upon the emission of a response, but we will nevertheless allow it for the sake of argument, since it has certain implications. If the stimuli generated by a response are included in the stimulus category, then our model would predict that the resulting excitation should be greater in introverts than in extraverts. Even if we accept that a separate category of effects exists which is associated with the organisation of the response per se, for a given response

to produce a greater total increase in excitation in extraverts than in introverts, one would have to suppose not only that such 'pure response' effects were greater in the former, but also that the size of the difference was sufficiently great as to more than counteract the greater susceptibility of the introverts to the stimulus feedback associated with the response.

It is the present author's view that such a supposition is both unparsimonious and unnecessary. The empirical findings are that extraverts in a free response situation often emit more responses than introverts. Brebner and Cooper also found that there was evidence for an element of 'positive feedback' associated with this greater responsiveness, such that in an extravert the organisation of a response makes him more likely to emit a further response (see the original paper for the empirical data on which this is based).

It is certainly perfectly reasonable to suggest that not only does the excitation state of the nervous system determine the subjects level of response, but also that the subject's response influences his excitation state. It is not necessary, however, to assume that the size of this latter effect per response is greater in extraverts than in introverts.

We are still left though with the need to explain the greater responsiveness of the extraverts. We need not look far for an answer. If the excitation produced by a given level of stimulation is less in extraverts than in introverts, and if we also assume that an individual attempts to achieve a certain optimal level of excitation (associated with maximal hedonic tone), then it makes

sense to suggest ^{that} individuals should attempt to increase their level of excitation by responding, and that this tendency should be greater in extraverts than in introverts. In other words, we can accommodate the behaviour of extraverts and introverts into our general model without any additional postulates.

One example of such an additional postulate is the view that whereas introverts are 'stimulus hungry', extraverts are 'response hungry'. Brebner and Cooper make this suggestion again in the light of the differential tendencies of introverts and extraverts to inspect and respond in their experiment, which involved looking at a picture slide and then making a response to move onto the next slide. However, this ignores the fact that looking at a slide for a longer period (which is behaviour that was characteristic of introverts) does not necessarily provide a greater degree of stimulation. Prolonged inspection of an unchanging stimulus might result in a lessening of excitation due to habituation. This would not be out of line with the view that if the level of excitation is supra-optimal, the individual may, in fact, try to reduce it, and that this tendency is more likely to manifest itself in introverts.

Furthermore, although Brebner and Cooper tried to separate stimulus and response related effects by ensuring that a response did not always bring on the next slide, it is nevertheless true that the production of a response was a necessary (if not sufficient) condition for the next slide to appear, so that the subject would be correct in

thinking that emitting a response would increase the likelihood of a change in the stimulus to which he was being subjected. Moreover, even if this were not true, the fact still remains that an increase in responding would be expected to increase the level of excitation of the subject, and might therefore be expected to occur more readily in extraverts. We need, therefore, only suppose that, under certain conditions at least, extraverts have a greater need for stimulation than introverts. The fact that this need manifests itself as a greater tendency to respond may simply be a reflection of the fact that a subject's response is under his own control, whereas the stimuli to which he is subjected may not be, and even where they are, a response of course must intervene. Also, one may suppose that excitation associated with responses might be less subject to habituation effects than the excitation associated with stimuli, since in a controlled experiment the latter may be very regular or monotonous, due to the fact that they are usually produced by precision equipment. Responses, on the other hand, are a product of the subject's own body, which is less likely to be so regular and precise.

To summarise, the argument so far, it is suggested that the greater responsiveness of extraverts in a free response situation can be explained by reference to their relatively greater need to raise their level of excitation towards some optimal level. Responding may be the best way of achieving this, since by making an active response to a stimulus the extravert benefits not only from the excitation due to the stimulus itself, but also from the

excitation due to the stimuli generated by his own response. Also it may be the only way of achieving his aim, since stimuli may not be under his control whilst his responses are. Thus it may indeed 'profit' the extravert more than the introvert to respond, but this may be because his need for excitation of any kind is greater, and it is not necessary to suppose that the excitation per response is greater for the extravert than for the introvert. This is a point which is of great theoretical importance, as we will now see.

ii) The tapping task

White and Mangos (1972) have drawn attention to the fact that not only do extraverts perform better than introverts on motor tasks, such as 'tapping' tasks, but also that ergographic measures of 'strength' (which involve motor activity) correlate very poorly with other measures of 'strength'. They therefore suggest that in the motor analyser, extraverts are 'weaker' than introverts (where 'weakness' is defined in terms of the 'theory of strength' see p. 46).

Let us go back to our original definition of 'strength'. It will be remembered that a 'strong' nervous system performs better than a 'weak' nervous system when the levels of the determinants are relatively low, whereas the reverse is true when the levels are relatively high, due to the relatively low threshold of transmarginal inhibition in the 'weak' subject. The important point to notice is that these relationships hold under standard conditions - i.e. when the levels of the determinants (other than individual differences) are controlled by the

experimenter at fixed levels which are the same for the 'strong' and the 'weak' nervous system alike. Only under these conditions does a fair basis for comparison exist. In contrast, in a free operant situation, one vital factor is not under the experimenter's control - namely, the subject's own level of responding. We have also argued that responding can itself influence the level of excitation, and that the theory would predict that extraverts would have a greater incentive to make use of this facility, in order to optimise their level of hedonic tone.

At this point, it is worth reminding ourselves of the two basic techniques of measuring hedonic tone (which we have argued could be included in the list of determinates). The first is to measure it directly by getting the subject to rate his level of hedonic tone. The second, and much more indirect way, is to assess the behaviour the subject displays in order to optimise this level, if he is given the opportunity to do so.

A free operant situation gives him just such a chance, and therefore the number of responses he emits is a measure of his level of hedonic tone and therefore his level of excitation, but it is an inverse measure of it. A high level of responsiveness is an indication that the level of excitation of the subject is low, and is a result of his attempts to compensate for this. Thus we are not justified in concluding that this higher level of responsiveness corresponds to the higher level of performance displayed by the 'weak' nervous system when the levels of the determinants are relatively low.

Equally, in a free operant situation the response level is itself one of the determinants (due to the stimulus feedback), as well as a determinate. Furthermore, since it is not under the control of the experimenter, we are not justified in concluding that the greater decrement in performance also found in extraverts (e.g. Wilson et al, 1971, in a tapping task) corresponds to the decrement found in 'weak' nervous systems under the influence of a prolonged or frequent stimulus. This latter phenomenon is due to the fact that at a given level of stimulation the 'weak' nervous system is operating further to the right along the 'X' axis of the inverted 'U', resulting in an effective lowering of the threshold of transmarginal inhibition relative to that of a 'strong' nervous system.

However, if we arranged it so that the 'strong' nervous system received more stimulation (measured in objective terms) than the 'weak' nervous system, we might well find that people with 'strong' nervous systems, despite their lower excitability, passed their threshold of transmarginal inhibition (T.T.I.) sooner than those with 'weak' nervous systems. This might well happen in a free operant situation (such as a tapping task) due to the larger number of responses emitted by the extraverts, and consequently the greater stimulus feedback generated by them. Thus we have no grounds for concluding that the initial higher level of responsiveness, and subsequent greater decrement in responsiveness of the extravert, are an indication that he has a relatively 'weak' nervous system. In fact, both can be predicted if we assume that he has a relatively 'strong' nervous system

and hence tries to compensate for a relatively low level of hedonic tone under conditions where the stimulation provided by the experimenter is relatively low.

All the same, there is an element of paradox in the finding that the extravert's attempts to compensate actually take him beyond his threshold of transmarginal inhibition (as evidenced by the decrement in his responsiveness). The fact that he emits more responses is perfectly understandable, but we would expect him to do so only to the extent that is necessary to enable him to 'catch up' with the introvert. If the level of hedonic tone is indeed a determinate, as we have suggested, then passing the T.T.I. should result in a lowering of the level of hedonic tone. In other words, why does the extravert go on responding till he passes beyond his threshold of transmarginal inhibition? The explanation of the paradox is that in the above analysis we were concerned to show that even if we accepted the assumption that ^{the} decrement in response in extraverts can be interpreted as due to transmarginal inhibition, this would not prove that extraverts have relatively 'weak' nervous systems. However, we did not actually question the assumption itself, and there are good grounds for doing so.

Just as we regarded the initial greater responsiveness of the extravert as an inverse, rather than a direct measure of his level of excitation, we can regard his subsequent lowering of responsiveness as due to the fact that as the excitation resulting from his responses builds up, the discrepancy between his actual and desired level

of hedonic tone decreases, and so his level of responsiveness decreases. The fact that it decreases more than in introverts may simply be a consequence of its initial higher level (i.e. due to the law of initial values). Thus the behaviour of the extravert throughout could be regarded as an example of homeostatic adaptation, (although an alternative explanation will be advanced later). Furthermore, this behaviour is predictable from our general model.

However, as has been pointed out earlier, the connection between an individual's level of excitation and his attempts to modify it is not a simple, direct one. There are a number of intervening steps in the argument if one wishes to make inferences about the former from the latter. For this reason, the author wishes to suggest that indices such as tapping tasks are not the ideal ones to test the present hypotheses. Gray (1967) suggested the exact opposite - namely that there was an urgent need to investigate the relative performance of 'strong' and 'weak' subjects (defined in terms of some classical measure of 'strength') on a tapping task. However, this was in the light of the findings relating introversion to tapping task performance, which seemed at the time to suggest that introverts might have relatively 'strong' nervous systems. This was contrary to the prevailing hypotheses. We have, however, advanced an alternative explanation for the findings, and despite our reservations about the use of the tapping task we have argued that in fact these hypotheses are not threatened by the data.

For this reason, no attempt has been made by the author to use tapping tasks or other free operant indices during the course of his experimental work. However, there are one or two other theoretical issues arising out of the tapping task which should be considered.

iii) Reactive inhibition

The decrement in response that has been found on this measure has often been attributed to 'reactive inhibition'. This concept has certain apparent similarities to that of transmarginal inhibition, since the conditions under which both are thought to arise (i.e. prolonged performance) are similar. This is a point made by Gray (1967), though he criticises some workers for their use of the term 'reactive inhibition' to refer to a decrement in general responsiveness, when it was originally used to refer to the decrement in a specific response. He points out that transmarginal inhibition is also an example of a specific response decrement, but in an earlier formulation (Gray 1964), he suggests a physiological mechanism for it which implies that, though it may be produced by specific stimulus conditions, the resulting effects may be more general.

The question as to whether transmarginal inhibition is ^a general phenomenon or not can be approached in two ways. According to the first, individuals who have a relatively low T.T.I. in one performance index might be expected to have a relatively low T.T.I. in other performance indices. Such an assumption is implicit in the view that 'strength' of the nervous system is a

general nervous system property. In this respect, of course, transmarginal inhibition and reactive inhibition do not differ since susceptibility to reactive inhibition is also thought to be a general nervous system property and one which, according to Eysenck (1957), is more marked in extraverts than in introverts. It is interesting that the phenomenon of partial properties might suggest that, in fact, transmarginal inhibition is not a general nervous system property. The phenomenon is exemplified, firstly, by the fact that performance on the same response index, for example sensory thresholds, shows imperfect correlations between different sensory modalities (e.g. Ippolito 1972). Secondly, by the fact that performance on different response indices (which are nevertheless all thought to measure 'strength') show incomplete correlation with one another, even if measured in the same sensory modality.

Such 'partial properties' have been less widely studied in the West, but it is not unreasonable to suggest that similar findings might be obtained if different indices of reactive inhibition were compared to one another. (Part of the problem is that, as Gray points out, satisfactory measures of reactive inhibition are relatively scarce. He suggests that the tapping task is one). So whether we regard susceptibility to reactive inhibition and susceptibility to transmarginal inhibition as both general or both partial nervous system properties, comparisons of them across individuals are not necessarily inimical to the view that they are identical, or at least similar.

However, the distinction that Gray was drawing was based on within subject comparisons, and this brings us to

the second way in which reactive and transmarginal inhibition can be compared. Gray argues that for a given individual, reactive inhibition represents a tendency to cease making a specific response, whereas his proposed mechanism for transmarginal inhibition would result in a lowering in the overall level of functioning (general 'de-arousal' as Gray puts it). At the conceptual level we will not quarrel with the view that transmarginal inhibition may be a general phenomenon for a given individual at a given moment in time, though to test it one would have to measure several response indices simultaneously, but arrange that the levels of determinants, such as stimulus intensity, were relatively high for only one of these indices. If under these conditions, transmarginal inhibition appeared in all of them then the hypothesis would be supported.

Nor is such a hypothesis necessarily in conflict with the view that across subjects susceptibility to transmarginal inhibition may be a partial nervous system property. It is not impossible that a single transmarginal inhibition mechanism exists which, when operating, produces a general lowering of response, but that the relative likelihood of it being activated in different individuals, depends on the particular response index or sensory modality under test. However, it should be noted that there are difficulties

associated with the view that reactive inhibition is a specific phenomenon, at least if it is measured by the tapping task method. If the hedonic tone of an individual is related to his total level of excitation then the decrement in responsiveness found in tapping tasks (particularly in extraverts) could be considered to be a general phenomenon. Clearly the problem is partly a question of definition of the term 'reactive inhibition'. If one defines it as a decrement in a specific response, and if our analysis of the tapping task results is correct, then this index may not after all be a valid measure of this form of inhibition.

There is also a second consideration which leads us to question its validity in this respect. We mentioned earlier that there was another possible explanation for the greater decrement in the response of extraverts in a free operant situation such as a tapping task. This explanation would assume that the decrement was due simply to neuromuscular fatigue. Hogan (1966) has pointed out that measures of reactive inhibition are only valid where precautions are taken to prevent neuromuscular fatigue from building up, since reactive inhibition is considered to be a central rather than a peripheral phenomenon. This explanation like the earlier one in terms of hedonic tone (see pp. 389-91) is presented tentatively. We do not assume that either is necessarily the correct explanation of the findings, we would simply suggest that the tapping task has perhaps been invested with too much theoretical significance, since the associated data is not necessarily inconsistent with our theory and since the task does not

in any case, provide the most suitable test of the latter (see pp. 312-7).

iv) The pursuit rotor

One example of a task which might seem more promising is the 'pursuit rotor', in which the subject is required to keep a metal stylus in contact with a rotating disc. The length of time for which such contact is maintained is the measure of performance. This task has also been linked by some workers to the concept of reactive inhibition. The evidence for this connection comes mainly from the phenomenon of 'reminiscence'. This is the improvement in performance that results from a rest pause, and it is thought to arise from the dissipation of the reactive inhibition. It is found that extraverts show greater reminiscence - i.e. a greater improvement in performance - following a rest pause than introverts, and this has been explained by the greater amount of reactive inhibition which extraverts are presumed to accumulate prior to the rest pause.

Explanations of the decrement in performance of the extraverts in terms of homeostatic adaptations or neuromuscular fatigue are more difficult than in the tapping task, since the subject in a pursuit rotor situation is not really at much liberty to alter the amount of excitation which he receives, nor are the demands placed upon him for muscular effort particularly high.

However, Eysenck (1967) in a review, has pointed out that the extraverts do not differ from the introverts in terms of their pre-rest performance, but in terms of their

post-rest performance. He, therefore, concludes that a reactive inhibition interpretation is untenable, and he proposes an alternative 'consolidation' theory (the details of which need not concern us here).

Let us now consider another index in which like the pursuit rotor (but unlike the tapping task) the amounts of stimulation which the subject receives appears to be more a function of the experimental conditions than of the subject's own behaviour, and which, therefore, would seem to be a good one to use to test our hypotheses: simple reaction time.

2. SIMPLE REACTION TIME : THE DETERMINANTS

Reaction time (i.e. the interval between the onset of a stimulus and the subject's response to it) has been widely used as a response index both in the West and in the Soviet Union, since it has the advantage that it provides a fairly easily measurable and fairly objective index.

Its relationship to the determinants of 'arousal' and the 'excitatory process' will now be considered.

1) Stimulus intensity:

A number of studies (e.g. Teichner 1954) show that the speed of reaction (the reciprocal of the reaction time) is a positive, monotonic function of stimulus intensity. Furthermore, Bartlett and Medved (1954) have argued that the relationship is of the form :

$$\text{Reaction speed} = K \times \log. \text{ Stimulus Intensity (S)}$$

Vaughan et al (1966) have suggested that it could also be described by :

$$R = K S^n$$

where $n = 0.3$ (exactly the same value is obtained where the latency of the evoked potential is considered instead of the latency of the subject's behavioural response).

Both of these equations would predict a positive, monotonic, negatively accelerated function which would correspond to portion 'B' of the inverted 'U' curve (i.e.

the left hand portion which is convex upwards, see p. 83).

A similar shape is produced if one uses individual differences to manipulate reaction time rather than stimulus intensity alone, with fast reactors showing less of a difference between a strong and a weak stimulus (i.e. a less steep slope) than slow reactors (Kohlfeld 1969). Thrane (1960) , however, did not find this.

To date the author knows of no study which has demonstrated transmarginal inhibition due to a rise in stimulus intensity in normal subjects in simple reaction time. Nebylitsyn (1960) used the point at which the reaction time /intensity curve flattens off as a measure of the threshold of transmarginal inhibition. In this study, the reaction time to the strongest stimulus was longer than the reaction time to the second strongest stimulus in subjects with 'weak' nervous systems under conditions where the stimulant drug caffeine was administered, but no statistical analysis of this effect was carried out.

Vasilev (1960) argued that the failure to find transmarginal inhibition was due to insufficiently large values of stimulus intensity and duration used. The alternative measure he developed to try to get round this problem, (based on the difference between the reaction times to the onset and offset of the stimuli), has only shown very weak correlations with established measures of 'strength', though Mangan and his co-workers have recently been working on a slightly different measure, also based on the reaction time to the offset of a stimulus (e.g. Mangan 1967).

Transmarginal inhibition in simple reaction time has been found in schizophrenic subjects (e.g. Venables and Tizard 1956). It has also been demonstrated by Keuss (1972) using normal subjects in a choice reaction time task, though both Russian (Borisova 1972) and Western workers (e.g. Grite et al 1976) argue that the processes underlying choice reaction time are complex and not identical to those underlying simple reaction time.

ii) Drugs:

Plotnikoff et al (1960) and Weiss and Laties (1962) have shown that the stimulant drug amphetamine increases speed of responding. Also, Nebylitsyn (1960) found that the stimulant drug caffeine increased the overall speed of responding, decreased the slope of the curve relating speed to stimulus intensity, and that the latter effect was more pronounced in the 'strong' nervous system than in the 'weak'. All of these effects are predictable on the basis of portion 'B' of the inverted 'U', although, as Frigon (1976) has pointed out, Nebylitsyn's analysis of variance was inappropriate and therefore the statistical validity of these effects must remain in doubt (see p.136).

iii) Accessory stimulation:

A large number of studies have looked at the effect of accessory sensory stimulation on reaction time, often with conflicting results.

Isaac (1960) found that reaction speed in the cat was significantly increased by a 71'dB white noise in combination with bright light. A number of studies on human subjects have also been carried out .

Kallman and Isaac (1977) showed that two levels of noise (70 dB and 40 dB) and two levels of ambient illumination interacted in their effect on reaction time in a way that is predictable from the inverted 'U'.

Zenhausen^{et al} (1974) demonstrated that a 70 dB level of white noise increased the speed of reaction, whereas Kohnfeld and Goedecke (1978) found that a 70 dB white noise had no effect on reaction time unless it was unpredictable, in which case it slowed down reaction time - an effect produced by a 105 dB white noise whether unpredictable or not.

Finally, Theologus^{et al} (1974) found that a random, intermittent 85 dB noise slowed down reaction time on the first and second block of trials, and Nosal (1971) found that a 90 dB noise increased reaction time significantly.

There are, however, a number of studies which have shown no effect of white noise. Two of these - Jeffrey (1969) and Miezefeski (1974) - used a fairly low intensity (75 dB), but Ahlers (1973) used a range from 40- 100 dB and still found no effect.

iv) Drive: See section on individual differences
(page 408)

(v) Fatigue:

Daftuar and Sinha (1972) have shown that sleep deprivation produces a lengthening of response time, but it affected choice reaction time more than simple reaction time, and it affected auditory simple reaction time more than visual simple reaction time.

vi) Novelty:

Boiko (1961; 1964) has reviewed evidence which suggests that with practice, speed of response (especially to a low intensity stimulus) increases. Though this is probably due to some form of learning, we will see in the section on 'individual differences' (page 412) that under certain conditions, at least, changes with time may produce effects which are more likely to be due to shifts along the 'X' axis of the inverted 'U', than to learning alone. However, we will also see later (see pp. 731-47) that in some cases learning effects may also be explicable in terms of such shifts.

vii) Individual differences:

a) Western measures.

The findings relating simple reaction time to introversion are conflicting. One study (Cheng 1968) has shown that introverts have a significantly faster speed of response than extraverts. However, Buckalew (1973) has shown the exact reverse - namely, that extraverts have a significantly faster speed of response than introverts. Another study has supported the latter conclusion, though this is based on the finding that level of extraversion and speed of simple motor response load positively on the same factor rather than on a direct statistical comparison of extraverts and introverts (Werre et al, 1975). Several studies have found no evidence of an overall significant difference in the simple reaction time of introverts and extraverts e.g. Mangan and Farmer - personal communication regarding the overall speed of response; Taylor 1971; Brebner and Cooper 1974; Lolas and Andraca 1975; Calcote, 1977 ; Brebner and Flavel 1978; Hummel and Lester 1978 .

It is a cardinal principle of the present thesis that when one is considering the possibility of an inverted 'U' relationship, overall main effects for a factor such as introversion are not particularly informative, and that negative, positive and non-significant relationships are all easily predictable. We will, therefore, move on to consider those studies which have factorially manipulated one or more of the other determinants along with introversion .

Stimulus intensity

One study (auditory) shows that the rate of increase in the speed of response as stimulus intensity increases is greater in extraverts than in introverts (Cheng 1968 op.cit.) . Unfortunately, no statistical analysis of this difference was carried out and attempts by the author to obtain the raw data so that this could be done failed to elicit any reply.

Three studies have shown the reverse - i.e. that the rate of increase is greater in introverts than in extraverts. Two of the studies were auditory and in both cases the results were based on the coefficient of the line of best fit to the curve relating reaction time to stimulus intensity. But the result was only significant at the 10% level in one case (Zhorov and Yermolayeva-Tomina 1972) , and in the other it was based on the fact that the coefficient and the level of introversion both loaded positively on the same factor, not on a direct statistical comparison of introverts and extraverts (Loo 1979).

The other study which (Mangan and Farmer, 1967) found that the slope of the curve was greater in introverts than in extraverts, was in the visual modality. In this case, the measure of slope used was Nebylitsyn's $\Sigma t/t_{min}$. measure (see page 136).

Finally, two studies have failed to find any significant relationship between the level of introversion and the slope of the reaction time / intensity curve. One of these studies, Sidde et al (1969) was visual, whilst

the other, Kovac and Halmiova (1973) was auditory.

We will discuss all of these findings below.

Drugs -

The author knows of no studies which have looked at the joint effects of introversion and drugs in a simple reaction time task.

Accessory stimulation -

The author knows of no studies which have looked at the joint effect of accessory stimulation and introversion. Werre et al (1975) did include a condition ('distraction') in which, in addition to the simple reaction time task, the subjects also had to count how many times a specific number occurred in a sequence of digits read out over a loud-speaker. The authors do not report any interaction between introversion and condition on the reaction time measure itself, but they do report some interesting relationships between personality and a physiological measure : 'the contingent negative variation'. These will be described and discussed later (see p. 136).

Drive -

Calcote (1977, op.cit.) looked at the effect of level of introversion and neuroticism on simple reaction time under three different conditions. The first ('no audience') was a standard reaction time situation in which the subject performed the task in isolation. In the second ('audience') the subject had to perform the task while watched by a group of people. In the third ('evaluative audience') the subject was watched and also

told that the audience would be assessing his performance and his level of motivation. It is not unreasonable to assume that the subject's actual level of motivation would be higher in the 'evaluative audience' condition than in the 'audience' condition, and that the latter would involve a higher level of motivation than the 'no audience condition'. There were no significant main effects for introversion or neuroticism, nor any significant interaction between the two. However, there were significant interactions between both (separately and combined) with condition. Subjects high on introversion or neuroticism performed worse under the 'evaluative' condition than under the other two conditions and also worse than subjects low on the respective personality dimension under any condition. Also, subjects high on both introversion and neuroticism performed worse than any other group under any condition. These relative decrements in performance could be regarded as due to transmarginal inhibition since introversion, neuroticism and drive all figure in our list of determinants. Since introversion, neuroticism and drive are all, ex hypothesi, determinants, Calcote's results are in line with our general model. Taylor (1971, op.cit.) has also suggested that high anxiety is related to relatively poor performance, especially in subjects high on introversion and especially in complex tasks such as choice reaction time. We have seen already that anxiety is related closely to neuroticism and that stimulus complexity could also be regarded as one of the determinants so that this is also in line with prediction.

Fatigue -

The author knows of no studies which have looked at the joint effect of sleep deprivation and introversion on simple reaction time.

Novelty -

Hummel and Lester (1978) found no evidence of an interaction between introversion and time on task using a standard simple reaction time set-up. Brebner and Cooper (1974) , however, investigated, the effect of time on task in a study in which the stimuli were presented to the subject without warning, but at regular intervals of 18 seconds. It was found that although there was no significant difference between the reaction time of introverts and extraverts at the beginning of the task, by the end of the task (which lasted one hour) the introverts were responding significantly faster than the extraverts. This study is intermediate between standard simple reaction time tasks (in which a warning signal usually precedes the stimulus to which the subject is required to make a response), and standard vigilance tasks (in which the response stimulus usually occurs at irregular, unpredictable intervals). It will, therefore, be mentioned again under the heading of 'vigilance'.

Werre et al (1975, op.cit.) and Lolas and Andraca (1977, op.cit.) also looked at the effect of time on task and introversion in the context of a simple reaction time task, though the dependent measure was a physiological one and not the simple reaction time itself. We will consider their findings later.

It is worth also considering some studies which have looked at the effect of introversion and certain other factors.

Stimulus complexity -

This has not actually been manipulated jointly with introversion in simple reaction time tasks, since a complex, simple reaction time task is, of course, a contradiction in terms. We will, however, look at the results of studies which have investigated the effect of introversion in more complex reaction time tasks, though we do not intend to provide an exhaustive account.

On a dimension of complexity, the reaction time task which is perhaps closest to that of simple reaction time is one involving disjunctive reaction time, in which the subject is required to make a response to only one kind of stimulus, but not to other kinds. Clearly the degree of complexity can also be manipulated by altering the number of different stimuli included in the response and no-response categories. At the simplest level, each category would contain one kind of stimulus. A task employed by Stein (1976) is described by its author as a 'disjunctive' reaction time task, but unfortunately there is sometimes terminological confusion in the reaction time literature. Some authors refer to what we have described as disjunctive reaction time tasks as 'choice reaction time tasks', whilst other authors refer to what we will describe below as choice reaction time tasks, as disjunctive reaction time tasks. Stein gives very few details of his experimental procedure and an attempt

to obtain clarification from him failed to elicit a reply. We will nevertheless describe his results - namely that there was a significant interaction between introversion and delinquency level. Amongst non-delinquent subjects, speed of reaction was greater in introverts than in extraverts, whereas the reverse was true amongst delinquent subjects. It is unclear what particular variables are associated with delinquency, so such a result is difficult to interpret. However, since Eysenck (1967 op. cit.) has suggested that delinquency and psychopathy are associated with a high level of neuroticism, Stein's result would not be difficult to accommodate within our general model.

At the next level of complexity we have choice reaction time tasks in which the subject is required to make different types of response to different types of stimuli. At the simplest level, there would be two categories of stimuli and two categories of response. An example of a study of this kind is that of Keuss and Orlebeke. (1977). In this experiment the subject was required to make different types of response to two auditory stimuli which differed in their frequency (1000 or 3000 Hz). The stimuli also differed in intensity at each frequency level. Significant interactions were found between ^{introversion and neuroticism,} stimulus frequency and introversion and also between stimulus frequency and stimulus intensity. At the low stimulus frequency, high N subjects were faster than low N subjects, and extraverts were faster than introverts. Thus, the 'neurotic extravert' group was the fastest, and the largest number of errors was also

found in this group. At the high stimulus frequency there were no significant differences between the groups.

At low frequency, there was a significant, positive, linear relationship between stimulus intensity and response speed, but no evidence of a significant quadratic trend. Such a trend did, however, appear at high frequency in all groups (except the extraverts) and was due to a tendency for response speed to decrease at the higher stimulus intensities. There was also some indication that the stimulus intensity at which this reduction (which we could interpret as due to transmarginal inhibition) first appeared, was lower in introverts than in extraverts, and this is in line with our hypothesis. It might also be possible to explain the interaction between introversion and stimulus frequency if one assumed that, due to the high level of complexity of the task, the introverts had already passed their threshold of transmarginal inhibition at the low frequency. However, if this is true, the fact that they did not show any evidence of transmarginal inhibition, due to a rise in stimulus intensity, would indicate that it may not be possible to include stimulus intensity and introversion on the 'X' axis of the same inverted 'U' curve. We have already mentioned the possibility that stimulus intensity may be different from the other determinants in our discussion of the magnitude estimation results from the taste experiment (see p. 324).

Kok (1975) also employed measures of introversion and neuroticism (and physiological measures of heart rate and skin conductance) in a choice reaction time task (2 stimulus and response categories). However, he makes no report of any relationship between response speed or

number of errors and any of the variables mentioned.

Thackray et al (1973) employed a choice reaction time task with four stimulus and response categories. This study differed from the previous ones in that it involved serial choice reaction time - i.e. it involved the next stimulus being presented immediately the preceding response had been made. There were no significant overall effects of introversion or neuroticism on speed of reaction, or number of errors, but there was a significant interaction between introversion and time on task, and this will be considered under the heading of vigilance.

Claridge (1961) also employed a serial choice reaction time task (5 stimulus and response categories). The study involved 3 groups: normal subjects, dysthymics (i.e. subjects suffering from psychoneurotic disorders) and hysterics. He found that in terms of overall response speed, dysthymics were the fastest with the normals second and the hysterics last. The differences between the hysteric group and the other two groups were both significant, but the difference between the normals and the dysthymics was not. There were no significant differences between the groups in the rate of decrease in speed, or in the number of errors made. Claridge found that both the psychiatric groups were more introverted than the normal group and that the dysthymics were more introverted than the hysterics. However, an explanation of the differences in overall response speed in terms of an inverted 'U' relation between introversion level and

performance is not tenable (if anything the reverse seems to be true). Also, since both the psychiatric groups had higher N scores than the normal group, this variable cannot explain the findings either. We should point out, though, that hospitalised psychiatric groups differ from each other and from normals on many variables, other than level of introversion and neuroticism, so interpretation of Claridge's findings in terms of our present model may be unwise from the outset.

However, Wilkinson (1958) looked at the effect of introversion and sleep deprivation on performance in a 5 choice serial reaction time task, using 'normal' subjects. He found evidence that sleep-deprived introverts behaved like extraverts under normal sleep conditions. This is predictable if we assume that introversion and sleep deprivation move subjects in opposite directions along the 'X' axis of the inverted 'U'. (See Corcoran 1972 for a fuller analysis of this study).

Finally, before leaving this section, we will just recall Taylor's suggestion (1971, *op.cit.*) that introversion level, anxiety level (which is closely related to both introversion and neuroticism, particularly the latter) and task complexity may interact in such a way that an increase in anxiety produces a greater decrement in performance at high levels of introversion and at high levels of task complexity, such as are characteristic of choice reaction time tasks. This clearly fits in with our model.

Stimulus probability -

A study by Brebner and Flavel (1978) has looked at the effect of the inclusion of 'blank' trials (i.e. trials on which no response stimulus was presented) on reaction time in introverts and extraverts. The proportion of such trials was varied from zero to 0.7 and the probability of the occurrence of the response stimulus on a given trial, therefore, varied in a corresponding, but inverse, fashion.

It was found that in the condition in which there were no blank trials (and in which, therefore, the task was identical to a standard simple reaction time set-up) there was no significant difference in the speed of response of the introverts and the extraverts. The overall main effect of introversion was also non-significant. However, the interaction of condition and introversion was significant, due to the fact that speed of response decreased as the proportion of blank trials was increased, but more so in the extraverts than in the introverts. Also the number of false alarms (i.e. the number of occasions on which the subject made a response on a blank trial) was significantly greater in extraverts than in introverts, and the number of anticipating responses (i.e. the number of occasions on which the subject responded before the stimulus was presented on non-blank trials) was also greater in extraverts than in introverts.

Manipulation of the proportion of blank trials actually affects ^{two} possibly relevant parameters. The first as we have seen is 'stimulus probability'. The second is

the frequency of the response stimulus (which we will call the 'signal' in anticipation of the account of vigilance) - i.e. the average number of signals per unit time.

In fact, it is possible to think of both these two parameters as probabilities, since the signal frequency is the probability that a signal will occur per unit time. However, to avoid confusion we will use the terms signal frequency and signal probability.

Brebner and Flavel's study could have been included with the studies which looked at the joint effect of introversion and stimulus intensity, since the latter is thought to act in an analagous fashion to stimulus frequency. It could also have been included in our discussion of disjunctive reaction time tasks since it has certain similarities to tasks in which the subject is asked to respond to one kind of stimulus, but not to another (a point to which we will return later). We have considered it fit to mention it here, since it provides a suitable entrée to our analysis of the nature of simple reaction time as a whole. We will postpone any further discussion of its results very briefly till we have completed our account of the relationship of the determinants to simple reaction time.

Neuroticism -

As before, the personality dimension of neuroticism has been largely ignored in studies of simple reaction time. However, some findings have emerged.

Lolas and Andraca (1977, op.cit.) found that high N subjects were significantly slower than low N subjects.

Werre et al (1975, op.cit.), however, found that the loading of neuroticism on the speed factor was negligible. Kovac and Halmiova (1973, op.cit.) also failed to find any significant relationship between neuroticism (or anxiety) and the slope of the reaction time/intensity curve.

However, we have seen that neuroticism does interact with drive and introversion, together, in predictable ways (Calcote 1977, op.cit.) and with introversion (Taylor, 1971, op.cit.), if one accepts the use of anxiety scores as a valid measure of neuroticism.

In this context it is worth mentioning two other studies which also looked at the relationship of anxiety to simple reaction time. Wenar (1954) found that low-anxiety subjects were slower than high-anxiety subjects overall, though there was no interaction between stimulus intensity and anxiety level.

Castaneda (1956) discovered that the amplitude of response was greater in high-anxiety subjects than in low-anxiety subjects. The slope of the reaction time/intensity curve was also greater in the high anxiety subjects than in the low-anxiety subjects amongst girls, but the reverse was true amongst boys. There was a slight, but non-significant decrease in amplitude in high-anxiety boys as stimulus intensity was increased.

As far as the actual speed of reaction was concerned, this was greater in the low-anxiety subjects at low intensities. The slope of the reaction time/intensity curve was also lower in low-anxiety subjects so that at high intensities, the high anxiety subjects were the faster group.

b) Russian measures.

Nebylitsyn (1960) has shown that, although the mean reaction time of 'strong' subjects (as defined by the method of 'extinction with reinforcement' of the photochemical reflex) is not significantly slower than that of 'weak' subjects, the slope of the curve is significantly greater (see p.136). The reaction time slope has also been validated as a measure of 'strength' subsequently by Nebylitsyn (1966), Nebylitsyn et al (1965), Olshannikova and Aleksandrova (1969) and Ravich-Scherbo (1969).

CHAPTER EIGHT : THE NATURE OF SIMPLE REACTION TIME

1. BREBNER AND FLAVEL'S STUDY

We will now return to the findings of Brebner and Flavel (see pp. 418-9). It was argued that the variables (other than introversion) that were being manipulated in this study were signal frequency and signal probability - i.e. the frequency of signals and the probability of a signal on a given trial, where a 'signal' is defined as a stimulus to which the subject has to make a response. It will also be remembered that as signal frequency and probability were jointly decreased (since they were confounded), reaction speed decreased, but significantly more so in extroverts than in introverts.

1) A hedonic tone model

The first explanation that we will advance is that as signal frequency decreases, so the opportunity to respond decreases and hence the extroverts are placed at a disadvantage relative to the introverts. In our discussion of free operant situations, we suggested that extroverts, ex hypothesi, are in a state of lower excitation than introverts (at least when the levels of the determinants are relatively low), and that increases in level of responding can help to mitigate this fact, due to the excitation associated with emitting a response. However, in a simple reaction time situation the subject does not have the same freedom to alter the frequency of

by the experimenter the extraverts' performance, relative to that of the introvert, declines. However, the subjects in Brebner and Flavel's experiment did have one way of maintaining their level of responding, despite the experimenter's machinations - namely to respond on the blank trials. This idea is, however, not in line with the finding that, though the number of false alarms was greater overall in extraverts than in introverts, the number decreased as signal frequency was reduced, and by a significantly greater amount in the extraverts. We, therefore, must provide an alternative explanation.

Such an explanation is that, under certain conditions, extraverts adopt a lower response criterion than introverts. We have met the concept of a response criterion already in our discussion of sensory thresholds, but to see how it relates to simple reaction time it is necessary to consider the processes underlying the latter in more detail, and we shall see later that the criterion explanation can account for many of the other findings relating the determinants to simple reaction time.

ii) The criterion model of simple reaction time

The first thing which must be stated is that, like the method of limits (to measure the sensory threshold), reaction time is affected by the criterion of the subject - i.e. his willingness to decide that a signal has occurred. This fact has been recognised by a number of workers and some of them have put forward theories of simple reaction time incorporating the criterion (McGill 1963;

John 1967; Grice 1968). Perhaps the most influential

theory is the 'counting model' first developed by McGill. This will now be considered.

According to McGill, reaction time consists essentially of two components - a sensory one and a motor one. The sensory component is the time taken by the subject to decide that a stimulus has occurred and should be responded to. The motor component is the time taken to execute the response:

$$\text{Reaction time} = \text{Sensory decision time} + \text{motor time.}$$

Let us now consider sensory decision time. McGill proposes that the nervous system is capable of 'counting' the frequency of nerve impulses in the relevant sensory pathways. When no stimulus is present there will be a certain amount of 'noise' in the system and the frequency will have a certain value. When a stimulus is presented, this frequency will rise. If it reaches a certain critical value (the subject's criterion) the subject will decide that a stimulus has occurred and will respond to the stimulus. Furthermore, the reaction time/intensity relation can be explained by the assumption that the frequency will rise faster for a high intensity stimulus than for a low intensity one.

This can be represented as follows:

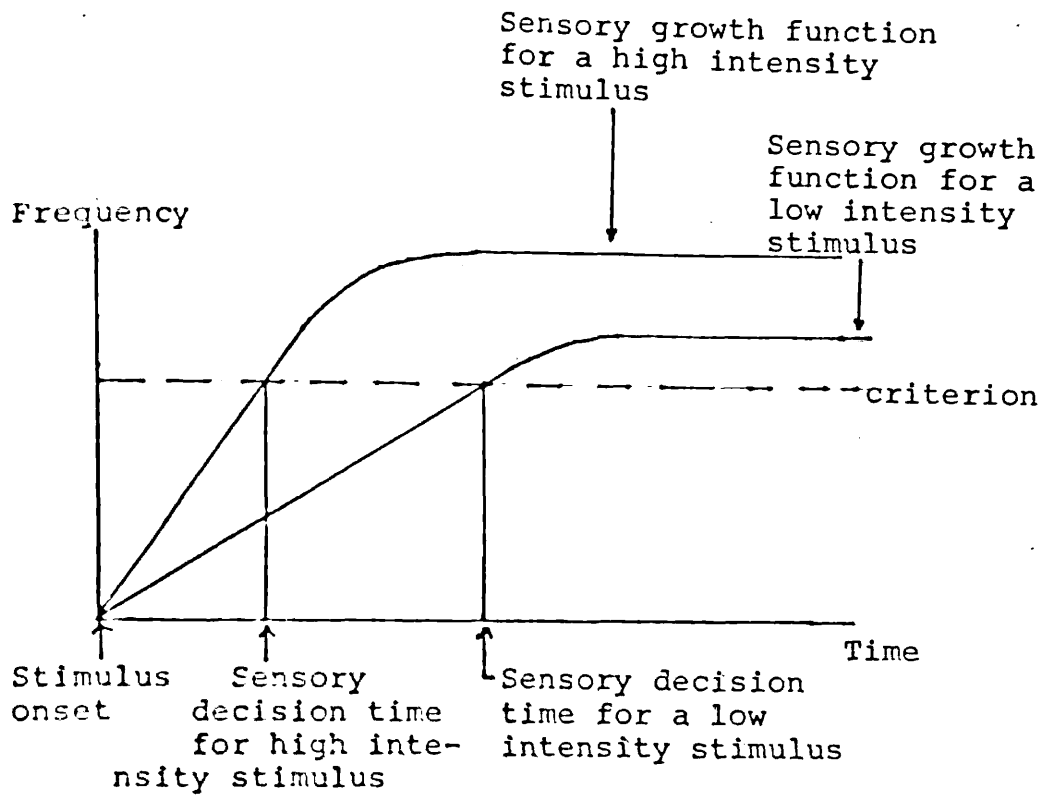


Fig. 30. The counting model of simple reaction time

As figure 30 shows, a 'sensory growth function' describes the way the neural frequency (as measured by the counter) changes with time, following stimulus onset. The model, as it is usually presented, assumes that the sensory growth functions, up to the criterion point at least, are straight lines (though a slight departure from this would not alter the overall effect).

There is a large body of evidence to support this model, but it will not be reviewed here. The reader is referred to Speiss (1973) and Grice (1968) for some examples.

There is an important difference between McGill and Grice in theoretical approach. McGill assumes that the sensory growth function for a given stimulus intensity is variable (according to the level of other factors), whereas

the criterion is by and large fixed (for a given individual at least). Grice, on the other hand, assumes that for a given individual the sensory growth function is fixed, whereas the criterion varies, even from trial to trial under certain circumstances. He has shown, in fact, that differences in the criterion alone can explain differences in reaction time, not only between conditions, but even across individuals (Grice 1968). This has important implications for our present concerns.

In the discussion of work on sensory threshold^s, we mentioned the finding by Harkins and Geen (1975) that extraverts adopt a lower response criterion than introverts. In this study, subjects had to respond to a signal which occurred randomly on a proportion of trials only.

Also, although reaction times were not actually measured, subjects were required to respond to the stimulus as fast as possible. The similarities to the experimental set up in Brebner and Flavel's study are obvious. If we were to assume that extraverts adopted a lower criterion than introverts in the latter, would the findings be more explicable? Certainly a lower criterion would predict a larger number of false alarms on blank trials and anticipatory false alarms on non-blank trials, since extraneous stimuli would be much more likely to trigger a response. The fact that extraneous stimuli can do this in reaction time situations has been amply demonstrated (e.g. Bernstein et al 1973).

Another possible source of false alarms is the random level of neural activity within the subject's own nervous system. This may at first seem surprising, in view of our description of the counting model, but McGill in fact postulated the existence of two counters, one to count the frequency of background nerve impulses and the other to count the frequency of nerve impulses due to a possible incoming stimulus. When the difference between the two counters reaches a certain prescribed value (the criterion) the response is triggered. On this basis, the point at which the X axis cuts the Y axis in figure 30 does not in fact represent zero frequency, but the value of the frequency in noise. However, this is, of course, an average value. It is a cardinal tenet of signal detection theory that the level of background noise varies about this average level, so that it is quite possible that at a given moment in time, ^{the} criterion might be exceeded even in the absence of a signal, and the lower the criterion the more likely this is.

Thus a criterion explanation for the difference in the overall number of false alarms between introverts and extraverts would seem to be tenable, and it should also be apparent that the setting of a relatively low criterion by extraverts would have a certain instrumental value for them in terms of hedonic tone, since the number of trials on which they actually made a response would then be greater than if they set a high criterion.

Can the explanation, however, accommodate the finding that the number of false alarms actually decreased as

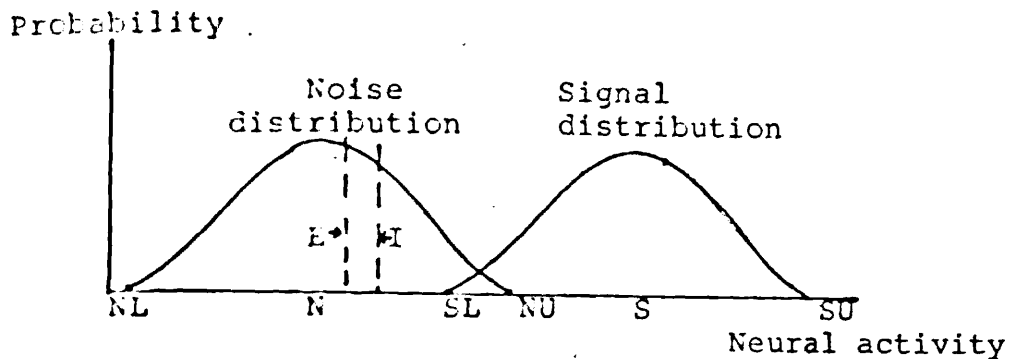
signal frequency was reduced and that this effect was more marked in the extraverts? To explain these findings we must take into account the fact that as the proportion of blank trials increased, not only did the signal frequency decrease, but so also did signal probability.

iii) Implications of signal detection theory

Signal detection theory predicts that as the probability of a signal falls, so the response criterion rises. This would therefore explain why the number of false alarms decreases as the proportion of blank trials increases. This explanation illustrates the fact that the level of the criterion can be expected to depend on many factors. The need to respond in order to maintain a high level of excitation (and a high level of hedonic tone) may well be one of them, but this apparently is not enough to counteract the effect of signal probability. The demands of hedonic tone would predict a lowering of the criterion as the proportion of blank trials increases, whereas signal detection theory would predict a rise. In this particular instance, signal detection theory seems to be paramount, though this may not always be the case.

Let us now consider the finding that with a decrease in signal frequency/probability the decrease in the false alarm rate is greater in extraverts than in introverts. Does this imply that the increase in criterion level is greater in extraverts than in introverts? Not necessarily. Consider figure 3| overleaf.

Fig. 31. A signal detection model of Brebner and Flavel's study



This depicts a signal detection^m model of what may be happening in Brebner and Flavel's study. The noise and signal distributions would correspond to the blank and non-blank trials respectively, and the lines E and I represent hypothetical locations for the criteria of extroverts and introverts respectively. If on any given trial the level of neural activity was higher than that corresponding to the appropriate criterion, the subject responded. The proportions of the noise and signal distributions which lie to the right of the criterion represent the proportions of blank and non-blank trials, respectively, on which a response was made. The whole of the signal distribution is shown as lying to the right of the criteria, since subjects never failed to respond to a signal if it was presented.

Consider now the effect of a shift in criterion along the axis to the right, such as we have hypothesised to take place, as signal frequency/probability is reduced.

Since the criterion of the introvert is already further to the right than that of the extravert , the proportion of the noise distribution that the introvert criterion would traverse would be less than the proportion that the extravert criterion would traverse, assuming that both criteria moved by the same amount (as measured in terms of units of neural activity). Therefore, the reduction in the area of the noise distribution which lies to the right of the criterion (which is itself proportional to the number of false alarms) will be less in the introverts than in the extraverts. Therefore the reduction in the number of false alarms would be less in introverts than in extraverts, which is exactly what was found.

We have seen, therefore, that a criterion explanation is capable of accounting not only for the overall difference in false alarms between introverts and extraverts, but also the differential effect on false alarm rate of a decrease in signal frequency/probability.

Let us now see if it is equally successful in explaining the reaction time data. Consider figure 31 again. It should first be pointed out that the 'Y' axis in figure 30 is equivalent to the 'X' axis in figure (p. 31). This may seem confusing, but the use of different axes to represent the same dimension stems from the different conventions which have been adopted by the theorists who have employed the concepts embodied in the two diagrams. The diagram in figure 31 represents an essentially static model, whereas the diagram in figure 30 represents a dynamic model. Both approaches are necessary to explain the data from an experiment such as

Brebner and Flayel's.

Let us see if we can combine the static and dynamic aspects in a single diagram (see figure 32). We have chosen the 'Y' axis to represent frequency of nerve impulses (which is equivalent to level of 'neural' activity in figure 31). The point of intersection of this 'Y' axis with the 'X' axis represents the average frequency in 'noise' (i.e. in the absence of a signal), and corresponds to the point 'N' in figure 31 . The sensory growth functions shown in figure 30 are averages. As figure 31 indicates, the level of neural activity due to both 'noise' and 'signal' (the latter term is being used synonymously with 'signal plus noise', which is the more usual term in signal detection theory) varies about this average. The points NL and NU, and SL and SU represent the lower and upper limits of this variation for noise and signal, respectively. The points N and S represent the means of the noise and signal distribution, respectively. These 6 points have been shown on both figure 31 and figure 32 and are meant to correspond to each other.

At time zero, the frequency of nerve impulses varies between NL and NU with a mean of N. When the signal is presented this frequency rises and the final level varies between SL and SU with a mean of S. We have shown three separate sensory growth functions to represent what would happen if the initial frequency in noise had levels of NL, N and NU.

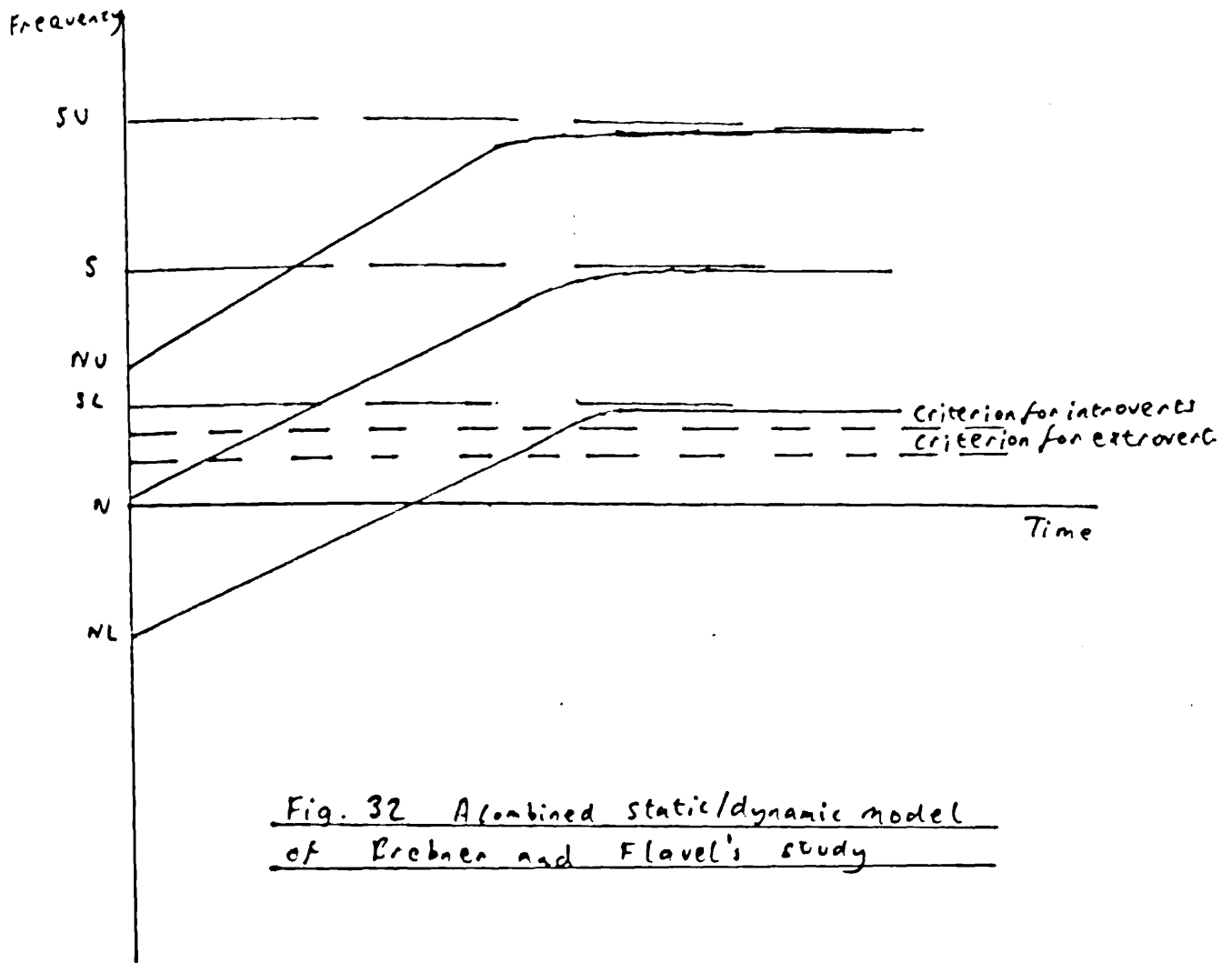


Fig. 32 Combined static/dynamic model of Brebner and Flavel's study

We will assume that the distance apart of S and N is proportional to the slope of the sensory growth functions. In other words, if the slopes had been steeper we would have drawn the points SL, S and SU correspondingly higher above the X axis (i.e. point N). This connection between the slope of the sensory growth function and its final levelling off point is not a logically necessary one. It might be possible for two sensory growth functions to have different slopes and yet level off at the same point, for instance. However, it is a reasonable and parsimonious assumption to make because our inverted 'U' model (which as it stands is essentially a static one) predicts that the greater the stimulus intensity, the greater the final level of excitation (when the levels of the determinants are relatively low at least), and as we have seen, the counting model predicts that the greater the stimulus intensity, the greater the slope of the sensory growth function.

The assumption also enables one to predict Brebner and Flavel's reaction time data, since the separation of S and N is proportional to the signal detection index d^1 - i.e. the index of discriminability. We have seen already that there are two studies which have looked at the relation between d^1 and introversion, and both have shown that the relationship is a positive one. One of these studies we have already mentioned - i.e. Harkins and Geen (1975). However, in this experiment subjects were asked to detect the momentary straightening of an otherwise oscillating line on an oscilloscope. For

this reason, their index d' is a little difficult to interpret in the present context, although the value of the criterion is safely interpretable as an inverse measure of the subject's 'tendency to respond'.

The other study (Stelmack and Campbell 1974), however, required the subject to discriminate between the presence of a signal and its absence (i.e. noise), and as such the experimental set up is similar to that of Brebner and Flavel (though one difference is that the former was auditory, whereas the latter was visual). If we assume that the introverts in the latter study had a higher value of d' than the extraverts (as in the Stelmack and Campbell study), then this implies that the slopes of their sensory growth functions are also greater.

Consider now figure 30 again. This shows the sensory growth functions for a high and a low stimulus intensity, but if we were to substitute the words 'introvert' and 'extravert' for these two terms we would have a diagram depicting the hypothesised relationships in Brebner and Flavel's experiment, apart from the fact that we have suggested that introverts and extraverts also differ in their criterion levels. This is shown in figure 33 below.

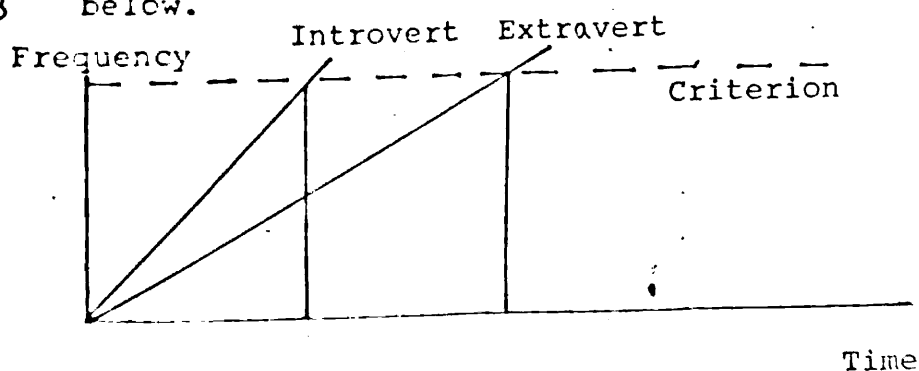


Fig.33. The counting model and introversion

What would be the effect of raising the criterion by a fixed amount (in units of frequency) ? The slope of the sensory growth function is a measure of the change in frequency per unit time. This rather inverted relationship is a consequence of the fact that we have drawn the frequency as the dependent variable and time as the independent variable. The change in position on the time axis per unit change in the frequency axis is inversely related to the slope of the sensory growth function. In other words, a given change in the criterion, measured in units of frequency, will produce a greater change in reaction time if the sensory growth function is shallow rather than steep. If, as we have hypothesised, extraverts do have a shallower sensory growth function than introverts we would predict that if the criterion of both groups is raised by the same amount, (due for instance to a decrease in signal frequency /probability) the extraverts would suffer a greater lengthening of their reaction time. This is exactly what was found.

The assumption that extraverts and introverts differ in the slopes of their sensory growth function is also necessary if we are to explain another feature of Brebner and Flavel's results. The interaction between personality and signal frequency/probability in the reaction time measure was due only in part to a greater increase in reaction time in the extraverts as signal frequency/probability decreased. It was also due to the fact that when the signal frequency/probability was high, extraverts had faster reaction times than introverts, whereas when

the signal frequency/probability was low it was the introverts who were faster. The assumption of a higher criterion in introverts on its own cannot explain the latter finding. However, if we assume that the relative speed of the introverts and the extraverts is determined by the interplay of two opposing factors, then we can explain the results quite easily. At high signal frequency/probability, the lower criterion of the extraverts outweighs their shallower sensory growth function and they respond more quickly than the introverts. However, as the criterion of both groups increases (we will assume by the same amount for the sake of parsimony), the extraverts' reaction times are affected more (for reasons we have explained) and the sensory growth function factor becomes relatively more important, resulting in faster reactions in the introvert group.

iv) A possible difficulty

Before proceeding any further, we should point out that the model depicted in figure 30 may be an oversimplification of what is happening in Brebner and Flavel's experiment. Grice et al (1976) have proposed a model to explain the processes underlying disjunctive reaction time performance. We have seen that in disjunctive reaction time tasks there are at least two kinds of stimulus and the subject is required to respond to certain of these ('imperative' stimuli). Grice et al suggest that both kinds of stimuli have sensory growth functions and that the slope of this function, as in simple reaction time, is positively related to stimulus

intensity.

However, they also suggest that the imperative stimuli have an extra 'associative' growth function and the response is triggered when the sum of the sensory and associative growth function exceeds the criterion. Furthermore, they also argue that the data can be best explained by assuming that the slope of the associative growth function is negatively related to stimulus intensity.

The reasons for this assumption are not important here. What is important is that there are certain obvious similarities between Brebner and Flavel's study and a disjunctive reaction time task. In the former, there were no actual catch trial stimuli, but instead blank trials. However, since extraneous stimuli or the subject's own background neural noise may trigger a response on these blank trials, this difference may be more apparent than real. Grice's model does not prejudice what we have already said so long as we assume that even if there is an associative growth function operating, its slope is unrelated to introversion-extraversion. We have seen that in the case of the slope of the sensory growth function, level of introversion and stimulus intensity can be thought of as acting in the same way (i.e. to increase the slope). If, as Grice et al suggest, stimulus intensity is negatively related to the slope of the associative growth function, are we to assume that the same is true of the level of introversion?

Apart from the analogy between introversion and stimulus intensity, there seem to be very few data which bear on this point. Furthermore, Nissen (1977) has pointed

out that Grice's model is not the only one which can account for disjunctive reaction time performance, and though it would still be necessary to assume that certain higher level processes are involved in such tasks, it is not necessary to assume that stimulus intensity affects the speed with which these processes are completed. By analogy, then, it is possible that the level of introversion may also not be relevant to such processes. Because of the uncertainty surrounding this area we will not take our speculations regarding Grice's model and introversion level any further.

To summarise, the assumption that introverts have both a higher criterion level and a steeper sensory growth function enables us to provide a very adequate explanation for Brebner and Flavel's data. We will now see that explanations involving criterion factors can also enable us to account for other differences between introverts and extraverts in simple reaction time which are of even greater theoretical importance.

2. THE SLOPE OF THE REACTION TIME/INTENSITY CURVE

1) A new theory

It is the present author's contention that the relatively large slope of the reaction time/intensity curve found in introverts (e.g. Mangan and Farmer 1967) can be explained by assuming that introverts adopt a higher criterion than extraverts. Figure 34 depicts this hypothesised relationship.

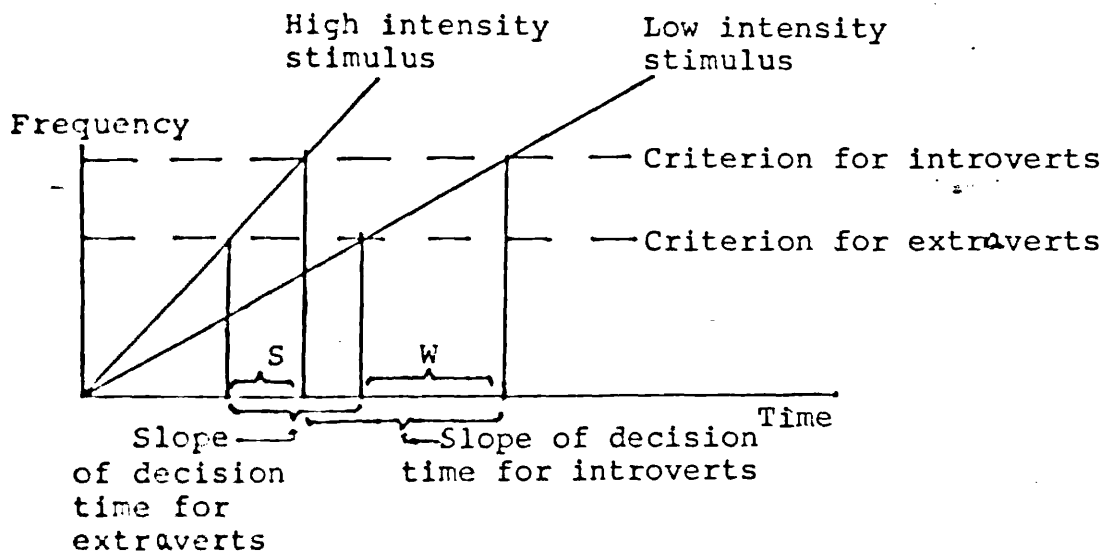


Fig. 34. A criterion interpretation of Mangan and Farmer's study.

For the present we will assume that the slopes of the sensory growth functions for both high and low stimulus intensities are the same for introverts and extraverts, and also that the two groups do not differ in motor time (which we saw earlier is also a component of simple reaction time). The figure shows that since the sensory

growth function⁵ for a low and high intensity stimulus diverge, the higher the criterion the greater the difference in reaction time to the two stimuli and therefore the greater the slope of the reaction time/intensity curve.

If the author's theory is correct, then it could have extremely important implications since the finding that introverts have a steeper reaction time/intensity slope has been regarded as one of the most damaging pieces of evidence against the dual hypotheses that

a) level of introversion is one of the determinants - i.e. that an increase in the level of introversion moves one to the right along the 'x' axis of the inverted 'U' curve.

and

b) introverts have relatively 'weak' nervous systems.

Let us consider (a) first. Our model would predict that if one is operating on portion B of the curve - i.e. the left hand part of the curve which is convex upwards - any group of subjects who were operating further to the right, in relative terms, would have a shallower slope of the curve relating stimulus intensity to performance measures (such as simple reaction time). There is sound evidence to suggest that in studies which have been quoted as showing that introverts have steeper slopes, both groups were operating on portion B of the curve. Firstly, the overall shape of the reaction time/intensity curve supports this interpretation. As stimulus intensity increased, so speed

of reaction increased. But the rate of increase was less at the high stimulus intensities than at the low stimulus intensities. Furthermore, the group which showed the steeper slope (the introverts) also showed a slower overall reaction time, though the difference on this measure was not significant.

At first glance, therefore, the results do strongly suggest that it is the extraverts who are operating further to the right along the 'x' axis. However, the author's theory is able simultaneously to explain both the fact that the introverts had a steeper slope and the fact that their overall reaction time was slower than that of extraverts, since figure 30 predicts that a higher criterion is associated with a slower mean reaction time. It can also explain the fact that the difference in the mean reaction time of extraverts and introverts was greatest at the low stimulus intensities (compare lengths 'S' and 'W' in figure 34).

The alternative explanation, which is implicit in the statements of those authors who have interpreted the data as refuting the hypothesis that introverts are further to the right on the inverted 'U' than extraverts, is depicted in figure 35.

E=Extravert

I=Introvert

H=High intensity stimulus

L=Low intensity stimulus

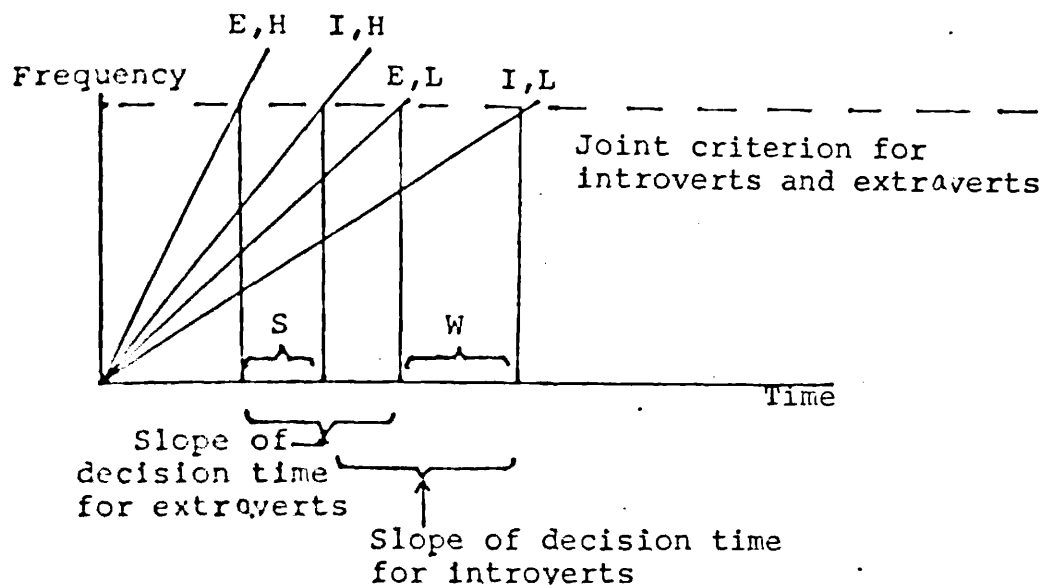


Fig. 35 .A sensory interpretation of Mangan and Farmer's study

This can explain the findings, but it is less parsimonious than the author's explanation in two respects. The first and most obvious one is that it is at odds with the view that level of introversion is a determinant, and to the author's knowledge no satisfactory account integrating it with the other findings in this general area has been presented so far. It might be consistent with the view expressed by White and Mangan (1972) that introverts are relatively 'strong' in the motor analyzer, but this is an unparsimonious explanation of the findings, especially since we have seen that the other sets of data which might be explained by it (such as the tapping task results) have an alternative interpretation which is consonant with the general model in its original form (see pp. 392-7).

The other sense in which the author's explanation is more parsimonious than that embodied in figure 35 is that both the fact that the reaction time/intensity slope is greater in introverts and the fact that their mean reaction time is slower, are predictable from a single assumption - namely, that they adopt a higher criterion than extraverts. In the alternative explanation, on the other hand, one has to assume not only that for a given stimulus intensity the slope of the sensory growth function is steeper for extraverts than for introverts, but also that the difference between the slopes of the sensory growth functions for a high and a low intensity stimulus is less in extraverts than in introverts. In fact this latter relationship could be predicted if we assumed, contrary to hypothesis, that extraverts were indeed operating further to the right along the 'x' axis of the inverted 'U' than the introverts. The two respects in which the explanation embodied in figure 35 is unparsimonious are therefore not entirely distinct.

However, parsimony is not the only ground for choosing the author's explanation. Our discussion of Brebner and Flavel's study has not only provided strong evidence in favour of the view that extraverts adopt a lower criterion than introverts, but also evidence against the view that they have steeper sensory growth functions than introverts. This has implications, since the findings in this area are very conflicting. Before we discuss this, though, there are one or two other points which need to be cleared up.

It will be remembered that the reliability of the difference in the slope of the reaction time/intensity curve between extraverts and introverts was only statistically established at the 5% level in one study, that of Mangan and Farmer, 1967. The correlation between the slope and introversion in this study was, nevertheless, a large one (0.55) and would have been significant on a two-tailed test. The authors actually used a one-tailed test due to the fact that they predicted that introverts would have the steeper slope. The basis for their prediction was the apparent similarity which exists between the introvert and the 'strong' nervous system when we consider 'strength' with respect to inhibition. However, as we have argued at length elsewhere (see pp. 151-7), there are problems with this view which arise from the rather undefined nature of the concept of 'strength of inhibition'. Moreover, even if we were to accept that introverts do have relatively 'strong' nervous systems with respect to 'inhibition', there is no reason to suppose that it is 'strength of inhibition' that is relevant in this context. On the contrary, Nebylitsyn (1960) has shown that the slope of the reaction time/intensity curve is closely related to 'strength of excitation', as measured by the classical index of extinction with reinforcement of the photochemical reflex (EWR of the PCR).

However, though we have reservations about Mangan and Farmer's predictions, their findings are quite closely in line with what we would predict from our own criterion model.

11) The role of response sets

The question arises though: why do extraverts adopt a lower criterion than introverts? One possible explanation (though as we will see not the only one) would be based on the concept of hedonic tone. It will be remembered that we used this to account for the hypothesised low criterion level of extraverts in Brebner and Flavel's study (see pp. 418-9). However, a hedonic tone explanation for a difference in the criterion of introverts and extraverts is perhaps less clear in simple reaction time than in disjunctive reaction time, since a lower criterion in the latter actually increases the number of trials on which the subject responds, whereas in simple reaction time it simply increases the speed with which he responds. We would, therefore, have to assume that the excitation resulting from a fast response is greater than that due to a slow one. This might seem intuitively plausible, but there are certain problems.

Consider figure 30 (p. 425) again. It will be noted that what is actually being considered here is not reaction time but only one component of the latter - i.e. decision time, since we assumed that motor time was constant before embarking on our criterion analysis. The reduction in reaction time consequent upon a reduction in the level of the criterion is not, therefore, dependent on the motor aspect of the response but on the sensory-perceptual aspect. In other words, a subject who sets a relatively low criterion would respond faster

simply because he took a shorter time to decide that a stimulus had occurred, not necessarily because he responded with greater force or vigour.

However, there is evidence that the motor and the sensory-perceptual aspects of simple reaction time are not as distinct as might seem at first glance. For instance, studies have shown that the effect of adopting a motor response 'set' is to increase the speed of response, but also that this effect is not due to the direct action of the muscular tension associated with the response set but due to its feedback effect on the central nervous system (Freeman 1937). Gray (1964) has suggested that this feedback may exert its effect on an 'arousal' mechanism. If so then a faster speed of response due to a response set would be associated with a high level of excitatory feedback. But let us also consider the possibility that the increase in 'arousal' due to the response set exerts its effect on response speed partly at least by resulting in a lowering of the criterion. This may seem speculative; to test it, one would need to measure the subject's criterion and electromyographs at the same time. Nevertheless, we will consider at length below evidence which suggests that there may indeed be a link between the levels of the proposed determinants of 'arousal' and the level of the criterion.

For the present, however, we will simply look at what such a link might imply for the hedonic tone hypothesis. If the response set does lead to a lowering of the criterion, then such a lowering would indeed be

associated with a faster speed of response and a high degree of excitatory feedback, though it would be the cause of the former and an effect of the latter. There is in fact evidence that extraverts do have a higher preparatory set than introverts (Narayanan and Natarajan 1975). So if we are correct in believing that an increase in 'arousal' leads to a lowering of the criterion, the various pieces in this jigsaw may start to fit into place. The adoption of a relatively low criterion would explain the reaction time data itself, and if associated with a higher preparatory set, it would also be consonant with a hedonic tone interpretation.

We have suggested the possibility that one factor from the motor side (i.e. muscular tension) and one factor from the non-motor side (the criterion) may be related to each other. Of course, if the muscle tension affects the 'arousal' mechanism it may also affect the other non-motor factor - i.e. the slope of the sensory growth function. Again, we could only test this by using electromyographs. But if such an effect occurs, and if extraverts do adopt a higher preparatory set than introverts, this could have important effects.

It will be remembered that we would predict a steeper slope of the sensory growth function in introverts both from our general model and from our analysis of Brebner and Flavel's study (see p. 434). However, if the higher preparatory set of extraverts influences the 'arousal' mechanism, it could mitigate the steeper sensory slopes in introverts or even reverse the rela-

tive positions of the two groups under certain circumstances.

We therefore have another possible explanation of the findings relating introversion to the gradient of the reaction time/intensity curve - i.e. that the situation depicted in figure 35 (see p.442) is accurate but that this is because the extraverts manage to increase their level of excitation beyond that of introverts by adopting a greater preparatory set. Such an explanation is unlikely since the hedonic tone argument (which we have used to explain such differences in preparatory set) would not predict that extraverts would try to raise their level of excitation to the point at which it surpassed that of introverts. Furthermore, the findings of Calcote (1977) (see p.410) do suggest that in simple reaction time it is the introvert who is further to the right along the 'x' axis of the inverted 'U'. Finally, we have seen that the data of Brebner and Flavel suggest that the slopes of the sensory growth functions are steeper in introverts rather than extraverts. The explanation, therefore, would seem to be an improbable one. If it were tenable, though, it would rescue the idea that level of introversion is a determinant just as effectively as the criterion hypothesis, though for different reasons. As we have stated already, comparisons between introverts and extraverts are valid only when both groups are subjected to the same level of stimulation. If on the other hand extraverts manage to covertly increase the stimulation to which

they are subjected by tensing their muscles (whether consciously or not), then the basis for comparison is undermined.

In this respect, therefore, simple reaction time is not as dissimilar to the free operant situation as might be imagined, since although the rate of responding is not normally under the subject's control, the excitatory feedback from each response (and also of course between responses if the preparatory set is maintained) may well be. It is, therefore, of great advantage if electromyographs can be used since one may not be able to prevent differences in response set from arising, but one may at least be able to measure them and possibly allow for them.

If such differences in response set do act in opposition to the hypothesised greater slope of the sensory growth functions in introverts, they could explain the conflicting findings relating introversion to the slope of the reaction time curve. Whenever a given relationship depends on the interplay of two opposing factors whose levels may depend on the circumstances of the individual study, we should not be surprised if different studies yield different results. However, let us look at an alternative explanation, though again one involving two factors acting in opposition to each other.

iii) The joint effects of criterial and sensory factors

Let us make, for the present, the assumption that differences in response set between introverts and extraverts do not exist. This makes our original contention

that 'the slopes of the sensory growth functions are steeper in introverts than in extraverts,' more tenable. But if this is true it would work against the higher criterion also presumed to exist in the introverts. A high criterion would lead to a slow overall response speed and a steep slope. Steeper sensory growth functions would result in a faster overall response speed. If, furthermore, they were steeper because the introverts were operating further to the right along the 'x' axis, then we would expect the difference in the slopes for a low and a high intensity stimulus to be less in introverts than in extraverts.

This basically assumes that the slope of the sensory growth function is a determinate, and that we are operating on the left hand portion of the inverted 'U' which is convex upwards (portion B). We have seen that there is evidence to support the latter assumption. Furthermore, the idea that the slopes of the sensory growth function is a determinate is consistent with our view that the levelling off point of a sensory growth function (which is equivalent to the level of excitation due to a stimulus in our inverted 'U' model) is positively related to its slope (see p. 433).

Thus the smaller difference between the slopes of the sensory growth functions for stimuli of differing intensity in introverts would counteract the effect of their higher criterion on the slope of the reaction time/intensity curve. It is important to distinguish the slope of the reaction time/intensity curve from the

slope of an individual sensory growth function for a particular stimulus intensity. From now onwards, to avoid confusion, we will refer to the slope of the reaction time/intensity curve as a 'gradient'.

If our analysis is correct, it is not surprising that different studies have produced different results, since again we have the interplay of two opposing factors. We explained the changeover in the relative speeds of the introverts and extraverts in Brebner and Flavel's study in terms of the interplay of criterion levels and sensory growth function slopes as signal frequency/probability was altered. This was a within-study comparison. Here we are employing a similar argument to explain disparate findings across studies. It is not, in fact, necessary to assume that both the criterion levels and the sensory slopes differ from study to study. Alterations in the level of one would be enough, due to its masking and unmasking effect on the influence of the other factor. If Grice (1968) is correct, then the criterion is perhaps the more likely to vary, but if we are correct in our view that the slope of the sensory growth function is a determinate, then both factors may be involved. Later we will advance the hypothesis that the reciprocal of the criterion (which we will call the subject's 'tendency to respond') may be a determinate also, so we have quite a complex situation.

iv) Implications for the hypothesis that introverts have 'weak' nervous systems

Before we do this, however, let us briefly consider the second of the two hypotheses (see p.133) that were apparently threatened by the finding in some studies that the gradient of the reaction time/intensity curve is greater in introverts than in extraverts.

This is the hypothesis that introverts have 'weak' nervous systems relative to extraverts. The gradient of the reaction time/intensity curve is known to be a measure of 'strength', but if our analysis is correct, then it is determined by two factors: the slope of the sensory growth function and the criterion. In addition, one or both of these may be affected by response sets. Do the findings of studies such as those of Mangan and Farmer (1967) still indicate, therefore, that it is the extravert who has the 'weak' nervous system? The answer to this question depends on whether one is willing simply to take the gradient of the reaction time/intensity curve as an operational definition of the term 'strength' without regard to the underlying mechanism. If so, then one is compelled to give the answer 'yes'.

It will be remembered that at the outset of the present thesis the author deliberately chose to separate the two hypotheses that identified introversion as a 'determinant' on the one hand, and as a variable which is negatively related to 'strength' on the other (see p.130). The reason for this was to avoid the ambiguity and confusion that result from the fact that

'strength' can be defined either in terms of the theory of 'strength' or in terms of certain classical indices such as extinction with reinforcement on the photochemical reflex (EWR or the PCR). The two are related but they are not identical, and the author chose to look at the first aspect - i.e. the definition of 'strength' - by investigating the interaction of various proposed determinants of the 'excitatory process' (including introversion). He chose to look at the second aspect by measuring the gradient of the reaction time/intensity curve and assuming that it measures the kind of 'strength' that is involved in indices such as the EWR of the PCR. This assumption is validated by the high degree of correlation found between the two measures (e.g. Nebylitsyn 1960, op. cit.). But it has the implication that having decided to make the separation between the two definitions of 'strength' we must now accept the conclusion - and the apparent contradiction - that introversion level may be a determinant but that introverts have 'strong' nervous systems. However this contradiction is not a serious one, given what is meant by a 'strong' nervous system in this particular context.

The reason the author is unperturbed by the apparent necessity to conclude that introverts have 'strong' nervous systems is ^{that} in his opinion the first hypothesis is the more important one - i.e. to prove that level of introversion is a determinant and that as it is increased one moves to the right along the 'x' axis and that predictable interactions with the other proposed determinants occur as a result. To prove that introverts have

'weak' nervous systems as defined by a classical index such as the EWR of the PCR (via the intervening link of the gradient of the reaction time/intensity curve) is a worthwhile aim since it provides a possible means of linking the research carried out in the West and the East (see pp. 137-144). However, such a bridging process through the use of the reaction time/intensity curve, though valuable, could not be more than suggestive and indirect.

v) Implications for Soviet work on 'strength' and for experimental design

If our analysis is correct, then we could of course advance the hypothesis that the individuals defined as 'strong' in the Soviet Union by using the reaction time measure may differ from their 'weak' counterparts in that they adopt a higher criterion. Within the context of standard signal detection tasks, the response criterion is sometimes regarded as an inverse measure of the 'risk-taking' propensities of a subject, since the setting of a lower criterion would lead to more false alarms, all other things being equal. There is some indirect evidence that 'strong' subjects, in fact, take more risks than 'weak' subjects (e.g. Kulyutkin^{et al}, 1972; Kozlowski, 1977). However, the relationship of such tendencies to the criterion in a simple reaction time task is unclear, so we do not regard the results of these studies as proof that the hypothesis that 'strong' subjects have a relatively high criterion is incorrect.

Furthermore, we have seen that the gradient of the reaction time/intensity curve depends on the interplay of the criterial and sensory slope factors which may act in opposite directions. This calls into serious question the validity of using the gradient to define 'strong' and 'weak' groups of subjects, since one cannot assume that this distinction has the same meaning in different studies. In other words the 'strong' and the 'weak' group may differ in one respect in one study but in another respect in a different study. It is not safe to assume that 'strength' defined in this way has the same meaning in different contexts.

It could be argued that the same strictures apply to the author's own use of the gradient of the reaction/time curve. However, it will be remembered that the plan is to use the same group of subjects throughout, and to derive from each one a single value for the gradient of the reaction time/intensity curve under conditions which are the same for all subjects. This means that the results obtained using the gradient

as an independent variable will at least have a consistent interpretation since the same ^{values} will be used throughout. It should be noted that this would not apply if we had used separate groups of subjects for each experiment and employed the gradient index in each separately to divide the subjects into 'strong' and 'weak' groups.

3. THE CRITERION AS A POSSIBLE DETERMINATE

We have seen that a criterion explanation can account for most of the findings in the study of disjunctive reaction time by Brebner and Flavel (1978) and in the studies of the relation between introversion and the gradient of the reaction time/intensity curve. We have also suggested that in many cases explanations in terms of the slopes of the sensory growth functions or in terms of the criterion are either complementary or alternatives.

In the course of developing one of these explanations we argued that the slope of the sensory growth function may be a candidate for inclusion in our list of determinates - i.e. that it may show an inverted 'U' relationship to the levels of the proposed determinants. We will now develop the hypothesis that an inverted 'U' relationship exists between the reciprocal of the criterion - i.e. the degree of 'riskiness' of the subject or his 'tendency to respond' - and the determinants. To introduce this possibility we will first consider the findings of Cheng (1968) in more detail.

1) Cheng's study

In this experiment, reaction time was faster in introverts than extraverts in normal subjects, but the reverse was true in schizophrenic subjects. Cheng, like other workers, assumes that schizophrenic subjects are more 'aroused' than normal subjects. If one also assumed that introverts are more 'aroused' than extra-

verts (i.e. that the level of introversion is a determinant), Cheng's result might on the face of it be explained by transmarginal inhibition in the sensory growth function - i.e. by assuming that in schizophrenics the slope of the sensory growth function was steeper in extraverts than in introverts. However, this cannot be the case since stimulus intensity is also a determinant, and if the threshold of transmarginal inhibition had been passed in schizophrenics the reaction times to the low intensity stimuli would have been faster than the reaction times to the high intensity ones. This was not the case.

Thus the relationship between stimulus intensity and the determinate may remain positive and monotonic, even though the relation between other determinants (e.g. introversion) and the determinate becomes negative and monotonic. Thus the assumption that stimulus intensity can be represented on the same 'x' axis as the other determinants may break down. We have seen evidence for this already (e.g. pp. 324-7).

It is also the present author's view that if, on the above basis, we assume that Cheng's data can be explained by transmarginal inhibition (T.I.) due to the manipulation of individual differences, this could be due to T.I. either in the slopes of the sensory growth functions (i.e. steeper slopes for introverts in normal subjects, but for extraverts in schizophrenics) or due to T.I. in the degree of 'riskiness' or 'tendency to respond' of

the subjects (it will be remembered that the 'tendency to respond' is defined as the reciprocal of the criterion). This latter hypothesis is depicted in figure 36

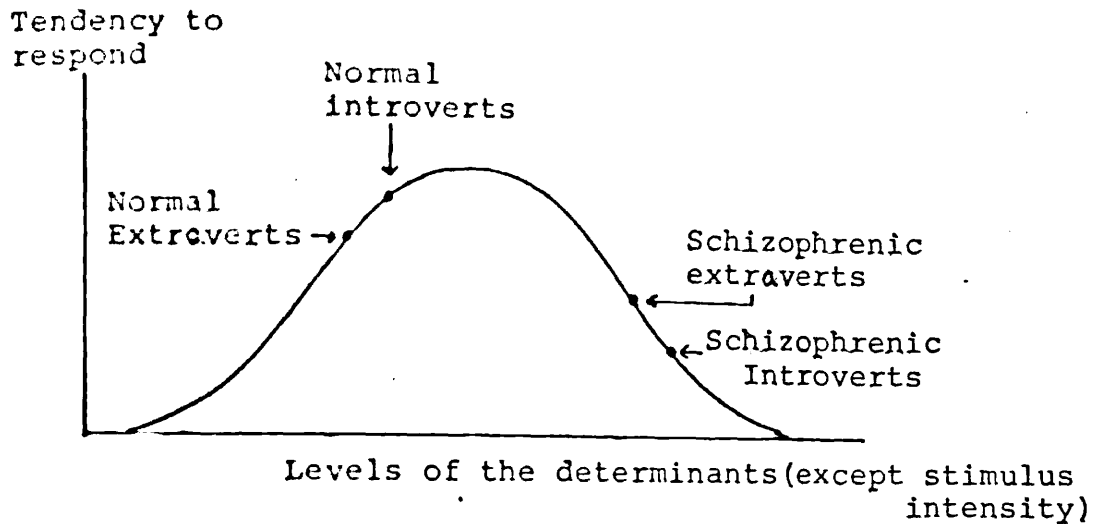


Fig. 36 .Cheng's study, the inverted 'U' and the tendency to respond.

The relative positions of the four groups would explain the relative values of the reaction times, since an increase in the 'tendency to respond' - i.e. a fall in the criterion - lowers reaction time.

ii) The criterion model and the determinants

We can also use this hypothesised relationship between the tendency to respond and the determinants to explain many other findings. For instance it can account for the results of those studies which have looked at the joint effect of introversion and one or more of the other determinants and found evidence of an inverted 'U' relationship between the levels of these determinants and the speed of response (e.g. Calcote, 1977. See p. 410). But what of the other determinants considered alone? Let us consider them in turn:

a) Stimulus intensity

It should be readily apparent that the increase in speed of response as stimulus intensity increases cannot be explained by differences in criterion level for the different intensities, if the latter are presented to the subject in a random order, since the subject will not know which intensity he is going to receive on a given trial. Even if, however, the subject does know (for instance if the intensities are presented in blocks), differences in criterion cannot explain the effect. If anything, the evidence is that in such a situation the subject tries to compensate for the rise in stimulus intensity by raising his criterion. In fact one of the principal lines of evidence that led to the development of the counting model of reaction time was the finding that the slope of the reaction time/intensity curve is less (presumably due to such compensation) if the intensities are presented in blocks than if they are randomised (see Grice 1968).

Thus it is still necessary to assume - as the graphs shown earlier do - that the sensory growth function (which we will call 'm' for convenience) is steeper for a high intensity stimulus than for a low intensity one.

Furthermore, it is also necessary to assume that the relationship between 'm' and stimulus intensity is curvilinear, since the reaction time/intensity curve is curvilinear (see earlier - e.g. Teichner 1954). As intensity increases, the increase in reaction speed becomes

progressively less and less, and we must therefore assume that as intensity increases the increase in 'm' becomes less and less;

Slope of the
sensory growth
function (m)

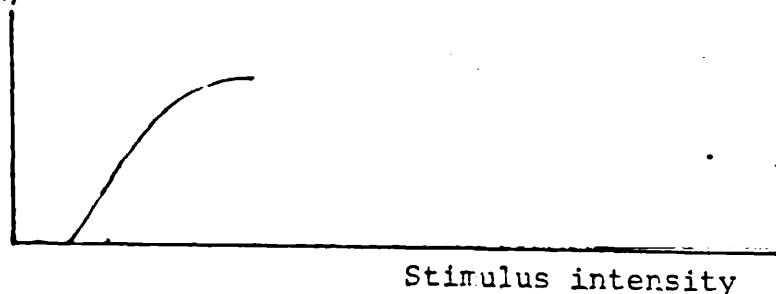


Fig. 37. Stimulus intensity and the slope of the sensory growth function.

It is clear that this corresponds to portion 'B' of the inverted 'U'.

Stimulus intensity, it would seem, may again be different from the other determinants, since its effect on simple reaction time can only adequately be explained by referring to the sensory growth function, whereas the effects of the other determinants can also be explained with reference to the criterion (this will become clearer below, but we will anticipate the result here).

This supports the suggestion we made earlier that it may not be possible to predict the joint effect of the determinants by assuming that they all can be represented on the 'x' axis or a single inverted 'U' curve, though in subsequent experimental work we will retain this assumption as a working hypothesis.

It is also at this point worth considering another set of results which support the view that under certain circumstances, at least, stimulus intensity may become dissociated from the other determinants. It could be argued that the finding (e.g. Shigehisa and Symons, 1973a) that strong accessory stimulation raises sensory thresholds in introverts but lowers them in extraverts could be explained by the inverted 'U' in its original form. But this is not so. It will be remembered that Shigehisa used the method of limits in which a rise in the threshold is revealed by the fact that a higher intensity stimulus is necessary before the subject will report its presence. However, such a higher intensity stimulus would move the subject even further to the right along the 'x' axis of the inverted 'U' so that if a subject had already passed the T.T.I., this would result in an even greater reduction in the level of the 'excitatory process'. We, therefore, cannot explain the rise in threshold in introverts under strong accessory stimulation by transmarginal inhibition in the context of the original inverted 'U' model.

An alternative explanation would be that stimulus intensity is dissociated from the other determinants, as we have already suggested, and that an inverted 'U' relationship exists between the other determinants and either perceptual sensitivity or the subject's 'tendency to respond' (since the method of limits is a criterion-dependent measure).

b) Drugs

The increase in the speed of responding and decrease in the slope of the reaction time/intensity curve due to stimulants such as caffeine (Nebylitsyn 1960) can be explained if we assume that the latter lowers the subject's criterion.

c) Accessory stimulation

Where this factor affects reaction time it is usually in the form of an increase in reaction speed at low levels of accessory stimulation and a decrease in reaction speed at high levels (e.g. Kallman and Isaac 1977). This can also be explained by the inverted 'U' relating tendency to respond to the determinants of 'arousal' and the 'excitatory process'.

d) Drive

We have seen already that the interaction between drive, introversion and neuroticism in Calcote's study (1977) could be explained in terms of the criterion rather than purely sensory factors.

e) Fatigue

The decrease in response speed due to sleep deprivation (e.g. Daftvar and Sinha 1972) could be due to a rise in the subject's criterion.

f) Novelty

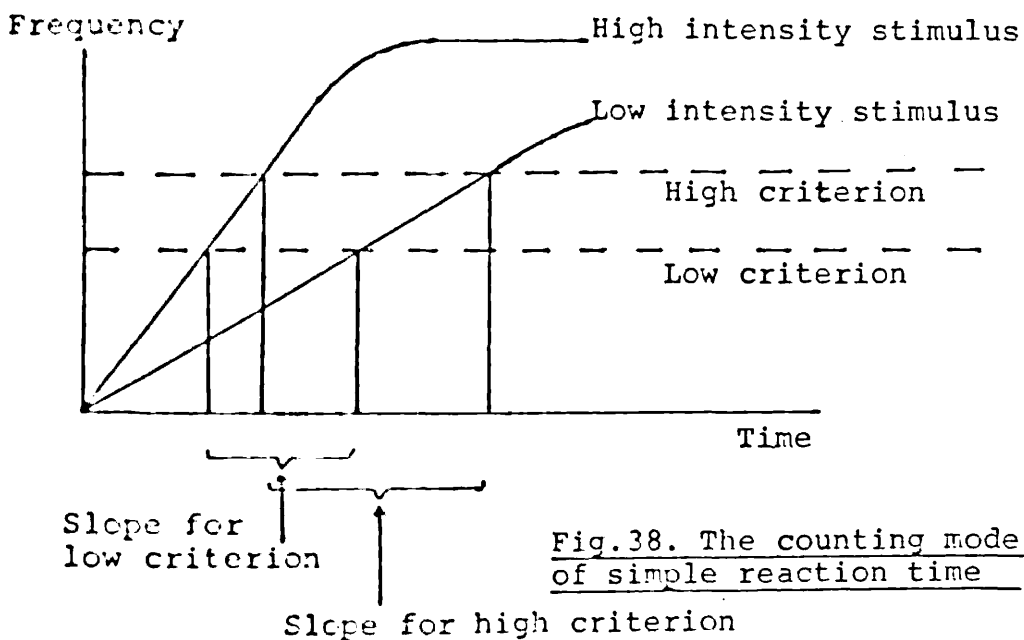
We will argue in the section on vigilance that the effects of practice could be due to changes in the level of the criterion whether these were due to learning per se or to shifts along the 'x' axis of the inverted 'U'.

g) Russian measures

The positive relationship found between the reaction time gradient and the absolute sensory threshold (e.g. Nebylitsyn 1960, Sales ^{and Throop} 1972) can be explained by the fact that the latter was measured by the method of limits which, like reaction time, is a criterion-dependent measure. . Also, the relationship of the reaction time gradient to other measures of 'strength' (Nebylitsyn 1960) could be explained if we assumed that under certain conditions at least, 'strong' subjects adopt a 'higher' criterion than 'weak' ones, though as yet there is no direct evidence that bears on this point. We will attempt to make good this omission.

111) A resumé

Let us summarise the argument so far. The counting model predicts that both the gradient of the reaction time/intensity curve and the mean reaction time are positively related to the criterion of the subject. It also predicts that the gradient of the reaction time/intensity curve is positively related to the difference in the slopes of the sensory functions for a weak and a strong stimulus. Finally the mean reaction time is positively related to the absolute values of these slopes.



It has also been argued that whether the intensities are randomised or presented in blocks, the fact that reaction time decreases as stimulus intensity rises must be due to a steeper slope ('m') of the sensory growth function for a strong stimulus than for a weak stimulus. The fact that the reaction time/intensity curve is non-linear also implies that the relation be-

tween 'm' and intensity is non-linear. But there is little evidence as yet in normal subjects that this relationship ever becomes negative, i.e. that 'm' gets less as stimulus intensity increases, and there is little evidence as yet that a rise in stimulus intensity in normal subjects causes a fall in reaction speed.

There is, however, evidence that a rise in the level of certain other determinants of 'arousal' and the 'excitatory process' such as accessory stimulation, introversion and neuroticism can sometimes lead to a rise in reaction speed at low levels but a fall in reaction speed at high levels. It is therefore suggested that there may be an inverted 'U' relation between 'm' and these other determinants, but not stimulus intensity.

Also, when the intensities are randomised, the criterion is of necessity unrelated to the intensity, but when the intensities are blocked, subjects raise their criterion at the higher intensities to compensate. This results in a lower slope of the reaction time/intensity curve. But the compensation is apparently not sufficient to outweigh the effect of the rise in stimulus intensity on the sensory growth function, so that even when the intensities are blocked, reaction speed never falls as intensity rises.

However, it is suggested that the inverted 'U' relation between reaction speed and the determinants other than stimulus intensity could be explained by an

inverted 'U' relation between these factors and the tendency to respond (i.e. the reciprocal of the criterion) rather than 'm' (the slope of the sensory growth function). Incidentally, support for the criterion hypothesis comes from the finding by Davies and Hockey (1966) that an increase in the level of accessory stimulation produces an increase in the tendency to respond in extraverts, but a decrease in introverts. This result was based on a re-analysis of the data from a vigilance task (see Davies and Tune, ^{1970,} p. 149).

iv) A reassessment of the criterion model as applied to Mangan and Farmer's study

But what has happened to our original hypothesis that extraverts adopt a lower criterion than introverts in simple reaction time tasks? Clearly, if there is an inverted 'U' relationship between the levels of the determinants and the reciprocal of the criterion, extraverts will have a lower criterion than introverts only when the levels of the determinants are relatively high. If we assume that extraverts do have a lower criterion, we can very successfully explain the interaction between introversion and stimulus intensity found in a number of studies, particularly that of Mangan and Farmer (1967) - see pp.439-41. Can we assume that the levels of the determinants are relatively high in this study? It is difficult to test such an assumption unless the levels of as many of the determinants as possible are actually manipulated within the same ex-

periment. In Mangan and Farmer's study, only two of the determinants were manipulated: introversion and stimulus intensity. Nevertheless the interaction between them ought to give us some clue as to which half of the inverted 'U' we are operating on. It will be remembered that in this study there was an increase in the speed of response as stimulus intensity was increased, and although the rate of increase also decreased there was no evidence of transmarginal inhibition - i.e. a fall in response speed - as stimulus intensity increased. We seem, therefore, to be operating firmly on the left hand side of the inverted 'U', not on the right hand side, as our assumption of a lower criterion in extraverts would require. However, we have already come across two studies in the reaction time literature alone in which there are strong indications that if a threshold of transmarginal inhibition exists at all for stimulus intensity, it may be higher than for the other factors (Keuss and Orlebeke 1977; Cheng 1968). There are possible modality effects to take into account here, since both of these studies were auditory, whereas the Mangan and Farmer study was visual. However, for the present we will countenance the possibility that despite the lack of transmarginal inhibition due to stimulus intensity in the latter study, we may still be operating on the right hand side of an inverted 'U' relating the other determinants to the tendency to respond.

v) The criterion model, hedonic tone and the optimisation of performance

There is another question to be considered though. It was argued earlier that the individual may attempt to maximise his level of hedonic tone by altering his level of responding. However, in our account of Brebner and Flavel's experiment we mentioned that the apparent increase in the subject's criterion, as signal frequency/probability increased, indicated that hedonic tone was not the only factor to be considered. The subject is presumably motivated also to perform well at the task. Signal detection theory predicts that in a task involving blank trials, for example, there are certain values associated with responding to a stimulus ('hit') but not responding in a blank trial ('correct rejection'). Also there are certain costs associated with responding on a blank trial ('false alarm') and not responding to a stimulus ('miss'). The 'ideal observer' is thought to try to maximise the values and minimise the costs, but the theory also predicts that factors such as signal probability affect this balancing process, and that as the signal probability falls the criterion will tend to rise. The fall in signal probability in Brebner and Flavel's study was confounded with a fall in signal frequency, and we argued that the hedonic tone argument would predict a fall in the criterion. In this case the prediction of signal detection theory was borne out so that the desire of subjects to optimise their per-

formance appeared to override their desire to optimise their level of hedonic tone.

An experiment by Nettlebeck (1973) suggests that subjects may adopt a higher criterion at both the extreme ends of the 'arousal' continuum because under these conditions discriminability is low (i.e. d' is low as our model would predict), and the subject is more cautious in order to compensate. This is completely in line with our suggestion that there is an inverted 'U' relationship between the determinants and the tendency to respond (the reciprocal of the criterion). So our hypothesis is not only capable of explaining many of the findings in reaction time studies but it is also consistent with the view that the observer is attempting to maximise his level of performance.

We see, then, that if we consider the subject's need to maximise his level of hedonic tone and his need to optimise his performance we may generate quite different predictions about the relationship between the criterion and the determinants.

vi) Welford's theory and a reinterpretation of the criterion model

There is another theory which predicts a third relationship between the determinants and the criterion level. This is proposed by Welford (1972). Consider figure 39 below.

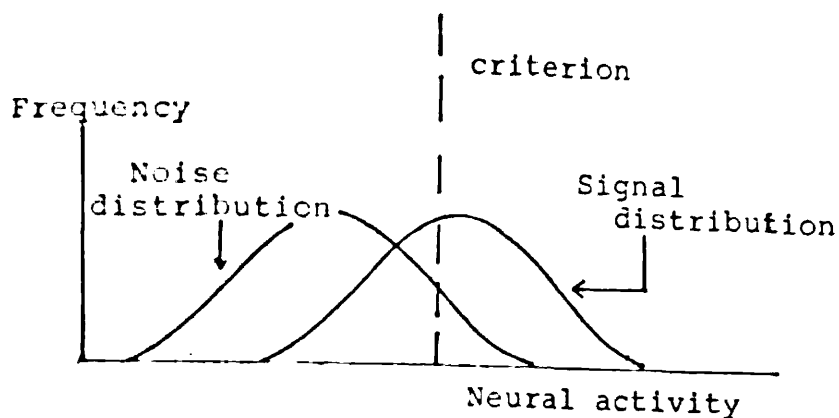


Fig 39. The postulates of signal detection theory

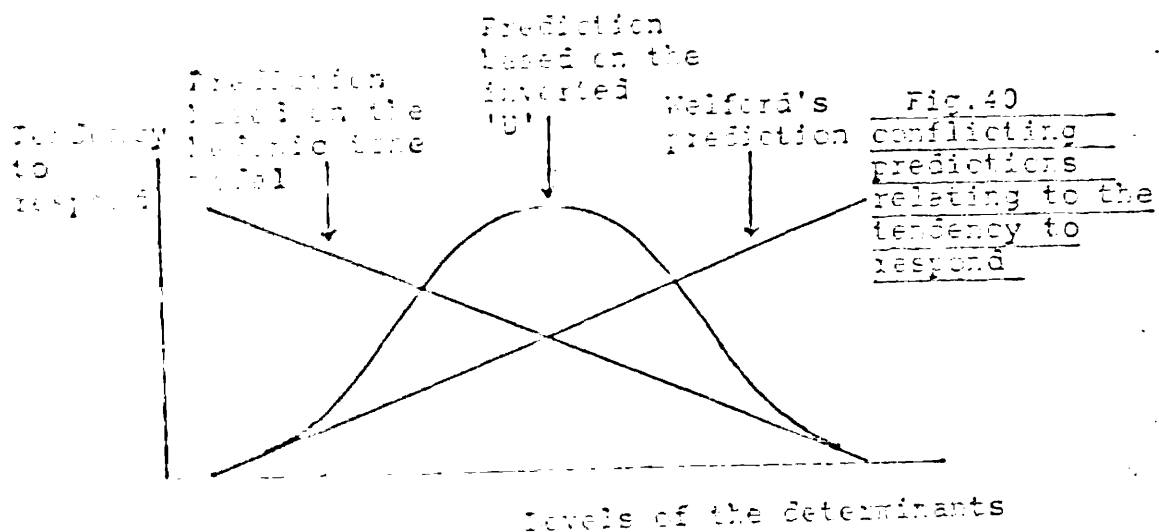
This depicts the basic postulates of signal detection theory and is a diagram which we have frequently had recourse to. Consider the effect of moving both the signal and the noise distributions to the right along the 'x' axis whilst keeping the criterion at the same point. As Welford points out, the number of false alarms and hits would both increase, and the criterion would appear to have decreased - i.e. shifted to the left despite the fact that in terms of level of neural activity it is ^{at} exactly the same point. This rather surprising result stems from the fact that the criterion is defined operationally as the ratio of the heights of the signal and noise distributions. This means that it provides an inverse measure of the subject's tendency to respond. But this measured criterion is only positively and monotonically related to the position of the actual criterion on a dimension of neural activity (such as the 'x' axis in figure 39) if we assume a constant position

for the signal and the noise distributions. A similar point has been made by Mackworth (1969). She argues that if the signal and noise distribution move in the opposite direction - i.e. to the left along the 'x' axis (due, for instance, to habituation of the evoked potential) - the criterion will appear to have been raised.

Let us again consider the situation described by Welford. It implies that as the level of 'arousal' increases, the subject's tendency to respond also increases. But if the level of 'arousal' is itself increased by increased responsiveness due to excitatory feedback then we would appear to have a positive feedback situation in which the level of 'arousal' would simply continue to rise unabated. Positive feedback systems, unbridled by some form of compensatory mechanism, are rare in living organisms, since by their very nature they would lead to the destruction of the organism. They are therefore usually only found in disease states. Furthermore, such a positive feedback mechanism is completely at odds with the concept of negative feedback control of hedonic tone.

Our hypothesis of an inverted 'U' relationship between the determinants and the tendency to respond also conflicts with the hedonic tone model, but only when the levels of the determinants are relatively low. Under these conditions the hedonic tone model would predict that as the levels of the determinants are increased the tendency to respond would decrease, since

Although the level of the 'excitatory process' or 'arousal' may still be below the optimum level corresponding to maximal hedonic tone, the discrepancy between the two would be decreasing. Our hypothesis would on the other hand predict that the tendency to respond would increase. However, when the levels of the determinants are relatively high, both models would predict a reduction in the tendency to respond as the levels are increased yet further. Welford's argument, however, would imply that even when the levels were high, the tendency to respond would still increase. Figure 40 summarizes all three predictions.



There may, however, be a way of reconciling these conflicting views. Consider figures 41 and 42

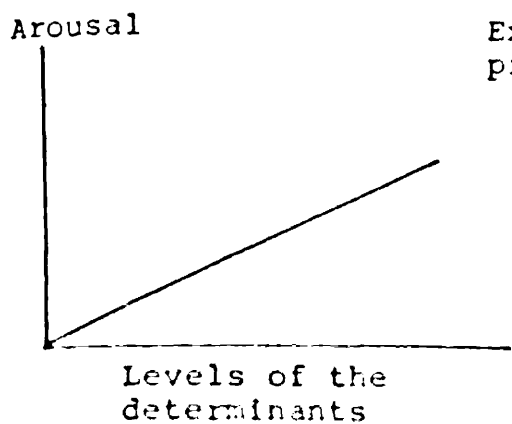


Fig. 41. The Western model

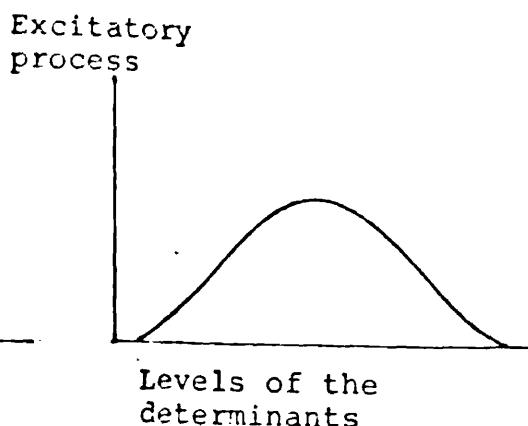


Fig. 42. The Russian model.

These show in idealised form the presumed relationship between the levels of the determinants on the one hand and the constructs of 'arousal' and 'excitatory process' on the other, presented by Western and Soviet workers respectively. It was argued earlier that the difference between them was under most circumstances merely of academic importance. In this context, however, the difference is an important one since both constructs are measures of neural activity and the 'x' axis in figure 39 is also a dimension of neural activity.

Consider the effect of an increase in the levels of the determinants. If the Western view is correct, the level of 'arousal' would rise, the signal and noise distributions would both move to the right (in figure 39), and the tendency to respond would increase (i.e. the criterion would fall). This is the situation envisaged by Welford.

If the Russian view is correct, however, as the determinants are increased, the level of the 'excitatory process' would first increase but then later decrease. In other words, the signal and noise distributions would at first move to the right and then to the left, and the tendency to respond would first increase and then decrease. So our hypothesis that there is an inverted 'U' relationship between the tendency to respond and the levels of the determinants would be confirmed.

What of the remaining prediction - i.e. the one based on the concept of hedonic tone? Consider again figure 41 . Let us assume that there is an inverted 'U' relationship between the level of the 'excitatory process' and the level of hedonic tone. If so, then the Russian model would predict that the fall in the level of the 'excitatory process' at very high levels of the determinants would automatically produce an increase in the level of hedonic tone, so long as we assume that the level of the excitatory process which maximises hedonic tone is lower than the peak value shown in figure 41 . Our discussion of the results of the taste experiment suggests that this assumption may be valid. It will be remembered that the apparent T.T.I. for hedonic tone was reached even though salivation and magnitude estimates (which we could regard as indices of the 'excitatory process') continued to increase as stimulus intensity was raised (see pp. 341-3).

We see then that the Russian model itself incorporates a mechanism which would at least partially meet

the need to maximise the level of hedonic tone. This is not surprising, since the concept of homeostasis has always been implicit in the Russian theory. An alternative name for 'transmarginal inhibition' is 'protective inhibition' - in other words, the decrease in the level of the excitatory process (or, more precisely, its replacement by protective inhibition) is thought to be a device to protect the nervous system from damage at high levels of the determinants.

This does not mean that alterations in the tendency to respond cannot also under certain circumstances be involved in hedonic homeostasis. The above analysis, however, does show that the relationship between our prediction and that of the pure hedonic tone model is closer than we might at first imagine.

To summarise, then. The Russian model (which as we have seen derives support from a number of physiological studies) not only provides support for our hypothesis of an inverted 'U' relationship between the tendency to respond and the levels of the determinants, but it also provides grounds for a rapprochement between the latter and the hedonic tone hypothesis. Furthermore it incorporates Welford's suggestion that alterations in the level of neural activity may produce apparent changes in the position of the criterion without suggesting that this would lead to a counterintuitive positive feedback process.

vii) Implications for simple reaction time

It is worth considering at this point, though, what such apparent changes in the position of the criterion imply for our counting model and simple reaction time. If we look back to figure 30, which is reproduced below, we see that the criterion concept employed in the counting model, is defined in terms of the frequency of neural counts - i.e. in units of neural activity.

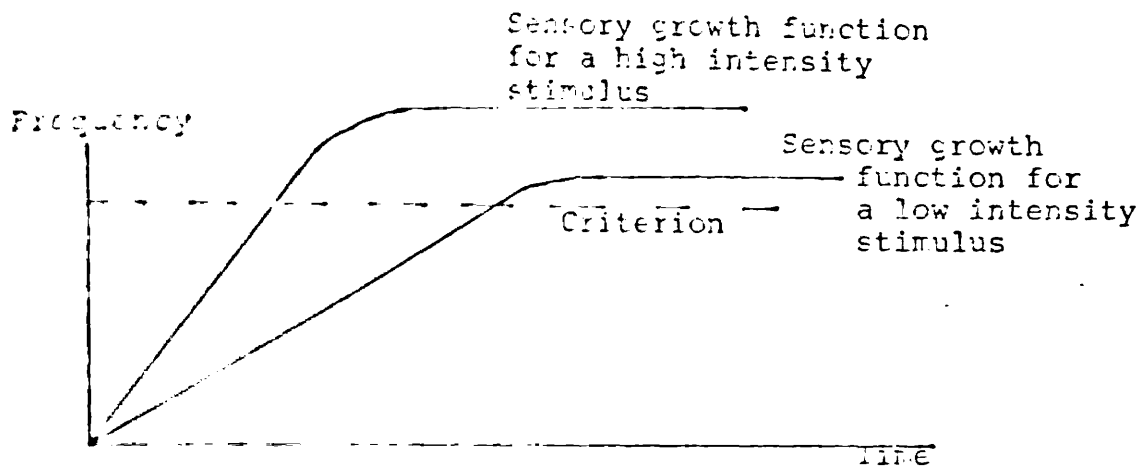


Fig. 30. The counting model of simple reaction time

What Welford's suggestion means is that alterations in the levels of the determinants could leave the position of this criterion unchanged but result in alterations in the intercepts of the sensory growth functions - i.e. the points at which they intersect the 'y' axis - even though their slope may remain unchanged (though our alternative hypothesis would predict that these too might change). In other words, simple reaction time may depend not only on the level of the criterion and the slopes of the sensory growth function, but also on the

intercepts of the latter. This possibility was not mentioned earlier as it would have complicated an already intricate argument. However, even if this view is correct it does not alter the nub of our criterion hypothesis, since vertical shifts in the positions of the sensory growth functions are operationally equivalent to alterations in the level of the criterion and lead to the same predictions regarding reaction time. Furthermore, since such shifts would also affect the final levelling off points of the sensory growth functions, they would also be reflected in actual experimental measurement of the criterion.

Furthermore, we can retain our hypothesis that when the levels of the determinants are relatively high, the criterion of introverts will be higher than that of extraverts. This view would have been threatened, though, if we had accepted Welford's hypothesis in its original form - i.e. if we had supposed that an increase in the levels of the determinants would always produce a shift to the right along the 'x' axis in figure 39 (and consequent reductions in the level of the criterion). If this were so, then an increase in the level of introversion would always result in a lowering of the criterion since such an increase, ex hypothesi, would result in movement to the right along the 'x' axis of the inverted 'U' and therefore would always result in a movement to the right along the 'x' axis of figure 39 if Welford was correct. However, we have seen that a more coherent and parsimonious theory is obtained if we adopt

the Russian model, and on this basis an increase in the level of introversion would produce a shift to ^{the} left (and an increase in the criterion) when the levels of the determinants were relatively high, which is exactly what our theory predicts.

4. A PROPOSED EXPERIMENTAL TEST

i) Summary of analysis of simple reaction time

We have two hypotheses:

- a) There is an inverted 'U' relationship between the levels of the determinants and the tendency to respond (i.e. the reciprocal of the criterion).
 - b) There is an inverted 'U' relationship between the determinants and the slope of the sensory growth function.
- We have described the effects of the various proposed determinants on reaction time and we have seen that each of the above hypotheses by itself can account for nearly all of these effects. As such, the two hypotheses could be considered to be alternative explanations of the reaction time data that we have discussed.

In some situations, though, (e.g. the study by Eretner and Flavel) we seem to need an explanation in terms of both criterial and sensory factors. On other occasions, as in the case of stimulus intensity, only one of the two theories seems tenable.

ii) A problem

Ideally, therefore, we would like to be able to conduct an actual experiment to measure the criterion and the slope of the sensory growth function separately in a simple reaction time situation. It may be thought that signal detection methods would automatically answer this need, since we have seen that they provide separate indices of the criterion and the index of discriminability (d'). However, the techniques involve the use of catch

trials in which the subject is required to withhold his response. From the proportion of catch trials on which he fails to do this, and from the proportion of ordinary trials on which he correctly responds, the value of the criterion and d' are calculated.

It should be clear that if we introduce catch trials into a simple reaction time task, we no longer have a simple reaction time task but a disjunctive reaction time task, such as the one employed by Brebner and Flavel. We have also seen that some theorists consider that the processes which determine the latency of response in a disjunctive reaction time task are different from those which determine the latency of response in a simple reaction time task, though they do not agree on what these processes are (Grice et al., 1976; Nissen, 1977).

So we are faced with the problem that the latency measures which we are most interested in derive from simple reaction time tasks, but the signal detection measures we are interested in derive from disjunctive reaction time tasks.

iii) A possible solution

Is there a way out of this dilemma? The answer is 'yes', if we are willing to make an assumption - namely, that although the latency of response in a disjunctive reaction time task may depend on different processes to those which obtain in a simple reaction time task, the signal detection indices which are derived from the disjunctive task can nevertheless be used as reliable

guides to the mechanisms involved in the simple reaction time task.

This may not seem a particularly tenable assumption at first glance. However, it will be remembered that when we applied the results of signal detection tasks, such as those employed by Stelmack and Campbell (1974) and Harkins and Geen (1975) to simple reaction time tasks we were able to provide an adequate explanation of the findings. Furthermore, although reaction times were not actually measured in these signal detection tasks, this was simply an omission on the part of the authors; the actual experimental paradigm was basically very similar to that of disjunctive reaction time. Furthermore, in the case of Erebner and Flavel's study (in which, this time the authors measured reaction time but failed to calculate signal detection indices), we were even able to give an adequate explanation of the latency measures (i.e. disjunctive reaction time) in terms of simple criterion and sensitivity arguments. So the processes underlying simple and disjunctive reaction time may not be that different after all.

It would seem, then, that it would be a worthwhile exercise to approach the problem of simple reaction time indirectly via disjunctive reaction time. It would have been preferable if we could have found a way to partition reaction time directly into its criterial and sensory components (ignoring its motor component for the present), but there would seem to be no suitable technique available to do this at present, as the principal signal de-

tection theorists have themselves admitted (Green and Swets 1974).

iv) Outline of a joint study

The essential proposal, therefore, is to conduct an experiment in which simple and disjunctive reaction time tasks are used in sequence and in which the experimental conditions are kept as nearly the same as possible for the two tasks. This should minimise the possibility that differences in such conditions could undermine the validity of our assumption that the signal detection indices derived from the disjunctive task can be used to help explain the findings from the simple reaction time task. If the assumption is valid, it should be possible to eliminate by statistical means (the analysis of covariance) the influence of the criterion, and thus reveal the effect on simple reaction time of the sensory growth function factor alone.

In view of what has already been said, it would also be desirable to measure the electromyograph of the subjects so that any masking influence of response sets could also be allowed for statistically. However, for practical reasons this was not possible.

v) The choice of factors

For our experiment to be a valid test of our hypotheses it will also be necessary to investigate the levels of several of the determinants. The choice must, therefore, be made as to which ones to use.

Stimulus intensity is an obvious candidate. It has theoretical importance because of the findings relating personality to the gradient of the reaction time / intensity curve (e.g. Mangan and Farmer, 1967). Furthermore, this gradient is used as an index of 'strength' of the nervous system in the Soviet Union and Eastern Europe. If we employed it we would be able to carry out one of our professed aims - namely to try to elucidate the difference between subjects described as 'strong' and 'weak' using this index, since these could be compared on measures of criterion and discriminability derived from the disjunctive reaction time task. It would also enable us to look at the relationship between 'strength', defined in terms of the reaction time/intensity curve and the taste indices derived from the first group of experiments, and the vigilance indices which are to be derived from the last group of experiments.

We have also seen that there are certain peculiarities associated with this factor which could have important implications for our general model. We have already suggested that there may be a dissociation between stimulus intensity and the other factors, and that this is reflected in the fact that transmarginal inhibition due to the influence of these other factors may seem to have occurred despite the fact that response speed is still increasing as a function of stimulus intensity (e.g. Cheng, 1968). We could hypothesise, therefore, that the T.T.I. is higher for stimulus intensity than for other factors.

Transmarginal inhibition due to an increase in stimulus intensity has been demonstrated in schizophrenics (e.g. Venables and Tizard, 1956), but to provide a rigorous test of such a hypothesis we would need to demonstrate T.I. due to an increase in stimulus intensity in an experiment in which several of the other determinants were manipulated as well. This will, therefore, be a further aim of our experiment, and in addition we will test the hypothesis that such T.I. is more likely to occur when the levels of the determinants are relatively high, as the theory of 'strength' would predict.

We have already stated that the use of drugs in the present project was not possible for practical reasons.

Drive is a variable which has been found to interact in predictable ways with factors such as introversion and neuroticism (e.g. Calcote, 1977), but for reasons which were stated earlier it was decided not to use it in the present experiment.

Sleep deprivation was also ruled out for practical reasons and because of certain theoretical problems outlined elsewhere.

Novelty can be investigated by looking at within or between session changes, and, as will be seen an opportunity to do both was afforded by the particular design employed.

Introversion and neuroticism are of obvious interest within this study, and one aim of it was to make good the relative neglect of neuroticism in reaction time studies.

Russian measures of 'strength' were to be investigated both by means of the reaction time/intensity index and the questionnaire measure of strength which the author had recently received permission to use from Professor Strelau in Poland.

Time of day is a factor which is of great theoretical interest, so it was decided to include it also. The practical objections to it which prevented its use in the taste experiment were considered not to apply to the same extent in simple reaction time, and therefore did not outweigh its theoretical value.

We have left accessory stimulation until the end since it raises certain issues which must be discussed at greater length. One of these is the choice of sensory modality for the reaction time task. Accessory stimulation by its very nature should come from a different modality to that of the response stimulus. If it did not, one could argue that any decrement in response due to such stimulation could be due to direct interference, for instance if both the accessory and response stimuli are auditory. This being so, the factors governing the choice of modality for the two kinds of stimuli should be discussed side by side. Let us first consider the factors relating to the choice of the modality of the response stimulus.

The gustatory and olfactory modalities would raise too many practical problems and can therefore be ruled out. Tactile stimuli have been used successfully by Kallman and Isaac (1977, op. cit.), but stimulus intensity

would be difficult to manipulate in this modality. We are left, therefore, with the visual and auditory systems.

The visual modality has certain advantages. Firstly, the study which showed the clearest evidence of an introvert/extravert difference in the reaction time/intensity gradient was a visual one (Mangan and Farmer, 1967).

Also, Venables and Tizard (1956) found that even in schizophrenics, transmarginal inhibition due to a rise in stimulus intensity was only found in the visual modality.

However, these facts could be construed in the opposite way. If a genuine modality difference does exist it would pose problems for our general theory, so that if the same effects could be demonstrated for audition it would preclude the possibility of having to introduce a major revision of the theory over this point alone. We seem, therefore, to have no clear indication of which modality to use for the response stimulus. Let us now consider factors relating to the choice of the modality of the accessory stimulus.

Two studies (Isaac, 1960 and Kallman and Isaac, 1977) have used combined auditory and visual accessory stimulation and have produced results which are in line with the inverted 'U' hypothesis. However, it is difficult to disentangle the effect of the visual and auditory stimulation combined. Most studies which have used only one kind of accessory stimulus have employed white noise, and these have produced conflicting results (see p. 405).

We see then that the studies which have used accessory stimulation do not really tell us which of the two available modalities would be most profitably employed. Part of the problem is that, as we have seen, very few studies have employed visual accessory stimulation on its own and looked at its effect on auditory simple reaction time.

It was considered worthwhile, therefore, to conduct a preliminary experiment to look at just such an experimental set up before finally deciding which sensory modality to use for the combined simple and disjunctive reaction time task which was, of course, the main interest.

CHAPTER NINE. A PRELIMINARY STUDY: SIMPLE AUDITORY
REACTION TIME.

1. INTRODUCTION

The factors we intend to employ in the present study are by and large the same ones that we intend to manipulate later in our joint reaction time/signal detection task: stimulus intensity, introversion, neuroticism, time of day and accessory stimulation.

Due to limitations of time, subjects participated in one session only, so the effect of novelty could not be investigated by comparing session 1 with session 2.

Since the effects of visual accessory stimulation upon simple auditory reaction time have been relatively rarely studied, and since this was one of the main reasons for conducting the preliminary study, it was considered worthwhile to investigate the effects of two kinds of accessory stimulus: constant and variable. A variable stimulus might be expected to be potentially more 'arousing' than a constant stimulus, since the reduction in novelty due to habituation is more likely if the stimulus is unchanging.

However, Poulton (1977) has pointed out that a variable accessory stimulus is more likely to be distracting than a constant one. Gray (1964) has reviewed evidence which suggests that the relative importance of 'arousal' and distracting effects may depend on the 'strength' of the subject's nervous system, defined in terms of a classical index. During the first few minutes

of variable accessory stimulation (e.g. due to a flashing light), performance in 'strong' subjects is depressed relative to the control condition (no accessory stimulation), presumably due to a distraction effect, whereas performance in 'weak' subjects is improved, presumably due to an 'arousal' effect.

Also, it has been shown by Easterbrook, 1959, for example, that an increase in the level of 'arousal' results in a narrowing of attention - i.e. an increase in the ability to resist distraction (although Gray, personal communication, has suggested that in certain contexts - e.g. the study of the influence of the behavioural inhibition system in animals - this may not be true).

Introversion and neuroticism figure in our list of proposed determinants of 'arousal' and also have been hypothesised to be related negatively to 'strength' of the nervous system, defined in terms of a classical index. The above results, therefore, suggest that when the levels of introversion and neuroticism are relatively high, the ability to resist distraction will be relatively high. Furthermore, since time of day is also a candidate for inclusion in our list of determinants we could hypothesise that the ability to resist distraction will be maximal when the levels of all three factors are relatively high.

It is worth, at this point, recalling Siddle and Mangan's (1971) suggestion that 'overarousal' or trans-marginal inhibition effects, due to the action of an accessory stimulus, could be viewed as an example of 'distraction'. However, such effects would be most likely to occur when the levels of the determinants are relatively

high, so that whether we decide to call them 'distraction' effects or not, we certainly cannot regard them as equivalent to the distraction effects described above, since we have suggested that these would be least likely to occur when the levels of the determinants are relatively high. Planned comparisons between a control condition, on the one hand, and a variable and a constant accessory condition, on the other, would enable us to investigate the conditions under which one set of effects or the other are likely to predominate since they lead to opposite predictions. It was also decided to present the various intensities of the response stimulus in blocks rather than in a completely random fashion. Cheng (1968) showed that in non-psychiatric subjects introverts show faster overall speed of response than extraverts, whereas Mangan and Farmer (1967) showed that the reverse was true, though in this case the difference was not significant. In Cheng's study the various intensities were presented in blocks, whereas in Mangan and Farmer's study they were presented randomly.

Gale (1969) has shown that extraverts demand greater changes in stimulation than introverts rather than higher absolute levels. It is possible, therefore, that the presentation of the intensities in blocks in Cheng's study placed the extraverts at a disadvantage relative to the introverts. A rigorous test of this would have required the experimenter to manipulate mode of presentation as a factor in itself. Limitations of time made this impracticable, but it was decided to use blocked intensities in any case to see if Cheng's finding was replicated.

2. METHOD

i) Design

All subjects performed under all conditions. Two intensities of the response (auditory) stimulus and three accessory stimulation conditions were employed (dark, constant, variable). Each stimulus intensity was presented ten times consecutively under each of the variable accessory stimulation conditions. The order of stimulus intensities and accessory stimulus conditions was determined randomly. The stimuli were pure tones of 1000 c.p.s. of either 90 db. (high intensity) or 10 db. (low intensity) (ref. level : 0.0002 dynes/sq.cm.). Under the 'dark' condition, ambient illumination was 2 lux. In the case of the 'constant' condition it was 1250 lux. The 'variable' condition was produced by a light flashing at 10 c.p.s. producing an ambient illumination of 10 lux.

ii) Subjects

Not all of the subjects who took part in the taste experiment were available at the time the present study was undertaken, so it was decided to employ a fresh group. Since the experiment was only a preliminary one it was considered that this was an acceptable departure from our general policy of employing the same group of subjects throughout.

Subjects were 64 male students who reported no previous history of epilepsy and migraine, since these conditions can sometimes be affected by flashing light stimuli. They were administered Form A of the Eysenck Personality Inventory following the experiment. Forty-

two of the subjects had 'lie' scale scores of less than 4, and only these are included in the analysis. Three binodal splits on the basis of extraversion (E) score, neuroticism (N) score and time of testing resulted in eight groups. The two levels of the time of day factor will be referred to as 'early' and 'late'. Details of the ages and introversion and neuroticism scores of the subjects in the eight groups are given in Appendix B.

iii) Materials

Standard Morse key and digitizer equipment was used to measure reaction times. The ambient illumination in the 'dark' condition was provided by a small amount of light entering from under a window blind next to the experimenter's chair which allowed him to record the reaction times. The illumination under the 'constant' condition was provided by a 150 watt room light plus two 100 watt lamps, the light from which was directed onto a white screen. The 'variable' condition was produced by a stroboscope whose light was also projected onto the screen. All the lux. values quoted earlier were measured at the screen. The stimulus tones were produced by a standard tone generator and played to the subject over earphones.

iv) Procedure

Subjects sat at a table (on which the Morse key was placed, and with their back to the experimenter's table (on which the other equipment was placed). They were given the following instructions:

'Please put these earphones on. During the test I will be presenting you with several series of tones. There will be ten tones in each series and within each series the tones will be of equal intensity. However, sometimes all the tones in a series will be loud and sometimes they will all be soft'.

The subjects were then given one presentation each of the high and low intensity tone, in an order that was determined randomly.

They were then told :

'Before each tone I will say "ready" and about three seconds later I will present you with the tone. As soon as you hear the tone I want you to press this key down as fast as you can using the forefinger of whichever hand you prefer. Don't press the key before you hear the tone. I'm going to give you three practice trials using a tone whose intensity lies in between the intensities of the loud and soft tones which you will get during the main test'.

The experimenter then gave the subject three practice trials using a tone whose intensity was 50 dB - i.e. intermediate between the intensities to be employed in the actual test (90 dB and 10 dB). The interval between the 'ready' signal and the presentation of tones was measured by means of a stop clock placed on the experimenter's table.

Reaction times for the practice trials are not included in the analysis.

Subjects were then told :

'I will at times change the lighting conditions in the room. Your task is the same at all times though , - i.e. to respond as soon as you hear the tone. Keep your eyes open throughout.'

The experimenter then presented the subject with the tones under the various accessory conditions employing the design described above. If the subject responded before a tone was presented (an 'anticipatory false alarm') the experimenter made a note of this and presented the tone again.

After the completion of the experiment, subjects completed form A of the Eysenck Personality Inventory with the experimenter present (though he did not look over the subject's shoulder).

As the experiment was of relatively short duration (approximately fifteen minutes on average) subjects were not paid for participation.

Before leaving, subjects were given the Eysenck Personality Questionnaire, Spielberger's inventory of trait anxiety and Cattell's 16 P.F. to complete in their own time. They were informed that the results of these, like those of the Eysenck Personality Inventory (E.P.I.), were absolutely confidential and they were asked to return them to the experimenter in sealed envelopes, which were provided, as soon as possible. However, very few of the subjects complied and so the results that are to be presented relate to the E.P.I. scores alone.

v) Results for simple auditory reaction time task

Results for simple auditory reaction time (LSCORE).

The following results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels), time of day (2 levels), accessory stimulation - 'condition' (3 levels), stimulus intensity (2 levels).

The reaction times were skewed and so a logarithmic (base 10) transformation was initially carried out. The results were analysed using a standard Genstat computer package which incorporates an adjustment for unequal numbers in the cells. This adjustment gives relatively greater weight to those cells containing a relatively large number of subjects. For this reason any of the following tables of means which involve more than one between subject factor (introversion, neuroticism and time of day) will contain the adjusted values.

a) The interaction of introversion and neuroticism is significant at the 0.1% level (one tail). Amongst introverts, low N subjects display a faster speed of response than high N subjects, whereas the reverse is true amongst extraverts. Also amongst low N subjects, introverts show a faster speed of response than extraverts, whereas the reverse is true amongst high N subjects.

	Low N	High N
Introverts	2.2537	2.3174
Extraverts	2.2702	2.2203

Table XI Showing interaction of introversion and neuroticism (LSCORE).

b) The interaction of introversion and time of day is significant at the 0.5% level (one tail). Amongst introverts, speed of response was faster 'early' in the day than 'later' in the day, whereas the reverse was true amongst extraverts.

	'Early'	'Late'
Introverts	2.2746	2.3030
Extraverts	2.2710	2.2259

Table X2 The interaction between introversion and time of day (ISOCRE).

c) The main effect for introversion is significant at the 0.5% level (2 tail). Overall extraverts show a faster speed of response than introverts.

Introverts	Extraverts
2.2896	2.2493

Table ^{x3} showing main effect for introversion (LSCORE).

d) The main effect for stimulus intensity is significant at the 0.1% level (2 tail). Overall speed of response is faster at the high intensity than at the low intensity.

Low Intensity	High Intensity
2.3038	2.2352

Table ^{x4} showing main effect for stimulus intensity (LSCORE).

Results for anticipatory false alarms

The following results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels) and time of day (2 levels). The number of false alarms was too low to make the inclusion of the 'condition' factor meaningful so the results are based on the total number of false alarms for the experimental session. The values thus obtained were skewed and so a square root transformation was carried out. An element of skewedness remained despite the transformation, but there were in any case no significant main effects or interactions.

vi) Discussion

The most important finding that emerges from the present study is the interaction between introversion and neuroticism for the speed of response measure. This is significant at the 0.1% level and is due to the fact that amongst introverts, low N subjects display a faster speed of response than high N subjects, whereas the reverse is true amongst extraverts. Also amongst low N subjects, introverts show a faster speed of response than extraverts, whereas the reverse is true amongst high N subjects.

This result provides very strong support for the view that introversion and neuroticism are determinants - i.e. that they move subjects in the same direction along the 'X' axis of the inverted 'U' curve. Furthermore, the fact that the main effect for introversion is also significant, with extraverts having a faster overall speed of response, provides further clarification of the study by Buckalew (1973). It will be remembered that in his study, extraverts were found, as in the present experiment, to have a faster overall speed of response compared to introverts.

Buckalew argued that his result constituted evidence against the hypothesis that the level of introversion is a determinant - or, as he put it, that introverts are more 'aroused' than extraverts. However, he did not manipulate any of the other proposed determinants, so his study, in our view, was inherently incapable of testing the inverted 'U' hypothesis. Furthermore, our present result indicates that if he had also investigated the N scores of the subjects he might have found an interaction between the two

personality dimensions and, therefore, arrived at a very different conclusion.

The fact that in the present study extraverts are faster overall than introverts also provides indirect evidence that the opposite finding in Cheng's study was not due to the presentation of the stimulus intensities in blocks rather than in a completely randomised fashion (see p. 490). There must, therefore, be an alternative explanation though the author has none to offer. However, as already stated such main effects are not particularly important by themselves.

The interaction between introversion and time of day is also highly significant (0.5% level) and is due to the fact that amongst introverts, speed of response was faster 'early' in the day than 'late' in the day, whereas the reverse was true amongst extraverts. This strongly supports the view that introversion and time of day are determinants.

All of these interactions can be explained in terms of an inverted 'U' hypothesis : i.e. by assuming that, at least in the condition corresponding to the highest combination of the factors involved, subjects had passed their T.T.I. However, there is a very important dis-

crepancy. Not only is the main effect for stimulus intensity highly significant, showing that overall subjects responded more quickly to the high than to the low intensity stimulus, but also there is no indication in any of the conditions in which T.I. appears to have taken place, that the reverse is true - i.e. that subjects respond less quickly to the high intensity stimulus than to the low intensity stimulus.

Such a reversal is what we would predict on the basis of our inverted 'U' model in its most general form, so the present results provide perhaps the clearest indication so far that stimulus intensity may be special and may not interact with the other proposed determinants as predicted.

We must also consider the relative paucity of effects involving accessory stimulation. We do have one result for the planned comparison between the 'dark' and the 'constant' condition, but this was only marginally significant. It is possible that the illumination was not sufficiently bright, though to have increased its intensity further might have been painful to the subjects.

A similar problem arises when we consider the variable accessory stimulus. For practical reasons it was not possible to make this as bright as the constant stimulus, and this means that comparison of the two accessory conditions would have been complicated by the confounding of the factors of variability and absolute intensity of stimulation. In any case, only two independent comparisons are possible amongst three conditions and it was the comparisons between the 'dark' or control condition, on the one hand, and the two accessory conditions, on the other,

that we were most interested in.

The low absolute intensity of the variable stimulus probably made it less likely that the corresponding comparisons would be significant. It is also likely that because the stimulus was variable, but still regular, its 'arousing' effect was less than it would have been if the light had flashed at irregular intervals. Another possibility is that its 'arousing' and distracting effects may have cancelled each other out, since we saw that decrements due to 'overarousal' and decrements due to 'distraction' were most likely to occur under opposite conditions : when the levels of the determinants are high in the first case and low in the second. All in all, though, whatever the explanation the scarcity of effects involving visual accessory stimulation indicates that the use of visual modality for the response stimulus and the auditory modality for the accessory stimulus may be a better combination.

We should also note the failure to find any significant interactions between stimulus intensity and the other proposed determinants - e.g. personality. This is in line with similar failures to find such interactions at conventional levels of statistical reliability in other studies conducted in the auditory modality (e.g. Zhorov and Yermolayeva-Tomina 1972). If we now conducted our joint reaction time/signal detection task using the visual modality for our response stimuli, we might be more likely to find such interactions (as did Mangan and Farmer 1967), and we might be able to determine whether it was due to sensory and/or criterial factors (the results of the present study can, of course, be interpreted in

terms of either). Furthermore, if we did find such an interaction it would provide indirect support for the view that modality differences may need to be taken into account when constructing theories in this area (a suggestion made by Mangan 1978, for example).

CHAPTER TEN : REACTION TIME AND SIGNAL DETECTION THEORY :
THE DESIGN AND EXECUTION OF A JOINT STUDY.

We have seen that our proposed joint simple reaction time and signal detection task would probably be most profitably conducted with the response stimulus presented in the visual modality. We must now consider its overall design and the detailed predictions for the measures we hope to derive from it.

1. OVERALL DESIGN:

We have already considered the choice of experimental factors to be employed in our joint task, and we will simply list them here:

Stimulus intensity, accessory stimulation, novelty, introversion, neuroticism, time of day.

All of these factors can be included directly in our experimental design for the simple reaction time experiment and in our subsequent analysis of variance of the results.

The situation is slightly different for the disjunctive or signal detection task. This is intended to provide measures of the criterion and of the slopes of the sensory growth functions. However, it will be remembered that the index derived from signal detection theory to measure sensory rather than response factors is the discrimination index (d^1). Under normal circumstances this provides a measure of the ability of the subject to discriminate between the presence of a stimulus ('signal') and its absence ('noise'). We argued in the introduction

to the taste experiment that d^1 is a measure of the gradient of the inverted 'U' curve rather than its absolute height (see pp. 218-20). In the situation described above, we would be measuring the average gradient of the inverted 'U' between the points corresponding to 'stimulus present' and 'stimulus absent'. Grice (1968) has shown, however, that signal detection theory is equally applicable to situations where the subject is required to discriminate between two suprathreshold stimuli. The value of d^1 would then correspond to the average gradient of the inverted 'U' between the points corresponding to these two stimuli.

We must decide whether to employ 'stimulus present' v 'stimulus absent' in our signal detection task, or, alternatively, to use two suprathreshold stimuli. The choice is governed by the fact that we wish the results of the task to be applicable to the results of the simple reaction time task. We have seen that of all the reaction time studies, perhaps the one which has proved most damaging to our hypotheses is that of Mangan and Farmer (1967), which showed that the gradient of the reaction time/intensity curve was greater in introverts than in extraverts.

We have advanced a detailed model to account for this and other findings, and it would seem to be judicious to try to test this model by replicating to a reasonable extent the general experimental set up employed by Mangan and Farmer. In their study a range of suprathreshold stimuli of differing intensities was employed. It would

seem sensible to employ a similar range for our simple reaction time experiment, and to use two suprathreshold stimuli located in the middle of this range for our signal detection task.

It should be noted that the d^1 measure derived from such a task would be an index not of the absolute slopes of the sensory growth functions for these two stimuli, but of the difference in the final levelling-off points of these functions. However, we argued elsewhere (see pp. 432-3) that it was reasonable to assume that the slope of a sensory growth function and its final levelling-off point are positively related to one another. Furthermore, the fact that the d^1 measure will reflect the difference between the characteristics of the two functions is in line with the fact that in Mangan and Farmer's study it was not the absolute reaction times that differentiated introverts from extraverts, but the difference between the reaction times to stimuli of varying intensity.

This brings us to the point that our two supra-threshold stimuli in the signal detection task will differ only in intensity, the subject being asked to respond to the brighter stimulus, but not the dimmer one. This means that although we are not actually employing stimulus intensity as a separate experimental factor in the signal detection task (unlike the simple reaction time task), the stimulus intensity factor will be there, nevertheless, 'concealed' within the discrimination index (d^1). So although stimulus intensity will not figure directly in our analysis of variance of the results of the signal detection task, the effect of the other factors on

the discrimination index will tell us about the relationship between these determinants and stimulus intensity. This will become clearer when we consider our detailed predictions for the joint task below.

2. PREDICTIONS

i) Simple reaction time task

Our predictions for the simple reaction time task are relatively straightforward and stem directly from our general model and from the preceding account of the processes deemed to underlie this particular measure.

a) General predictions

We would predict firstly an inverted 'U' relationship between the speed of response and the levels of the determinants employed (i.e. stimulus intensity, accessory stimulation, novelty (as revealed by the session factor), introversion, neuroticism and time of day). Such an inverted 'U' would be expected to manifest itself in the interactions between these determinants. The sort of interactions that the general model would predict have been dealt with already in detail elsewhere (see p.234) and they will not be repeated here.

b) Transmarginal inhibition

In order to determine whether or not transmarginal inhibition due to a rise in stimulus intensity occurs, and to see if it conforms to the prediction of the general model, we will also include a planned comparison between the highest and the second highest stimulus intensities. The prediction would be that if the subjects overall show evidence of T.I. due to stimulus intensity, the planned comparison associated with this factor would be significant and in the direction of a slower speed of

response for the highest than for the second-highest intensity. If on the other hand (as is more likely in view of previous failures to find such an effect in normal - i.e. non-psychiatric - subjects), T.I. only appears in certain subgroups and/or under certain experimental conditions, the general model would predict that the planned comparison would not be significant for the stimulus intensity main effect, but it would be for the interaction between stimulus intensity and the other factor(s) involved.

If so, then the model would predict that a fall in speed of response between the second-highest and highest stimulus intensity would either only occur in the combination which corresponded to the highest levels of the determinants which were involved, or, if it occurred for more than one combination, that the fall would be greatest in this 'highest' combination. This latter prediction depends on the assumption that the groups in question were operating on portion 'C' of the inverted 'U' (i.e. the right hand portion which is convex upwards) and not portion 'D' (i.e. the right hand portion which is concave upwards) - see p 83 .

This assumption would seem to be justified in view of previous findings which have failed to find T.I. at all. But even if it were not, it would be clear from the overall results which part of the curve the groups were operating on. To state the prediction more generally, one would expect that the combination with the highest levels of the determinants (e.g. the

'neurotic introverts' under 'noise' for the interaction between noise, neuroticism and introversion) would show the greatest fall if it were portion 'C' that was applicable, or the least fall if it were portion 'D' that was applicable.

ii) Signal detection task

a) General background

We come now to the predictions for the disjunctive reaction time task which for convenience we will henceforth refer to as the 'signal detection task' to avoid confusion with the simple reaction time task. The situation is a little more complicated here because we have five different measures:

- 1) The criterion
- 2) The index of discriminability
- 3) The probability of a hit - i.e. the probability of responding to the 'signal' (the brighter of the two stimuli and the one to which the subject is instructed to make a response)
- 4) The probability of a false alarm - i.e. the probability of responding to a 'non-signal' (the stimulus to which the subject is asked to make no response)
- 5) The speed of response.

From the point of view of interpretation of the simple reaction time data, the signal detection measures (nos (1) and (2)) are the most important. This was one of the main reasons which motivated the author to employ the signal detection task. However, to the extent that the general model is capable of generating predictions for the other measures (which it can), these are of value in their own right. We shall see, also, that they have a bearing on a number of specific but important theoretical issues.

The following predictions will be based jointly on the Russian interpretation of the hypothesised inverted 'U' and the postulates of signal detection theory. The reasons for this choice have already been discussed in detail, so we will not repeat them here. Suffice it to say that they provide the most parsimonious, consistent and intuitively plausible explanation of the data in this area. They are summarised in figure 43 and figure 44 below.

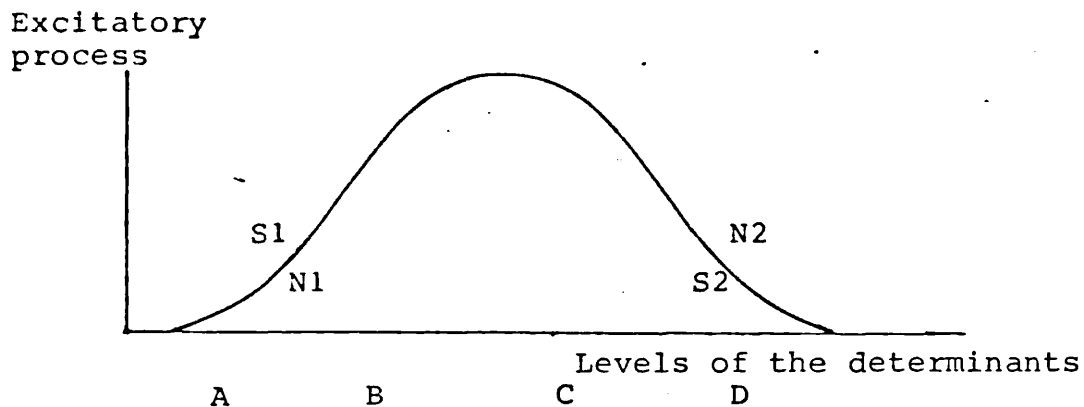


Fig. 43 The inverted 'U' hypothesis

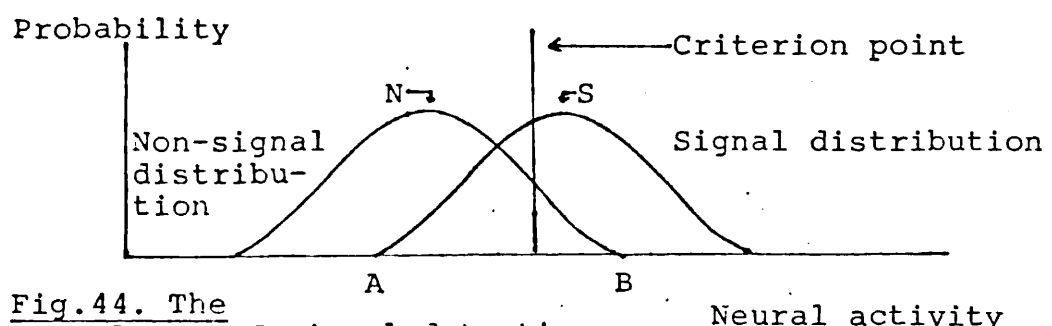


Fig.44. The postulates of signal detection theory.

Figure 43 shows the hypothesised 'U' shaped relationship (adapted to our general model) between the levels of the determinants and the level of the 'excitatory process', suggested by the Soviet workers (the meaning of the other symbols will be explained below).

The other graph normally presented with it, showing an essentially positive and monotonic relationship between the level of the 'excitatory process' and performance, has been replaced by the signal detection diagram in figure 44 because it is a fundamental contention of the present author that the term 'performance' has been used too vaguely, and that a more detailed analysis is required such as the one that is to be presented here. This does not mean that the present analysis is necessarily correct, but simply that if it is not, the aspects of it which are deficient will be clearly apparent and the necessary changes will be facilitated (a similar point has been made by Gray (1972) in his comparison of Western and Russian approaches to factor analysis).

To return to our diagram in figure 44, 'N' and 'S' represent the means of the 'noise' and the 'signal' distributions. In fact, as we have seen, in the task that we will employ, the subject will be asked to discriminate between two suprathreshold stimuli rather than between 'no-stimulus' ('noise') and 'stimulus' ('signal plus noise'). In the present context it means that 'N' refers to the mean of the 'non-signal' distribution (i.e. the distribution corresponding to the stimulus to which the subject is instructed to make no response), whilst 'S' refers to the mean ^{of the} 'signal' distribution (i.e. the distribution corresponding to the stimulus to which the subject is asked to respond).

The non-signal and signal differ only in intensity, with the signal being slightly more intense in objective terms than the non-signal. For this reason it is valid to represent the 'x' axis in figure 44 as a dimension of neural activity, and we will regard it in the present context as functionally equivalent to the 'y' axis in figure 43 (i.e. the excitatory process). The fact that different axes have been used to represent the same dimension in the two diagrams again stems from conventions that have been employed to date. To have flouted the conventions might have been confusing in itself since we have already employed both diagrams separately in their original form and since they are also widespread in the literature. The reader is also cautioned not to confuse the inverted 'U' in figure 43 with the non-signal and signal distributions in figure 44. Their similarity is coincidental and they refer to separate things.

Nevertheless we will try to show how the two diagrams are connected. To do this, consider the points N_1 and S_1 in figure 43. These correspond to the points N and S, respectively, in figure 44 - i.e. the means of the non-signal and signal distributions can be considered as corresponding to two points on the inverted 'U' relating the 'excitatory process' to the levels of the determinants. The fact that the signal distribution in figure 44 is further to the right along the 'x' axis than the non-signal distribution, is reflected in the fact that the point S_1 is higher than the

point N_1 in figure 43 . This correspondence stems from the fact that the intensity of the signal is in objective terms greater than that of the non-signal, and from the assumption that stimulus intensity is one of the determinants and interacts with the other determinants as predicted by the general model (of which figure 43 is an aspect).

This assumption is very important. It is one which we have seen has been challenged by certain results from other workers but also, more directly, by the results of the simple auditory reaction time experiment carried out by the present author (see p. 500). However, such contradictory evidence is not abundant so far . For this reason, and also because of the possibility that the results of the simple auditory reaction time task may have been specific to the auditory modality, we will retain the assumption for the present as part of our overall working hypothesis.

b) Detailed predictions

The exact positioning of the criterion is arbitrary in figure 44 . It could have been placed to the left of the point of intersection of the two distributions rather than to the right. Our hypothesis, in fact, is more concerned with the positioning of the signal and non-signal distributions themselves. Consider the effect of an increase in the levels of one or more of the determinants. This would result in a movement to the right along the 'x' axis of figure 43 and hence an increase in the heights of the points N_1 and S_1 , as predicted by the inverted 'U' curve - i.e. an effective movement upwards along the 'y' axis of this curve. But we have argued already that the 'y' axis of this curve (the 'excitatory process') corresponds to the 'x' axis in figure 44 ('neural activity'). Thus an increase in the levels of one or more of the determinants would result in a movement to the right along the 'x' axis of the signal detection diagram in figure 44 .

It will be remembered that the probability of a 'hit' corresponds to the proportion of the signal distribution which lies to the right of the criterion. If the criterion position remained unchanged on the 'x' axis, the result of an increase in the levels of the determinants would be (initially at least) an increase in the proportion of the signal distribution which lies to the right of the criterion and hence an increase in the probability of a 'hit'. Analogously the probability

of a false alarm is related to the proportion of the non-signal distribution which lies to the right of the criterion. An increase in the level of the determinants, therefore, would also be expected to result initially in an increase in the probability of a false alarm.

1) The criterion

The effect on the measured criterion is also easily predictable. The operational definition of the criterion is the ratio of the heights of the signal and the noise distribution. Let us imagine that the criterion in figure 44 was in fact placed initially at point A. At this position the height of the signal distribution is zero, so that the criterion would be infinitely low. Such a situation in which there are no 'misses' - i.e. no occasions on which the subject fails to respond to a 'signal' - poses problems for signal detection theory, though we will see that we can get round it if we make certain assumptions. If the criterion now moves to the right, the ratio of the heights of the signal and noise distribution will tend to increase, so the measured criterion will also increase. At point B, the height of the non-signal distribution is zero, so the criterion would be infinitely high. In such a situation, where the number of false alarms is zero, we can again perform certain adjustments to enable the criterion to be measured, and also to enable d' , the discrimination index, to be measured, since this too

depends on having non-zero values for both the probability of a 'miss' and the probability of a false alarm.

The important point to consider, however, is that as the 'true' or actual criterion moves to the right, so its measured value increases. In this situation, therefore, we have a positive, monotonic relationship between the actual criterion as measured in units of neural activity and the criterion as measured in operational terms. However, we argued earlier (following Welford, 1972) that a movement to the left of the signal and noise distributions is in terms of the operational measure equivalent to a shift in the actual criterion to the right. Such shifts are also equivalent in terms of the 'tendency to respond' which is negatively and monotonically related to the measured criterion. Equally, a shift in the criterion to the left is equivalent operationally to a shift in the distributions to the right. This is just what we have suggested would happen if the levels of the determinants were increased. The distributions would shift to the right, and there would be an increase in the tendency to respond (as evidenced by an increase in the probability of both a hit and a false alarm) and a fall in the measured value of the criterion.

It should be pointed out that we are assuming, effectively, that the criterion remains somewhere between the limits defined by the points A and B. It could

theoretically lie outside these limits, but if so the subject would be making a great many omissive errors ('misses') or commissive errors ('false alarms') both of which he would be instructed to avoid. Thus if we assume that the 'payoff structure' is roughly symmetrical (i.e. that avoidance of neither type of error is particularly heavily emphasised), an 'ideal observer' would set his criterion between A and B. Furthermore, to be consistent we must assume that the subject does behave like an 'ideal observer' since the postulates of signal detection theory are based on this concept.

So we see that although changes in ^{the} signal and the non-signal distributions would be the primary factor, if these movements were large, one might expect movements in the same direction by the criterion to follow in their wake to keep the criterion between A and B. If the subject is in fact determined not only to keep the criterion between A and B, but also to keep it in exactly the same position relative to the two distributions, one would expect no change in the measured value of this criterion. We have seen already that this measured value is inversely related to the tendency to respond. We will see when we come to consider vigilance later that there is evidence for a mechanism which is indeed designed to maintain the subject's level of responding.

However, there are several reasons why this fact does not negate our present hypothesis that the measured criterion will change as the levels of the determinants

change. Firstly and most importantly, the mechanism is designed to maintain a steady level of responding within subjects over the course of time (as in a vigilance task) - i.e. within a single session. The determinants that we will be mostly interested in consist either of between subject factors (such as introversion, neuroticism and time of day) or within subject factors (such as accessory stimulation), the different levels of which the subject receives in different sessions. It is difficult to see how the mechanism could operate across subjects, and the finding (e.g. Harkins and Geen, 1975) that different groups of subjects have different tendencies to respond argues against such a view.

Furthermore, even if it were possible for it to operate across sessions for the same subject, there are other reasons why its effect can largely be discounted. The mechanism proposed is a compensatory one. It operates on the principle of negative feedback or homeostasis. Negative feedback systems only attempt to compensate for a given change in some external factor (such as the level of accessory stimulation) because this factor produces a discrepancy between the desired and actual level of the control parameter (in this case the tendency to respond). In technical terms, the compensation that they effect is dependent on the existence of an "error signal" so they can only counteract such changes; they cannot obliterate them (unless they overcompensate and overshoot).

We will assume therefore that, in the present context at least, an increase in the levels of the determinants will initially produce a decrease in the measured value of the criterion. However, if the levels of the determinants continued to increase, the point of T.I. in figure 43 would be reached and the level of the 'excitatory process' would begin to fall. This would have two effects. Firstly, the signal and the non-signal distributions in figure 44 would stop moving to the right and start moving to the left. Thus the measured criterion would first fall and then rise as the levels of the determinants are increased. It is at this point that we part company from Welford, who suggests that the distributions will continue to move to the right, and that the measured criterion will continue to fall. We thus have described in detail a mechanism for our proposed inverted 'U' relationship between the tendency to respond (the reciprocal of the criterion) and the levels of the determinants, which we saw was capable of explaining so much of the simple reaction time data.

2) The discrimination index

The other main effect of passing the T.I. would be a reversal of the relative positions of the non-signal and signal distributions on the 'y' axis of figure 43 (represented in the extreme case by N_2 and S_2) and on the 'x' axis of figure 44. This is a necessary consequence of the assumption that stimulus intensity is one of the determinants and can be represented as

moving one to the right along the 'x' axis of the inverted 'U' in a manner analogous to the determinants. If this assumption is warranted, transmarginal inhibition in the tendency to respond would be accompanied by a greater number of responses to the non-signals than to the signals and a negative value of the discrimination index (if the parametric measure of the latter were used since for this measure a complete inability to discriminate is represented by the value zero).

However, if the assumption is not valid, and if such a reversal of the sign of d' does not occur, this does not detract in any way from our hypothesis of an inverted 'U' relationship between the tendency to respond and the levels of the determinants, since it is not dependent on this assumption. All we would have to do is to remove stimulus intensity from the list of determinants that could cause movement to the right along the 'x' axis of figure 43 . The other determinants could still have this effect and produce the corresponding changes in the absolute positions of the distributions in figure 44 .

We have already made some predictions, above, regarding the index of discrimination. For convenience we will refer to this as d' , though as we shall see there are grounds for considering a non-parametric measure also. The predictions, though, are the same in both cases.

If we assume that stimulus intensity is a determinant and therefore interacts with the other determinants in a manner predicted by the inverted 'U', it follows that d' will be proportional to the gradient of the inverted 'U' curve, so long as the two stimuli to be discriminated differ in terms of intensity. In figure 44 the value of d' is positively related to the separation of the non-signal and signal distributions. This horizontal separation, measured in units of neural activity, is the distance between N and S, and is equivalent to the vertical distance between the corresponding points on the inverted 'U' - e.g. N_1 and S_1 . This is because the vertical or 'y' axis of figure 43 (excitatory process) is regarded as being functionally equivalent to the horizontal, or 'x' axis of figure 44 ('neural activity'). The average gradient of the inverted 'U' between two points such as N_1 and S_1 is defined as the vertical separation of these points divided by their horizontal separation. Their horizontal separation is proportional to the objective difference in intensity between them, since on our assumption, stimulus intensity can be represented along the 'x' axis of the inverted 'U' in figure 43. If this difference in objective intensity is constant (which it is in the present experiment), the average gradient of the inverted 'U' between the points corresponding to the means of the non-signal and signal distributions will depend only on which part of the inverted 'U' these points lie on, since its curvature changes. This in

turn will depend on the levels of the other determinants. (ex hypothesi).

This is a complex argument, so we will summarise it briefly. The value of d' is proportional to the distance between N and S in figure 44. This itself is proportional to the vertical separation of the points N_1 and S_1 in figure 43. If the objective difference between the intensities of the signal and non-signal remains constant, the vertical separation of N_1 and S_1 depends only on the average gradient of the inverted 'U' between these points. The average gradient of the inverted 'U' depends on the levels of the other determinants. We thus reach the final conclusion that the value of d' depends on the levels of the other determinants. But the relationship is a complex one, since the gradient of the inverted 'U' alters in a complex fashion as we move to the right on the 'x' axis of figure 43. The expected change in d' is depicted in figure 45 below.

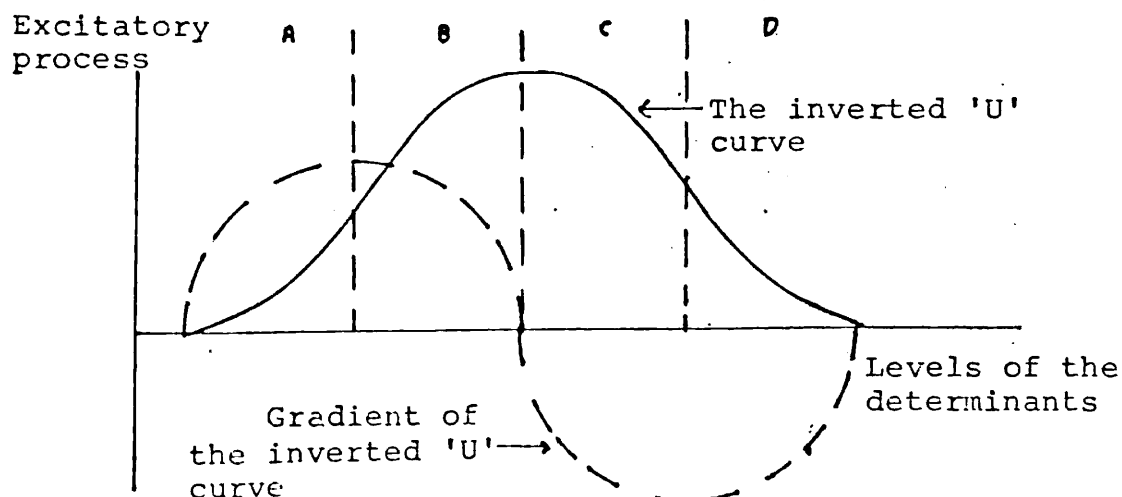


Fig. 45. Predictions for the discrimination index

The broken line function represents the value of the gradient of the 'excitatory process' curve and d' is proportional to the height of this function. In the initial position, when N_1 and S_1 lie on portion A of the inverted 'U', a movement to the right results in an increase in d' since the gradient of the inverted 'U' is increasing in this portion (i.e. the curve is concave upwards). The gradient reaches a maximum at the borderline between A and B after which both it and the value of d' begin to fall, reaching a value of zero at the T.T.I. Up to this point, however, the absolute value of the gradient and of d' is still positive - i.e. S_1 is still higher than N_1 in figure 43, and the subject, therefore, makes more responses to the signal than to the non-signal - i.e. more 'hits' than 'false alarms', since the signal distribution in figure 43 would lie further to the right along the 'x' axis.

However, once the T.T.I. had been passed, the gradient of the inverted 'U' would become negative, S_1 would lie vertically below N_1 , and d' would become negative. This is because the non-signal distribution would now lie further to the right along the 'x' axis of figure 44. As we moved further to the right, the value of d' would continue to fall as predicted by figure 45, and would reach its most negative value at the borderline between portions C and D. After this point (i.e. when N_1 and S_1 have become N_2 and S_2 in figure 43), the value of d' would still be negative, but it would start to rise and would reach a

value of zero if and when the inverted 'U' touched the 'x' axis. It should be pointed out that at both extremes of the 'x' axis the height of the inverted 'U' might not be zero, since the nervous system might still be expected to have some level of activity. However, it is difficult to envisage such situations, so it is preferable simply to consider the extremes as being indeterminate.

It is interesting to note that the fall in the value of d' after the border between portions A and B had been passed could be construed as T.I. if the latter is defined as a fall in performance following an initial rise as the levels of the determinants are increased. This is really only a question of semantics. By itself the presence of this apparent T.T.I. (at the border between portions B and C) poses no serious problems for the theory of 'strength'. This is because the measures used to define the two thresholds are quite different. D' is a measure of the gradient of the inverted 'U', whereas the measures which are usually used to define the 'true' T.T.I. depend on its absolute height. The above theory does not, therefore, indicate that there is more than one T.T.I. and that a conception of the latter in terms of a generalised lowering of responsiveness (such as is predicted by Gray's theory - 1964 op. cit.) is consequently incorrect. We will see that there are certain objections to such a conception, but this is not one of them.

The important thing is that the proposed mechanism underlying d' in this context should be clearly explained and that fairly unambiguous predictions regarding it should be made from the inverted 'U' hypothesis. In one sense the above analysis suggests that d' is a particularly good measure to use to test such a hypothesis, since it is highly sensitive to changes in the gradient of the curve. As we have seen, the direction of change in d' actually reverses even before we have passed the 'true' T.T.I. It would, for this reason, seem to be useful in an area (such as reaction time) in which 'true' T.I. effects are relatively rare.

However, there are certain problems associated with the discrimination index. Astonishing as it may seem, the picture presented in figure 45 and the accompanying analysis is in some ways an oversimplification. This is because the value of d' depends not only on the horizontal separation of the points N and S in figure 44 (i.e. the means of the signal and the non-signal distributions), but also on the variances of these distributions. Both an increase in the separation of the distributions and a decrease in their variances will reduce their degree of overlap and hence increase the value of d' .

Mackworth (1970) has tentatively suggested that the variances of the distributions will decrease as the level of 'arousal' increases. If this were so, and if we consider 'arousal' as she uses the term to be equivalent to the 'excitatory process' as we have used it,

then the relationship between d' and the levels of the determinants might appear to be more complicated than we have so far suggested. This is because the change in the overall level of the 'excitatory process' and the change in its gradient are related in a complicated way. We can see this simply by comparing the unbroken with the broken line in figure 45, since the former shows the way the height changes and the latter shows the way the gradient changes (i.e. the way the separation of the distributions changes). If the variances of the distributions are negatively related to the height of the inverted 'U' curve (i.e. to the level of the 'excitatory process') then d' will depend on the combined effect of both curves and not just on the broken curve (i.e. on the gradient).

What effect would this have on our predictions? In fact it would not alter them markedly. If Mackworth is right, the two factors (the separation of the distributions and the variances) will act in concert over portions A and C, since in both cases the two curves are changing in the same direction - both increasing in portion A and both decreasing in portion C. On the other hand, they will act in opposition over portions B and D, since here the curves are changing in opposite directions. The effect that this would have would be to leave the overall shape of the curve describing the relationship between d' and the levels of the determinants unaltered. Up to now we have assumed that the broken line represented this curve. The new curve

would have the same shape but it would have higher peaks and deeper troughs since, for instance, the additional effect of the unbroken curve would be to enhance its rise over portion A and then delay and retard its fall until at the point of T.T.I. both curves would be falling so that it would accelerate this fall from a higher level. Also, these peaks and troughs would not lie in the same place as those on the broken line but would be shifted towards the right.

Conversely, if Mackworth is wrong and the variance of the distributions is positively related to the level of the 'excitatory process', the peaks would be less high and the troughs would be less deep, and they would be shifted towards the left.

We have not attempted to draw such curves on figure 45 since their exact shapes and positions would depend on the exact shapes of the unbroken and broken curves which are hypothetical.

The important point is that so long as there is a linear relationship between the variances of the distributions and the level of the 'excitatory process', (whether positive or negative), the curve for d' will have roughly the same shape as the curve for the gradient (the broken line). It is, of course, possible that the relationship is not a linear one, but instead something more complicated. However, we will make this simplifying assumption. When we come to discuss the results for d' we will also employ the assumption that the actual positions of the peaks and troughs

of the curve for d' coincide with those of the broken line in figure 45 . But we make the *Qualification* here that this would only apply if alterations in the variances of the distributions have no appreciable effect on the value of d' . Since it is in fact the overall shape of the curve for d' which is the most important, violation of these assumptions would not be serious.

3) An adjustment to allow for transmarginal inhibition effects

In our above analysis, we suggested that if the 'true' T.T.I. were passed, the value of d' would become negative - in other words the non-signal distribution would lie further to the right along the 'x' axis of figure 44 than the signal distribution. This has certain complications for our theory regarding the criterion.

It will be remembered (see pp.516-20) that the criterion is defined as the ratio of the heights of the signal and the non-signal distributions and that this provided an inverse measure of the tendency to respond. The basis for this relationship is that if the actual criterion moves to the right from A to B in figure 44 (or if the distributions move to the left by an equivalent distance), both the tendency to respond decreases and the ratio of the heights of the signal and noise distribution increases (i.e. the measured criterion increases). However, this relationship holds only if the signal distribution lies further to the right along

the 'x' axis than the non-signal distribution. If their relative positions are reversed, the opposite relationship will hold - i.e. the tendency to respond will be positively related to the ratios of the heights of the signal and the non-signal distributions (i.e. the measured criterion).

This poses a problem. We have argued that if the Russian interpretation of the inverted 'U' is correct, the distributions will first move to the right and then to the left in figure 44, as the levels of the determinants are increased. This is because on the Russian interpretation the level of the 'excitatory process' first increases and then decreases. But how do we know that such alterations in the absolute positions of the distributions, and in the tendency to respond, have taken place? Answer: from the measured value of the criterion. However this only provides a valid measure of the absolute positions of the distributions and the tendency to respond, if the relationships between these two factors, on the one hand, and the measured value of the criterion, on the other, are invariant. We see that if the relative positions of the signal and non-signal distributions reverses, so does this relationship. We therefore must make an adjustment if we want the measured criterion to be a consistent index of the absolute positions of the distributions relative to the actual position of the criterion measured in terms of neural activity (which is itself related in an invariant fashion to the tendency to respond).

When we obtain the results of the experiment we will have two probabilities - the probability of a 'hit', and the probability of a 'false alarm'. Interpretations of signal detection theory invariably assume that the former is larger than the latter (i.e. that the signal distribution is further to the right in figure 44 than the non-signal distribution), and the formula for the criterion is therefore defined in terms of the probability of a 'hit' and the probability of a 'false alarm'. This will provide a consistent measure of the positions of the distributions relative to the actual criterion, only if the probability of a 'hit' is indeed greater than the probability of a false alarm. This is true under most circumstances. However, in our present project we are deliberately including as many of the determinants as possible in the hope that in certain combinations of these the threshold of T.I. will be surpassed. If this happened, though, in our present experiment the probability of a 'false alarm' would exceed the probability of a 'hit', so we must take this possibility into account.

The way to do this is to substitute the terms 'the higher probability' and 'the lower probability' for the terms 'the probability of a hit' and 'probability of a false alarm', respectively, in the formula for the criterion. If this substitution is made, the latter does provide a consistent inverse measure of the tendency to respond (and the positions of the distributions relative to the true criterion). To put it more simply,

where the probability of a false alarm exceeds that of a hit, we will, when calculating the value of the criterion, treat the probability of a false alarm as if it were the probability of a hit and vice versa.

4) Summary of predictions for signal detection indices

To summarise the argument so far: we predict an inverted 'U' relationship between the levels of the determinants and the tendency to respond, or alternatively, a 'U' shaped relationship between the levels of the determinants and the criterion, since the tendency to respond is defined as the reciprocal of the criterion.

We predict a more complex relationship between the discrimination index and the levels of the determinants, of the form depicted by the broken line in figure 45

Furthermore, if stimulus intensity interacts with the other determinants as predicted by the general model, the point at which transmarginal inhibition appears in the tendency to respond should coincide with the point at which the discrimination index becomes negative (assuming that the parametric measure is used) - i.e. the point at which the subject begins to make more false alarms than hits.

If these two points did not coincide (as would be implied if one effect appeared but the other did not), this would indicate that we could not include stimulus intensity with the determinants along the 'x' axis of the same inverted 'U' curve.

5) The probability of a hit and the probability of a false alarm

The predictions for the probability of a hit and the probability of a false alarm are easily derivable from the above analysis and do not depend on the assumption that stimulus intensity is a determinant, since stimulus intensity itself was held constant in the signal detection task and only the levels of certain of the other determinants were altered. We would predict an inverted 'U' relationship for both measures since as the levels of the determinants were increased, both the non-signal and signal distributions in figure 44 would move first to the right (thus increasing the proportions of each lying to the right of the criterion), and then to the left (thus decreasing the proportions of each lying to the right of the criterion). These movements are predictable from the inverted 'U' curve in figure 43 .

It should be noted that the expected relationship for the false alarm rate is contrary to what the earliest formulations of the inverted 'U' hypothesis in terms of 'performance' might predict. This is because a false alarm is an error, and an error could be regarded as an inverse measure of performance. On this basis we might have predicted a 'U' shaped relationship between the false alarm rate and the levels of the determinants. However, it is a cardinal tenet of signal detection theory that all types of error are not equivalent to each other and should not therefore be bracketed to-

gether or simply added to each other. Specifically, an 'omissive error' (i.e. a 'miss') and a 'commissive error' (i.e. a 'false alarm') will be inversely related to each other since if d' is constant, the number of omissive errors will decrease as the tendency to respond increases, whilst the number of commissive errors will increase. Since the probability of an omissive error is inversely related to the probability of a hit, we are predicting an inverted 'U' relationship between the levels of the determinants and the level of 'performance' if we define performance in terms of the number of omissive errors (i.e. misses). However, we are predicting a 'U' shaped relationship between the levels of the determinants and the level of performance if we define performance in terms of the number of commissive errors (i.e. false alarms). Our results will show whether the signal detection theory analysis, as we have presented it, is applicable or not.

6) Disjunctive reaction time

We come now to the final measure derived from the signal detection task: the disjunctive reaction time. We suggested earlier that simple reaction time depended on the slopes of the sensory growth functions and the level of the criterion. We also suggested that with the exception of stimulus intensity (for which only the sensory growth functions provide an adequate explanation), an inverted 'U' relationship between response speed and the levels of the determinants could be explained by an inverted 'U' between the latter, on the

one hand, and the slopes of the sensory growth functions or the tendency to respond, on the other. We also showed that there was a fair body of evidence to suggest that such an inverted 'U' did exist for simple reaction time.

Grice et al. (1976) have suggested that the mechanisms underlying disjunctive reaction time tasks (which is essentially what our signal detection task is) are more complex than those underlying simple reaction time tasks. However, in our discussion of this point we maintained that this was an area of relative uncertainty. Also Brebner and Flavel's (1978, op.cit.) disjunctive reaction time task did suggest that there was an inverted 'U' relationship between the level of introversion and the signal frequency/probability on the one hand, and the disjunctive speed of response on the other (we will argue in the section on vigilance that there are good grounds for considering signal frequency/probability to be one of the list of determinants). We also showed that we could explain these results quite adequately if we assumed that the processes underlying disjunctive reaction time were similar to those underlying simple reaction time. So whilst accepting the possibility that the former may indeed be more complex than the latter, we will adopt the working hypothesis that there will be an inverted 'U' relationship between disjunctive response speed and the determinants employed in our present experiment.

iii) The relationship between the simple reaction time and signal detection tasks

So far we have considered the predictions for the simple reaction time task and for the disjunctive reaction time task (signal detection task) separately. However, the rationale for combining them into a single experiment was to see if the signal detection indices derived from the latter - particularly the criterion - could help us explain the results from the former.

We argued at length that most differences in simple reaction time performance could be explained by differences in criterion levels as well as or instead of differences in the slopes of the sensory growth function. It should, incidentally, be pointed out that when referring to differences in criterion level we are really referring to differences in the vertical distance separating the criterion and the intercepts of the sensory growth functions - see figure 30 , p. 425 . Changes in this distance could be due either to changes in the criterion level and/or alterations in the intercepts. Our preceding account is based mainly on the latter possibility but operationally the two are equivalent.

Interpretations of simple reaction time data in terms of the slopes of the sensory growth function are valid only if the criterion either cannot be influencing the results (e.g. when stimulus intensity is being considered and where the stimulus intensities are presented in a random order), or where steps have been taken

to 'correct' statistically the data for the possible influence of the criterion. Workers in this area are becoming increasingly aware of the role of the criterion in measurements of the absolute sensory threshold (e.g. Edman et al., 1979), though many researchers ignore it. However, awareness of its role in simple reaction time is even more rare, so the assumption that it is the slopes of the sensory growth function that count is, therefore, implicit (though not explicit) in the approaches of many workers to reaction time data. Unfortunately, attempts to validate such an assumption in the manner described above are hardly ever found.

We will attempt to make good this omission by using an analysis of covariance technique to analyse the simple reaction time data which we will derive from the first half of our combined experiment. The criterion of the subject derived from the second half of the experiment will be the covariate. The basic assumption that we are making here is that whatever differences may exist between the simple reaction time task and the signal detection task, there is nevertheless a high degree of correlation between the criterion adopted by the subject in the simple reaction time task (which we cannot measure directly) and the criterion adopted by him in the immediately ensuing signal detection/disjunctive reaction time task (which we can measure directly). As will be seen, we will attempt to improve the chances of this assumption being valid by making the conditions under which the two tasks are con-

ducted as similar as possible.

If the assumption is valid, and if our theory about the nature of simple reaction time is correct, then the introduction of the criterion as a covariate should statistically eliminate its influence, and the altered 'F' ratios thus obtained should give a much more accurate representation of the influence of the slopes of the sensory growth functions. What the nature of this influence will be is predictable from our hypothesis of an inverted 'U' relationship between the slopes of the sensory growth functions and the levels of the determinants - i.e. an inverted 'U' relationship between these determinants and response speed.

Our alternative hypothesis of such an inverted 'U' between the tendency to respond and the determinants would predict the same and we have stated already that these two hypotheses may not be mutually exclusive. Nevertheless, if they are both true the two inverted 'U' curves involved will not necessarily be identical. Our previous account of the predictions for the signal detection task indices on their own would suggest that they are identical since the point at which the tendency to respond would be expected to start to fall is identical to that at which the value of d' would be expected to become negative. However, we pointed out that this account was based on the assumption that stimulus intensity and the other determinants could all be represented on the same 'x' axis of the same inverted 'U' function. If this is not a valid assumption,

it is still possible that there is an inverted 'U' relationship between the levels of the determinants and the slopes of the sensory growth functions, but its T.T.I. would be different from that describing the relationship between the determinants and other measures which are not dependent on stimulus intensity (e.g. the tendency to respond).

If so, then the effects of the levels of the determinants on simple reaction time would depend on the interplay between the criterion factor and the sensory growth function factor. Furthermore, we have suggested that under certain conditions, the tendency to respond may be under the influence of other factors such as the need to maximise the level of hedonic tone. For these reasons it is highly advisable to try to separate out the influences of the criterion and the slopes of the sensory growth function on simple reaction time. These influences might or might not coincide.

3. METHOD.

i) Subjects

Of the original 36 subjects who completed the taste experiment, thirty-five were available to take part in the joint reaction time/signal detection task. The remaining subject was a 'stable introvert' who left the University shortly before this task was due to begin and who was unable to participate in it, therefore.

ii) Design

Each subject completed two sessions separated by exactly one week. The simple visual reaction time task was conducted during the first part of each session. Six stimulus intensities (2000, 200, 20, 2, 0.2 and 0.02 lux.) were each presented twice within each of three blocks of trials. The intensity values chosen are the same as those employed by Mangan and Farmer (1967). The order of the stimuli in each block was completely random, and the blocks were separated by two minute intervals.

The simple visual reaction time task was immediately followed by the signal detection task in which the subject was required to discriminate between two visual stimuli whose characteristics, other than intensity, were exactly the same as those employed in the reaction time task and which differed from each other only slightly in intensity. They were labelled 'bright' and 'dim' and were located almost exactly in the middle of the range of intensities employed in the reaction time task, as measured on a logarithmic scale. Thus, if the six intensities employed in the latter (2000, 200, 20, 2, 0.2, 0.02 lux.) are denoted as 6, 5, 4, 3, 2 and 1, respectively,

the two intensities employed in the signal detection task can be denoted as 3.6 and 3.5. The absolute values were approximately 8 and 6 lux, respectively. The separation in the intensities of the two stimuli was chosen on the basis of pilot experiments which showed that they yielded measurable values of the signal detection indices and a reasonable spread across subjects.

The two stimuli were presented thirty-six times each, resulting in a total of seventy-two trials presented in sequence. An equal number (12) of 'bright' and 'dim' stimuli were presented in each of the trial groups 1-24, 25-48 and 49-72, but otherwise the order of the stimuli was completely random. Subjects were not informed of this restriction on randomness.

In both the reaction time and signal detection tasks the trial periods were delimited by the onset and offset of a tactile stimulus to the subject's non-preferred hand (see below). The duration of each trial was six seconds and the intertrial interval was fifteen seconds. The length of the trial and the position of the stimulus within it (see below) are the same as in the study by Mangan and Farmer (1967). The intertrial interval, however, was half that employed in the latter study. This was to increase the overall number of trials that could be presented in the limited time available. It was not decreased further, since the experimenter had to manually perform a number of operations in the intertrial period (see below).

One of the two sessions was carried out under 'quiet' conditions (55 dB white noise to mask extraneous sounds)

and the other under 'noise' conditions (90 dB white noise). The order of the noise conditions was counter-balanced within each of the four personality groups. The value of 55dB was the lowest that would still provide a masking effect, when average ambient noise conditions were taken into account. The value of 90dB was the highest that was safely permissible. This value is in absolute terms much greater than the corresponding 'noise' condition in the taste experiment. It will be remembered that a relatively low level was chosen in the latter to help obviate the possibility that apparent transmarginal inhibition effects might appear in the salivation index due to a direct effect on the autonomic nervous system (see p. 322). No such precautions were necessary in the present task.

Also, unlike the taste experiment, only one of the two noise conditions was presented in each session, since it was desirable both that the conditions under which the reaction time and signal detection tasks were conducted should be as similar as possible (including the level of accessory stimulation) and also that the number of trials presented in each condition should be large enough to yield meaningful and reliable values. Taking these considerations into account and the fact that, for practical reasons, the duration of each session had to be kept to about one hour, it was decided that it would be better that the two accessory conditions should be presented in separate sessions rather than in the same session.

Half of the subjects in each of the four personality groups were tested in the morning (one quarter began at 10.00 a.m. and one quarter at 12.00 noon), the other half in the afternoon (one quarter began at 2.00 p.m. and one quarter at 4.00 p.m.). There were, therefore, four subjects in each of the eight cells created by the crossing of the three factors introversion (2 levels), neuroticism (2 levels) and time of day (2 levels). Half of the subjects in each cell performed under 'quiet' in the first session (Group 1) and half under 'noise' in the first session (Group 2).

Subjects were assigned to the time of day condition and the group condition at random, unless a particular combination was already full. This meant that in all of the four quadrants, except the 'stable introverts' for whom only eight subjects were available in any case, there was one subject left over at the end once the combinations were all complete. These subjects were assigned at random to the time of day and group conditions. They were tested, since their scores for the gradient of the reaction time/intensity curve were required to analyse the results of the earlier taste experiment and the vigilance task which was to follow. The data for these subjects are not, however, included in the analysis of the results of the present study.

iii) Materials

The light stimuli were produced by directing the light from a projector in a control room through a 4" x 4" exposure panel into an adjacent experimental room. The two rooms were connected by an intercom system which enabled

the experimenter to hear what the subject said at all times. Subjects, however, could not hear any sounds that were made in the control room unless the experimenter pressed a switch. The subject was seated in the ^{experimental} room (at a distance of 2 m. from the panel) at a table (on which a morse key was placed) and facing the panel. The position of the projector (whose aperture was 1.5" in diameter) was adjusted so that in the absence of filters, the level of illumination on the panel in the experimental room was 2000 lux (as measured by a photometer). The other stimulus intensities were produced by the insertion of Kodak filters of densities 1, 2, 3, 4 and 5 in the projector. The only thing that was visible to the subject was the aperture of the projector. Great care was taken to ensure that the subject could gain no visual or auditory cues as to any changes in the filters between trials.

These conditions were essentially similar to those employed by Mangan and Farmer (1967). The latter used an auditory warning stimulus. Since the auditory modality was being employed in the present study to administer accessory white noise stimulation, a tactile warning stimulus, consisting of a lever which gently touched the top of the subject's non-preferred hand, was used.

Each trial was initiated by the contact of the lever with the subject's hand. This was followed 2 secs. later by the onset of the light stimulus due to the activation of the shutter of the projector. The light stimulus' duration was 2 secs. and its offset was followed 2 secs. later by the cessation of contact between the warning lever and the subject's hand. This signalled the end of

the trial. The intertrial interval was 15 secs. The sequence of stimuli was controlled electronically and reaction times were measured by standard apparatus.

The white noise stimulation was produced by playing a standard broad band white noise tape to the subject binaurally over earphones.

An attempt was also made to measure the subjects body temperature at the beginning and at the end of each experimental session. The deep core body temperature thermometer was not available so a clinical thermometer was used. Unfortunately, the results for body temperature were lost so elucidation of this point was not in fact possible.

iv) Procedure

When the subject arrived he was seated in the experimental room facing the exposure panel. If he was wearing a watch this was removed. He was then told:

'Please put on these earphones and keep them on throughout the experiment. Can you hear me clearly? (Subjects all stated that they could)

Later on I'm going to be playing you some noise which will sound like this.' The experimenter then entered the control room and switched on the white noise (set at the appropriate level for that session) for five seconds. He then returned to the experimental room and said:

'I will let you know before I turn on the noise during the actual test and if at any time when I do so you can't hear it let me know.

Are you right or left-handed?'

Depending on the subject's reply the morse key and the device which was to deliver the tactile warning stimulus were arranged on the table in front of the subject so that the key was opposite the subject's preferred hand and the warning stimulus was opposite his non-preferred hand.

'Please put your left/right hand (the subject's non-preferred hand) under this lever like this.' The experimenter then demonstrated by placing his hand underneath the lever which was to administer the tactile stimulus until it touched the base of the stand on which the lever was mounted.

The subject then did the same and the experimenter adjusted the height of the lever so that when it was in the 'down' position (i.e. when the tactile stimulus was activated) it just touched the top of the subject's hand, but did not do so when it was in the 'up' position (i.e. when the tactile stimulus was not activated).

'Please keep your hand in that position throughout.

In the first part of the experiment what is going to happen is that every now and then that lever will come down and gently touch the top of your hand. That is a signal to pay attention because shortly afterwards a light will come on in that window (the exposure panel) opposite. As soon as it comes on I want you to press that key down as fast as you can, but don't press it before the light comes on.

Please press it down once so that I know you understand.'

The experimenter then checked that the subject performed correctly.

'Shortly afterwards the light will go out and the lever will come back up. That whole sequence of events is called a trial : the lever coming down signals the beginning of the trial, the lever coming back up signals the end of the trial. There will then be an interval before the next trial. There will be a whole series of trials like that and in each trial there will be a light which I want you to respond to as fast as possible.

Please describe to me what is going to happen and what you are required to do so that I know you understand.'

The experimenter corrected any misunderstandings, though these were very rare.

'The lights will be of differing intensities, jumbled up in a totally random order. Every now and then there will be a somewhat longer period separating successive trials. Just rest during these periods. Please keep your forefinger lightly touching the top of the key throughout in readiness to respond.

Please do not alter the position of your chair and please do not lean forwards.

If you need to speak to me you just have to talk, the intercom picks it up and I hear you next door. Any questions?

Before we start I'd just like to take your body temperature.'

The experimenter then placed a clinical thermometer under the subject's tongue for two minutes and noted the temperature at the end of that period.

'Before we begin the actual test I'm going to leave you in here doing nothing for a short while to get your eyes accustomed to the darkness.'

The experimenter then switched off the light in the experimental room , left it, entered the control room and closed a pair of shutters over the exposure panel. Light was also prevented from entering the experimental room by a black drape over the door and by a blind over the window. The latter was slightly open to allow some ventilation to enter between the blind and the window frame on the side furthest from the subject. A small amount of light did also enter through this opening, but it was minimal and its extent was kept constant by fastening the blind appropriately.

The subject was dark adapted for ten minutes. At the end of this period the experimenter switched off the light in the control room and drew back the shutters from the exposure panel. The only light that entered the control room was from the window (which was partially covered with a blind) and this was just enough to enable the experimenter to carry out the various procedures described below.

Other than the light stimulus itself, virtually no light from the control room could enter the experimental room, in any case, due to the strategic positioning of heavy black cloth around the neck of the projector and over the periphery of the exposure panel.

The experimenter then pressed the intercom switch and said :

'In a moment we're going to begin. Remember the lever will come down and shortly afterwards the light will come on. As soon as it comes on I want you to press the key down as fast as you can. I'm now going to switch on the noise and then we'll start.'

The experimenter then switched on the white noise and ten seconds later activated the electronic digitimer which was to control the time sequence. Once the trial had ended the experimenter recorded the subject's reaction time, and pressed a switch that changed the filter in the projector to that corresponding to the next stimulus.

If an anticipatory false alarm occurred, the same stimulus was repeated. However, this was extremely rare and the number of such alarms was certainly too small to make any meaningful analysis possible, unlike the simple auditory reaction time task. This is in line with a modality difference of this kind found by other workers (see Nissen 1977).

At the end of each block of trials the experimenter switched off the digitimer, thus suspending the electronic time sequence, closed the shutters and switched on the light in the experimental room. He then removed the filters from the projector and replaced them with a new set in the correct (but random) sequence for the next block of trials. Two sets of filters were employed in an alternate fashion, instead of just one set, in case some fading occurred due to continued use. They were checked regularly with a photometer and no appreciable deviation from the prescribed values was found with time.

The changing of the filters took less than two minutes, but in order to standardise the time the experimenter waited till a full two minutes had elapsed before resuming. These two minute intervals between blocks were the 'somewhat longer periods' separating successive trials which were referred to in the initial instructions to the subjects.

At the end of the two minutes the experimenter switched off the light in the control room, opened the shutters and reactivated the electronic time sequence.

At the end of the third block of trials he switched off the white noise and said :

'Okay, that is the end of the first part of the experiment. There will be a short rest period before the second part begins.'

During this period the experimenter removed the original filters from the projector and replaced them with the two filters which were to be used in the signal detection task. These were placed adjacent to each other on the slide carriage of the projector so that they could be interchanged easily.

He then said :

'In the second part of the experiment there will be trials as before, but this time you will be getting one of two lights, and one of these lights - the 'bright' light - will be slightly brighter than the other one - the 'dim' light.

On each trial you will get either the bright light or the dim light. On any one trial the chance that it will be a bright or a dim light will be exactly the same, but I'm going to mix up the bright and the dim lights in

a totally random, jumbled up order so that you will not be able to predict beforehand whether the light is going to be bright or dim. Do you understand?'

'What I want you to do is this. If it is the bright light that comes on, I want you to press the key down as fast as you can as soon as it comes on, exactly like you did in the first part of the experiment. But if it is the dim light that comes on I don't want you to press the key. Do you understand?'

'Remember, I have taken every possible precaution to ensure that you will not be able to predict beforehand whether it is going to be bright or dim. You will, therefore, do best if you do not try to guess, but instead rely entirely on what the lights look like. Also do not fall into the trap of thinking that if there has been a run of several bright or several dim lights in a row that there is likely to be a change soon (this admonition regarding the 'gambler's fallacy' is recommended by Green and Swets 1974 for signal detection tasks). In a random sequence, such as the one you will be getting, anything is possible so just rely on what the lights look.

Could you repeat the instructions please to make sure you understand.'

Any misunderstandings were corrected, though this was rarely necessary.

'Now I'm going to show you the bright and the dim light four times each alternately, just to show you what they are like. Each time I will tell you beforehand which light you are going to get. During this period just watch, don't press the key.'

The experimenter then activated the timing sequence and presented the two lights alternately by changing the filter in the projector between trials by means of appropriate manipulation of the buttons on the projector's control device.

He informed the subject beforehand which light he was about to receive. Which of the two lights was presented first was determined randomly.

He then said :

'I emphasise that the alternating pattern that you have just had was simply to show you the difference between the two types of light. In the actual test the sequence will be totally random. Remember, press the key as soon as possible if it is the bright light that comes on, but don't press it if it is the dim light that comes on.

I'm going to turn on the noise and shortly afterwards we'll begin.'

The experimenter then checked that the filter corresponding to the first stimulus in the pre-determined random sequence was in the projector. He then switched on the white noise and ten seconds later activated the time sequence.

He noted the trials on which the subject responded and the response time. Between trials he altered the filter in the projector appropriately where two adjacent stimuli in the sequence were different (i.e. where one was 'bright' and the other was 'dim').

At the end of the seventy-two trials, he suspended the time sequence, switched off the noise and entered the experimental room. Having switched on the light he

measured the subject's body temperature again. If the subject had had a watch it was returned to him.

If it was the subject's first session, he was reminded of the second session and given a copy of the E.P.Q. to take away, complete in his own time and bring back on the occasion of the second testing. Nearly all of the subjects did this and the remainder returned the completed E.P.Q. to the experimenter within a few days of the completion of the second session. As a result introversion, neuroticism and psychoticism scores obtained at approximately the same time as the experiment was conducted, were available for all subjects.

At the end of the second session, the subject was given the E.P.I., Spielberger's trait anxiety inventory and Strelau's questionnaire to take away, complete in his own time and return to the experimenter.

These questionnaires were not given to the subject at the same time as the E.P.Q. because the latter was particularly important (see later) and previous experience suggested that subjects often did not return questionnaires if many were given at one time, especially if some were long (as the Strelau questionnaire, for instance, was). Not unexpectedly, therefore, whilst all subjects returned the E.P.Q., not all of the subjects returned the other questionnaires, so the results for these will not be presented.

At the end of the second session subjects were paid at the rate of 60p per hour.

CHAPTER ELEVEN- REACTION TIME

AND SIGNAL DETECTION THEORY: RESULTS AND

DISCUSSION



1. E.P.I. ANALYSES

i) The signal detection task

a) Results

The results for the signal detection task will be presented first since they will help to clarify the results of the simple visual reaction time task. They are based on the subject's EPI scores measured prior to the taste experiment (see p. 250).

An analysis of variance of introversion (2 levels), neuroticism (2 levels), accessory stimulation - 'noise' (2 levels), time of day (2 levels), and session (2 levels) was carried out on each of the following indices (calculated separately for each noise condition):

The non-parametric measure of the criterion

The values for this can vary from -1 to +1. A relatively high value indicates a relatively low tendency to respond. Its formula is as follows (Grier, 1971):

$$BE = \frac{Y(1-Y) - X(1-X)}{Y(1-Y) + X(1-X)}$$

where Y = the probability of a hit

and X = the probability of a false alarm (see below).

For reasons which have already been stated (see pp. 529-31) where the probability of a false alarm exceeded the probability of a hit the value of Y was set equal to the former and the value of X was set equal to the latter (i.e. the reverse of the relationships shown above). This only happened in three cases (out of a total of sixty-four: thirty-two subjects with two noise conditions each): for

The actual values obtained were skewed, so a transformation was carried out based on a suggestion by J. Valentine (personal communication) and McNicol (1973). The actual value of the criterion is called 'EE'. The transformed value is called 'TEE'.

$$TEE = 2 \times \text{Arcsin} \left(\sqrt{\frac{EE + 1}{2}} \right)$$

The analysis of variance was carried out on the transformed value - i.e. TEE.

The parametric measure of the criterion, which is the more normal measure, was not used since the signal detection task has certain similarities to a visual vigilance task and it has been pointed out that (e.g. Mackworth, 1970) in such experiments the assumptions underlying parametric signal detection indices may not be valid (for instance the assumption that the signal and noise distributions in Fig. 44, p. 511, have equal variances).

The non-parametric discrimination index

This will be referred to as 'DY' and its formula is as follows (Grier, 1971):

$$DY = 0.5 + \frac{(Y - X)(1 + Y - X)}{4 Y (1 - X)}$$

where Y = the probability of a hit

and X = the probability of a false alarm.

When $X = Y$ (i.e. when the subject's ability to discriminate successfully between the signals and the non-signals is zero), DY has a value of 0.5. If $X > Y$ (i.e. if the probability of a false alarm is greater than the probability of a hit) the correct value of DY can be obtained by subtracting the value obtained using the above formula from 1 (McNicol, 1973), having first reversed the values of X and Y .

The non-parametric discrimination index was used, again, because of the possibility that the assumptions underlying the parametric measure may have been violated. However, McNicol (1973) has pointed out that the non-parametric discrimination index tends to underestimate the true value when the subject is biased either in favour of making responses or in favour of not making responses (a subject who had no such bias would have a criterion located at the point of intersection of the signal and non-signal distributions in Fig.44, p.511. His non-parametric criterion measure would have a value of zero). As an additional check, therefore, the parametric discrimination index was also calculated using a formula based on the 'standardised normal 'z' scores' for the probability of a hit and the probability of a false alarm (McNicol, 1973. See Appendix B). When the probability of a false alarm exceeds the probability of a hit the parametric discrimination index has a negative value.

Since the values obtained were skewed it was necessary to transform the results. This was not possible for the three negative results as they stood and so a constant of 0.23 was first added to all of the sixty-four values rendering them all positive. A square root transformation was then carried out (the resulting values will be referred to as SPR). The whole procedure was based on a recommendation by J. Valentine (personal communication).

c. The probability of a hit

This will be referred to as 'PH'. Its formula is:

$$PH = \frac{\text{Total number of responses made to signals}}{36}$$

where a 'signal' is a 'bright' light (see p.505).

The value of the denominator is 36 because, as stated earlier, the values were calculated separately for each noise condition and there were 36 signals in each noise condition.

The probability of a false alarm

This will be referred to as PF. Its formula is as follows:

$$PF = \frac{\text{Total number of responses made to non-signals}}{36}$$

where a 'non-signal' is a 'dim' light. There were 36 non-signals in each noise condition.

The results for the disjunctive reaction time will be presented separately.

All of the results were analysed using a standard GENSTAT computer package.

Results for the non-parametric criterion (signal detection task)

The main effect for neuroticism is significant at the 1% level (2 tail). Overall, high N subjects responded more readily than low N subjects.

High N	Low N
1.401	1.525

Table B1. The main effect for neuroticism (TBE).

Results for the non-parametric discrimination index (signal detection task)

a) The interaction of neuroticism and time of day is significant at the 5% level (one tail). In the morning, high N subjects discriminated better than low N subjects, whereas the reverse was true in the afternoon. Also, low N subjects discriminated better in the afternoon than in the morning, whereas the reverse was true for high N subjects.

	Morning	Afternoon
High N	0.715	0.644
Low N	0.669	0.691

Table B2. The interaction of neuroticism and time of day (DY).

b) The interaction of session and time of day is significant at the 2.5% level (one tail). In the morning subjects discriminated better in session 1 than in session 2, whereas the reverse was true in the afternoon. Also, in session 1, subjects discriminated better in the morning than in the

afternoon, whereas the reverse was true in session 2.

	Morning	Afternoon
Session 1	0.698	0.625
Session 2	0.686	0.709

Table B3. The interaction of session and time of day (DY).

c) The interaction of noise, session and introversion is significant at the 5% level (2 tail). See discussion.

	Session 1		Session 2	
	Introverts	Extraverts	Introverts	Extraverts
No Noise	0.708	0.648	0.660	0.710
Noise	0.585	0.706	0.713	0.708

Table B4. The interaction of noise, session and introversion (DY)

d) The interaction of introversion, neuroticism and time of day is significant at the 5% level (2 tail). The reader is referred to the discussion for further consideration of this result.

Results for the parametric discrimination index (signal detection task)

The results for this measure are identical to those for the non-parametric measure (DY) so they will not be presented here.

Results for the probability of a hit (signal detection task)

The interaction of noise, session and time of day is significant at the 5% level (2 tail). See discussion.

	Session 1		Session 2	
	Morning	Afternoon	Morning	Afternoon
No Noise	0.674	0.694	0.740	0.687
Noise	0.736	0.618	0.674	0.757

Table B5. The interaction of noise, session and time of day (PE)

Results for the probability of a false alarm (signal detection task)

a) The main effect for neuroticism is significant at the 2.5% level (two tail). Overall, high N subjects recorded more false alarms than low N subjects.

High N	Low N
0.5052	0.4392

Table B6. The main effect for neuroticism (PF).

b) The interaction of noise and introversion is significant at the 2.5% level (2 tail). Under 'no noise' extraverts are more likely to record false alarms than introverts, whereas the reverse was true under 'noise'. Also, introverts are more likely to record false alarms under 'noise' than under 'no noise', whereas the reverse was true for extraverts.

	Introverts	Extraverts
No Noise	0.4514	0.4983
Noise	0.4983	0.4410

Table E7. The interaction of noise and introversion (PF).

c) The interaction of noise, session and time of day is significant at the 5% level (2 tail).

	Session 1		Session 2	
	Morning	Afternoon	Morning	Afternoon
No Noise	0.3958	0.5347	0.5035	0.4653
Noise	0.5000	0.4896	0.4375	0.4514

Table B8. The interaction of noise, session and time of day (PF)

d) The interaction of noise, session and neuroticism is significant at the 2.5% level (2 tail).

e) The interaction of noise, session, introversion and neuroticism is significant at the 1% level (2 tail).

Further consideration of (d) and (e) will be postponed until the discussion.

b) Discussion of results of the signal detection task

The criterion

The most striking finding that emerges from the signal detection task is the highly significant effect of neuroticism on the response criterion. High N subjects have a greater tendency to respond than low N subjects. Such a finding is difficult to explain in terms of a hedonic tone model alone, since this would predict a negative relationship between the determinants (of which neuroticism is presumed to be one) and the tendency to respond. It is also out of line with studies on the relationship between the degree of stimulation sought by individuals in motor tasks (e.g. Elias 1973), which suggest that high N subjects seek less stimulation than low N subjects in such situations. However, we argued earlier that the need to maximise the level of hedonic tone was not the only factor which is relevant here.

The present finding is also out of line with the suggestion made by Edman et al. (1979) that high N subjects adopt higher criteria than low N subjects. However, shocks were used in their study and although the level of stimulation was low, it is quite likely that some degree of 'threat' was involved. Gray (1970) has argued that under such conditions the 'behavioural inhibition system' (B.I.S.) is activated and furthermore that the ease with which it is activated could be greater in subjects who were high on introversion and/or neuroticism, especially the latter. If we assume that under conditions of threat the behavioural inhibition system re

sults in a raising of the response criterion, Edman et al.'s finding becomes more explicable.

It could be argued that the higher criterion level amongst introverts (compared to extraverts) in the study by Harkins and Gaten (1975 op. cit.) could also be explained in terms of the action of the B.I.S. on the response criterion. However, the criterion is lower in high N subjects than in low N subjects in the present study, despite the fact that the activity at the B.I.S. is thought to be more closely related to neuroticism than to introversion. A more consistent overall explanation of the results from all the above studies therefore is to suggest that the B.I.S. only exerts a significant influence on the response criterion when a measure of 'threat' is involved.

It is interesting to note that this argument bears certain similarities to the suggestion made by some investigators that the dimension of 'strength' or 'arousability' influences the speed of conditioning only when the levels of stimulation are extreme. At all other times speed of conditioning may depend largely upon other factors such as 'dynamism' or 'susceptibility to reward and punishment'. Here we have the other side of the coin: susceptibility to punishment, as determined by the B.I.S., seems to influence the response criterion only when the level of punishment involved is relatively high. At all other times the response criterion depends on the 'strength/arousability' dimension.

It should be noted that in the present experiment, and in the study by Harkins and Geen the element of reward and punishment was minimal. The present author did pay the subjects, but this was only for agreeing to participate. Although he did exhort subjects to do their best, performance-contingent reward and punishment were totally absent and no feedback was given to the subjects about their performance, so this too could not have been construed as being either rewarding or punishing, though subjects may themselves, of course, have come to conclusions about their own performance.

It is still necessary, though, to explain why a significant difference between introverts and extraverts on the criterion measure was found by Harkins and Geen (1975) but not in the present study. One possible reason is that Harkins and Geen employed a signal frequency which was somewhat lower than that in the present experiment. It is possible that under these conditions extraverts are placed at a relative disadvantage in terms of hedonic tone and adopt a relatively low criterion to compensate.

Let us return to the finding that high N subjects in the present study adopted a lower criterion than low N subjects. This result is consistent with the suggestion made by Welford that at high levels of 'arousal' the response criterion would be relatively low, and with a similar suggestion made by Duffy (1962) that subjects with 'labile' autonomic nervous systems would display a relatively large number of commissive errors in reaction time tasks.

Lacey and Lacey (1958) had indeed found that this was so (although Kok, 1975 later failed to confirm this) and Eysenck (1967) has argued that high N subjects have relatively labile autonomic nervous systems. Furthermore, Kok (op. cit.) did find a positive correlation between neuroticism and the number of commissive errors in a choice reaction time task. As we will see, a similar result was obtained in the present task, and it is likely that this is related to the difference in the criterion between the low and high N subjects.

However this difference by itself does not support the view that there is an inverted 'U' relationship between the determinants and the tendency to respond, and in the present set of results, at least, there is no other evidence in favour of this hypothesis. It is possible that the levels of the determinants were not sufficiently high to reveal transmarginal inhibition for the criterion, which we suggested earlier would be less sensitive to such effects than other indices such as the discrimination index (see p. 526). It is to this measure that we will now turn.

b) The discrimination index

The results are identical for the non-parametric and the parametric measure so we will refer to the index as d' .

The most noticeable finding is that the interaction between neuroticism and time of day is significant at the 5% level (one tail). This is due to the fact that in the morning, high N subjects discriminated better than

low N subjects, whereas the reverse is true in the afternoon. Also, low N subjects discriminated better in the afternoon than in the morning, whereas the reverse was true for high N subjects.

This is in line with the inverted 'U' hypothesis, but as has been seen there was no corresponding interaction for the tendency to respond. This is not, in fact, surprising since we have shown that d' is a measure of the slope of the inverted 'U' (assuming that stimulus intensity does interact as predicted with the other determinants), and that apparent transmarginal inhibition effects can, therefore, occur using this index even though the peak of the curve (the true T.T.I.) has not been passed.

The interaction of session and time of day is 'significant' at the 2.5% level (one tail). In the morning, subjects discriminated better in session 1 than in session 2, whereas the reverse was true in the afternoon. Also, in session 1, subjects discriminated better in the morning than in the afternoon, whereas the reverse is true in session 2. These results are exactly what we would predict assuming that novelty (which would be greater in session 1 than in session 2) and time of day are both determinants. But again there is no evidence in any of the groups that subjects **overall** responded more frequently to the non-signals than to the signals - i.e. that the true T.T.I. had been passed.

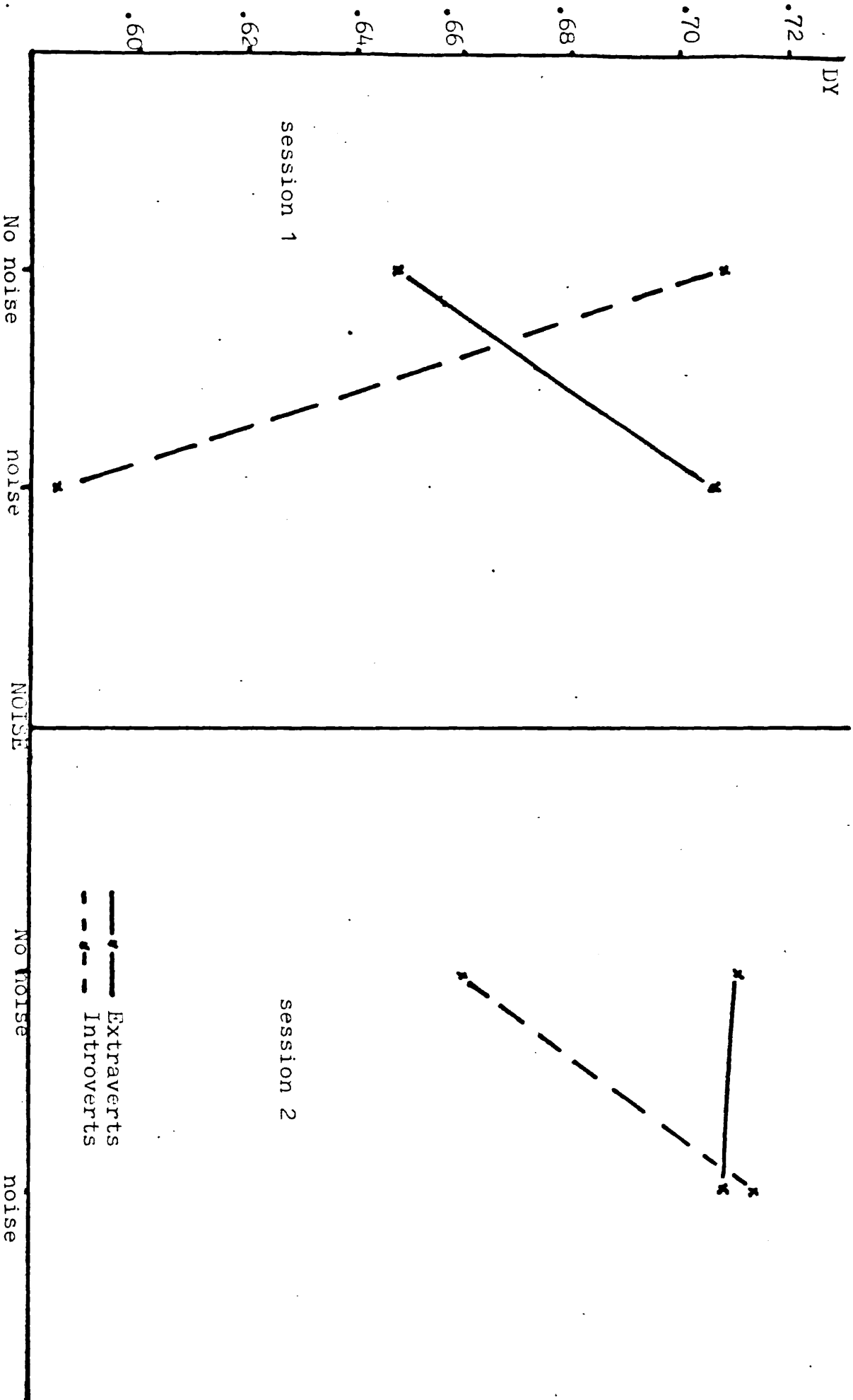
Two remaining interactions for d' must be reported here. Both are high order interactions involving three factors and both are significant at the 5% level.

The first interaction is between noise, session and introversion and is depicted in graph B(1). In many ways the results are in line with the prediction that up to the T.T.I., at least, there is an inverted 'U' relationship between d' and the determinants (see p.523).

In session 1, where the level of novelty of the task is relatively high, we might expect the introverts, at least, to have reached portion 'B' of the curve (i.e. the part which is convex upwards) and hence to show a greater value of d' in the 'no noise' than in the 'noise' condition (since d' depends on the gradient of the inverted 'U'), whilst the extraverts might be expected to show the reverse. The results fit in with these suggestions.

However, the results for session 2 are not so amenable to interpretation in terms of an inverted 'U'. Although introverts might be expected to show an increase in d' due to 'noise' when the level of novelty is rela-

B1 The interaction of noise, session and introversion (DY)

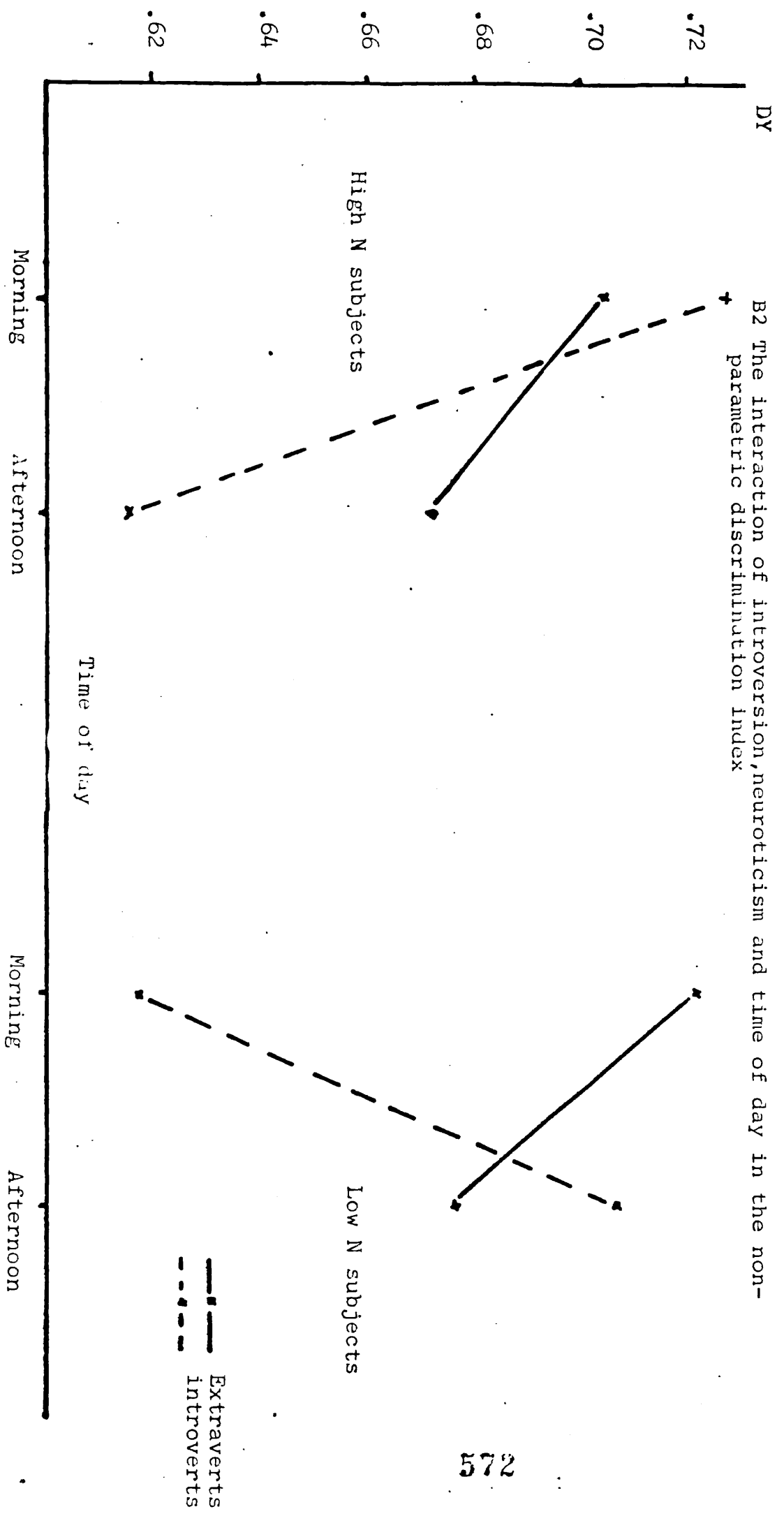


tively low, the fact that the extraverts show a higher overall level of d' than the introverts is not in line with prediction and the author has no adequate explanation for it.

Another aspect of the results which seems discrepant is the fact that the overall levels of discriminability are higher in session 2 than in session 1. This can be explained, however, by a learning effect - i.e. it is possible that performance in session 2 is superior to that in session 1 because subjects have to some extent learnt how to discriminate between the signals and the non-signals, though the exact mechanism is unclear since they received no feedback from the experimenter as to the correctness or otherwise of their responses.

The last interaction to be considered in this section is between introversion, neuroticism and time of day and is depicted in graph B(2).

Many features of this interaction are quite contrary to prediction, for instance the fact that amongst low N subjects, introverts show a sharp increase in discriminability from morning to afternoon, whereas the reverse is true for extraverts. The author has no explanation for this interaction, so it will not be considered further.

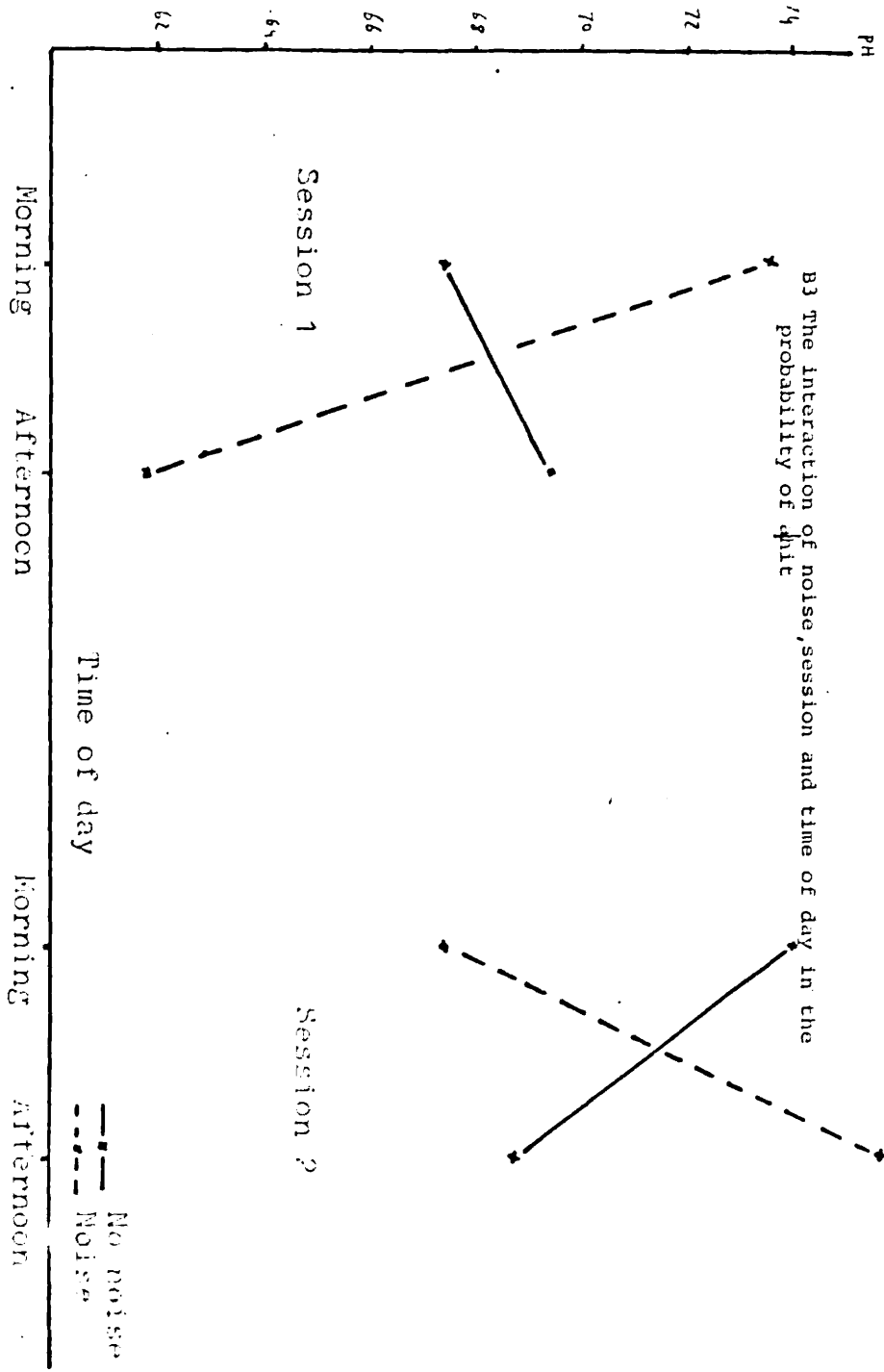


We will now consider the findings from the signal detection task which relate to the probability of a 'hit' and the probability of a 'false alarm'. These refer, respectively, to the probability of making a response to a signal (i.e. in this case the brighter of the two stimuli) and the probability of making a response to a non-signal (in this case the dimmer of the two stimuli).

3. The probability of a hit

The interaction of noise, session and time of day is significant at the 5% level (2 tail). This is depicted in graph B(3). At first glance the results might seem explicable. The relationships in session 1 and the higher level of performance in the afternoon than in the morning in the 'noise' condition in session 2, are not out of line with the theory. However, the fact that performance is much worse in the afternoon than in the morning in the 'no noise' condition of session 2 is unexpected when taken in conjunction with the other relationships depicted in the graph.

It will be remembered, though, that in the present study a repeated measures design was used in which half the subjects carried out the 'no noise' condition in



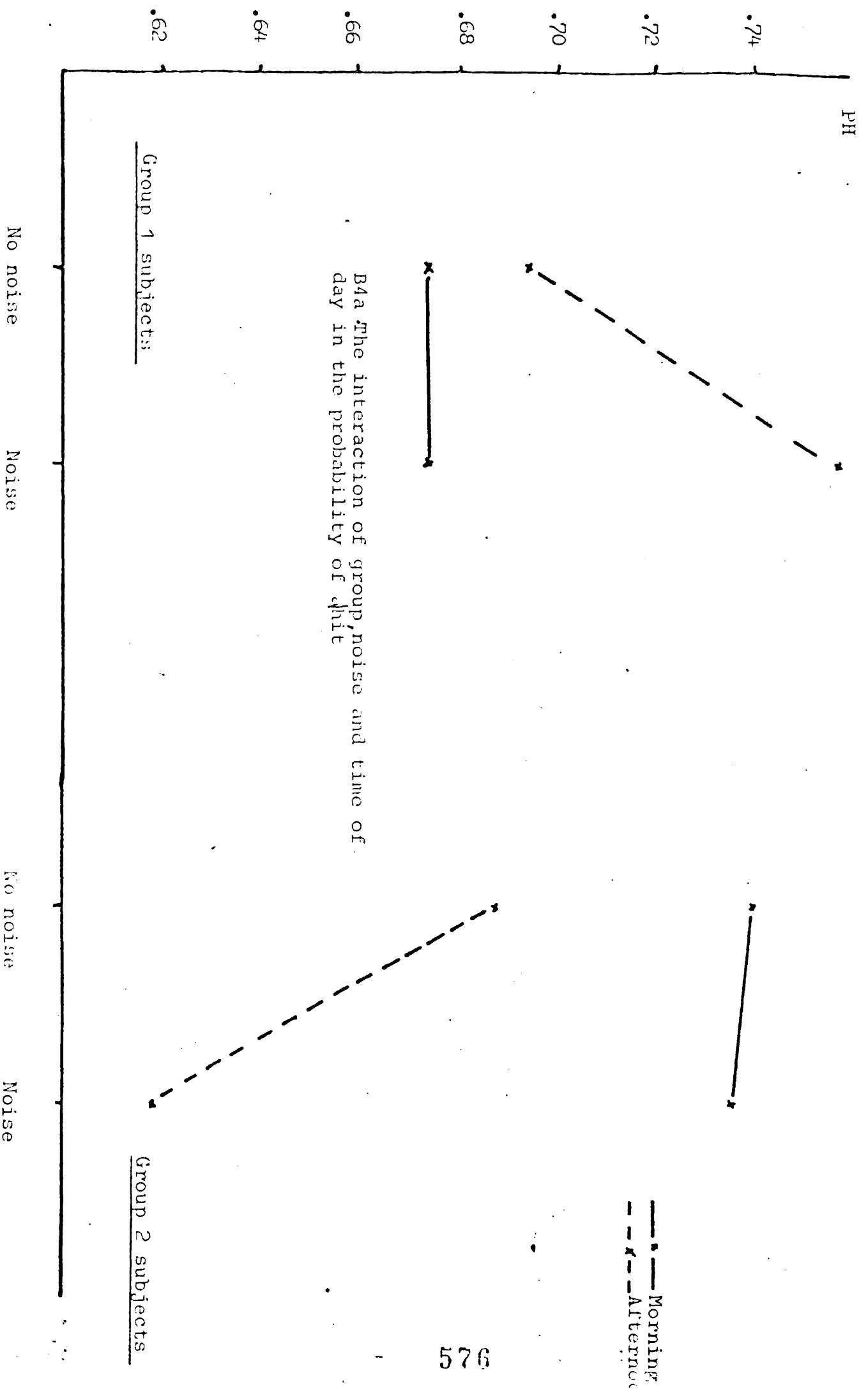
session 1 and the 'noise' condition in session 2 (Group 1) whereas the other half (Group 2) performed the two noise conditions in the reverse order. Thus the factors of group, session and noise condition are unavoidably confounded with each other (reasons why a repeated measures design was necessary for the present project have already been stated: see p.172).

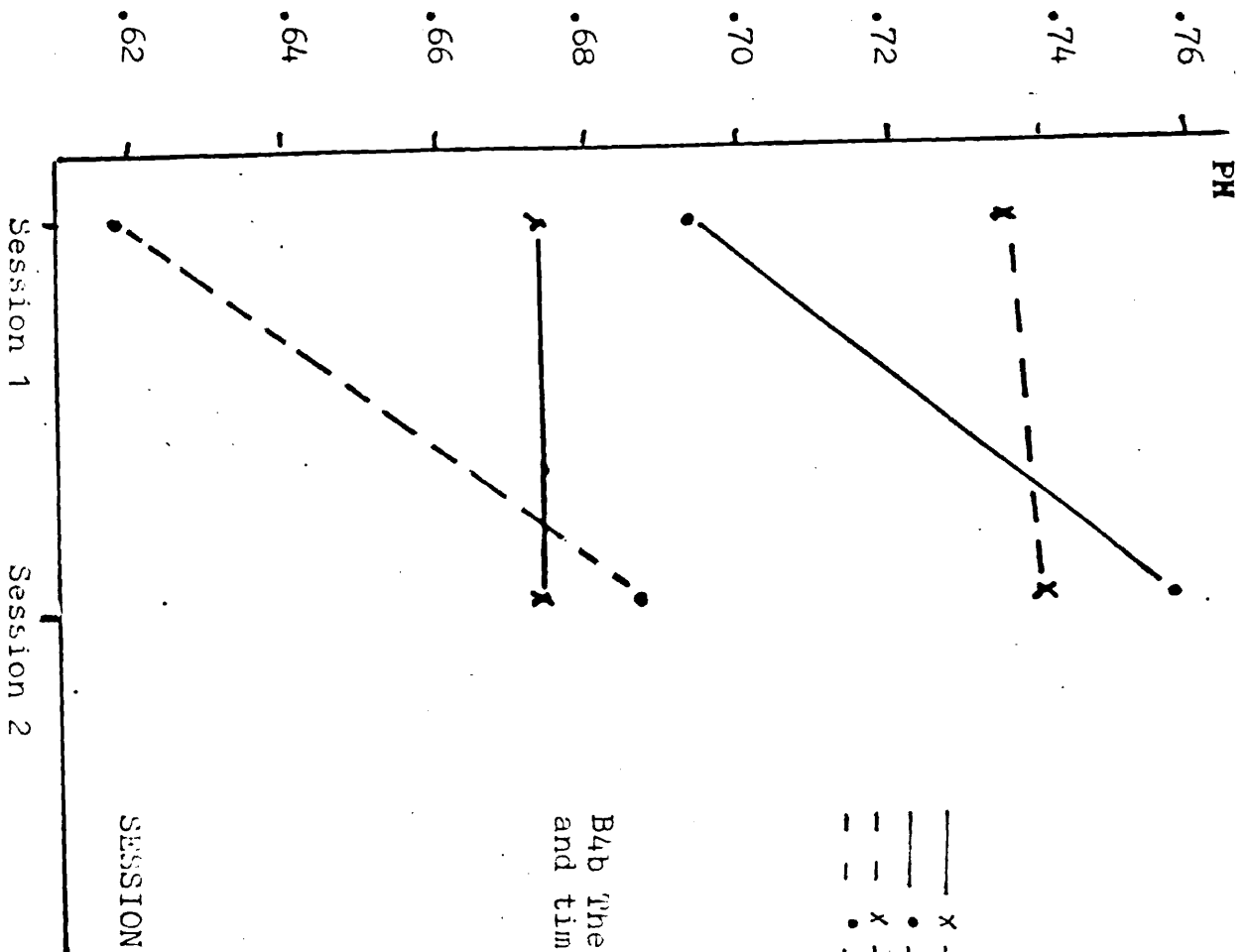
It was decided to include the factors of noise and session in the present analysis since they were of theoretical interest, whilst the factor of group was not. However, the group factor is concealed within interactions involving both noise and session, and the table below shows the results of the present interaction re-arranged to show its influence.

The interaction of noise, session and time of day in the probability of a hit (signal detection task), rearranged to show the effect of order of testing (Group):

	<u>Session 1</u>	<u>Session 2</u>
Group 1	No Noise	Noise
Morning	0.674	0.674
Afternoon	0.694	0.757
Group 2	Noise	No Noise
Morning	0.736	0.740
Afternoon	0.618	0.687

Graph B(4)a depicts the results of the interaction with the group factor included and the session factor excluded. and graph B(4)b depicts the results with the noise factor excluded. We see now that the interaction could be interpreted in terms of the differential effect of time of day, session and noise on the two different groups of subjects.





— x — Group 1, morning
 — • — Group 1, afternoon
 - - x - - Group 2, morning
 - - • - - Group 2, afternoon

B4b The interaction of group, session and time of day

This could be construed in two ways. Either in terms of chance differences between the two groups despite the fact that subjects were randomly assigned to them, or to the different sequence of noise conditions to which they were subjected. Poulton and Edwards (1979) have argued that 'asymmetric transfer' effects occur in experiments which employ several 'stressors' in a repeated-measures design, but their arguments apply mainly to main effects which we have seen are not particularly relevant in studies of the inverted 'U'. Furthermore it is difficult to see how such transfer effects could explain the present interaction.

The most likely explanation of the present findings would seem to be in terms of chance differences between the groups. Such differences are not impossible in a relatively small sample (the necessity for which has also been explained elsewhere - see p. 164), despite the random allocation of the subjects. It is unlikely, though, that they have had any major distorting effect on the results. Firstly they have not affected the overall level of performance, since the interaction of noise and session, which is equivalent to the main effect for group, is not significant. Secondly, in most other cases where a significant interaction involving noise and session is involved, we can account for the result without reference to possible differences between Group 1 and Group 2.

This applies to an interaction between noise, session and stimulus intensity in the speed of response in the simple reaction time task, as we will see when we come to

consider the results from the latter. We will anticipate, however, these results in stating that there is also an interaction between noise, session and time of day for the speed of response (depicted in graph B12 p. 625) which is in some ways quite similar to the present one. This indicates two things. Firstly, that some of the factors which influenced speed of response in the simple reaction time task may also have influenced the probability of a 'hit' in the signal detection task. Secondly, almost as a corollary, since they are both reasonably similar and yet derive from separate tasks, they may represent a real effect and not one due simply to the fact that there are a large number of 'F' values involved.

This could, however, explain some of the other apparently inexplicable interactions arising out of the fairly large analyses of variance which we have employed in the present project. One example of this is the interaction between noise, session and introversion for the discrimination index. This too could be due to chance differences between Group 1 and Group 2, but since there is no such interaction for any other measure, the result may be a 'false positive'.

If we accept, though, that for the interaction between noise, session and time of day, at least, the result may be due to differences between Group 1 and Group 2, we are still left with the task of explaining what these differences are and how their effects are mediated. Certainly differences on dimensions such as introversion and

neuroticism acting within the framework of the original inverted 'U' are unlikely to be responsible.

One possibility is suggested, though, by work published very recently by Revelle et al. (1980). They found that the dimensions of 'sociability' and 'impulsivity' may interact with other factors such as time of day, drug dose and day of testing leading to reversals of the effects of a given factor (e.g. drugs) at different levels of another factor (e.g. time of day). Furthermore, they argue that such reversals are not explicable on the basis of a simple inverted 'U' model, but require us to assume, for instance, that the positions of low and high impulsives on the 'x' axis of the inverted 'U' reverse between morning and evening testing.

To investigate the possibility that the interaction between noise, session and time of day may have been due to similar effects, the impulsivity and sociability items of the E.P.I.'s extraversion scale (Eysenck and Eysenck 1969) were extracted and the mean scores for Group 1 and Group 2 calculated. These were found to be 5.5 and 5.7 respectively for the impulsivity dimension and 6.5 and 6.4 respectively for the sociability dimension. These differences between Group 1 and Group 2 are only slight and are not significant, so it is unlikely that they are responsible for the present interaction. Furthermore, Revelle et al.'s subjects were tested in the evening (from 19.00 hrs. onwards) whereas the subjects in the second of the two time of day conditions in the present study were tested in the afternoon (i.e. between 14.00

and 17.00 hrs.). We will see when we come to consider Revelle et al.'s work in more detail that this difference may be an important one.

To conclude, then, differences in impulsivity and sociability may be relevant to interactions based on chance differences between Group 1 and Group 2 but this is very unlikely. The author has, however, no satisfactory alternative explanation to offer.

4. The probability of a false alarm

The main effect for neuroticism is significant at the 2.5% level (two tail). Overall high N subjects recorded more false alarms than low N subjects. In view of the findings in relation to the criterion, which showed that high N subjects adopted a lower criterion than low N subjects, which we have already discussed (p. 564), this result comes as no surprise.

The interaction of noise and introversion is significant at the 2.5% level (two tail). Under 'no noise' extraverts recorded more false alarms than introverts, whereas the reverse was true under 'noise'. Also, introverts recorded more false alarms under 'noise' than under 'no noise', whereas the reverse was true for extraverts.

This result suggests a 'U' shaped relationship between introversion and noise, on the one hand, and the false alarm rate, on the other. It may, therefore, seem surprising in view of the earlier finding of an interaction between noise and introversion (though only marginally significant) which indicated an inverted 'U' relationship between these factors and the discrimination index. The two findings are discrepant but not for the obvious reason. This is because the introverts under 'noise' still responded more often to signals than to non-signals, indicating that they had not passed their true T.T.I.

The interaction was interpreted as being due to the fact that d' is an index of the slope of the inverted 'U' and due to the fact that the left-hand portion of the latter

is initially concave upwards and later convex upwards. If the subjects were operating on the left hand side of the curve then one would not expect to find evidence of an inverted 'U' relationship between the determinants and the false alarm rate. One would, however, expect to find a positive monotonic one, since the determinants would produce a shift to the right of the non-signal distribution in figure 44 (see p.511). The apparent 'U' shaped relationship is quite unexpected on this basis.

However this analysis was based on the assumption that stimulus intensity interacts with the determinants as predicted by the general model. We argued earlier (see p. 533) that if this was true then one would predict an inverted 'U' relationship between the determinants and the false alarm rate - despite the fact that a false alarm is an error and consequently could be regarded as an inverse measure of 'performance'. Since early formulations of the inverted 'U' hypothesis, such as the Yerkes-Dodson Law, were couched in terms of 'performance' it could be argued that the false alarm rate would be expected to have a 'U' shaped relationship with the determinants, which is what the present result would suggest.

The interaction between noise and introversion here is therefore supportive of the earlier descriptions of the inverted 'U' hypothesis in terms of 'performance' conceived of in a very broad sense, and is not in line with the general model as we have presented it, based on the assumption that stimulus intensity is a determinant like the others. However, we have already seen evidence that

stimulus intensity may be special. One example of this was the failure to find a T.I. effect due to stimulus intensity in the 'neurotic introvert' group in the simple auditory reaction time experiment (see p.500).

It should also be mentioned that though the interaction of noise and introversion for d' is consistent with the general model, that does not mean that it is the only model capable of explaining it. The general model and the earlier formulations of the inverted 'U' do, of course, coincide when considering indices such as d' since both predict that they have an inverted 'U' relationship with the determinants. In the former case this is because of the proposed interaction between stimulus intensity (which differentiates the non-signal and the signal in the present experiment) and the other determinants (see p.520). In the case of the latter, it is because d' is a measure of the ability to discriminate and is palpably a measure of 'performance'.

The discrepancy between the two formulations only reveals itself when we consider an index such as the false alarm rate, which would be predicted to have an inverted 'U' relationship with the determinants by the general model, but a 'U' shaped relationship by the original formulation.

Let us consider, however, what implications the proposed dissociation or discordance between stimulus intensity and the other determinants would have (it is of course this dissociation which underlies the opposite predictions relating to the false alarm rate). We can still explain the

inverted 'U' relationship between the other determinants and measures such as response speed in terms of a revised general model which excludes the factor of stimulus intensity. An example of this would be the interaction between introversion and neuroticism in the simple auditory reaction time experiment, which we could explain on the basis of our criterion hypothesis.

However, in order to explain the effects of these and other determinants on measures such as d' which clearly contain the factor of stimulus intensity hidden within them, we would still have to propose some sort of mechanism by which the effect of these determinants on such measures could be mediated, and it would still have to be couched in terms of an inverted 'U' hypothesis, though it would have to be different from the general model since as we see this leads to contradictions.

What such a mechanism might be is not entirely clear. Eysenck (1967, pp. 42-43) reviews a number of mechanisms that have been suggested to explain Yerkes-Dodson-type effects (e.g. the differential effect of drive on responses associated with different degrees of 'habit strength'). We will not discuss them all in detail. In any case, Eysenck points out that they are not necessarily mutually exclusive.

Perhaps the one which seems most relevant here is that put forward by Jones (1960). He suggests that in discrimination tasks, the effect of increased 'drive', which in this context could be considered as analogous to the increase in the levels of the determinants, has two

opposite effects. One is to improve performance due to its 'energising effect'. The other is to worsen performance by virtue of the fact that the two stimuli which must be discriminated are contributed to by incidental experimental stimuli including the drive stimulus. The greater the level of drive, the more difficult the discrimination, since it will then account for a greater proportion of the total stimulus complex for each stimulus and since the drive element is common to both stimuli, the difference between the two stimuli will be proportionately less. These two opposing influences are presumed to interact to produce an inverted 'U' relationship with performance.

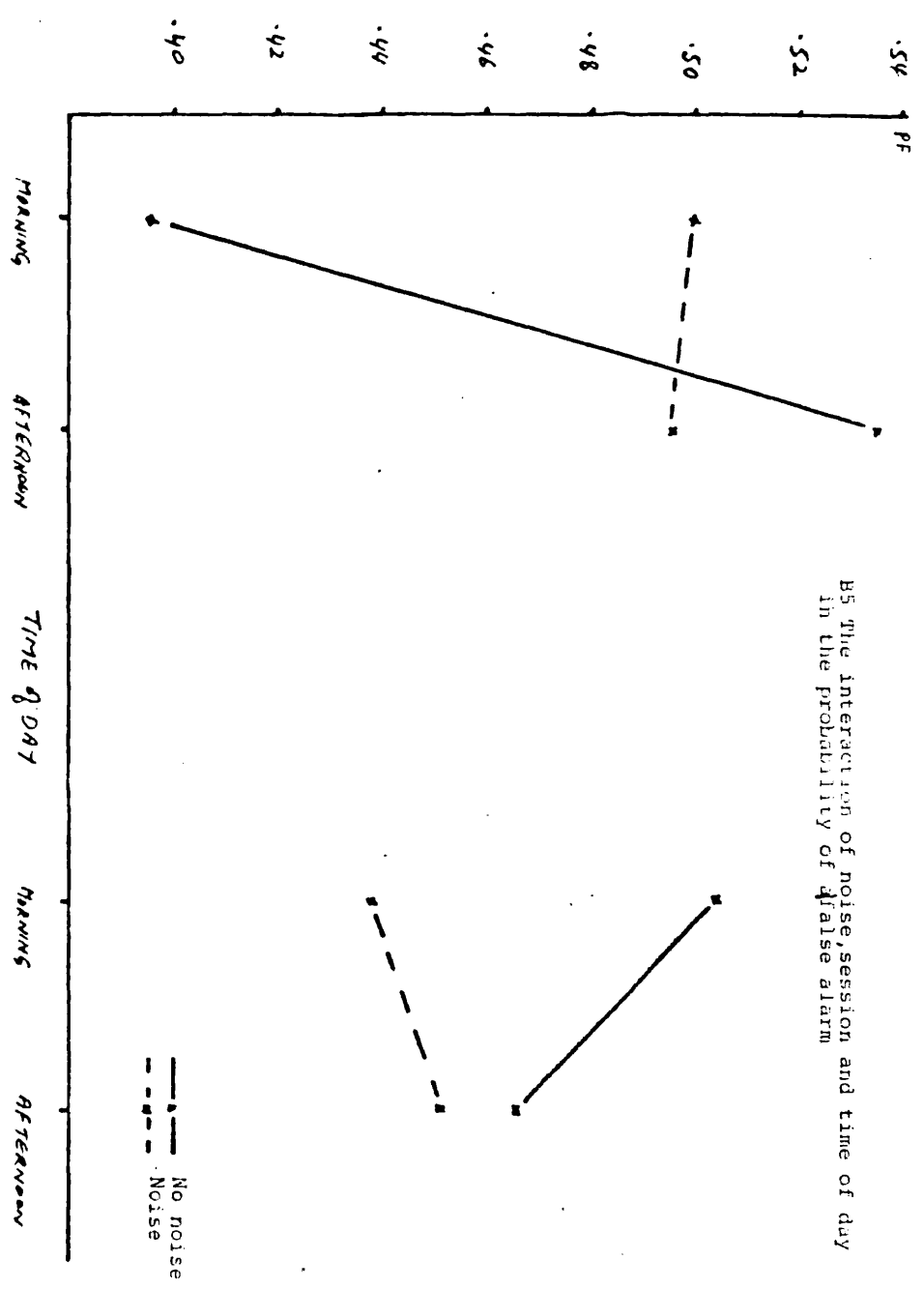
This explanation is not totally dissimilar to our previous one in terms of the conjoint action of the determinants; whether it is capable of accounting for the present results is difficult to say, especially since, as Eysenck shows, it is only partially successful in explaining many of the other sets of results to which it has been applied. The main point we wish to make is that results such as the present ones will make it necessary for some such alternative explanation to be found. The general model as it stands cannot adequately accommodate them.

One final point that should be made is that though the general model seems to be inadequate, whereas the earlier formulations in terms of 'performance' can embrace the present data, this does not alter the author's view that the general model was superior in one respect; namely

that it was more explicit. The above analysis is an example of the virtue of a detailed theory. If it fails, as it has, it is possible to see exactly where it has failed (in this case it has foundered on the apparent dissociation between stimulus intensity and the other factors), and the search for an alternative can begin.

We must now consider the remaining significant effects for the probability of a false alarm. The first is an interaction between noise, session and time of day. This is depicted in graph 65. It does resemble the corresponding interaction for the probability of a hit measure, but there are notable differences. For example the functions for the two noise conditions in session 2 do not cross for the false alarm measure whereas they do for the hit measure. Furthermore, we have argued above that the relationship between the determinants and the false alarm measure may be quite different from the relationship between the determinants and the hit measure. For these reasons, though it is possible that, as for the latter, the interaction could be due to chance differences between subjects who completed the noise conditions in different orders (i.e. between a Group 1 and a Group 2) it may alternatively simply be a 'false positive'. The author certainly has no satisfactory explanation for it.

The same applies to the remaining interactions for the false alarm measure: noise x session x neuroticism and noise x session x introversion x neuroticism. Since they contain the factors noise and session, they too could be rearranged to include the factor 'group', but



B5 The interaction of noise, session and time of day in the probability of false alarm

again they may be due to purely chance factors unrelated to differences between Group 1 and Group 2, especially since the corresponding interactions do not appear for any of the other measures.

ii) The simple visual reaction time task

a) Results

The following results are based on the E.P.I. scores of the subjects, measured prior to the taste experiment. Two indices have been used:

1) The reaction time to each of the six intensities calculated as the mean of two values in each block. As reaction time distributions are often skewed, an inspection of the results indicated that there were some high values, a logarithmic transformation (base 10) was carried out on these mean reaction times. The result - which we will label 'LSCORE' - was then subjected to an analysis of variance involving introversion (2 levels), neuroticism (2 levels), accessory stimulation or 'noise' (2 levels), time of day (2 levels), stimulus intensity (6 levels), session (2 levels) and block ('BLK' - 3 levels).

The results for block will be deferred until the section on vigilance.

The above analysis of variance was also repeated, with trends for stimulus intensity excluded, but a planned comparison between the highest and the second-highest intensity included.

2) The $\Sigma t/t$ min. measure of the reaction time/intensity curve's gradient. This is defined as the sum of the ratios of the reaction time for each individual intensity to the reaction time for the highest intensity. It will be referred to as 'sigma'. Sigma was calculated separately for each

of the three blocks ('BLK') in the reaction time task, and the results were subjected to an analysis of variance involving introversion (2 levels), neuroticism (2 levels), accessory stimulation or 'noise' (2 levels), time of day (2 levels), session (2 levels) and BLK (3 levels). The effects involving BLK will not be reported here but deferred till the section on vigilance.

Results for simple visual reaction time (LSCORE)

a) The main effect for stimulus intensity is significant at the 0.1% level (2 tail). Speed of reaction increased as stimulus intensity increased. The linear and quadratic coefficients were also significant at the 0.1% and 0.5% levels (2 tail) respectively. The latter effect was due to the fact that the rate of increase of speed of reaction decreased as stimulus intensity was increased - i.e. the curve tended to flatten off.

Stimulus intensity (lux)	2000	200	20	2	0.2	0.02
LSCORE	2.3828	2.3889	2.4100	2.4293	2.4453	2.4845

Table B9. The main effect for stimulus intensity (LSCORE).

b) The planned comparison associated with the interaction between neuroticism and stimulus intensity is significant at the 2.5% level (one tail). This is due to the fact that between the two highest intensities, low N subjects show an increase in speed, whilst high N subjects show a decrease.

Stimulus Intensity	Neuroticism	High N	Low N
2000		2.3716	2.3940
200		2.3626	2.4151
20		2.3955	2.4246
2		2.4057	2.4530
0.2		2.4235	2.4671
0.02		2.4707	2.4983

Table B10. The interaction between stimulus intensity and neuroticism (LSCORE).

c) The quadratic component associated with the interaction between stimulus intensity and session is significant at the 5% level (2 tail). In session 2 a fairly linear rise in speed of response with increase in stimulus intensity was found, whereas in session 1 the curve is markedly convex upwards.

Stimulus Intensity	Session	1	2
2000		2.3977	2.3680
200		2.4018	2.3759
20		2.4096	2.4104
2		2.4297	2.4289
0.2		2.4498	2.4408
0.02		2.4944	2.4747

Table B11. The interaction of stimulus intensity and session (LSCORE).

d) The quadratic component associated with the interaction between stimulus intensity, session and neuroticism is significant at the 5% level (2 tail). See discussion.

Stimulus Intensity	Neuroticism	Session 1		Session 2	
		High N 1	Low N	High N 2	Low N
2000		2.3827	2.4127	2.3606	2.3753
200		2.3810	2.4227	2.3443	2.4075
20		2.3967	2.4226	2.3942	2.4266
2		2.4152	2.4442	2.3961	2.4618
0.2		2.4272	2.4724	2.4198	2.4618
0.02		2.4748	2.5139	2.4667	2.4826

Table B12. The interaction of stimulus intensity, session and neuroticism (LSCORE).

e) The interaction of noise, neuroticism and time of day is significant at the 5% level (2 tail). See discussion.

Noise	Neuroticism	High N		Low N	
		Morning	Afternoon	Morning	Afternoon
'No Noise'		2.3892	2.4405	2.4543	2.4260
'Noise'		2.3900	2.4101	2.4190	2.4687

Table B13. The interaction of noise, neuroticism and time of day (LSCORE).

f) The cubic component associated with the interaction between stimulus intensity, session and introversion is significant at the 5% level (2 tail). See discussion.

Stimulus Intensity	Session		1		2	
	Introversion	Extraverts	Introverts	Extraverts	Introverts	Extraverts
2000		2.3588	2.4386	2.3-32	2.392	
200		2.3630	2.4406	2.3539	2.397	
20		2.3786	2.4427	2.3990	2.421	
2		2.3966	2.4627	2.4051	2.452	
0.2		2.4218	2.4778	2.4067	2.474	
0.02		2.4486	2.5-01	2.4577	2.491	

Table B14. The interaction between stimulus intensity, session and introversion (ISCOPE).

g) The interaction between noise, stimulus intensity and session is significant at the 5% level (2 tail). The linear component is also significant at the 1% level. See discussion.

	Noise		'No Noise'		'Noise'	
	Session	1	2	1	2	
Stimulus Intensity						
2000		2.3863	2.3881	2.4090	2.3479	
200		2.4010	2.3990	2.4027	2.3529	
20		2.4139	2.4205	2.4054	2.4003	
2		2.4276	2.4375	2.4318	2.4204	
0.2		2.4467	2.4601	2.4529	2.4215	
0.02		2.4917	2.4579	2.4970	2.4915	

Table B15. The interaction between noise, stimulus intensity and session (LSCORE).

h) The interaction of noise, session and time of day is significant at the 2.5% level (2 tail). See discussion.

	Session 1		Session 2		
	Time	Morning	Afternoon	Morning	Afternoon
Noise					
'No Noise'		2.4641	2.3917	2.3795	2.4748
'Noise'		2.3783	2.4879	2.4206	2.3909

Table B16. The interaction of noise, session and time of day (LSCORE).

i) The interaction of noise, session, introversion, neuroticism and time of day is significant at the 5% level (2 tail). This result will be considered in the discussion.

Results for Nebylitsyn's index of ^{the} gradient of the reaction
time/stimulus intensity curve (SIGMA)

The main effect for neuroticism is significant at the 5% level (one tail). High N subjects have 'weaker' nervous systems than low N subjects - i.e. they have relatively low values for Nebylitsyn's index.

High N	Low N
6.617	6.868

Table B17. The main effect for neuroticism (SIGMA).

b) Discussion of results of simple visual reaction time task

Before beginning our discussion it should be noted that the graphs depicted in this section are based on the values of 'L SCORE' - i.e. the logarithm of the mean reaction times. Since reaction time is reciprocally related to response speed which is a measure of performance, the 'Y' axes of the graphs have been reversed.

The 'X' axes are not reversed, but where they represent stimulus intensity they are drawn on a logarithmic scale.

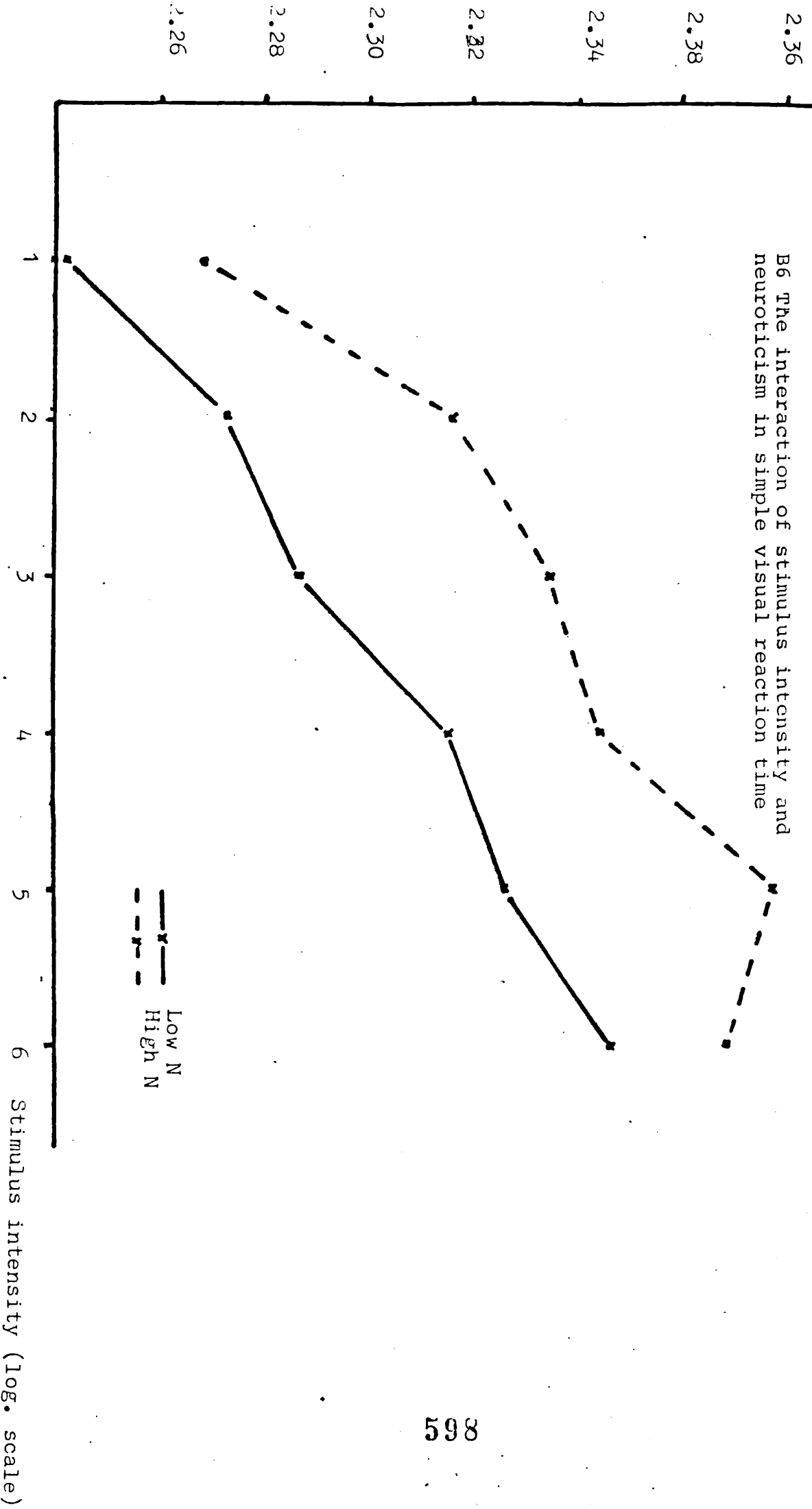
The role of neuroticism

The most important group of findings that arises out of the results of the simple visual reaction time task relate to the interaction between stimulus intensity and neuroticism. We find, firstly, that the planned comparison (between the highest and second highest stimulus intensities) associated with this interaction is highly significant (at the 2.5% level, one tail) and is entirely in the predicted direction. In the low N group speed of response continues to rise between the second highest and the highest intensity, whereas it falls in the high N group. These relationships fit the model.

Furthermore, as graph B(4) shows, the other features of the curves are in line with this interpretation. The overall shape of the curve for the high N subjects (i.e. convex upwards - by and large) suggests that they are operating on portion

Lscore

B6 The interaction of stimulus intensity and neuroticism in simple visual reaction time



B of the inverted 'U' curve. On the other hand, the curve for the low N subjects is more nearly linear, suggesting that they may be operating closer to the borderline between portions A and B. Also the overall height of the curve is greater for the high N subjects than for the low N subjects.

Taken together, then, these facts support the view that the high N subjects are operating further to the right along the X axis on the inverted 'U' than the low N subjects, and therefore also support the view that neuroticism and stimulus intensity are both determinants.

However, it should be pointed out that neither the quadratic component associated with the interaction, nor a post hoc comparison of the means for the two highest intensities in the high N group are significant.

A related finding is the significantly higher value for the $\Sigma t/t$ min. index in the low N subjects compared to the high N subjects. Nebylitsyn (1960, op. cit.) developed this index to measure the gradient of the reaction time/stimulus intensity curve, and this it does quite efficiently since a higher value for the latter will lead to a higher value for the index.

A study published whilst the present experiment was in progress (Grice et al., 1979) suggests that the sensory growth functions for two stimuli differing in

intensity may be more nearly parallel in the visual than in the auditory modalities, and that the difference in the reaction times to a low and a high intensity stimulus may be due, primarily, to a difference in the point at which the corresponding sensory growth functions cut the X axis - see Figure A.

If this is so, then our earlier explanation of the difference in the gradients of the reaction time/intensity curve between the extraverts and introverts in Mangan and Farmer's study, in terms of differences in criterion, may encounter some difficulties. This is because the effect of the criterion level on the gradient of the curve was based on the assumption that the sensory growth functions for a low and a high intensity stimulus diverge (see Figure 8), as the counting model predicts. The more nearly parallel these functions are, however, the greater the difference in criterion level that will be necessary to produce a given difference in the gradient of the reaction time/intensity curve. However, the fact, that Harkins and Geen (1975) found a significantly lower criterion in extraverts than introverts may make our theory tenable after all.

There are certain other features of Grice et al's work which should be discussed. Consider again their suggestion that the effect of stimulus intensity on reaction time, in the visual modality at least, is due to differences in the point at which the sensory growth functions for a low and a high intensity stimulus intersect the X axis (see Figure B). They also argue that the computed difference between these points of inter-

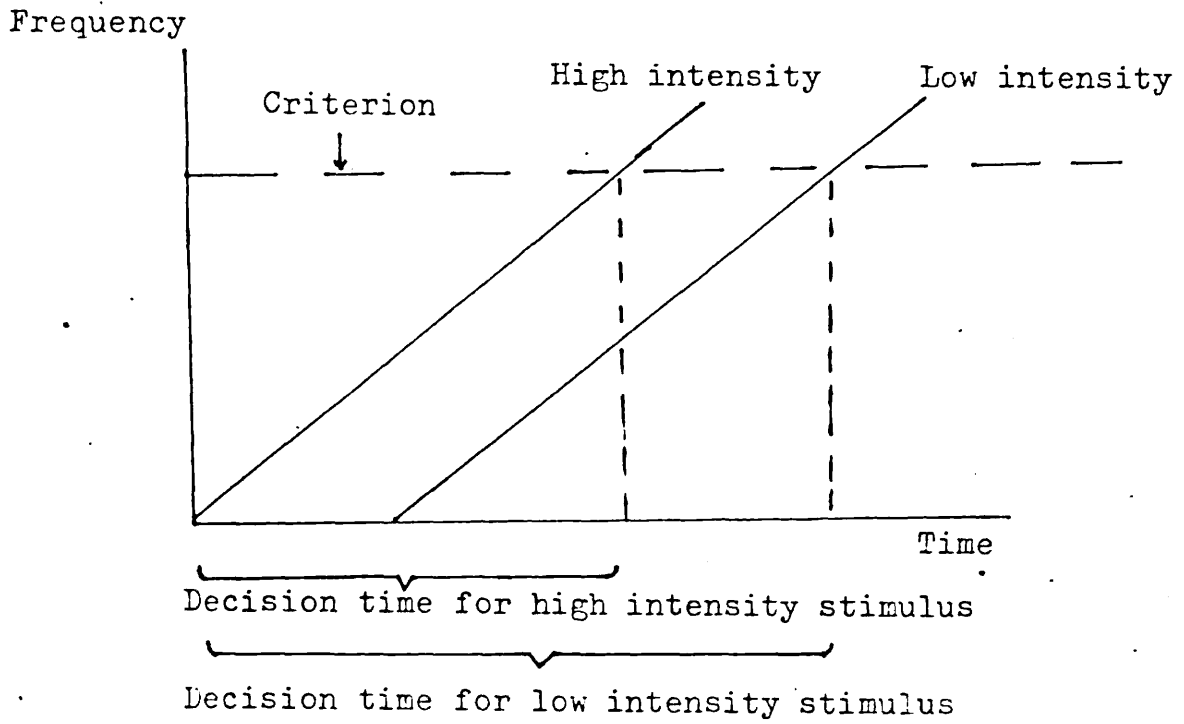


Fig. A. Grice et al's formulation for vision

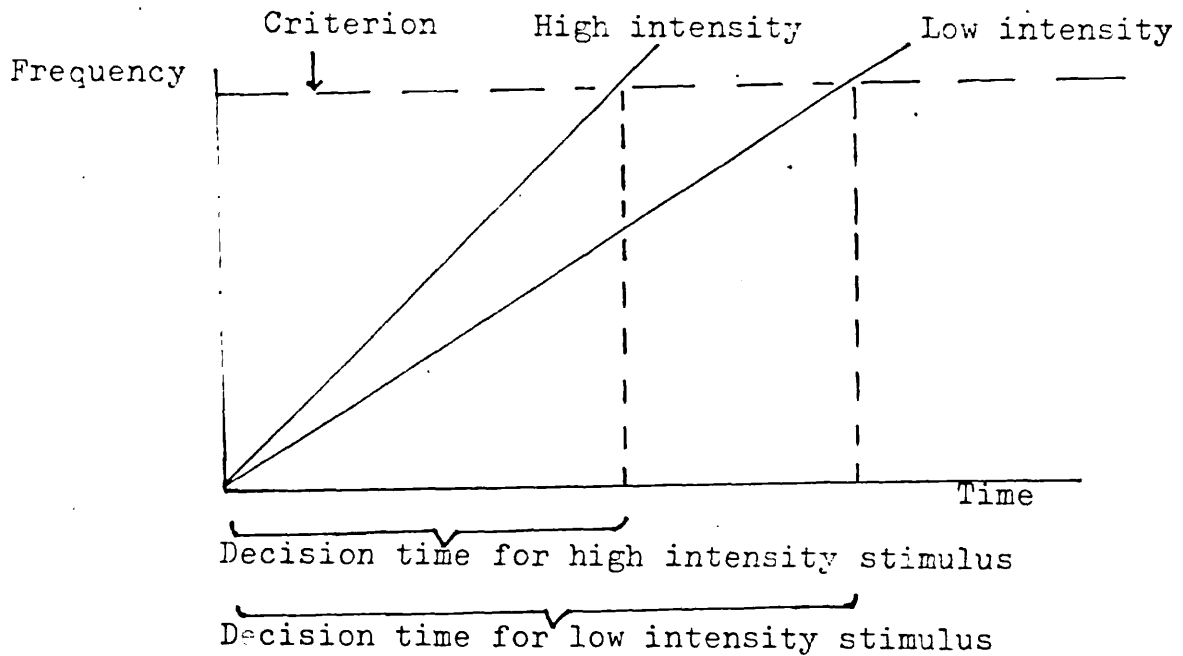


Fig. B. Original formulation of the counting model

section per logarithmic unit in stimulus intensity is 11 msec, which is roughly the same as the 10 msec. value quoted by Nissen (1977) for the delay in the initial firing of retinal ganglion cells and optic nerve fibres.

In other words, they suggest that, in vision at least, the effect of stimulus intensity on simple reaction time may be based on a peripheral retinal effect rather than a central one. It is not impossible that, though the effect of stimulus intensity itself may be due to peripheral factors, the interaction between stimulus intensity and other variables such as neuroticism may be due to central ones. However, we are faced with the possibility that a major personality dimension, such as neuroticism, which is thought to be based on central structures, may be exerting its effects via a peripheral mechanism.

This is not as serious as might at first sound, since there is ample evidence that central structures do exert a moderating influence on peripheral ones through efferent fibres (Moruzzi, 1960). Also Irvine and his coworkers (1970) have suggested that peripheral structures acting on their own may play less of a part in modifying the information that reaches higher structures than had originally been thought.

Their study was an auditory one, but there is other evidence, this time in the visual modality, that Grice's suggestion of a peripheral mechanism may not be able to explain all the facts. Galifret (1962) looked at recordings from single neurone of the pigeon's lateral geniculate nucleus. His results showed that though there was a negative logarithmic relationship between the stimulus

intensity and the delay in the firing of the neurone, there was an inverted 'U' relationship between the frequency of the neural discharge and the logarithm of the stimulus intensity. Assuming that the results from his study are applicable to humans, it indicates that stimulus intensity does affect the slopes of the sensory growth functions in the visual modality and not just the intercepts of these sensory growth functions with the 'X' axis.

It also supports one of our two hypotheses, namely the hypothesis that there is an inverted 'U' relationship between the slope of the sensory growth function and the determinants. However, the determinant concerned was stimulus intensity, and we have already stated that this variable may be special. Furthermore, we did not attempt to explain the effect of stimulus intensity per se by our alternative criterion hypothesis, since we pointed out that if stimulus intensities were randomised (as they were in the present study), alterations in criterion levels cannot account for its effects. So our criterion hypothesis is certainly not harmed by Galifret's work.

In fact, it is helped since it rescues the notion that interactions between stimulus intensity and other variables (such as introversion and neuroticism) can be explained by criterion effects, since it shows that stimulus intensity affects the slope of the sensory growth functions.

What are we then to conclude about Grice et al's study and its implications for our present hypotheses? We have seen that though its findings seem to dovetail with those of certain physiological studies, this is more than counterbalanced by other physiological data which it cannot account for. Theoretically, also, its postulates are difficult to assess. This is because throughout the whole , impressive, body of work produced by Grice and his co-workers, it is assumed that apart from stimulus intensity itself, the effects of all other variables can be explained by criterial factors.

This premise does enable Grice and his co-workers to provide a coherent explanation for their data, but so too does the model advanced by the rival school (founded by McGill) which is based on the opposite premise - namely, that differences in simple reaction time are due to sensory rather than criterial factors. The whole point of the present exercise (i.e. the use of the joint simple and disjunctive reaction time task) was to make it unnecessary to adjudicate between these opposing views on the basis of intuition or speculation alone, though we too have to make an assumption: namely, that the signal

detection indices derived from the disjunctive task are valid indications of the underlying relationships in the simple reaction time task.

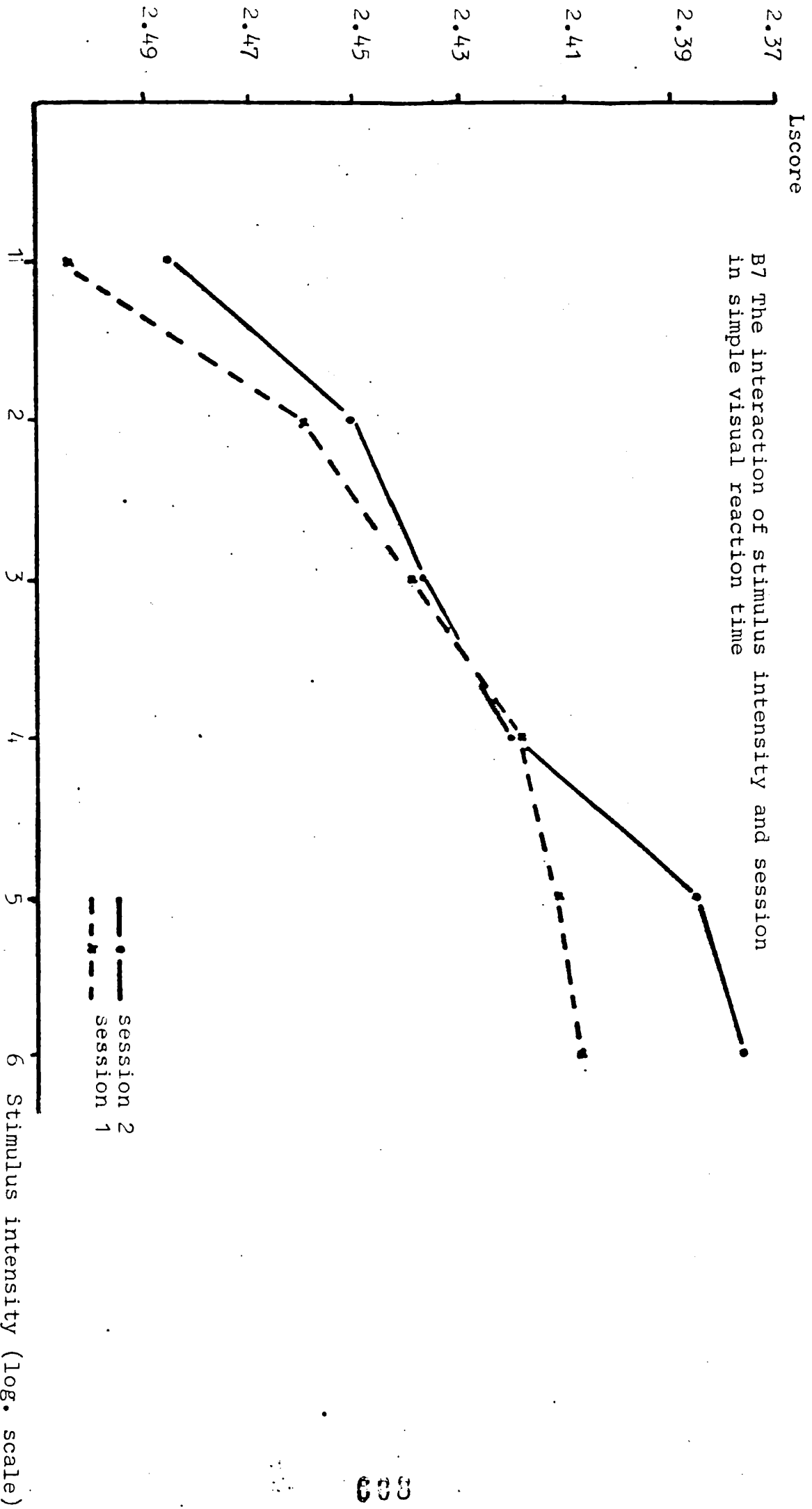
Furthermore, even if Grice et al are correct, this would not affect our contention that an inverted 'U' relationship between the determinants and the tendency to respond (i.e. the reciprocal of the criterion) can explain the results of simple reaction time tasks which do not involve stimulus intensity at all. This is because even if the sensory growth functions are parallel for stimuli differing in intensity, alterations in the level of the criterion will still affect the overall reaction time.

Let us now return to the finding that low N subjects have a significantly higher value of Nebylitsyn's index than high N subjects. It will be remembered that this index was validated against the method of EWR of the PCR, and for this reason we decided to use it as an index of 'strength' in the present project. The finding, therefore, provides support for the view that the level of neuroticism^{is} positively related to 'weakness' of the nervous system.

THE INFLUENCE OF LEARNING

We will now consider an unrelated result, because it may help us to clarify some of the other interactions involving neuroticism. The quadratic component associated with the interaction between session and stimulus intensity is significant (5%, 2 tail). This is depicted in Graph B (7). The shapes of the curves are predictable if we assure that novelty is a determinant, but their relative heights are not in line with expectation. A learning interpretation may be possible here, however. If we look at the graph, we see that speed of reaction is by and large slower in session 1 than in session 2, and that this difference is greatest at the lowest intensities. In order to explain this we would have to suppose that the effect of learning was different at different intensities.

There is a more simple explanation, though. Our theory would predict that in session 2 the curve would be steeper, and possibly fairly linear, whilst that for session 1 would show a more quadratic relationship. If we assure, therefore, that learning has the effect of simply shifting the whole curve for session 2 upwards relative to that of session 1, the picture becomes more clearly explicable. Such an effect would not be impossible, since it has been shown that in simple reaction time subjects develop expectancies about when the main stimulus is due to arrive following the warning signal, and alter their degree of preparedness accordingly.

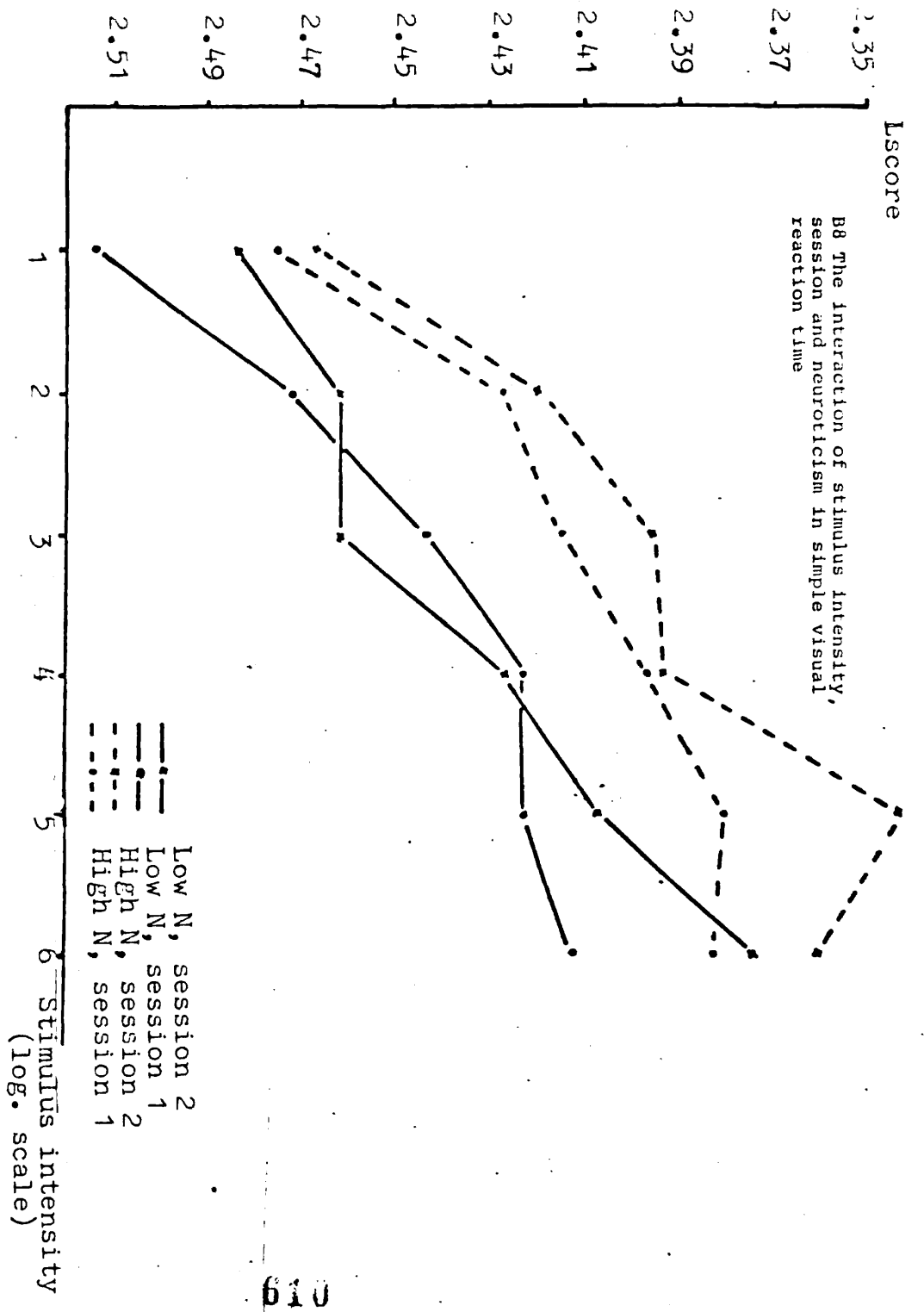


B7 The interaction of stimulus intensity and session in simple visual reaction time

Since the interval between warning signal and response stimulus was constant in the present experiment, it is quite possible that subjects would learn when to expect the main stimulus, and that their performance would accordingly improve. The effect of within-session changes (as reflected in the 'block' factor) supports this interpretation, as we will see later in the section on vigilance, at which time we will consider the role of learning in more detail.

It is possible that such learning might occur across sessions as well, though it would be expected to be weaker due to the fact that the interval between sessions was much longer than the interval between blocks within a given session. This view is in line with the finding that, though the main effect for block is highly significant (see later), the main effect for session is not significant. It is, however, in the direction that we would predict on this basis (i.e. faster speed of response in session 2 than in session 1).

Let us look now at some of the other findings. The quadratic component associated with the interaction between stimulus intensity, session and neuroticism is significant. This is depicted in Graph B(8). In many ways this is in line with what one might predict. The subjects who would be expected to be operating furthest to the right along the 'X' axis of the inverted 'U' are the 'high N, session 1' group, since the level of neuroticism and novelty are highest in this condition. These subjects have a curve which is clearly convex upwards, which would be consistent with the view that they are operating on



portion B of the inverted 'U'.

On the other hand, the group who would be expected to be operating furthest to the left (i.e. the low N group in session 2) show some evidence of concavity upwards. This would be consistent with the view that they were operating, partly at least, on portion A of the curve. One would indeed expect that with the addition of extra factors (in this case neuroticism, if one compares this to the interaction between stimulus intensity and session), the separation of the two extreme groups on the X axis would increase. This was one reason why multifactorial experiments were recommended.

The significant quadratic component is probably due to the fact that the low N group in session 2 seem to be operating on a different part of the inverted 'U' to the other groups, since the remaining curves are convex upwards. There are some features of the curves which do not fit this picture, for instance the fall in speed of response at the highest stimulus intensity in the high N group in session 2. The associated planned comparison is not significant, and it does not seem to have affected the quadratic component, since the latter takes into account all the points on the curve and not just one of them. However, there are other features of the interaction which do not fit directly into the inverted 'U' model. For instance, the heights of the curves again show discrepancies with their slopes, though these are possibly explicable in terms of learning effects. The overall height of the session 2 curve is greater than that for the session 1 curve in high N subjects, as this

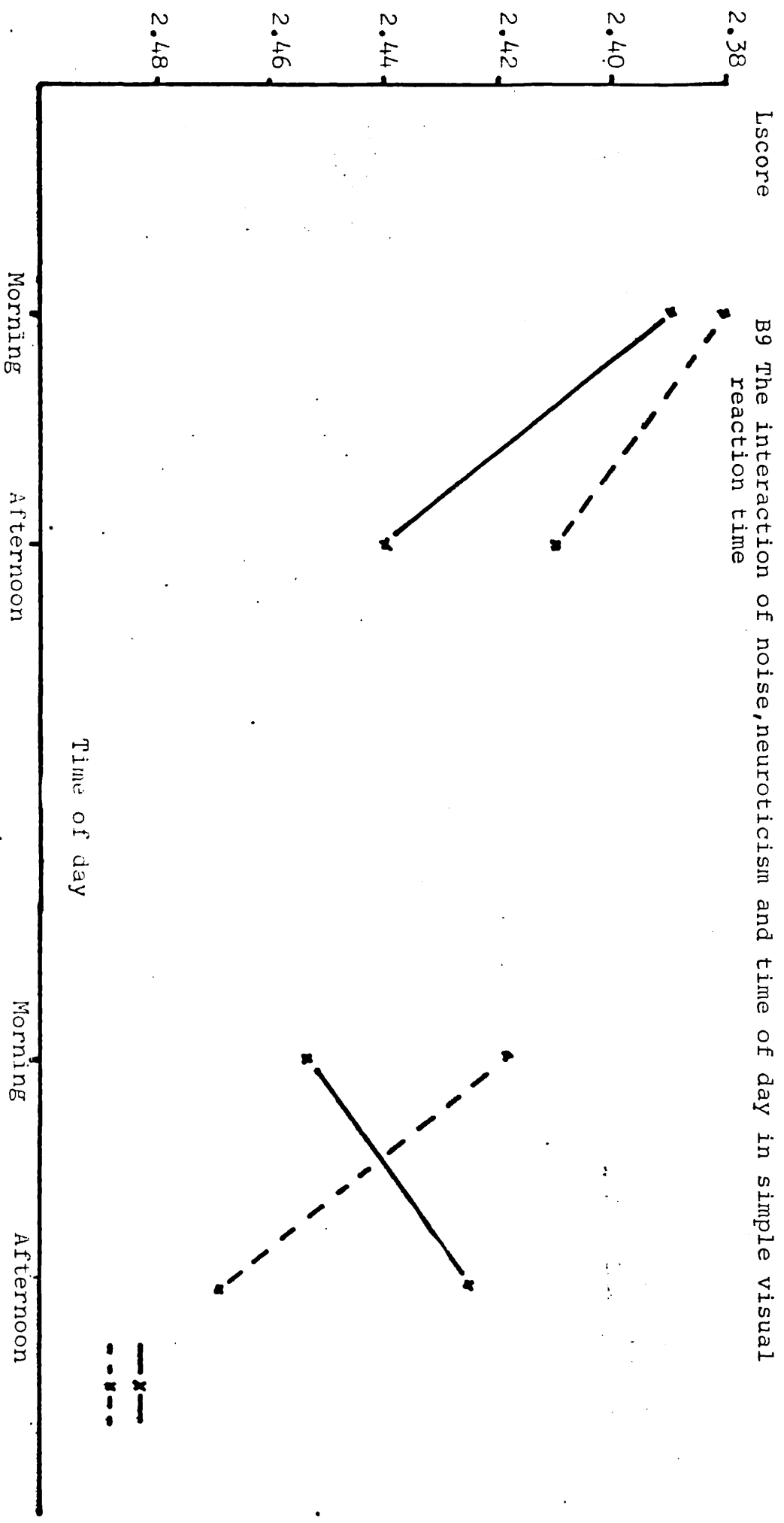
learning interpretation might predict. There is less difference between the two curves for the low N subjects, but learning could certainly explain why the low N , session 1 curve shows greater convexity upwards, but is not also higher than the low N session,2 curve.

One other effect involving neuroticism , but not introversion is significant. This is the interaction between noise, neuroticism and time of day, depicted in Graph B (9).

At first glance it might seem very much in line with our predictions. Speed of response is faster in the afternoon than in the morning in the group who would be expected to have the lowest level of 'arousal' - i.e. the low N subjects under 'no noise' conditions. On the other hand, all the other groups show the reverse effect of time of day.

However, if we are to interpret this as due to transmarginal inhibition we must also explain why the absolute heights of the high N subjects are higher than those of the low N subjects under 'noise', and also why amongst the high N subjects the 'noise' condition is higher than the 'no noise' condition. Neither our criterion nor our sensory growth function hypothesis on its own , would predict this. Furthermore, in this case we do not have any other factor, such as learning, to explain the discrepancies, since the factor of session is not involved.

Could we explain the results if we assumed that one of the two variables (i.e. the criterion or the sensory growth function) affected the overall height of the curve



only, but was not responsible for the effect of time of day? In view of what we said earlier regarding Grice et al's work, the criterion might seem an obvious candidate for this role. However, we are not here considering stimulus intensity, and it was only in relation to this factor that there was any external evidence that factors which influenced the criterion alone would fail to show predictable interactions with factors which influenced the sensory growth functions alone.

Nevertheless, let us consider the possibility that an analogous effect might be operating here, and see if we can, after all, find some external evidence to support it. One possible source is, of course, our signal detection task which we employed for this very purpose. We do see that in this the high N subjects seem to adopt a much lower criterion than low N subjects, and this could explain why the overall heights of the high N groups are greater than those of the low N groups. We pointed out earlier that the relationship between the discriminability index and the overall speed of response is less clear than for the criterion, and in any case there is no evidence for a significant difference between high and low N subjects on this measure using either the parametric index or the non-parametric one.

However, there is also no evidence of a significant difference in the criterion between the 'no noise' and the 'noise' conditions, nor any evidence for an interaction between noise and neuroticism. For this reason, the results of the signal detection task do not help us to explain the higher level of performance in the 'noise'

condition relative to the 'no noise' condition amongst
the high N subjects in the reaction time task.

The Role of Introversion

The first thing that we must consider with respect to the dimension of introversion is the failure to find a significant effect of this factor on Nebylitsyn's index. It will be remembered that the present study did attempt to replicate to a reasonable extent the conditions of Mangan and Farmer's (1967) study which did find such an effect. We suggested that the higher value for the index found in the latter study amongst introverts was due to the adoption of a relatively high criterion by these subjects. Furthermore, we explained the failure to find such a difference in our signal detection task, in terms of the relatively high opportunity to respond, compared to the study by Harkins and Geen (1975) which did find such a difference on the criterion measure.

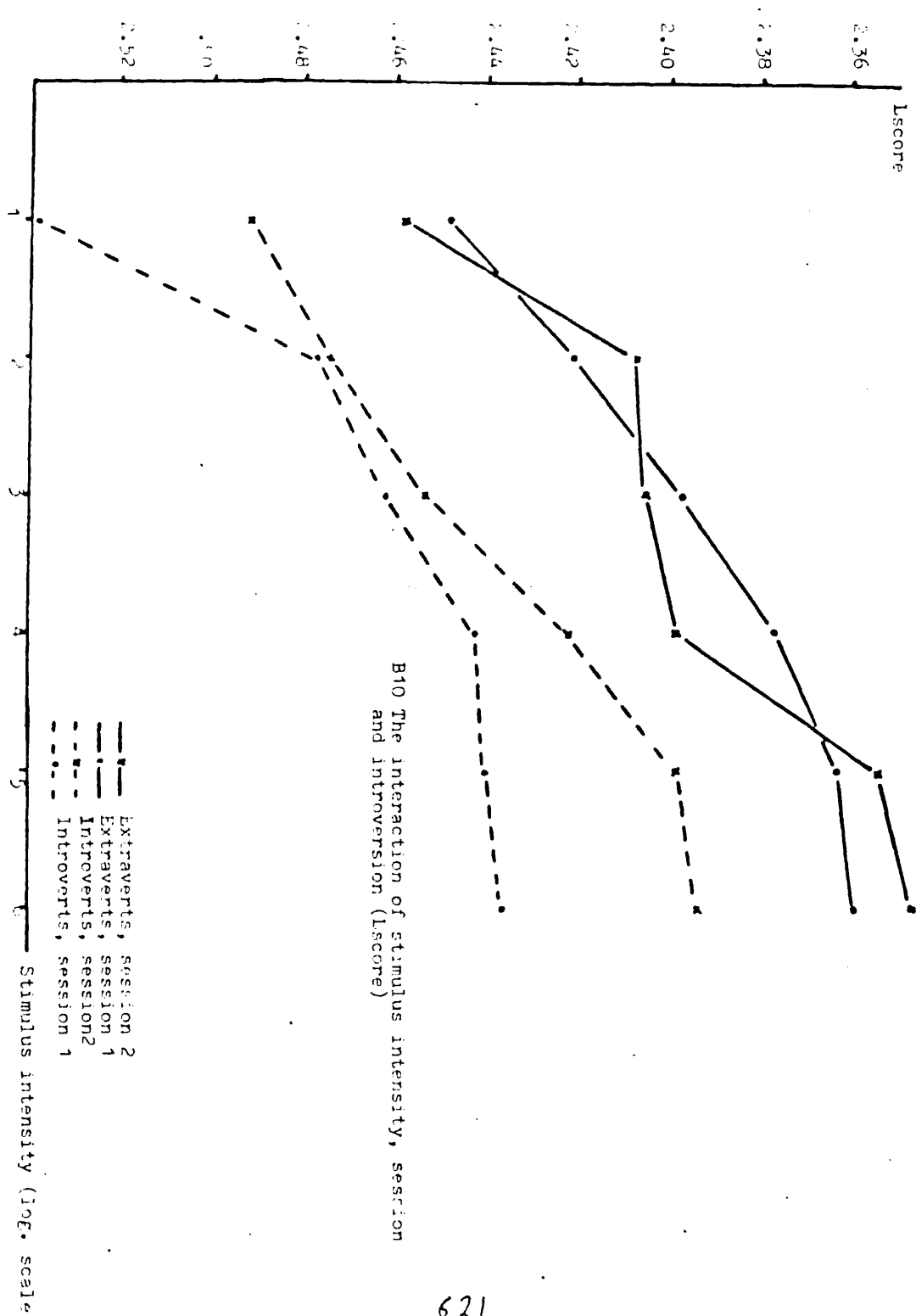
It is possible that a similar argument may apply to our simple visual reaction time task. The intertrial interval was longer in Mangan and Farmer's study than in the present one (reasons for the difference were given earlier) and so it is possible that under these conditions the extraverts adopted a relatively low criterion to compensate.

Let us now consider some of the effects for introversion which were significant.

The cubic component associated with the interaction between stimulus intensity, session and introversion is significant. This is depicted in Graph B_A¹⁰. The effect is clearly due to the fact that all of the curves are convex upwards except for that of the extraverts in session 2, which shows a more complicated relationship. This latter curve would fit in perhaps with the left hand portion of the inverted 'U' curve, but the sharp increase in speed of response between the two lowest intensities in this group of subjects is at variance with such an interpretation.

In other respects, the shapes of the curves seem to conform fairly well to prediction. But the absolute heights do not, and despite the fact that the session factor is involved, learning cannot explain the whole story. It could account for the fact that performance overall is not higher in session 1 than in session 2 (in fact the reverse is true in introverts), but it cannot explain why extraverts are overall superior to introverts. Nor is an explanation in terms of a differential effect of learning on the extraverts and introverts tenable, since the difference occurs in both sessions.

We could, however, explain the results if we assumed that extraverts adopt a lower criterion than introverts. This would be in line with our explanation of Mangan and Farmer's study and the findings of Harkins and Geen (1975), though not with our own signal detection task.



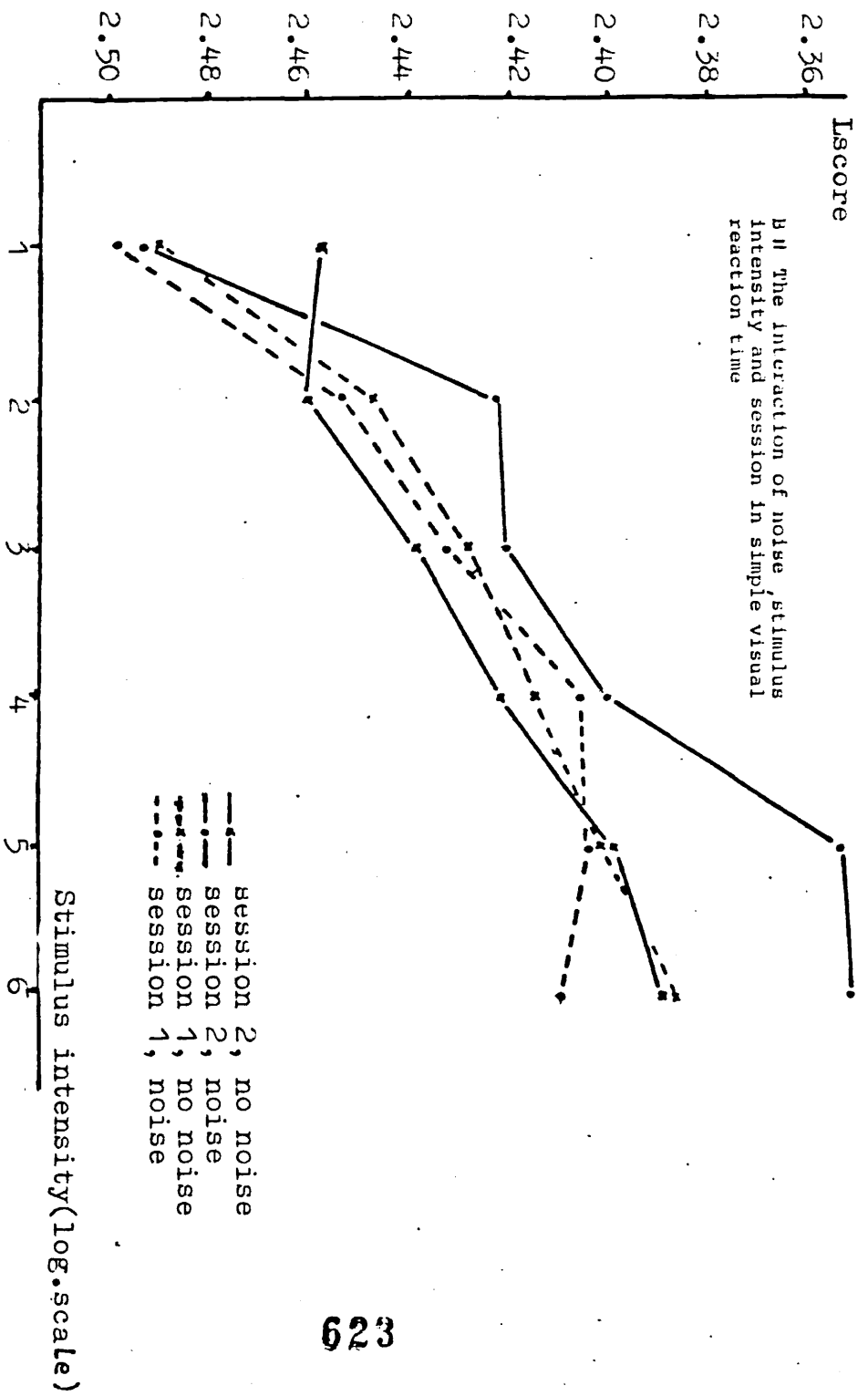
B10 The interaction of stimulus intensity, session and introversion (Lscore)

It should also be pointed out that although the criterion may be affecting the overall heights of the curves, it may also be affecting their shape, so that this result does not necessarily support Grice et al's suggestion that the sensory growth functions for vision are parallel. Discussion of that suggestion arose in the context of the interaction between stimulus intensity and session. In that case the difference in the shapes of the two curves was sufficiently clear to suggest that some factor (either learning or the criterion) was affecting the overall heights of the curves, but not their overall shapes. In the present instance, however, no such clarity exists, and it is quite possible that an effect of the criterion on the shapes exists but cannot be easily discerned, due to the random variations in the data and the masking effect of the stimulus intensity factor acting via the sensory growth functions.

c) Discussion of remaining significant effects.

The interaction between noise, stimulus intensity and session is significant as is the associated linear component. This is depicted in Graph 6// . The overall shapes of the curves conform fairly well to what one might expect. For instance, the group who would be expected to be operating furthest to the left on the 'X' axis of the inverted 'U' (i.e. session 2, 'no noise') shows some concavity upwards at the lower intensities, whereas the group who would be expected to be operating furthest to the right (session 1, 'noise') show the clearest evidence of convexity upwards.

Again the overall heights of the curve do not conform

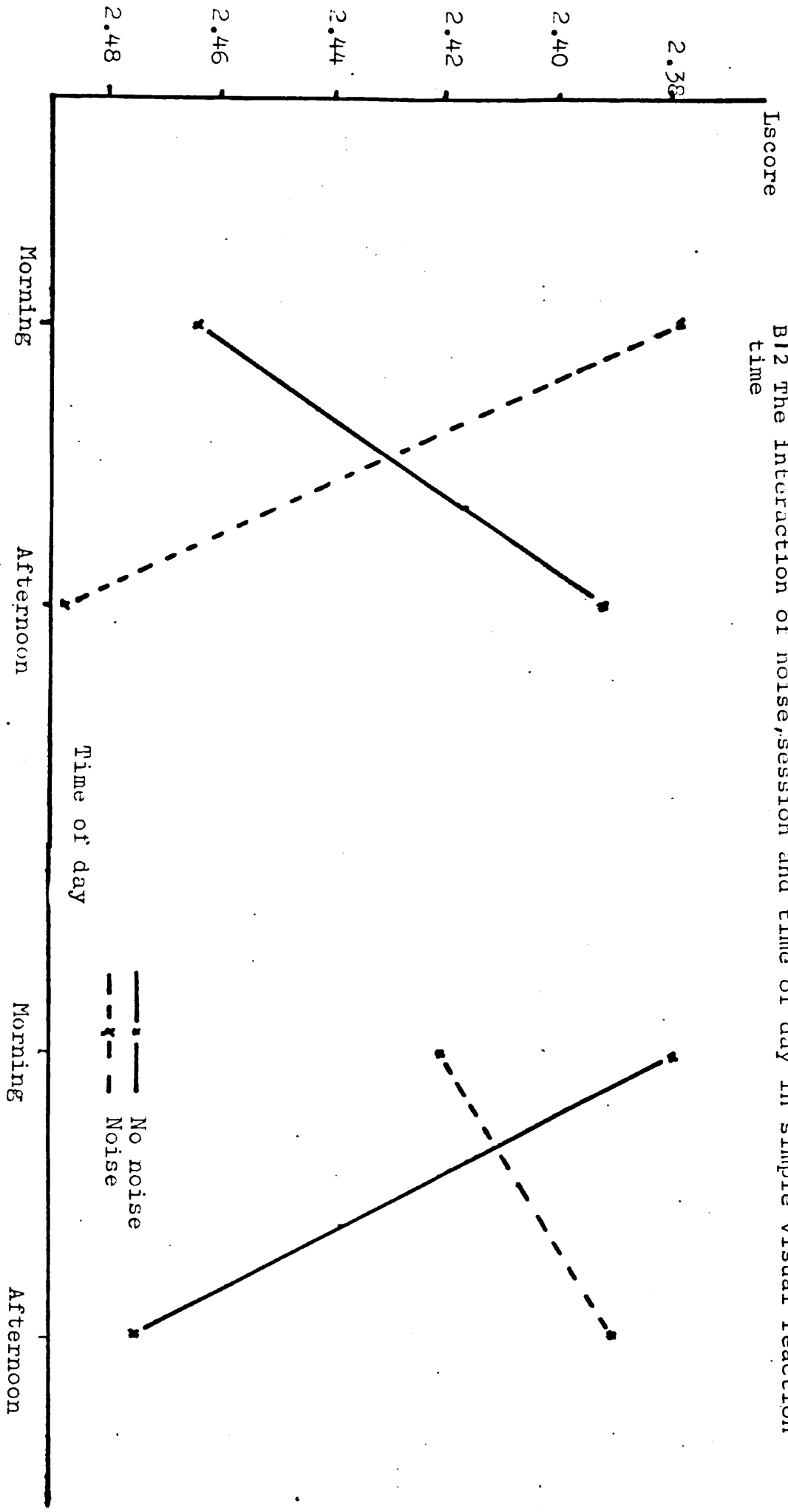


to expectation, but this time an explanation in terms of learning seems more plausible. Under 'noise', Session 2 performance is clearly superior to that of Session 1. There is very little difference between the two sessions under 'no noise' though. This could be due to noise, enhancing the effect of learning, due to its 'arousing' properties. An explanation in terms of the criterion hypothesis might also be possible. We could suggest that the lower level of performance in Session 1 under noise compared to Session 2 was due to T.I. in the tendency to respond. However, in the absence of a difference between the two sessions under 'no noise' and the corresponding interaction in the signal detection task, this is very speculative.

The interaction between noise, session and time of day is significant at the 2.5% level (two tail), and is depicted in Graph B12 .

The Session 1 curves would be consistent with the present hypotheses, since the level of novelty is highest in Session 1. Also, the fact that Session 2 performance level is higher than might be expected could be explained by a learning interpretation. However, the very steep fall in performance between 'morning' and 'afternoon' testing under 'no noise' in Session 2 is quite unexpected. The results could, however, be explained in terms of chance difference between Group 1 and Group 2, i.e. between the groups of subjects who performed the noise conditions in different orders. We have considered this point in connection with the corresponding interaction for the probability of a 'hit' in the signal detection experiment (see pp. 573-81), and we will not

B12 The interaction of noise, session and time of day in simple visual reaction time



repeat the discussion here.

Finally, the interaction of noise, session, introversion, neuroticism and time was significant at the 5% level (two tail). Inspection of the means shows that the interaction does not conform to prediction and the author has no explanation for it, so it will not be considered further.

c) Results for latency measures derived from signal detection task

Speed of response to signals

No significant effects

Speed of response to non-signals

No significant effects

d) Discussion of latency measures derived from signal detection task

We have postponed discussion of these results till this point to facilitate comparison with the results of the simple visual reaction time task.

We see that there are no significant main effects or interactions for the measure of speed of response to the signals in the signal detection task. Clearly, then, this measure does not provide any evidence either in favour of or directly against the model. Furthermore the fact that none of the effects which appeared in the simple visual reaction time task are significant for the signal detection task latency measures does indicate indirectly that the processes underlying simple and disjunctive reaction time may be rather different. However, it should be remembered that in the simple visual reaction time task, most of the significant effects involved stimulus intensity which was not a relevant factor for the reaction time measures from the signal detection task, so on this basis the difference between the results for the two tasks is not so great after all.

There are, however, no significant effects for the speed of response to non-signals measure either.

The relationship between the signal detection and the simple visual reaction time tasks

So far we have considered the signal detection and reaction time tasks separately and looked at the extent to which the general model receives confirmation from each individually. We have at times made comparisons between the two, but these have been, by their very nature, indirect. It will be remembered that one of the reasons for conducting the joint reaction time/signal detection task was to investigate the possibility that the measure of the criterion derived from the latter could be used to directly correct the measure of response speed derived from the former, thus revealing the influence of the slope of the sensory growth functions alone.

For this reason, the analysis of variance on the simple visual reaction time measure was repeated, but this time with the non-parametric criterion as a covariate. However, the inclusion of the covariate did not have a statistically significant influence on the results of the reaction time task.

There are several possible reasons for this. Firstly, the differences between the various conditions on the criterion index may not have been sufficiently great to produce a significant effect in the analysis of covariance. In line with this view is the failure to find any significant effects in the analysis of variance on the criterion measure itself, except for the main effect for neuroticism.

Secondly, it is possible that the criterion values derived from the signal detection (disjunctive reaction time) task were not an accurate guide to the criteria adopted by the subjects in the corresponding conditions of the simple

reaction time task. We argued earlier that such concordance was one of the assumptions that underlay the use of the joint task and we adduced evidence to support its validity. It is possible, nevertheless, that the assumption is suspect, but if so it is not likely to have been due to any deficiencies in the experimental design since we have seen that the two tasks were conducted under as similar conditions as possible. The differences that did exist between them were inherent in the nature of the tasks themselves and were, therefore, unavoidable. For instance the signal detection task was more complex than the simple reaction time task and if task complexity is a determinant it is possible that subjects were not operating on the same portion of the inverted 'U' in the two tasks.

Such differences may be responsible for the apparent failure to measure the criteria adopted in the simple reaction time task via the signal detection task. However, the author is at a loss to suggest a better way to tackle the problem, and as we have seen he is not alone in this (Green and Swets 1974).

A third possibility is that the counting model, as originally presented, may not have been a completely accurate reflection of the processes^{es} underlying the simple reaction time task. It will be remembered that the main focus of interest in discussing this model was the predictions it made for the relationship between the gradient of the reaction time/intensity curve and the criterial and sensory growth function factors.

To investigate this relationship further the value of

Nebylitsyn's index was calculated separately for the two noise conditions and was correlated with the corresponding measures of the criterion and the discrimination index derived from the signal detection task. The only significant correlations were between Nebylitsyn's index and the non-parametric and parametric discrimination indices under 'noise'. These were 0.41 (1% one tail) and 0.39 (2.5% one tail) respectively. These values are not only highly significant but they are also in the expected direction since we predicted a positive relationship between the gradient of the reaction time/intensity curve and the difference in the slopes of the sensory growth functions for stimuli of differing intensity. Furthermore, we argued that this difference would be reflected in differences in the levelling off points of the sensory growth functions and this in turn would be reflected in the value of the discrimination index for two stimuli differing in intensity.

The fact that the correlations are not significant under 'no noise' is puzzling, though. It is possible that in this condition subjects were operating on the border between portions A and B of the inverted 'U' where in absolute terms the gradient of the curve is large but where slight movements to the left or the right (due for instance to the individual differences factors) would produce little change in its gradient thus reducing the spread of values and masking any correlation that might exist. This is speculative, however.

The failure to find any correlation between the criterion and Nebylitsyn's index under either accessory stimulation

condition is possibly explicable in terms of Grice et al's suggestion that in the visual modality the degree of divergence of the sensory growth functions for stimuli differing in intensity is relatively slight, since it is this divergence which led us to predict a positive relationship between the criterion and Nebylitsyn's index. It would be interesting to see what the correlations would be in the auditory modality.

It is also interesting to note that there were large, highly significant (1% two tail) negative correlations, under both accessory stimulation conditions, between the non-parametric criterion, on the one hand, and the non-parametric and parametric discrimination indices, on the other. The correlations range from -0.52 to -0.62 and support Nettlebeck's (1973) suggestion that when subjects find a discrimination difficult they adopt a relatively high criterion to compensate.

2. E.P.Q. ANALYSES

The Western individual differences parameters which are of most interest in the present project are introversion and neuroticism as operationally defined by the Questionnaires developed by Eysenck and his co-workers. The latter regard the scores derived from these Questionnaires as indices of underlying predispositions to respond in a particular way and since these predispositions are seen as being genetically based they would regard introversion and neuroticism as being fairly stable dimensions of personality.

This is supported by the fairly high test-retest reliabilities that have been found by Bartholomew and Morley (1959), for instance, in patients undergoing treatment and also by Knowles (1960) in both patients and normals. In both studies, furthermore, there was little change in the mean I. or N. scores of the subjects despite the fact that the successive tests were separated by 1-2 years.

However, other studies of patients undergoing treatment have shown larger changes in mean scores, particularly in psychotic groups (e.g. Copper and Metcalfe 1965) and Ingham (1966) has found that such changes are closely correlated with the degree of clinical improvement, concluding that variations in scores are related to the illness itself and that they are unlikely to reflect stable personality differences related to predisposition to neurosis.

Furthermore, Lunghi and Ryle (1969) have found comparatively low test/retest reliabilities for the E.P.I. when

measured over a two year period in normals (0.54 to 0.61 for neuroticism; 0.66 to 0.67 for introversion). They argue that this is due either to the instability of the trait itself or to the inability of the E.P.I. to measure the trait.

Eysenck and Eysenck (1969) certainly do acknowledge that the personality scales only provide indirect indices of the underlying genetic predisposition since they are of necessity phenotypic in nature. Furthermore, it has been shown that neuroticism scores, for example, are affected by life events such as those experienced by students subsequent to their entry to university (Kelvin et al 1965), though there is evidence that those with initially low N scores showed a decrease in measured neuroticism level whilst those with initially high levels showed an increase. One would expect, therefore, that their relative positions would not change markedly.

Nevertheless, in view of what has been said above, it was considered worthwhile to measure the subjects' personality scores on the occasion of each experiment and not just at the time of their initial recruitment. It could be argued that the same should have been done for the operational measure of 'strength' of the nervous system - i.e. Nebylitsyn's index of the slope of the reaction time/stimulus intensity curve. However, we have stated already the reasons why this was not practicable. We have seen already the difficulty encountered in obtaining questionnaire scores from subjects when a large number of lengthy questionnaires were given and subjects asked to complete them in their own

time. For this reason it was decided to obtain scores on the introversion and neuroticism dimensions (which were the main interest in the present project) using a questionnaire (the Eysenck Personality Questionnaire) which was given to the subjects separately from the other inventories, some of which were very long and of relatively peripheral interest, e.g. Strelau's temperament questionnaire.

This procedure was found to be successful as all of the subjects returned the E.P.Q. The latter was chosen in preference to the E.P.I. since it includes a measure of psychoticism, which though not of primary interest in the present project has been developed recently and shows some promise for future investigations in this area (see p.160). The E.P.Q. was not used initially in isolating a pool of subjects to take part in the project since it is much longer than the E.P.I. and the experimenter found great difficulty in getting potential recruits to complete it.

It could be argued that the failure to use the E.P.I. throughout makes it more difficult to assess whether or not changes in the relative scores of subjects are taking place over time. The experimenter was aware of this problem and it was for this reason that the E.P.I. was also given to the subjects to complete along with the other questionnaires such as the Strelau temperament inventory. However, as we have seen, not all of the subjects returned these. This does not constitute a serious problem though, since complete E.P.Q. scores were obtained from the subjects at the time of the vigilance task as we shall see, and since the latter and the joint simple reaction time/signal detection task

were widely separated in time, we do have an opportunity to look at the stability of the relevant personality dimensions.

Furthermore, Eysenck and Eysenck (1975) have argued that the relationships between personality and other measures should be essentially the same whether the E.P.I. or the E.P.Q. is used to define the former. It is true that for the introversion scale, at least, there are certain differences since this dimension is a composite of sociability and impulsivity (Eysenck and Eysenck 1969) and the ratio of the number of sociability items to impulsivity items is higher in the E.P.Q. than in the E.P.I. It is conceivable, therefore, that for this dimension some differences might emerge especially since Claridge (1967) and Revelle et al (1980), amongst others, have pointed to certain differences between impulsivity and sociability.

In fact, however, in the present project it is unlikely that this factor would be responsible for differences between the results of the joint simple reaction time/signal detection task when analysed using the initial E.P.I. scores, on the one hand, and the E.P.Q. scores obtained at the time of the experiment, on the other. The reason for this is that the correlation between the impulsivity scores from the E.P.I. and the E.P.Q. extraversion scores is ^{if} anything slightly higher than the corresponding correlation for the sociability scores from the E.P.I. and the E.P.Q. extraversion scores. The values are 0.4029 and 0.391, respectively, calculated for the 23 subjects who took part in the whole series of experiments that constituted the present project.

and both are significant at the 5% level (one tail). The correlation between the E.P.I. and E.P.Q. extraversion scores is 0.448 (2.5% one tail). The correlation between the E.P.I. and E.P.Q. neuroticism scores is 0.818 (a full matrix of correlations is given in Appendix B) which is significant beyond the 0.1% level (one tail).

These results support the view that these personality dimensions represent some fairly stable aspect of the subject's psychology, though the evidence is much clearer for the neuroticism scale. The lower value for the extraversion scale (which, for convenience, has been considered here in preference to the introversion scale, to which it is negatively related, of course) is unlikely to be due, furthermore, to the different sociability/impulsivity item contents of the E.P.I. and E.P.Q. since it is nevertheless higher than both of the correlations for the E.P.I. sociability and impulsivity scores cited above. It is likely, therefore, that it is due either to greater instability of the extraversion/introversion dimension or to failure of the questionnaires to provide an adequate test of it.

Let us now consider the relationship between the E.P.Q. scores and the measures derived from our joint simple reaction time/signal detection task.

The first question it was necessary to consider was whether or not to correct the scores for dissimulation. It was found that there was no significant correlation between the lie scale score, on the one hand, and the neuroticism or psychoticism scores, on the other, but there was a

negative correlation between the lie and extraversion scales of -0.4204 which is significant at the 2.5% level (two tail). Michaelis and Eysenck (1971) have shown that under conditions which provide a high motivation to dissimulate (e.g. where a job application is involved) there is a high, significant, negative correlation between the lie and neuroticism scales, whereas this correlation becomes very small or disappears under conditions which provide no motivation to dissimulate. Eysenck and Eysenck (1975) have, therefore, argued that the L/N correlation can be used as a marker for dissimulation and that where such a correlation is absent no correction for dissimulation should be made. This applies to the present situation since the L/N correlation is negligible (-0.08) and totally non-significant so it was decided not to correct the extraversion scores despite the significant L/E correlation. It was considered very unlikely that this correlation was due to 'faking' since one might expect such a tendency to be most marked for neuroticism and psychoticism neither of which correlate significantly with the lie scale score. Furthermore, there was no intuitive reason why subjects - particularly university students - should pretend to be introverted nor any reason why they should fake at all since they were informed that the results would be totally confidential and since nothing of any consequence (e.g. selection for a job) depended on their responses. Finally, it should be remembered that all of the subjects had previously scored less than four on the E.P.I. lie scale and there was no reason to

suppose that their motivation to dissimulate would increase since that time.

The large, negative L/E correlation is puzzling nevertheless. Eysenck and Eysenck (1975) have cited evidence suggesting that the lie scale may measure some stable personality dimension such as social naivety and it is not inconceivable that in the present sample, at least, introverts may show greater evidence of such characteristics than extraverts.

I) The signal detection task

a) Results

Two bimodal splits on the extraversion and neuroticism scores derived from the E.P.Q. resulted in an introversion/extraversion and neuroticism/stability factor with two levels each.

The results derived from the signal detection task were then subjected to an analysis of variance consisting of introversion (two levels) neuroticism (two levels), accessory stimulation - 'noise' (two levels), time of day (two levels) and session (two levels).

This analysis of variance was, therefore, identical in every way to the previous one except that the E.P.Q. scores obtained at the time of the experiment were used to define the introversion and neuroticism factors instead of the initial E.P.I. scores. All the various initial adjustments and transformations of the data values were the same as those described before (see pp. 555-8).

Only significant effects involving introversion and/or neuroticism will be reported.

Results for the non-parametric criterion (signal detection task) based on the E.P.Q. scores.

The interaction of neuroticism and time of day is significant at the 2.5% level (one tail). In the morning, high N subjects showed a greater tendency to respond than low N subjects, whereas the reverse was true in the afternoon. Also, amongst low N subjects, tendency to respond was greater in the afternoon than in the morning, whereas the reverse was true amongst high N subjects.

	Morning	Afternoon
Low N	1.516	1.483
High N	1.334	1.518

Table 818 . The interaction of neuroticism (EPQ) and time of day (TEE).

The interaction of session, neuroticism and time of day is significant at the 5% level (two tail). See discussion.

	LOW N		HIGH N	
	Morning	Afternoon	Morning	Afternoon
Session 1	0.6383	0.6541	0.7621	0.5929
Session 2	0.6805	0.7117	0.6914	0.7071

Table 619 The interaction of session, neuroticism (EPQ) and time of day (DY).

Results for the parametric discrimination index (signal detection task) based on the E.P.Q. scores:

Results are identical to those of the non-parametric measure.

Results for the probability of a hit (signal detection task) based on the E.P.Q. scores:

No significant effects.

Results for the probability of a false alarm (signal detection task) based on the E.P.Q. scores:

No significant effects.

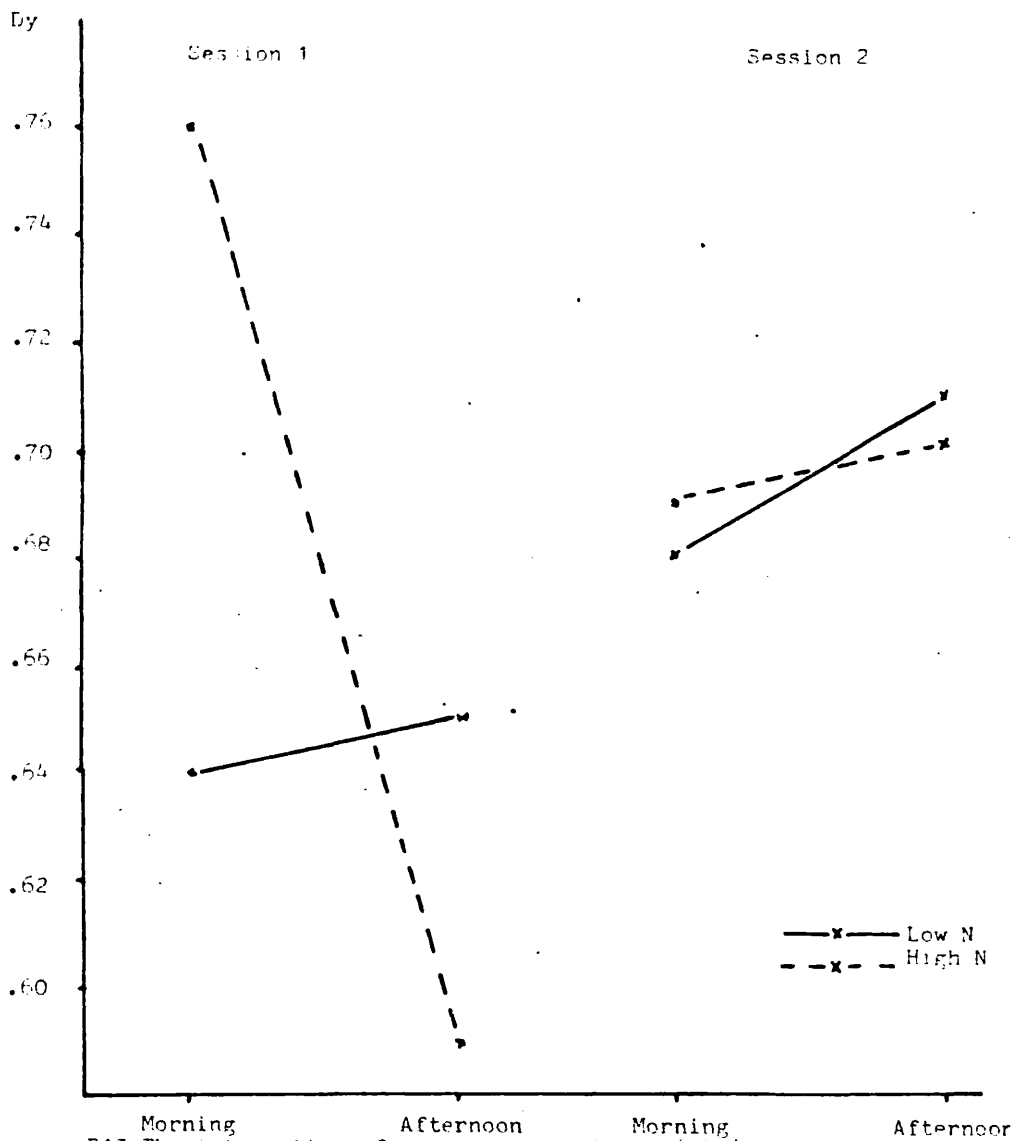
b) Discussion (signal detection task: EPQ scores)

The first measure that we must consider is the non-parametric criterion. We find that whereas the E.P.I. analysis yielded a significant main effect for neuroticism, with high N subjects having a higher tendency to respond than low N subjects, the E.P.Q. analysis instead displays an interaction between neuroticism and time of day. The above relationship holds good in the morning, but in the afternoon it is the low N subjects who have the higher tendency to respond. Also, amongst low N subjects, the tendency to respond is greater in the afternoon than in the morning, whereas the reverse is true amongst high N subjects. This interaction supports the hypothesis that there is an inverted U relationship between the determinants and the tendency to respond.

There are two effects which are significant for the E.P.I. analysis but not for the E.P.Q. analysis. These are the interactions between noise, session and introversion and between introversion, neuroticism and time of day. The former was only partially supportive of the general model and the latter was completely at variance with it so their demise does not represent any great loss from the point of view of the theory.

It should be noted, though, that both interactions involve introversion and this is in line with the much lower correlation between the E.P.I. and E.P.Q. scores for this dimension as compared to neuroticism.

Finally there is one result which is significant



B13 The interaction of session, neuroticism(EPQ) and time of day in the non-parametric discrimination index.

for the E.P.Q. analysis but not for that based on the E.P.I. results. This is the interaction between session, neuroticism and time of day, depicted in Graph B13. We see that the results are very much in line with prediction: in particular the sharp decline in discrimination ability between morning and afternoon in the high N subjects in Session 1 who are the group one would expect to be operating furthest to the right along the 'X' axis of the inverted 'U'. The values for Session 2 are higher than one would expect on this basis, but we could explain this in terms of a learning effect.

In the results for the probability of a hit there are no significant effects involving personality and this is in line with the E.P.I. analysis.

When we look at the results for the probability of a false alarm, we find that the main effect for neuroticism has disappeared as it did for the criterion measure. Perhaps a more significant loss is the interaction between noise and introversion which indicated that there was a 'U' shaped relationship between the determinants and false alarm rate and thus supported the earlier interpretation of the inverted 'U' model in terms of 'performance' (see pp. 582-7).

On the other hand the fact that the interactions between noise, session and neuroticism and between noise, session, introversion and neuroticism are significant for the E.P.I., but not the E.P.Q. analysis is not of any great importance since neither was supportive of the model or adequately explicable.

ii) The simple visual reaction time task (EPQ)

These results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels), accessory stimulation or 'noise' (2 levels), time of day (2 levels), stimulus intensity (6 levels), session (2 levels), and block (3 levels).

As such it is identical to the earlier analysis except that again the introversion and neuroticism factors are defined in terms of the subjects' E.P.Q. scores obtained at the time of the experiment rather than their initial E.P.I. scores.

Again, only results involving introversion and/or neuroticism will be reported.

Also, as before, results involving the 'block' factor will be deferred until the section on vigilance.

a) Results for simple visual reaction time (LSCORE) based on E.P.Q. scores:

a) The planned comparison associated with the interaction between stimulus intensity and neuroticism is significant at the 5% level (one tail). This is due to the fact that whilst the low N subjects showed an increase in speed of response between the two highest intensities the high N subjects showed a decrease in speed.

stimulus intensity (μ s)	High N	Low N
2000	2.3621	2.4035
200	2.3546	2.4232
20	2.3873	2.4328
2	2.3980	2.4606
0.2	2.4110	2.4796
0.02	2.4536	2.5154

Table B20. The interaction between neuroticism (EPQ) and stimulus intensity (LSCORE).

b) The quadratic component associated with the interaction of session, stimulus intensity and neuroticism is significant at the 2.5% level (two tail). See discussion.

stimulus intensity (Lux)	Session 1		Session 2	
	High N	Low N	High N	Low N
2000	2.3613	2.4340	2.3630	2.3729
200	2.3634	2.4403	2.3458	2.4060
20	2.3861	2.4331	2.3884	2.4325
2	2.3982	2.4612	2.3978	2.4601
0.2	2.4074	2.4912	2.4146	2.4670
0.02	2.4519	2.5369	2.4554	2.4939

Table B21. The interaction of stimulus intensity, session and neuroticism (EPQ) - (LSCORE).

c) The interaction of noise, neuroticism and time of day is significant at the 2.5% level (two tail). See discussion.

d) The main effect for introversion is significant at the 5% level (two tail). Extraverts are faster than introverts overall.

Extraverts	Introverts
2.3922	2.4548

Table B22. The main effect for introversion (EPQ) - (LSCORE).

e) The interaction of session, introversion and time of day is significant at the 5% level (two tail). See discussion.

As with the analysis based on the E.P.I. scores, the inclusion of the non-parametric criterion as a covariate did not significantly affect the results.

Results for Nebylitsyn's index of the gradient of
the reaction time/stimulus intensity curve based on the
subjects' E.P.Q. scores.

The main effect for neuroticism is significant at the 2.5% level (one tail). Overall, high N subjects have a lower value for Nebylitsyn's index than low N subjects.

Low N	High N
6.901	6.584

Table 823 . The main effect for neuroticism (EPQ) - (Sigma).

b) Discussion of results of simple visual reaction time task based on E.P.Q. scores:

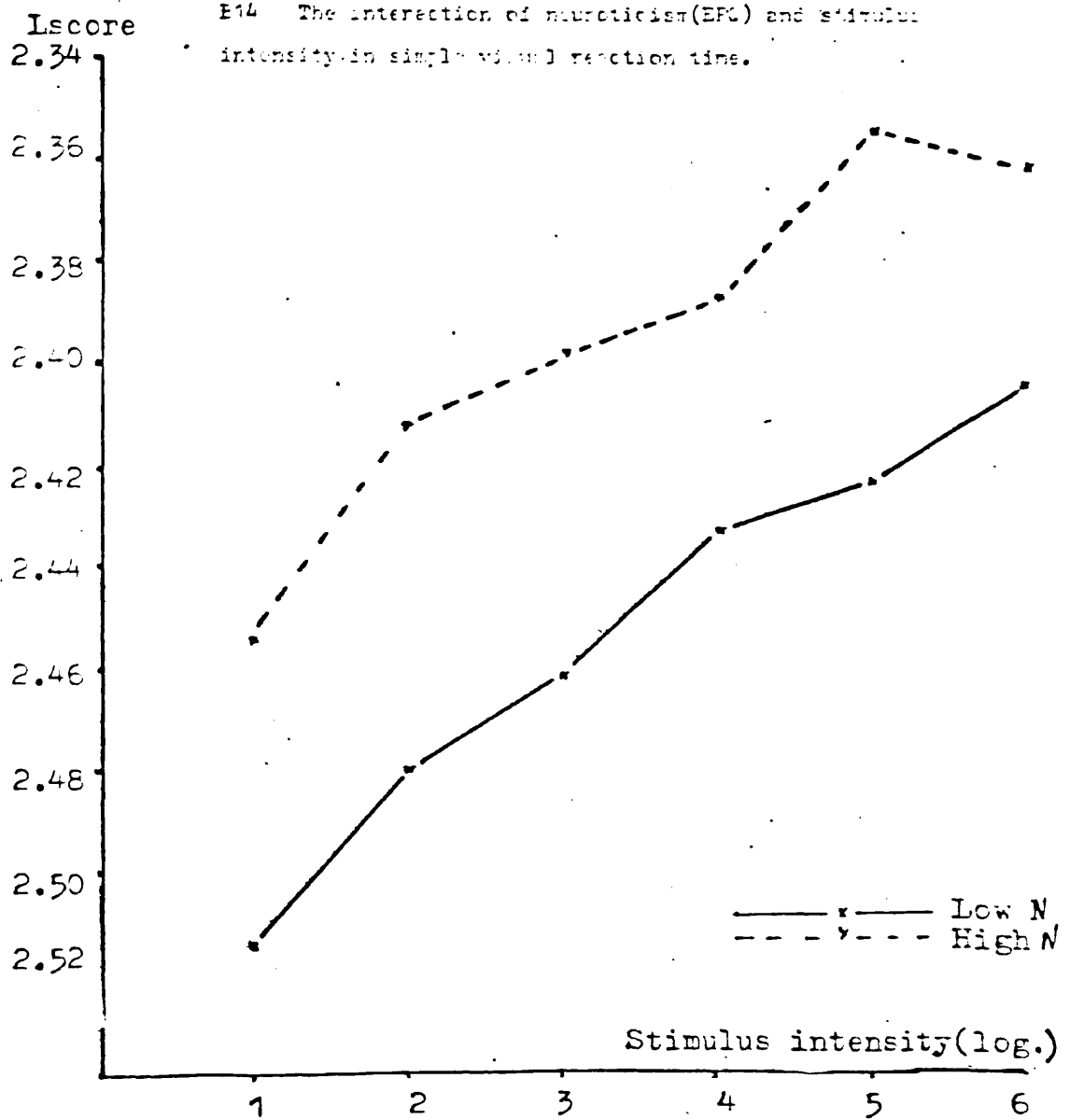
The most important feature of the present results is the persistence of the relationship between neuroticism and stimulus intensity which we saw in our discussion of the results of the E.P.I. analysis was of considerable theoretical importance for our conception of personality and for our ideas on the nature of simple reaction time. As before the planned comparison is significant due to the reduction in response speed between the second-highest and the highest stimulus intensity in the high N group (see Graph 8/4). Again this is consistent with the model though the post hoc comparison of means and quadratic component are not significant.

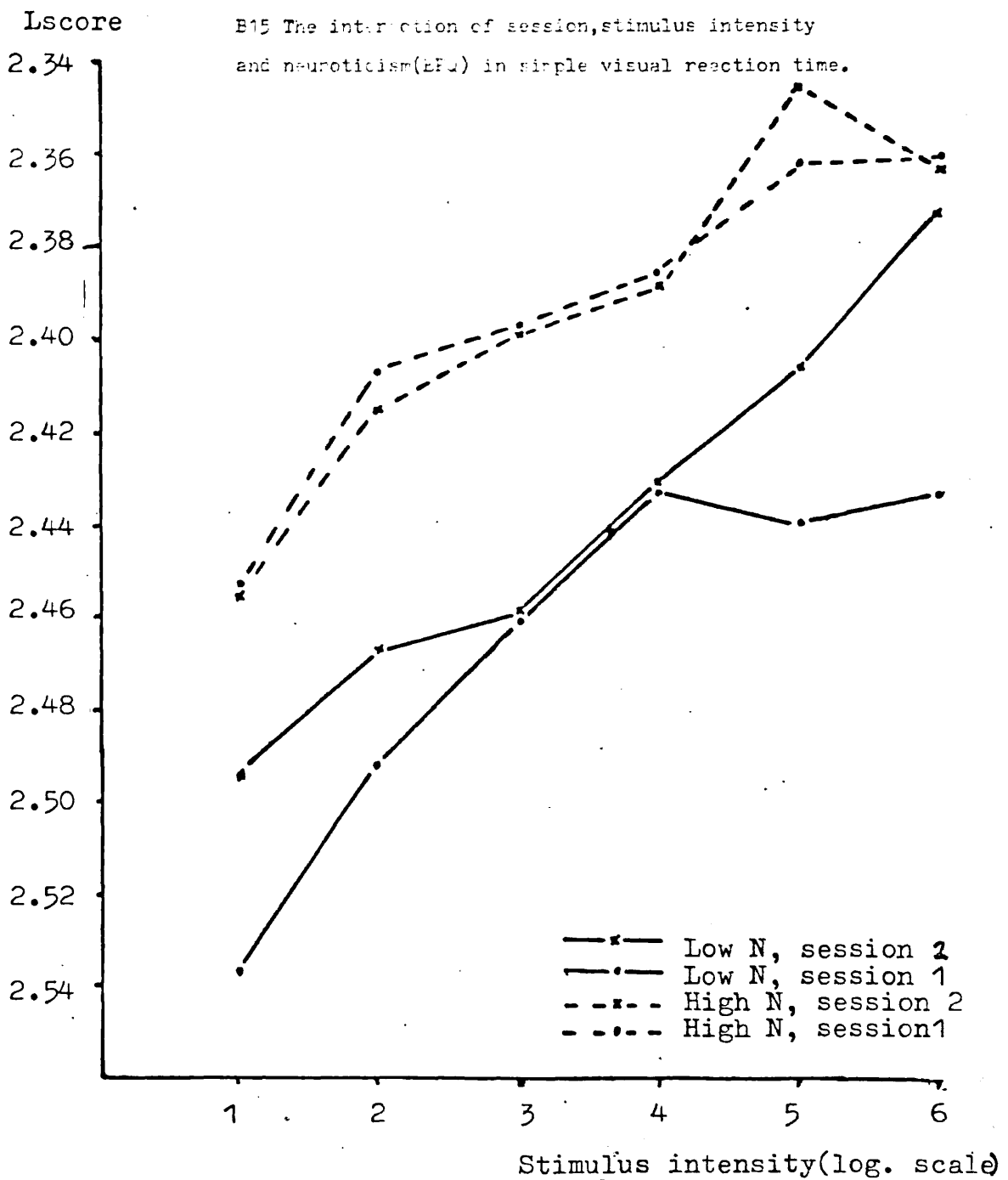
Furthermore, the analysis of Nebylatsyn's index of the gradient of the reaction time/stimulus intensity curve again shows a highly significant main effect for neuroticism, due to the fact that high N subjects have a lower value for the index than low N subjects. This supports our previous conclusion that neuroticism is negatively related to 'strength' of the nervous system.

There are two results which are significant for the E.P.I. but not the E.P.Q. analysis: the cubic component associated with the interaction of stimulus intensity, session and introversion, and the interaction between noise, session, introversion, neuroticism and time of day. However, neither of these was invested with much significance.

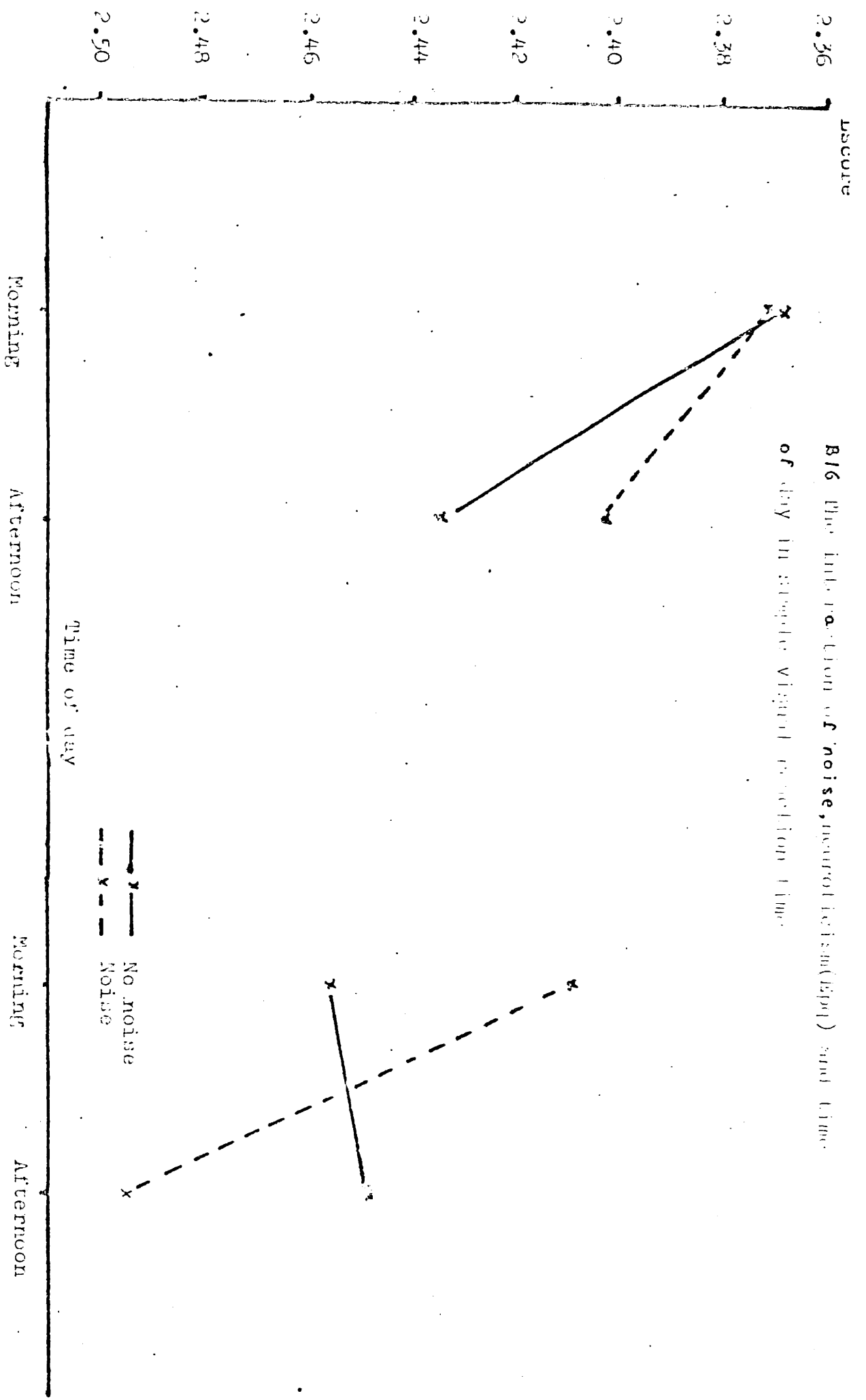
Two results are more statistically reliable for the E.P.Q. :

E14 The interaction of neuroticism (EPG) and stimulus intensity in simple visual reaction time.





B16 The interaction of noise, period (AM/PM) and time of day in single visual reaction time



the interaction of session, stimulus intensity and neuroticism and the interaction between noise, neuroticism and time of day. As Graphs 615 and 616 show these are very similar to the corresponding graphs for the E.P.I. scores (see pp. 610 and 613) .

The results section also includes one other effect, the interaction of session, introversion and time of day, which is significant for the E.P.Q. analysis but not for the E.P.I. analysis, but since it does not conform to prediction and is not amenable to adequate explanation it will not be considered here.

c) Results for latency measures derived from the signal detection task (based on the subjects' E.P.Q. scores)

Results for the speed of response to signals

a) The interaction of noise and neuroticism is significant at the 1% level (one tail). Amongst low N subjects, speed of response is greater under 'noise' than under 'no noise', whereas the reverse is true amongst high N subjects.

	Low N	High N
No noise	0.832	0.657
Noise	0.748	0.704

Table B24 . The interaction of noise and neuroticism (SIG)

b) The interaction of noise, session, introversion and time of day is significant at the 5% level (two tail). See discussion.

Results for the speed of response to non-signals

The interaction of noise, session, neuroticism and time of day is significant at the 2.5% level (two tail). See discussion.

d) Discussion of results of latency measures from signal detection task based on E.P.Q. scores:

As for the E.P.I. analyses none of the effects which are significant for the signal detection task latency measures are significant for the simple reaction time task. So again there is little evidence to support the view that the processes underlying simple and disjunctive reaction time are the same. On the other hand we do have one highly significant effect for the 'speed of response to signals' measure which supports the inverted 'U' model. This is the interaction between noise and neuroticism. Amongst low N subjects, speed of response is greater under 'noise' than under 'no noise', whereas the reverse is true amongst high N subjects. The remaining interaction for this ^{measure} - i.e. between noise, session, introversion and time of day - is, however, not in line with prediction and the author has no explanation for it.

Surprisingly, whilst the interaction between noise and neuroticism for the speed of response to signals measure appears in the EPQ analysis but not the EPI analysis, the reverse is true for the speed of response to non-signals measure. There is one significant effect for the latter in the present set of results: namely, the interaction between noise, session, neuroticism and time of day, but it is not in line with prediction and no explanation for it comes to mind.

3. PSYCHOTICISM ANALYSES

i) The signal detection task

a) Results

These results are based on an analysis that is identical to the previous ones except that the subjects' E.P.Q. P scores were subjected to a bimodal split resulting in a psychoticism factor which was substituted for the introversion and neuroticism factors.

Results for the non-parametric criterion:

The interaction of noise, psychoticism and time of day is significant at the 5% level (one tail). See discussion.

	Low P		High P	
	Morning	Afternoon	Morning	Afternoon
No noise	1.533	1.529	1.360	1.465
Noise	1.386	1.537	1.444	1.443

Table 925 . The interaction of noise, psychoticism and time of day (TEE).

Results for the non-parametric discrimination index:

No significant effects.

Results for the parametric discrimination index:

No significant effects.

Results for the probability of a hit:

No significant effects.

Results for the probability of a false alarm:

No significant effects.

Results for the speed of response to signals:

No significant effects.

Results for the speed of response to non-signals:

The interaction between noise, psychoticism and time of day is significant at the 1% level (one tail). See discussion.

	Low psychoticism		High psychoticism	
	Morning	Afternoon	Morning	Afternoon
No noise	0.793	0.779	0.624	0.857
Noise	0.780	0.843	0.650	0.683

Table B26 . The interaction of noise, psychoticism and time of day (SIG).
N
A

b) Discussion of results of signal detection task involving psychoticism

We find that there is a significant interaction between noise, psychoticism and time of day for two of the measures derived from the signal detection task, though it is verified at a different level of reliability in each.

In the case of the non-parametric criterion (5%, one tail) we find that amongst low P subjects, the tendency to respond is greater in the morning than in the afternoon under 'noise' whereas the reverse is true under 'no noise'. Also, in the morning, tendency to respond is greater under 'noise' than under 'no noise', whereas the reverse is true in the afternoon. All of these relationships are reversed in the high P group.

In the case of the speed of response to non-signals measure (1%), we find that the relationships in the low P group are identical to those obtained for this group with the tendency to respond measure (see above). However, the relative speeds of response under 'no noise' and 'noise' are reversed in the high P group: in the morning, speed of response is greater under 'no noise' than under 'noise', but in the afternoon it is greater under 'noise' than under 'no noise'.

Clearly, all of these relationships support the hypothesis presented earlier that there is an inverted 'U' relationship between the determinants and the determinates amongst low P subjects, but a 'U' shaped relationship amongst high P subjects.

ii) Results for simple visual reaction time involving
psychoticism:

The linear component associated with the interaction between stimulus intensity and psychoticism is significant at the 2.5% level (two tail). Overall, low P subjects show a less steep rise in response speed with rise in stimulus intensity than high P subjects.

Stimulus Intensity (lux)	0.02	0.2	2	20	200	2000
Low P	2.4729	2.4419	2.4155	2.4039	2.3891	2.3862
High P	2.4961	2.4487	2.4431	2.4162	2.3886	2.3794

Table 617. The interaction of stimulus intensity and psychoticism (LSCORE).

There were no significant effects involving psychoticism in the analysis of Nebylitsyn's index of the gradient of the reaction time/stimulus intensity curve.

Discussion:

The significant linear component associated with the interaction between stimulus intensity and psychoticism is due to the fact that overall, low P subjects show a less steep rise in response speed, due to a rise in stimulus intensity, than high P subjects. Though interesting, this result tells us little about the validity of the present hypotheses.

4. Overall Summary

i) Signal detection task

The most notable finding to emerge from the signal detection task is an interaction for the probability of a false alarm indicating a 'U' shaped relationship for this index. This result supports the earlier formulation of the inverted 'U' in terms of 'performance', assuming that we regard the probability of a false alarm as an inverse measure of the latter.

The second point we should note is that there is evidence in favour of our hypothesis that there is an inverted 'U' relationship between the determinants and the 'tendency to respond' - i.e. the reciprocal of the criterion (though there are also indications that this measure is also influenced by the opportunity to respond and also, under conditions of threat, by the 'behavioural inhibition system'). This evidence comes in the shape of the interaction between neuroticism and time of day for the criterion measure which is based on the E.P.Q. analysis. It should be noted though that this interaction is not significant for the E.P.I. analysis.

The discrepancy between the two analyses is also apparent for the interaction between noise and introversion mentioned above, though in the case of the latter it is the E.P.I. analysis that yields the significant result. These facts support our earlier suggestion that though introversion and neuroticism do seem to show a measure of stability, the effect of time does appear to be playing a part in moderating their influence.

It should also be noted that the number of results which are explicable in terms of our model (either in its original or a revised form) that involve introversion is greater relative to similar results involving neuroticism than in the taste experiment. This supports our earlier suggestion that as subjects became more familiar with the experimenter, the pre-eminence of neuroticism might become diminished to some extent, though the fact that the stimuli were probably less noxious than in the taste experiment may also have played a part.

Finally it is noteworthy that there are two significant interactions for the psychoticism dimension which support the view that in high P subjects the normal inverted 'U' relationship found in low P subjects is turned into a 'U' relationship, and since the same factors were involved, but two different determinates, it is probable that this represents a real effect and not a false positive.

ii) Summary of results for latency measures derived from the simple visual reaction time task and the signal detection task.

Elucidation of the nature of the relationship between neuroticism and stimulus intensity is the most notable feature of the results of the simple reaction time task. Firstly, the comparison between the high and low N subjects in the effect of intensity on response speed is in line with our inverted 'U' model and the fact that it must be due to sensory factors ties in with Galifret's (1962) finding that there is an inverted 'U' relationship between stimulus intensity and the frequency of neural discharge. These two findings together also support our hypothesis that there is an inverted 'U' relationship between the determinants and the slope of the sensory growth functions in simple visual reaction time.

In addition they counter Grice et al's (1979) suggestion that in vision, the effect of stimulus intensity on this index is mediated via the intercept of the sensory growth functions with the 'X' axis representing time-since stimulus-onset, rather than via the slopes of these functions. Our hypothesis that the difference in these slopes for stimuli of differing intensity can account for differences in the gradient of the simple reaction time/stimulus intensity curve remains tenable, therefore. Furthermore, the fact that high N subjects adopt a lower criterion in the signal detection task than low N subjects and also show a smaller value for this gradient provides further support for this hypothesis. It should be noted, though, that the result for the

signal detection task is only significant for the E.P.I. analysis, and the result from the simple reaction time task is not significant if one measures the gradient by the slope of the line of best fit.

This gradient can also be assessed, however, by Nebylitsyn's index and the fact that this is significantly lower in high N subjects than in low N subjects supports the hypothesis that neuroticism is negatively related to 'strength' of the nervous system.

The dimension of introversion displays none of these relationships to stimulus intensity, and the present results indicate that though the balance between introversion and neuroticism may have shifted towards the former in the signal detection task, the same is not true of the simple visual reaction time task, possibly because the latter was completed by the subjects before they took part in the signal detection task. It is likely, therefore, that the role of the behavioural inhibition system and anxiety was greater in the simple reaction time task.

It should also be noted that discrepancies between the E.P.I. and E.P.Q. analysis are more apparent for introversion than for neuroticism, thus supporting the view (based on the test/retest correlations) that the former has shown greater stability between the taste experiment and the present study, than the latter.

Finally we should note that there is little indication in the present set of results that the processes underlying the latency measures derived from simple and disjunctive reaction time tasks are the same.

CHAPTER TWELVE - VIGILANCE, A REVIEW OF THE LITERATURE

1. THEORETICAL BACKGROUND

i) Stimulus duration and frequency in a vigilance context

Up to now we have been mainly concerned with measures of average performance. We have treated the inverted 'U' as essentially a 'static' model providing a framework for prediction of the level of determinates at a given moment in time. The exception to this, of course, is the reaction time index since this is by its very nature based on temporal changes within the subject's nervous system. However, the time scale over which these changes take place is very limited - of the order of one or two seconds. We have not yet considered the effect of changes over a more extended time period.

In the introduction to this thesis we pointed out that stimulus duration was thought, within the Russian framework, to be analogous to stimulus intensity. However, we also pointed out there was an ambiguity associated with the term 'stimulus duration'. Firstly, it could be interpreted as the duration of a single stimulus. Sanford (1972) has shown that in a simple reaction time task stimulus duration, defined in this way, does indeed produce very similar effects to stimulus intensity. Secondly, however, it could be interpreted as meaning 'time on task' - i.e. the total time that has elapsed

since the beginning of the experimental session.

A similar ambiguity applies to the term 'stimulus frequency', which is also thought to act in an analogous fashion to stimulus intensity within the Russian framework. The term could be construed as referring to the frequency of a single stimulus, for instance, the pitch of an auditory tone, and we have already seen that this factor does interact in a predictable fashion with other proposed determinants (e.g. introversion: Stelmack and Campbell 1974, see p. 226). However, it can also refer to the number of stimuli per unit time.

Where both stimulus duration and stimulus frequency are concerned, the ambiguity resides essentially in the time scale being considered. If one is considering a time scale of the order of a second or even less, it is normal to think in terms of a single stimulus, although the energy conveyed by the latter does nevertheless have a discrete quality to it (for instance a light stimulus can be considered to be a stream of photons, though physicists argue that light has a continuous or 'wave' aspect as well). The question is whether the same predictions apply when one is considering stimuli which last for much longer periods of time or where the stimuli impinging on the subject are 'discrete' in the usual sense of the word.

ii) The nature of vigilance tasks.

This brings us directly to the topic of 'vigilance'. Mackworth defined the term as the 'state of readiness to

detect and respond to certain specified small changes occurring at random time intervals in the environment' (1957, pp. 389-390). The experimental paradigm which is usually employed to investigate such a state involves the sort of extended time scale mentioned above. Some of the stimuli which impinge on the subject tend to be unchanging (e.g. background stimuli totally unrelated to the task) and so represent 'stimulus duration' in its second aspect. Other stimuli are repetitive (though not necessarily regular), but the time interval between them is large (compared to the interval between light photons, for instance!) so that they are 'discrete' in the usual sense of the word, and represent 'stimulus frequency' in its second aspect. The 'small changes' mentioned in Mackworth's definition above, are known as 'signals', and these may either occur by themselves, or they may be embedded in a series of background, neutral stimuli to which the subject does not have to respond. For instance, the subject may be presented with a series of regular light stimuli with specified characteristics (intensity, duration etc.), and the signals may represent an occasional, irregularly occurring change in one or more of these characteristics (e.g. intensity) which the subject has to detect and respond to in some way.

The most usual pattern of response in vigilance tasks of this kind is a decline in the 'performance' of the subject with 'time on task'. This 'vigilance decrement' is usually measured in terms of a decline in the number of signals detected as time proceeds, but we shall

see that there are a number of other indices which have been used. Also, attempts have been made to account not only for the vigilance decrement and for the experimental variables upon it, but also to account for the overall, or average level of performance during the experimental session since this may also vary as a function of other factors. However it is the vigilance decrement which has been the main concern of vigilance theories.

These theories have been extensively discussed by other writers (e.g. Davies and Tune 1970; Broadbent 1971; Stroh 1971; Loeb and Alluisi; ¹⁹⁷⁷). We will only provide a brief account.

iii) Theories of vigilance

a) The inhibition theory

This particular theory has been couched in a number of different forms since its original conception. Mackworth (1948, 1950) suggested that during the training period that usually precedes a vigilance session, the subject's response to the experimenter's command (e.g. 'press' or 'now') is essentially unconditioned. Furthermore, since this command usually occurs immediately following the presentation of a signal, the subject's response would become conditioned to the latter. However, during the main test, unconditioned stimuli and reinforcement would no longer be provided by the experimenter and so the subject would enter an 'extinction' phase: hence the vigilance decrement. We will not go

into the details of the experimental support for this theory (see Stroh 1971, for example), since in its present form it founders on the discovery that an increase in signal frequency often produces a reduction in the vigilance decrement, whereas it ought to do the reverse since the number of non-reinforced trials per unit time is relatively high at high frequencies.

A number of variations of the inhibition theory have subsequently been presented. For instance, Broadbent (1958) has suggested that what actually extinguishes is the attentional responses to the background, neutral stimuli and that this generalises to the signals themselves.

More recently J.F. Mackworth (1968) has argued that the vigilance decrement is due to inhibition (through habituation) of the 'arousal' or alpha-blocking response and of the evoked potential to the task stimuli. Gale et al. (1977) have pointed out that the empirical evidence in support of the theory since its original presentation has not been overwhelming, though they suggest a number of reasons why this might be so. For instance, the wide variety of tasks which come under the general heading of 'vigilance'.

Loeb and Alluisi (1977) have pointed out that the vigilance decrement could also be due to the inhibition of 'observing' responses, the set of peripheral (Holland, 1958) or more covert responses (e.g. Jerison and Pickett, 1964) associated with the subject's monitoring of the stimulus display. However, they also point out that

experiments designed to test the theory have been inconclusive, though Broadbent (1971) has suggested that this may be due to inadequacies in the techniques employed.

b) Reinforcement theory

This theory is also based, like the inhibition theory, on a comparison between vigilance and conditioning paradigms, but this time the vigilance decrement is seen as an operant phenomenon rather than as an example of extinction in classical conditioning (Stroh, 1971). The theory assumes that the detection of a signal is intrinsically reinforcing and makes observing responses more likely. It explains the vigilance decrement in terms of the failure to provide adequate reinforcement due to the low signal frequencies normally employed. As such it is able to accommodate the finding that if signal frequency increases, the vigilance decrement often decreases. However, this would be most likely to apply when signals were easy to detect and the subject could be fairly sure that he was correct.

One problem with both the inhibition and reinforcement theories is that they are concerned almost exclusively with explaining the vigilance decrement. As Broadbent (1971) has pointed out, they cannot account for the overall level of performance in tasks in which no such decrement occurs. Davies and Tune (1970) have also criticised these theories on the grounds that they are too restricted and only attempt to account for a limited number of findings.

c) Expectancy theory

The basic tenet of this theory (Deese, 1955; Baker, 1958) is that subjects develop expectations of when the signals in a vigilance task are likely to occur, on the basis of preceding experience. An increase in signal frequency will result in superior performance because there will be more information on which to base the expectancies, and also because it is easier to judge when the next signal is likely to occur if the intervals between stimuli are small. For the same reason, an increase in the regularity of signals will also tend to improve performance. These factors, and others, will therefore tend to determine the overall level of performance. In addition, the probability of detecting a given signal is thought to be relatively large if the interval between this signal and the last one is relatively close to the mean intersignal interval up to that point in time.

Some support for these predictions is present in the vigilance literature (e.g. Mowrer, 1940; McGrath, and Harabedian, 1963) but the evidence is very equivocal (see for example Frankman and Adams, 1962; Davies and Tune, 1970). Stroh (1971) has also criticised the theory for its assumption that as the size or range of intersignal intervals is altered, the length of time for which the subject remains in a state of 'expectancy' remains constant. Instead he suggests that as these parameters are altered, subjects alter their limits of expectancy accordingly, so that if the signal frequency is reduced, for instance, the time interval during which the subject expects the signal is extended.

So far we have considered only the way in which the theory attempts to account for the overall level of performance. It explains the vigilance decrement by assuming that a failure to detect signals early on in the task results in inaccurate assessments of the signal 'structure' in the task and hence makes further failures more likely. This leads to a vicious circle and hence a decrement in performance. Broadbent (1971) has presented an interpretation of such an effect couched in terms of signal detection theory. However, he points out that the fatal flaw in the theory is that it can only account for the findings in situations where the signals are less frequent than the background, neutral stimuli. It cannot account for situations in which the reverse is true. The reader is referred to his account for a detailed explanation. Davies and Tune (1970) have also argued that the theory cannot explain the fact that the vigilance decrement sometimes occurs even though the subject initially detects all the signals and presumably, therefore, develops accurate expectancies.

There is, however, a variation to expectancy theory based on an analysis of the effects of the pre-task training session on subsequent performance. We will discuss this question later (see pp. 783-18).

d) Attention theory

Broadbent (e.g. 1953) has suggested that the nervous system contains a 'filter' which selects certain sensory inputs and directs attention towards these on the basis of certain criteria. Novel, intense and 'biologically

important' stimuli will tend to be selected preferentially. He explains the vigilance decrement by assuming that as the task stimuli become less novel, attention is more likely to shift towards other stimulus sources. Hence, the probability of detecting a signal will decrease. This theory can also explain the common finding that the vigilance decrement is greater if the frequency of the background, neutral stimuli is relatively high since they will, as a result, lose their novelty faster.

In later formulations (Broadbent, 1958; 1971) he proposes a combined filter/arousal theory, suggesting that deviations of attention alone cannot explain all of the vigilance data, but that they can explain the 'residual' decrement that occurs even when the subject enters the experimental session with a 'higher level of arousal than the situation will sustain'.

Stroh (1971) has also argued that the term 'biologically important' stimuli is not sufficiently well defined, and Loeb and Alluisi (1977) have concluded that at present the filter model is essentially speculative.

e) Signal detection theory

We have already discussed in detail the possible applications of signal detection theory to measures of overall performance level and also ^{to} indices dependent on changes over a very short time scale (e.g. in simple reaction time). A number of workers, however, have attempted to apply the theory to vigilance tasks. Some have found that the vigilance decrement is associated with an increase in the criterion of the subject (e.g.

Broadbent and Gregory, 1963; 1965; Colquhoun and Baddeley, 1964). Others have found it to be associated with a decrease in the discrimination index (d') - e.g. Mackworth and Taylor (1963).

The application of signal detection theory to vigilance has been criticised by some workers. For instance, Jerison (1967) has suggested that the values of the criterion usually obtained from vigilance tasks are much higher than those found in normal psychophysical signal detection tasks. However, this is not surprising since the signal probabilities normally employed in vigilance paradigms are much lower than in the latter, and the theory of signal detection predicts that as signal probability decreases, the criterion will increase.

Secondly he argues that calculation of the values of d' and the criterion depend on estimation of the subject's 'sampling interval' - i.e. the subjective time period which the subject treats as being equivalent to a trial in a normal signal detection task. However, this only applies to situations where signals are presented by themselves. Where they are superimposed on a background of neutral stimuli, it is reasonable to suppose that each of these corresponds to a 'trial'.

However, Jerison also contends that failures to detect signals may arise not only as a result of a failure of the signal distribution on a given occasion to exceed the subject's response criterion, but also (or alternatively) as a result of the subject's decision not to observe the stimulus display. He also suggests that the

vigilance decrement can be explained by assuming that the 'cost' of making an observing response increases as the task proceeds. We have seen already that there have been problems associated with the attempt to test the observing response hypothesis (see p. 676). Broadbent (1971) has also criticised Jerison on a number of grounds, for example he argues that Jerison's theory would not be able to explain situations in which the criterion of the subject rose but d' remained unaffected (though he accepts that it may be relevant in those studies in which d' does show a decrement).

Also, even if Jerison is right, it is still possible to separate purely sensory factors (reflected in the d' index) from response or decision factors, whether these relate to the decision to observe or to the placement of the criterion.

Other workers (e.g. Taylor, 1967 ; Craig, 1977) have suggested that the assumptions underlying conventional signal detection indices may not be upheld in vigilance tasks (e.g. the assumption that the 'signal' and the 'noise' distributions have equal variance). However, we have seen already that non-parametric indices are available which do not rest upon such assumptions.

We see then that signal detection theory is a potentially useful tool in vigilance research. However, it provides essentially an alternative description of the performance of the subject. One is still left with the need to explain the changes in the signal detection indices that take place during the vigilance session. We saw

in the section on 'reaction time and signal detection theory', how a combination of the signal detection and inverted 'U' models could be used to generate predictions regarding the behaviour of the subject in simple reaction time and conventional signal detection tasks. This brings us to the last theory of vigilance performance that we will consider.

f) The arousal theory

Like the other theories we have considered so far, the 'arousal' theory has been mainly concerned to explain the vigilance decrement. It suggests that in a vigilance task the level of 'arousal' steadily decreases and as a result the subject misses a greater and greater proportion of the signal. The reason for this reduction in 'arousal' and the conditions which influence it, however, have been a matter of some dispute. Jerison and Pickett (1964) have argued that a low frequency of background, neutral stimuli should produce a lower level of 'arousal' than a relatively high frequency. However, Stroh (1971) has argued the reverse - namely, that a high frequency will result in greater habituation due to a greater reduction in the novelty of the stimuli and hence a greater decrease in 'arousal' level. We shall see that this conflict in the literature is an important one since both stimulus frequency and novelty figure in our list of determinants.

'Arousal' itself is, of course, the intervening construct employed by Western theorists in their inverted 'U' model. Let us now consider the various determinants

in turn and their effect on vigilance performance. Again we would like to point out that with the exception of the work on personality we will only attempt to summarise briefly the findings. For a more detailed account the reader is referred to one or more of the extensive reviews of this area (Mackworth, 1969, 1970; Davies and Tune, 1970;; Broadbent, 1971; Stroh, 1971; Loeb and Alluisi, 1977; Rodriguez, 1977).

2. THE DETERMINANTS AND VIGILANCE

1) Stimulus intensity

As already stated, some vigilance tasks employ only one kind of stimulus - i.e. the signal itself, which is presented at irregular intervals. In such tasks an increase in the intensity of the signal results in an increase in the total number of signals detected, e.g. Davenport (1968). The same study also found a similar effect of an increase in the duration of the signals, though there is evidence that above a critical level (about two to four seconds), the duration of the signal does not affect vigilance performance.

It should be noted that Webb and Wherry (1960) have shown that where the signal is less intense than the background stimuli, performance is superior if the intensity of the signal is decreased since it is already fainter than that of the background stimulus. Thus it appears that it is the degree of signal differentiation that seems to be the important factor.

So far we have considered the effect on overall performance. The effects of signal intensity and duration on the vigilance decrement are far less clear-cut. Davies and Tune (1970) have concluded that the decrement has been found more often when low intensities have been used but in many cases the results were not statistically significant. Similarly an increase in signal duration does seem to reduce the likelihood of a decrement, but only under particular conditions (e.g. if the task does not involve a search requirement).

A more recent study by Lisper et al. (1972) does suggest, though, that there is a greater decrease in the speed of response to low intensity signals than to high intensity signals, with time on task.

We have already stated that within the Russian model, stimulus frequency is thought (like stimulus duration) to act in an analagous fashion to stimulus intensity. However there is a complication in the area of vigilance when we come to consider this factor. We have already seen that in vigilance tasks, subjects are often presented with a series of regular background stimuli or 'events', and that the signals in such a situation represent a change in these events along some parameter (e.g. intensity). We, therefore, have two stimulus frequencies to consider: the frequency of the background events and the frequency of the signals. Furthermore, the ratio of the latter to the former could be considered to be a factor in its own right - i.e. signal probability:

$$\text{Signal probability} = \frac{\text{Signal frequency}}{\text{Background-stimulus frequency}}$$

Background-stimulus frequency

Since these three factors are linked by the above equation, it is not possible to change any one of them without altering at least one of the others. It is not possible to alter one and keep both the other two constant, so in any single study the most one can do is to keep one factor constant and allow the other two to vary. They will, of course, be completely confounded with each other and so we cannot interpret the results solely in terms of one or the other. The fact that the three variables are not totally independent of each other does not mean that they should not be studied, but workers have often failed to point out that they were altering two of the variables and not one. We will consider some of their findings but the above strictures should be borne in mind.

In their review, Loeb and Alluisi (1977) report that an increase in signal frequency /probability is generally associated with an increase in the total number of 'hits' (e.g. Jenkins, 1958) and an increase in response speed (e.g. Smith et al. 1966), though they point out that some studies have failed to show an effect of this factor (Buckner et al., 1960). They also report that it may interact with the background event frequency (e.g. Johnston et al., 1966). However, since these two factors are in any case both related to the third factor of signal probability, interpretation of such interactions is difficult. The same applies to the conflict in the literature regarding the relative importance of signal frequency and signal probability. Some workers have

argued that it is the latter that is the primary determinant of performance (e.g. Baddeley and Colquhoun, 1969), whereas other researchers have disagreed (e.g. Loeb and Binford, 1968). Kishimoto (1979) has suggested that it is the background-stimulus frequency that is the main factor, and it is certainly true that many studies have found that changes in the level of this variable are associated with changes in performance. For instance, Parasuraman and Davies (1977) have found that an increase in the frequency of the background events is associated with a lower overall value of the discrimination index d' and a greater decrement with time in both this measure and the hit rate index. A high background-stimulus frequency was also related to a higher overall value of the criterion.

However, in this study, the signal frequency was constant and so the event or 'stimulus' frequency was confounded with signal probability. Kishimoto (op. cit.) has suggested that when signal probability is very high, it is the main determinant of performance.

ii) Drugs

A number of studies have shown that stimulant drugs help to prevent the normal vigilance decrement (i.e. the decline in the proportion of signals detected). This had been found for α -amphetamine (Mackworth, 1950), and for benzedrine and caffeine (Payne and Hauty, 1954) amongst others. Depressant drugs on the other hand tend to accentuate the vigilance decrement (see Mackworth, 1970).

Furthermore, Hink et al. (1978), have shown that the effects of drugs on the vigilance decrement are due to changes in some form of 'general state' (such as 'arousal') rather than to changes in some other process (e.g. selective attention).

However, Mackworth (1970) has pointed out that the effects of drugs on the 'hit rate' (i.e. the proportion of signals detected) are different from their effect on the 'false alarm rate' (i.e. the proportion of background stimuli to which the subject responds). Under normal conditions, both of these measures tend to decline with time on task. Stimulant drugs such as amphetamine tend to maintain the hit rate, whilst leaving the decline in the false alarm rate unaffected, so that by the end of the session, the value of the discrimination index (d') may be higher in the drug than in the placebo condition. Depressants seem to increase the false alarm rate, or at least maintain it, while increasing the decline in the hit rate.

Mackworth, therefore, suggests that the normal changes in the hit rate and false alarm rate may not necessarily be mediated by the same mechanism. She argues that the stimulant drugs decrease the rate of habituation of the 'arousal response' (or 'alpha blocking' response) whilst depressant drugs increase it. This explains the effect on the hit rate. The increase in the false alarm rate found under the administration of depressants may be due, she suggests, to a reduction in the rate of habituation of the evoked potential.

iii) Accessory sensory stimulation

The form of accessory stimulation which is most frequently employed in vigilance tasks is acoustic noise. As Loeb and Alluisi (1977) have pointed out, the effects of the latter may be to improve, worsen or leave untouched measures of performance, depending on the level of the noise or on its interaction with other factors. Teichner et al. (1963) found that response speed was increased by noise up to a certain level (81 dB), beyond which the noise impaired performance, which is what our theory would predict.

Davies and Tune (1970) have also summarised the effects of noise by stating that it tends to improve the performance unless the signal or non-signal (i.e. background or neutral stimulus) frequency is high, in which case the reverse is true. This too fits our model, particularly in the case of signal frequency. We will see later that the non-signal frequency factor carries with it a greater degree of ambiguity.

They also suggest that noise tends to impair performance if the duration of the signal is brief. This is not predictable from our model, but we have seen already that stimulus intensity may be special so that it is possible that stimulus duration (which is thought to act in an analogous way by Russian workers) may also be special.

It should be mentioned here that Poulton (e.g. 1977) has consistently argued that the impairment due to noise which has been found in some studies is due to the masking

of auditory feedback from the equipment or due to the masking of inner speech which the subject uses to assist his short term memory. This contention has been the subject of a dispute between Poulton and Broadbent (e.g. 1976; 1978). We do not propose to enter this dispute since it relates essentially to the main effect for the noise factor. We have argued repeatedly that the overall effect of factors (including noise) do not tell us very much where the possibility of an inverted 'U' relationship exists. It is their interactions with other proposed determinants that is the important thing.

So far we have mainly considered the effect of noise upon measures of overall performance in vigilance tasks. When we come to consider the effect of noise on the vigilance decrement, the situation is more complicated. As Davies and Tune (1970) have pointed out in their summary, noise sometimes increases the vigilance decrement and sometimes helps to prevent it. Furthermore, the effects of noise tend to be greater at the end of the experimental session, whether these effects are positive or negative - i.e. the difference between the 'noise' and the 'quiet' conditions is greatest at the end of the task.

Broadbent (1971) has argued that 'time on task' and 'noise' may act on different mechanisms. He suggests that time on task may result in a general increase in the subject's measured criterion of the kind that might be produced by shifts to the left along the 'x' axis of figure 44 (p. 511). On the other hand, instead of

producing a shift along the 'x' axis in one direction or the other, an increase in noise may produce a general 'expansion' of the 'x' scale so that the absolute distance apart of the noise and signal distributions will increase, along with their variability. His account is based mainly on one study which employed signal detection measures (Broadbent and Gregory, 1963). However, he also suggests an alternative explanation of the findings, namely that increasing time on task produces an increase in the subject's criterion, but that this is greater in 'noise' than in 'quiet', and he points out that which explanation one favours is a matter of choice.

He does argue, though, that noise and time on task may not simply move the subject in opposite directions along the 'x' axis of a function such as the inverted 'U'. He suggests that time on task may exert its effect on performance by altering the subjective 'value' associated with scoring a hit (see p. 468).

Broadbent's analysis is an interesting one because it illustrates the fact that where time on task is concerned, we may have a more complex situation than the original inverted 'U' model predicts. However, he points out that as yet no definitive explanation of the effects of time on task has been presented.

We will conclude this section by considering briefly a study which looked at the effects of noise on a vigilance task in which physiological measures were also used. Gulian (1970) found that if subjects were divided into 'hyporeactive' and 'hyperreactive' in terms of their

E.E.G. response patterns, an increase in noise level produced an increase in physiological 'arousal' in the 'hyporeactive' subjects but a decrease in the 'hyperreactive' subjects. This would fit in with the Russian model which predicts an inverted 'U' relationship between the level of the 'excitatory process' (which may be reflected in physiological measures such as E.E.G.) and the levels of the determinants. Furthermore, the hit rate measure changed very little in the hyporeactives as a result of noise, but showed an inverted 'U' relationship as a function of noise intensity and intermittency in the hyper^{re}active subjects.

iv) Drive

This variable has been manipulated in vigilance tasks by a number of different means.

Bergum and Lehr (1964) have found that if a group is rewarded in one session but not in a subsequent one, while a second group is not rewarded at all, the first group shows superior performance in the first session but inferior performance in the second. This may be analogous to the 'Crespi depression' effect found in other reinforcement paradigms (Crespi, 1947).

Instructions which stress the need to perform well are found to impair the overall level of performance (in terms of hit rate), but do not affect the vigilance decrement (Ware et al. 1964).

Knowledge of results has been found to improve vigilance performance in terms of the overall hit rate (e.g. Huntermark and Witte, 1978), but it has been found to

retard or prevent the vigilance decrement in some studies only (e.g. Weidenfeller et al., 1962). The fact that false knowledge of results also improves performance suggests that it may be having a motivational effect, though the long term effects of feedback are only evident where true knowledge of the results is used (see Stroh, 1971). Knowledge of results has also been investigated within a signal detection paradigm. Wilkinson (1964) found that the value of the discrimination index (d') was increased, and the value of the criterion decreased, when feedback was provided.

v) Fatigue

Sleep deprivation has been found to decrease the hit rate and to increase the false alarm rate in vigilance tasks (e.g. Williams et al., 1959), and it is also known to accelerate the vigilance decrement (e.g. Lubin, 1967).

Furthermore, Wilkinson (1963) has shown that acoustic noise and sleep deprivation cancel each other out when presented together, though they impair performance when presented separately. One could interpret this as meaning that noise moves subjects to the right along the 'x' axis of the inverted 'U', whilst sleep deprivation moves subjects to the left. However, Loeb and Alluisi (1977) have pointed out that the situation is not so simple, since manipulations which are normally thought to result in a lowering of 'arousal' reduce both the hit rate and the false alarm rate, whilst sleep deprivation reduces the former and increases the latter (see above).

Kjellberg (1977) has also presented a major theoretical reappraisal of the effects of sleep deprivation, particularly in the context of vigilance. We will not present his account in detail here; suffice it to say that he suggests that sleep deprivation does not by itself produce a reduction in 'arousal', but rather that the level of 'arousal' is an effect of the interaction between sleep deprivation and situational factors. He argues that sleep deprivation potentiates the effects of 'dearousing' features of the situation, and that this is mediated in part, at least, by the habituation of the orienting response. The reader is referred to his paper for a fuller account.

vi) Novelty

The vigilance decrement represents a within-session change as time on task proceeds, so it is, of course, associated with a decrease in novelty. However, there are some studies which have also looked at the effect of the decrease in novelty that results from repeated testing - i.e. across several experimental sessions.

Binford and Loeb (1966) have found that the number of hits tends to be fairly stable or increase slightly over sessions, whilst d' increases and the criterion of the subject decreases. Similar results have been obtained by Hatfield and Soderqvist (1969), except that they found that the criterion of the subject tended to increase due to a reduction in the number of false alarms, though performance tended to stabilise on all measures by

about the fourth session. Wiener (1967) has also reported that false alarms decrease across sessions.

Loeb and Alluisi (1977) have suggested that the effect of repeated sessions may interact with other factors such as the conspicuity of signals, and it is possible that this may help to explain some of the discrepancies mentioned above. However, from our point of view interpretation of the results is difficult since it is relatively rare for studies to investigate the interaction between repeated testing and other proposed determinants. For this reason it is not easy to disentangle the effects of a reduction in novelty from the effects of learning.

These two factors are, of course, confounded in considerations of within-session changes. This is a point to which we will return later.

vii) Individual differences.

a) Western measures

A great many studies have been carried out to investigate the relationship between the dimension of introversion/extraversion and vigilance performance. They are characterised by a great diversity in the experimental factors which have been manipulated, the response measures which have been studied and in the results obtained. Some workers (e.g. Bakan et al., 1963) have shown a superiority in introverts in terms of the rate at which performance declined with time. In the aforementioned study, there was a significant interaction between introversion and time on task due to the fact that performance in extraverts and ambiverts declined, whereas in introverts it did not (there was no report of a significant main effect for introversion). Other studies, however, have failed to show such an interaction (e.g. Gale et al., 1972)

On the other hand, in some cases it has been found that although there was no interaction between introversion and time on task, the main effect for introversion was significant. For example, we have already seen that in the Harkins and Geen study (1975), introverts overall scored more hits than extraverts, and also showed greater discrimination ability. Again, though, many studies have failed to show such an overall superiority on the part of introverts (e.g. Gale et al., op. cit.).

The number of studies which have shown superior vigilance performance in extraverts is very small. Hastrup (1979) did find that the introverts' hit rate

tended to decline more with time than that of the extroverts in one experimental condition (high task difficulty), but the interaction of introversion and time on task was not significant. Measures of overall performance are more encouraging. For instance, Kishimoto (1978) found that the overall hit rate of extroverts was higher than that of introverts, but this was only the case if the signal frequency was relatively high. We shall consider the results of this study in more detail below.

As the reviews of vigilance by Davies and Tune (1970) and others have shown, the number of variables which affect performance in such tasks is enormous. Furthermore, within the context of the proposed curvilinear relationship between the determinants and the determinates, we have already seen that the effect of any single determinant on a given determinate can be expected to depend on the level of the other determinants. Since the plethora of variables relevant to vigilance research has been to a large extent uncontrolled between studies of the relation between vigilance and personality, direct comparisons amongst such studies are difficult. For this reason, we will be mainly concerned with those studies which have individually attempted to manipulate one or more of the determinants in addition to introversion/extroversion to see if they provide any clues as to the source of the discrepancies within the literature on the subject.

We will take each of the determinants in turn:

Stimulus intensity

In vigilance research, stimulus intensity changes can refer to changes in the absolute intensity of the signal and

non-signal stimuli (or the background level of sensory stimulation if discrete non-signal stimuli are not employed) or the ratio of the intensities of the signal and non-signal stimuli.

Corcoran et al (1977) studied the effect of increasing the intensity of both the non-signal and signal stimuli by the same amount (20 dB). The stimuli consisted of auditory tones, and the signals were differentiated by the fact that they were of a slightly shorter duration than the non-signal stimuli. The fact that signals were defined by duration not amplitude, was taken by the authors to be a guarantee that the signal/noise ratio (where non-signal stimuli represent 'noise' in signal detection terms) would be unaltered by changing the absolute intensities of the two sets of stimuli by the same amount. In other words they assume that stimulus intensity and stimulus duration do not ^tinteract with each other. This is clearly not in line with the postulates of our present model, which assumes that both factors can be included amongst the lists of determinants and therefore may interact with each other.

The findings were, that if the intensity of the stimulus was raised halfway through the vigilance task from 70 dB to 90dB, the hit rate, false alarm rate and the value of d' were higher in the second half of the test than in the first half (though the effect was not significant for the false alarm rate). But the reverse was true if the intensity was decreased halfway through, or if it was maintained at a steady level of 70 dB or 90 dB. It was also found that there were no differences between introverts and extroverts in the

constant 70 dB group, but in the constant 90 dB group, extraverts' performance deteriorated more rapidly than that of introverts, both in terms of hits and d' . This was also true for the d' measure alone in the group in which the stimulus intensity was decreased halfway through. Finally, the increase in hits and d' in the group in which stimulus intensity was increased, was greater in extraverts than introverts. The interaction of group, introversion and time on task was, therefore, significant.

The last finding is possibly explicable in terms of our hypothesised inverted 'U' curve, or perhaps in the light of Hill's (1975) finding that extraverts seek changes in stimulation more than introverts, although it would not be successful in explaining the results in the group in which the stimulus intensity was reduced. However, comparison of the two groups whose stimulus intensity was unchanged shows that the performance of extraverts relative to introverts was adversely affected by a relatively high level of stimulus intensity. Why this should be so, and why between-subject and within-subject comparisons should produce such different results is unclear. The authors themselves do not discuss the personality findings. They simply state that they are in line with previous work.

One possible explanation for the between-subject findings is that performance overall in the steady 70 dB group was lower than in the other groups, and this could have restricted the range of individual differences due to a floor effect, though this explanation is speculative since this group did nevertheless show a significant deterioration in performance with

time.

Nevertheless, the authors argue that the fact that an increase in stimulus intensity increased d' at all is supportive of the 'arousal' hypothesis. This follows from their argument that stimulus duration and stimulus intensity do not interact with each other. If this is so, then the theory of signal detection would not by itself predict an increase in the signal/noise ratio (and consequently an increase in d') as a result of an identical increase in the intensity of the signal and non-signal stimuli. Corcoran et al therefore, surmise that since d' does alter, some other mechanism must be at work such as an effect of stimulus intensity on 'arousal' level which increases sensitivity and therefore increases the value of d' . They do not realise that this necessarily implies that the increase in 'arousal' has a differential effect on the signal and non-signal stimuli, and, since the two differ only in duration, this also necessarily implies that level of 'arousal' and stimulus duration interact with each other. Furthermore, since the increase in level of arousal is, ex hypothesi, due to a rise in stimulus intensity this also necessarily implies that stimulus intensity and stimulus duration interact with each other. So their assertion that "the arousal theory, in predicting a 'performance' improvement, overrides the signal detection prediction that proportionately increased signal and noise cannot affect d' ", is misleading. The change in d' shows that 'arousal' theory and signal detection theory are complementary, not that the former overrides the latter. Signal detection theory simply predicts that if the signal/noise

ratio increases, d' will increase. It is not specific about the conditions under which such changes in signal/noise ratio will arise: that is where the 'arousal' theory comes in.

Hastrup (1979) also conducted a study in which the intensity of the signal stimuli was manipulated, although in this case the intensity of the non-signal stimuli was kept constant so that the signal/noise ratio also varied in accordance with signal intensity. Thus, task difficulty, which is inversely related to signal/noise ratio, was also automatically a relevant variable. We will for convenience use 'task difficulty' to refer to the factor which was manipulated, with the proviso that it is in this context inseparable from the effects of signal/noise ratio and signal intensity - all three are completely confounded in this study.

A significant interaction between introversion, time on task and task difficulty was found in ^anon-parametric measure of discriminability based on signal detection theory (though not in the more conventional measure of hit rate). This was due to the fact ^{that} in the difficult task introverts tended to decline more with time than extraverts, but in the case of the easy task the reverse was true.

However, in neither task (considered separately) was the interaction of introversion and time on task significant. Also, the greater decline of introverts in the difficult task could have been due to the operation of the law of initial values, since the extraverts had a very low level of performance which changed very little with time, possibly due to a 'floor' effect. On the other hand, such an explanation cannot be applied in reverse to explain away the results of the easy task, since although the extraverts did have a higher level of performance than the introverts at the beginning of the task, their greater rate of decline resulted in actual crossover. By the end of the task, the introverts had superior performance, though as we have seen the interaction was not significant. The law of initial values cannot by itself explain crossovers of this kind.

The study illustrates the fact that variables which affect the overall level of performance in one way may alter the rate of change of performance with time in a different way and vice versa. A high level of task difficulty produced a lower level of overall performance in the extraverts, which was significant at the beginning of the task, whereas the overall performance of extraverts and introverts did not differ significantly in the easier task. On the other hand, the relative speed of decline was greater in the introverts in the easy task, but the reverse was true in the difficult task.

Stimulus Frequency/Signal Probability ;

Blakeslee (1979) conducted a study in which there were two tasks both of which employed the same signal frequency,

but which differed in stimulus frequency and signal probability. Although the number of correct detections was higher for the task with the lower level of stimulus frequency and the higher level of signal probability, there was no difference in the number of false alarms. Furthermore, there were also no significant main effects or interactions involving introversion. One problem with this study, however, is that the two tasks also differed in terms of the characteristics used to define a signal, so this factor is confounded with the other two variables.

Finally, a study was carried out by Stroh (1970) which again found no interaction between the joint factor of stimulus frequency/signal probability and personality.

Stimulus Frequency/Signal Frequency

The study by Stroh (op. cit.) also looked at this joint factor but found no evidence of an interaction with personality.

Signal Frequency/Signal Probability

Bakan (1959) investigated this factor in a two-part study. In the first part, subjects had to detect only one kind of signal, and in this case the performance of introverts was superior to that of extraverts at the beginning of the task in terms of the hit rate. In the second experiment, subjects had to detect the same signal as in the first task, but also a second type of signal, so that the overall signal frequency and signal probability was higher than in the first task.

It was found that if the initial periods of the two

experiments were compared, the performance of extraverts (but not introverts) was significantly higher in the second experiment than in the first experiment. In other words, the additional signal had improved their absolute level of performance. It also improved their performance relative to that of the introverts, since in the second experiment there was no significant difference between the introverts and the extraverts at the beginning of the task. The additional signal seems to have had little effect on the introverts at the beginning of the task, but it did produce a significant worsening of their performance at the end of the task. At this point in time the performance of introverts was also inferior to that of extraverts, though the author does not report whether or not it was significant.

For this reason, and since an analysis of variance was not carried out, the apparent interaction between introversion, signal frequency/probability and time on task must be based on inference. If such an interaction does exist, however, it is difficult to explain it on the basis of the inverted 'U'. If we were to assume that signal frequency/probability is a determinant, then the worsening in introverts implies that they were operating beyond the T.T.I. at the end of the task. The improvement in extraverts implies that they are operating on the left hand side of the curve at the beginning of the task (i.e. they had not passed the T.T.I.). The fact that both groups show a general deterioration in performance with time might suggest that the introverts were moving to the right along the 'X' axis, and the extraverts to the left.

However, the changes with time in Bakan's data are in some cases more erratic than this simple picture would imply, and furthermore, it would not explain why the additional signal did not produce a change in the extroverts' performance at the end of the task, unless, we assume that it was due to the fact that the gradient of the inverted 'U' is relatively flat at the extreme left hand end of the curve. A similar explanation in terms of the gradient of the curve in the intermediate portion of the curve might help to explain why the additional signal did not alter the performance of the introverts at the beginning of the task.

However, the data fit uneasily into this conceptual model and it must be admitted that when time on task is considered, an entirely satisfactory explanation of the data does not readily come to hand. In terms of the overall performance of the two groups, the data are somewhat more encouraging, but the statistical analyses are not based on this measure. However, we shall see later that other studies have provided clearer support for the operation of the inverted 'U' in determining overall level of performance in vigilance tasks. Before leaving this study it should be noted that although the curves were not entirely in line with the inverted 'U' model, there are some interesting relationships between them. In terms of overall shape, the curve for extraverts at high signal frequency/probability resembles that of the introverts at low frequency/probability. This is a point which has been noted by Corcoran (1972). By itself it might be consistent with the view that signal frequency/probability moves subjects in the same

direction as introversion on some conceptual dimension. However, Corcoran fails to point out that the shape of the curve for the introverts under high signal frequency/probability is also similar to that of the extraverts at low frequency/probability. This would suggest the exact reverse.

The second study we will consider in this section (Kennedy, 1972) also employed two separate tasks, and again in the first, the subject only had to detect one kind of signal and in the second he had to detect this signal plus two additional signals. When the two tasks are considered separately, there is no significant correlation in either between performance in terms of hit rate and introversion. However, the two correlations differed significantly from each other, and the results indicated that the performance of the extraverts relative to the introverts was improved by the introduction of the additional signals.

The signals were all auditory but differed in terms of their pitch, and Kennedy regards the two tasks as differing in the number of sensory 'channels' which the subject was required to monitor at any one time. He also suggests that one can differentiate two different kinds of ability: the ability to monitor a single channel over an extended period of time, and the ability to monitor several channels at any one moment in time. Kennedy used a number of different measures of overall performance and changes in performance with time, and he suggests that introverts may show a predominance of the first kind of ability whereas the reverse may be true for extraverts. This is an interesting possibility, but of course the results may also be explained in

terms of the overall signal frequency/probability, since this was higher in the multichannel task than in the signal task. We could alternatively suggest, therefore, that an increase in signal frequency/probability produces an improvement in the performance of extroverts relative to introverts.

It should be mentioned at this point that Claridge (1960) also conducted a study in which a primary and secondary task (consisting of two types of signal) were employed. In this study, however, the effect of the interaction was not significant overall, nor was it significantly related to introversion.

All of the previous studies in this section have looked at the effect of additional signals rather than the effect of increasing the frequency/probability of a single kind of signal. For this reason, the result could be interpreted in terms of task complexity, which we have seen is a possible candidate for inclusion amongst our list of determinants. We will now consider two studies in which task complexity and signal frequency/probability were not confounded with each other. The results of one of these (Davies and Hockey, 1966, *op. cit.*) will be considered in detail later under the section on 'accessory stimulation'. Suffice it to say that in terms of overall performance the authors conclude that the joint effects of signal frequency/probability, accessory stimulation and introversion on hit rate could be explained by assuming that all three are determinants, and that an inverted 'U' relationship exists between them and performance. However, they also conclude that where all

three factors are considered together, such a relationship does not seem to hold for the false alarm rate.

The final study we will consider is that of Kishimoto (1978). This study provides perhaps the clearest indication that signal frequency/probability interacts in a predictable way with introversion. In terms of the overall performance level (assessed by the hit rate) there was an interaction between introversion and signal frequency/probability which was significant at the 2.5% level due to the fact that at low signal frequency/probability the performance of introverts was superior to that of extraverts, whereas at high signal frequency/probability the reverse was true. Also the performance of introverts was higher at low frequency/probability than at high frequency/probability, whereas the reverse was true for extraverts. There was also a significant interaction between signal frequency/probability and time on task. At high frequency/probability neither introverts nor extraverts declined in performance with time, whereas both groups declined (and in roughly the same fashion) at the low frequency/probability. Measures of skin conductance were taken, but these were found to vary independently of performance.

Drugs

A number of studies have manipulated drug variables as well as introversion-extraversion.

Colquhoun (1962a) looked at the effect of the drugs hyoscine and meclozine on vigilance performance in introverts and extraverts. However, there were no significant effects

for introversion nor any evidence for an interaction between introversion and any drug effects. In a second study (Colquhoun 1962 b), it was found that alcohol produced a significant reduction in hit rate, but again there was no report of any interaction between alcohol and introversion. The latter did, however, interact with other variables and this will be discussed later.

Keister and McLaughlin (1972) looked at the effect of caffeine and introversion on vigilance performance. They found that although there were no significant effects on overall performance levels, extraverts under the placebo condition did decline more in hit rate than the other groups. The authors explain this by suggesting that the caffeine heightens the reinforcement effect due to the detection of signals (Holland, 1963), which is supposed to be less in extraverts than in introverts under placebo, as evidenced by the poor conditionability and faster extinction rates of extraverts (Eysenck, 1967). Alternatively, they suggest that caffeine counteracts the accumulated cortical inhibition, due to the repetitive and monotonous task, which is again presumed to be greater in extraverts (Eysenck, 1967).

Two studies have investigated the effect of smoking along with the effect of introversion. Tarriere and Hartmann (1964) found that whereas the hit rate of smokers who were deprived of cigarettes during the task and of non-smokers both declined with time on task (and were not significantly different from each other), the performance of smokers who were allowed to smoke remained fairly stable. They also found out that in terms of the overall number of

hits, introverts performed at a higher level than extraverts. There was no interaction between introversion and either being a smoker versus a non-smoker, or of being allowed to smoke during the task versus being deprived. In fact the authors conclude that the effects of high levels of introversion and smoking during the task are additive. It should also be noted that there was no significant relationship between smoking habits and introversion level.

Tong et al (1977) also looked at smoking and introversion. They found that non-smokers (NS) displayed a higher level of overall performance, but declined more than smokers who were allowed to smoke (SS) and smokers who were deprived (SNS). The SS group improved with time, whilst the SNS group remained fairly stable. In the NS group, extraverts had a higher hit rate than introverts in the last time block, whereas in the SS group, introverts had a higher hit rate than extraverts in the first time block. There were no differences between introverts and extraverts in the SNS group nor was there any relation between smoking habits and introversion (or neuroticism). All these personality results were based on tests of simple effects. There was no report of interaction between personality and group.

Accessory Stimulation of a Non-relevant Sensory Modality:

The first study we will consider in this section is that by Davies and Hockey (1966). The authors looked at the effect of two levels of white noise (70 dB 'quiet') and 95 dB ('loud') on a visual vigilance task. They also looked at the effect of introversion and the effect of doubling the signal frequency, and hence also the signal probability, since

the non-signal rate remained unchanged.

They found that significant effects only appeared where time on task was involved (i.e. there were no significant effects on overall performance levels), and that there was a general decline in hit rate with time. However, this decline was greater for extraverts than for introverts, as evidenced by a significant introversion x time on task interaction. The noise x time on task interaction was also significant due to the fact that hit rate declined less in 'noise' than in 'quiet'. There was also evidence that although noise had little effect on the rate of decline for introverts, high levels of noise helped to prevent the decline in extraverts (the noise x introversion x time on task interaction was significant).

Signal frequency did not interact with introversion for the hit rate measure but it did interact with time on task. This was due to the fact that in the first, third and fourth time blocks, performance in the high signal frequency group was higher than in the low signal frequency group, whereas the reverse was true in the second time block.

Analyses were also carried out on the false alarm rate. There was a significant interaction between introversion and noise due to the fact that introverts recorded more false alarms in 'quiet' than in 'noise' whereas the reverse was true for extraverts. There was also a significant interaction between introversion, noise and signal frequency. This was because at low frequency, extraverts recorded the same number of false alarms in 'noise' as in 'quiet', while introverts recorded twice as many in 'quiet' as in 'noise'.

At high frequency, on the other hand, introverts recorded the same number of false alarms in 'quiet' as in 'noise', whereas extraverts recorded more in 'noise' than in 'quiet'.

Significant interactions also appeared involving time on task, which by itself produced an increase in false alarms from the first to the second time block, followed by a decrease till the end of the task. The interaction of introversion, frequency and time on task was significant, but the authors do not provide an adequate description of this. The interaction of introversion, frequency, noise and time on task was also significant. At low frequency, introverts record more false alarms than extraverts during the middle part of the test session in 'quiet', but under the 'noise' condition there was difference only in the last time block and it was in the opposite direction. At high frequency, extraverts recorded more false alarms than introverts during the middle part of the test session in 'noise', but under the 'quiet' condition there was a difference only in the first time block and it was in the direction of more false alarms in introverts.

Finally, there was a significant interaction between noise, frequency and time on task. Under 'quiet', more false alarms were recorded under low frequency than under high frequency, but this difference gradually diminished as time went on. Under 'noise', there was much less difference between the high and the low frequency conditions than under 'quiet'.

The authors explain their findings with respect to hit rate in terms of the inverted 'U' relationship between the

determinants and the determinates and by assuming that signal frequency is a determinant as well as introversion and accessory stimulation (in the form of noise). They argue however, that the same relation does not seem to hold for false alarms.

In a later signal detection analysis of the data (cited by Mackworth, 1969, p.117) it was found that the criterion rose in all sessions, but that the criterion of the introverts was highest at the end of the noise session, whilst the criterion of the extraverts was most strict at the end of the quiet sessions. This would not be inconsistent with the view that a 'U' shaped relationship between the criterion and the determinants exist, if we also assumed that during the course of the test session introverts move to the right along the 'X' axis under 'noise' whereas extraverts move to the left in 'quiet'.

If this were so, and if we also accept the authors' conclusion that an inverted 'U' relation exists (in terms of overall performance) between introversion, accessory stimulation and signal frequency/probability, then the finding that the introverts showed an increase in d' with time, especially in noise, may seem discordant at first glance. This is since the above analysis would suggest that introverts (at least under 'noise' and high signal frequency/probability) were operating beyond the T.T.I. If so then not only might we expect that d' would decrease with time if they moved to the right, but also that the values would be negative. However, the task used by Davies and Hockey required subjects to detect discrepancies between digits

presented to them in turn on a rotating drum and a sequence of digits on a script. Signals and non-signals were, therefore, differentiated by cognitive features rather than sensory-perceptual ones such as stimulus intensity or duration. It will be remembered that in the diagram depicting the theoretical non-signal and signal distributions described by signal detection theory, the 'X' axis was conceived of as a dimension of neural activity. Though stimulus intensity and duration might be expected to influence the position of the distributions on such a dimension, the same cannot be said for cognitive features and the applicability of the index d' to studies which have used such features to distinguish the signal and the non-signal has therefore been seriously questioned. Furthermore, even if one accepted the use of d' by Davies and Hockey, our predictions for this index are based on the assumption that the factor which is used to differentiate signals from non-signals is also one of the determinants (e.g. stimulus intensity or duration). For this reason, we cannot regard Davies and Hockey's findings with respect to d' as a serious problem for the inverted 'U' hypothesis. Davies *et al* (1969) also looked at the effect of accessory auditory stimulation on visual vigilance. They compared the effect of varied auditory stimulation ('VAS') in the form of a mixture of music and speech with the effect of unvaried auditory stimulation ('control') due to an electric wall fan which was used to mask external noise. The sound pressure levels were 80 dB and 50 dB respectively, so that the effect of variety and intensity of the auditory stimulation were confounded. The authors argue that the

difference in intensity was not a relevant factor since according to them intensities below 90 dB rarely, if ever, significantly affect performance.

In terms of overall performance and change with time on the hit rate measure, there was no significant difference between the 'VAS' and 'control' conditions nor between introverts and extroverts. There was no report of an interaction between the accessory stimulation and introversion factors.

In terms of false alarms however, the 'control' group recorded significantly more than the 'VAS' group, overall. Separate analyses showed that this was true only for the extrovert group, but there was no report of an interaction between introversion and accessory stimulation. Overall, both hits and false alarms declined with time on task.

The authors also carried out two further experiments. In the first, the subjects performed the task under control conditions unless they actually requested a 30 second burst of VAS by pressing a button. Significantly more extroverts asked for varied auditory stimulation at least once than introverts, but there were no significant differences in hit or false alarm rates between the two groups. False alarms declined significantly with time on task.

In the third experiment, conditions were reversed so that subjects performed under VAS unless they requested a 30 second period of 'quiet'. Significantly more introverts than extroverts requested 'quiet' at least once, though again there were no significant differences between the groups on hits or false alarms. Again false alarms overall declined significantly with time.

A more recent study on accessory stimulation of a varied kind has been carried out by Fagerstrom and Lisper (1977). In this experiment subjects had to drive a car for an extended period and also had to respond to the irregular onset of a tone inside the car by pressing a footswitch down as fast as possible. The tone stayed on till the subjects responded, so that the experiment was of the 'unlimited hold' type described by Broadbent (1958), in which the relevant performance measure is the reaction time of the subject rather than his hit rate.

Subjects performed the task either in silence or whilst a tape consisting of speech or music (which had been pre-selected by the subject) was played to them.

A significant interaction was found between introversion, time on task and stimulation condition, due to the fact that although reaction time increased more with time on task for extraverts than for introverts, the rate of decline in extraverts was reduced more than in introverts by the varied auditory stimulation, either in the form of talk or music.

The authors also reported that the heart rate of the subjects decreased with time, but there is no evidence that accessory stimulation, personality or their interaction affected this relationship or the overall level of heart rate.

We will now consider three studies from Eastern Europe, all carried out by the same author.

In the first study (Gulian, 1971), subjects performed an auditory vigilance task with the stimuli presented to one

ear and auditory accessory stimulation, in the form of either loud intermittent noise or weak continuous noise, presented to the other ear. Gulian reports that there was a tendency for introverts to detect all signals (especially in noise), whereas extraverts and ambiverts had a lower hit rate, especially ⁱⁿ loud intermittent noise, whereas weak continuous noise tended to have opposite effects. Introverts tended to record more false alarms, especially in 'quiet' (the reverse is true for extraverts) especially in response to the first stimulus of a series, which Gulian interprets as due to a stronger orienting response. However, none of these differences are significant. She also measured skin conductance and found that loud, intermittent noise lowered the level of this in both introverts and extraverts, whereas weak, continuous noise had this effect only in introverts. In extraverts it produced an increase in conductance.

In the second study (Gulian, 1973), subjects had to carry out a combined auditory and visual vigilance task and at the same time were subjected to various kinds of auditory and/or visual accessory stimulation. The number of misses made were very small so the author combined misses and false alarms to produce a total error score. This was significantly higher in extraverts than in introverts. Changes in the accessory stimulation during the course of a session produced an increase in the number of errors, especially in introverts. Also errors decreased with time in introverts but increased in extraverts. Introverts also showed a lowering of skin conductance with time, but in extraverts this trend was interrupted by a change in background auditory

stimulation which produced a sharp increase in skin conductance and errors.

The last study was carried out by Gulian in 1974, but there was no difference in performance between introverts and extroverts in this experiment, nor any report of an interaction between introversion and 'noise'.

It should be mentioned that Singh et al (1979), failed to find any significant main effect for anxiety (which we have seen is related to both introversion and neuroticism) nor do they report any interaction between anxiety and noise.

Drive:

We have seen that knowledge of results probably exerts its effect on performance, partly at least, through its effects on motivation (see p. 116). Carr (1971) looked at the effects of this variable on vigilance performance by including a pre- and post-test during which feedback was supplied, after being withheld during the main test. During the course of the latter the hit rate of the introverts increased slightly, whereas that of extraverts decreased, and there was a significant difference between these trends. False alarms decreased significantly during the main test in both groups.

Reaction times increased slightly during the main test and tended to be higher in extraverts than in introverts, but neither of these effects was significant.

To test the effect of the post-test, the latter was compared to the last ten minutes of the main test. Both the hit and the false alarm rate of the **extraverts** increased in the post-test (as compared to the end of the main test) and to a significantly greater extent than those of the introverts. However, the absolute performance of introverts was higher than that of extraverts in both pre- and post-tests for hit rate.

Skin resistance was also measured, and relative to their respective baselines the extraverts' skin resistance was significantly lower than that of introverts during the main test. Furthermore, it decreased in the extraverts with time, whereas it stayed fairly stable in introverts. These trends were significantly different. Resistance was significantly

lower in the post-test than in the latter part of the main test for both groups.

Subjective reports from the subjects indicated that many of the extraverts felt quite anxious towards the end of the task, whereas the introverts rarely reported this. Also, the physiological data indicates that extraverts were more highly 'aroused' than the introverts, but the author points out that their poor performance was probably not due to 'overarousal' since their skin resistance decreased significantly from the last ten minutes of the test period to the post-test whilst their performance improved.

Thus, there would seem to be some discrepancy between the physiological data and the inverted 'U' hypothesis, whilst the effect of knowledge of results is in line with it if we assume it had a motivating effect, and that either it produced a differential increase in motivation in the two groups or that the same increase in motivation produced the differential increase in performance due to different initial positions on the inverted 'U' curve.

There is some evidence from Carr's study that the intrinsic level of motivation was higher for introverts than for extraverts, as assessed by a post-experimental questionnaire. It is possible, therefore, that the effect of knowledge of results (an extrinsic motivation) was to counteract this difference.

But the finding that introversion is related to motivation level in a vigilance task conflicts with the results of a study of Hogan (1966), which attempted to assess motivation post hoc rather than manipulate it experimentally

(the study by Carr did both). In this experiment, the overall performance level of introverts was higher than of extroverts (in terms of the number of hits), but there was no interaction between introversion and time on task. Moreover, the effects of level of motivation were the exact opposite. High levels of intrinsic motivation were associated with a slower decline in performance with time but not with a significantly higher overall level of performance. In addition it was found there was no relationship between introversion and intrinsic motivation. It is possible that the use of the word 'intrinsic' is a misnomer, since it is likely that different tasks produce different levels of motivation in different groups of subjects. Also different questionnaires were used to assess motivation in the two studies, and, as Hogan has pointed out, the attempt to assess such a nebulous concept at all is fraught with difficulties.

Fatigue:

The author knows ^{of} no studies which have factorially manipulated sleep deprivation and introversion together in the context of a vigilance task.

Novelty:

The author knows of no studies which have attempted to manipulate factorially novelty and introversion within the context of a vigilance task.

Time of day:

As we have seen already, time of day is a factor which probably merits addition to the list of determinants. It is also one which has been investigated along with introversion

in a number of studies of vigilance performance.

Colquhoun (1960) found that introverts detected more signals than extraverts in the morning, but that the reverse was true in the afternoon. This is in line with the view that both introversion and time of day are determinants and that there is an inverted 'U' relation between them and vigilance performance. Certain other variables - for example signal probability - were also manipulated, but there is no report of any significant interaction between these and introversion. However, the finding with respect to introversion and time of day was replicated by Colquhoun (1962 b, op. cit.) and by Colquhoun and Corcoran (1964). It should be mentioned that in the former study if the task was unpaced introverts detected fewer signals than extraverts in the morning as well as in the afternoon, though the correlation between introversion and speed of work was positive in the morning. The latter study was also unpaced and showed similar results for the speed measure. There has been one negative finding. Gale et al (1972, op. cit.) found no relation between introversion, time of day and vigilance performance, nor any evidence for an interaction between them.

RUSSIAN MEASURES

The role of individual differences in vigilance has also been studied in the Soviet Union and Eastern Europe, particularly in relation to the dimension of 'strength' of the nervous system. Here again, though, the findings are conflicting and contradictory. For example, Rozhdestvenskaya and Yermolayeva-Tomina (1966) have shown that under conditions of monotony (which is one characteristic of vigilance tasks) subjects with 'strong' nervous systems display greater signs of physiological fatigue than subjects with 'weak' nervous systems, and similar results have been found by Rozhdestvenskaya and Levochkina (1972). However, both Pushkin (1972) and Halmiova (1965) have shown that performance in vigilance tasks is inferior in 'weak' nervous systems. A clue to the possible source of these discrepancies comes from the finding that performance in monotonous tasks depends on the level of 'arousal'. Performance is better in 'weak' subjects, but only if the initial level of 'arousal' is low, and that, furthermore, an inverted 'U' relationship between performance and 'arousal' is found in the 'weak' subjects (Rozhdestvenskaya 1973). In addition, Rozhdestvenskaya et al (1972) have shown that while performance on a simple monotonous task was superior in 'weak' nervous systems, performance on a more complex task was slightly superior in the 'strong' nervous systems (though the effect was not significant).

We have seen already that task complexity may be a determinant (see p. 205). It is, therefore, possible that

in the Rozhdestvenskaya et al (1972) study, performance was superior in the 'weak' subjects on the simple task because when the level of the determinants (such as task complexity) are relatively low, 'weak' subjects perform better than 'strong' subjects. On the other hand, when the levels of the determinants are increased, performance is eventually superior in the 'strong' subjects. Furthermore, both of the studies which showed superior vigilance performance in 'strong' individuals (Halmiova op. cit.; Pushkin op. cit.) involved a virtually continuous rate of responding on the part of the subjects. This would result in a high degree of excitation due both to the stimuli themselves, and the 'stimulus feedback' effects due to the responses of the subjects. Since stimulus frequency is one of the factors which may result in movement to the right along the 'X' axis of the inverted 'U' curve this too may help to explain the results.

It should be mentioned, though, that a study in the West by Thackray et al ⁽¹⁹⁷³⁾ which also employed continuous responses found a significant interaction between introversion and time on task in the speed of response to signals. Introverts were initially slower but their speed at response gradually increased whereas that of the extraverts decreased so that by the end of the task the introverts were faster. In Halmiova's study the 'weak' subjects became slower with time whilst the 'strong' subjects became faster. On the face of it this might support the identification of extraverts and 'weak' nervous systems and introverts with 'strong' nervous systems. However, the interaction

between 'strength' and time on task was not significant in Halmiova's study and though the two experimental situations were similar they were not identical, so this set of results does not constitute strong evidence against the hypotheses under consideration.

3. ANALYSIS

i) Theories of vigilance and the determinants

In assessing the data that we have described relating the determinants to vigilance performance, we should first point out that the 'arousal' theory by itself may not be able to account for all of these findings (or, for that matter, all of the other data relating to vigilance that we have not considered). However the 'arousal' theory recast in the form of our inverted 'U' model, does seem to have certain advantages over the other theories.

Principal amongst these is the fact that it provides a better account of the overall level of performance, and this is particularly so where some form of interaction is involved. For instance, none of the other theories by themselves can adequately explain the interaction between introversion and frequency/probability found by Kishimoto (1978) - i.e. the fact that introverts showed better performance at the low signal frequency/probability than at the high signal frequency/probability, whereas the reverse was true for extraverts.

One reason why the other theories find difficulty in accounting for such interactions is that most of them were originally designed to explain the vigilance decrement, and in this area these theories may fare better. For example, nearly all of the theories (inhibition, reinforcement, expectancy, attention) have been linked in some way to experimental findings or theoretical notions relating to differences between introverts and extraverts,

and are, therefore, potentially capable of explaining the finding that extraverts show a greater vigilance decrement than introverts (e.g. Bakan et al. 1963). Eysenck (1957) has argued that extraverts are more prone to develop inhibition than introverts. Bakan (1959) has also suggested that under conditions of non-reinforcement, extraverts will extinguish more rapidly than introverts, and Eysenck (1967) has summarised some of the evidence in favour of this view. Also Vickers et al. (1977) have shown that extraverts adapt more quickly than introverts to a change in the expectation of a signal that follows the transition from a training session in which signal frequency is high to an experimental session in which signal frequency is low. This is a matter which we will discuss in detail later (see pp. 783-98).

Finally, it has been shown by a number of writers (e.g. Mohan et al. 1974) that fluctuation of attention (or 'filter' deviations) occur more readily in extraverts than introverts.

However, we have seen that even when one is considering the vigilance decrement, these theories have often come unstuck in the face of one experimental finding or another. The same applies to the two remaining theories: signal detection theory and the 'arousal' theory. We have seen that there is no agreement in the literature as to whether the vigilance decrement is associated with a rise in the criterion of the subject or a fall in the discrimination index, though Broadbent (1971) has argued

that the latter only occurs when the frequency of background, neutral stimuli is very high. Also, there is as yet no clear evidence that either explanation can adequately account for differences in the vigilance decrement between introverts and extraverts, since very few studies of vigilance and personality have employed signal detection indices.

ii) The problem of 'time on task'

We have also seen considerable conflict in the data relating the determinants to vigilance performance - particularly where changes in performance with time, rather than the overall level of performance, were concerned. When discussing our list of determinants, we pointed out that 'stimulus duration' could be construed in two ways: the duration of an individual, specific stimulus presented to the subject, or the time that had elapsed since the start of the task. Furthermore, if we consider the second interpretation of the term, it becomes problematic as a determinant since it is confounded with other factors.

The first of these is novelty, since the stimuli employed in the task will become more familiar to the subject as the task proceeds, and this will work in opposition to the supposedly greater excitation effect produced by a relatively prolonged stimulus (the total stimulus configuration employed in the task could be regarded as a 'stimulus' in this sense).

In addition, both these opposing effects of time on task will depend on another of the determinants - i.e. stimulus frequency, in the sense of the number of stimuli per unit time. An increase in stimulus frequency will enhance the ^exitatory effect of time on task since it will promote the summation of successive stimuli. But it will also enhance the reduction in the novelty of the stimuli. Furthermore, it is very difficult to predict in advance what the effect of a given stimulus frequency (or a given change in stimulus frequency) will have on the relative importance of the two opposing factors described above.

Time on task may also be confounded with other proposed determinants. We suggested earlier that 'time of day', for instance, may be a determinant, and time on task is, of course, inextricably confounded with this factor. It is difficult to say how important this is in most tasks whose duration is relatively short in comparison with the total length of the diurnal cycle, but Frazier et al. (1968) have suggested that it may be relevant to vigilance performance.

We are, therefore, faced with a situation in which one of our proposed determinants - i.e. stimulus duration construed in the sense of 'time on task' - may move the individual either to the right or to the left along the 'x' axis of the inverted 'U'. We pointed out earlier that there was an element of indeterminacy involved if we tried to represent all the determinants along the 'x' axis of a single inverted 'U'. However, at least in that

instance we were assuming that they all moved the individual in the same direction. Now we have a case where one of the determinants may under certain circumstances tend to move the individual in the opposite direction to the other factors.

Furthermore, it is very difficult to predict beforehand which effect the factor of time on task will have, since it depends on the interplay of several other factors. For this reason we would suggest that when time on task is involved the element of indeterminacy is much greater than otherwise. It is scarcely surprising, therefore, that studies on the relationship between a given determinant (e.g. introversion) and the vigilance decrement have produced such conflicting results.

Although one cannot predict beforehand what the effect of time on task will be, this does not mean that the results of studies which employ time on task are not interpretable in terms of the inverted 'U'. It simply means that such interpretation must be post hoc - i.e. one can only determine which direction time on task is moving the subject by looking at the results.

We gave an example earlier of the kind of interaction that could be expected if two factors resulted in movements in opposite directions along the inverted 'U' (see p. 89). So we can tell from the nature of the interaction between time on task and other factors, whether they have been moving the subject in the same or in opposite directions. Gray (1967) has made a similar point when he suggests that the direction in which the

level of 'arousal' changes during a task will determine the relative effects on subjects differing on an individual differences dimension such as 'strength' or introversion.

However, it should be noted at this point that since we cannot predict the direction of the interaction in advance, all statistical tests in the present project which involve time on task will be two-tailed ones.

We should also note a certain similarity between time on task and sleep deprivation. We pointed out earlier that many workers regard the effects of sleep deprivation as being dependent on the levels of other factors such as task complexity in a way that is not predictable by simply assuming that they always move the subject in the opposite directions along the inverted 'U' (Hebb, 1955; Kjellberg, 1977). In this respect, then, sleep deprivation is subject to the same indeterminacy as time on task.

Another factor that should be considered is learning since this may be a relevant variable when time on task is being considered. We might expect that the effect of learning would be to affect the overall level of performance rather than to move the individual along the 'x' axis of the inverted 'U'. We saw some evidence for this when we considered changes occurring across sessions in our simple visual reaction time task (see p.607). However, let us consider the situation a little more closely.

We can illustrate the way in which learning may exert its effects by considering again the results of our simple visual reaction time task. It will be remembered (see p. 540) that in the latter, the stimuli were presented in three blocks separated by an interval. This provided the opportunity to study the effect of time on task on simple reaction time, and our original analysis of variance included the factor of 'block' in it. However, we have deferred our consideration of the results involving this variable until now because it was necessary first to explain the various problems associated with 'time on task' effects.

iii) Results and discussion of simple visual reaction time effects involving time on task.

a) Results

a) The main effect for block is significant at the 0.5% level (two tail).

Speed^{of} reaction increased from block 1 to block 2 and from block 2 to block 3.

Block 1	Block 2	Block 3
2.4387	2.4210	2.4107

Table 828 showing main effect for block (LSCORE)

b) The interaction of block, stimulus intensity and session is significant at the 2.5% level (two tail). See discussion.

Stimulus Intensity (lux)	SESSION 1			SESSION 2		
	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
2000	2.4364	2.3960	2.3605	2.3828	2.3619	2.3592
200	2.4109	2.4014	2.3931	2.3814	2.3628	2.3836
20	2.4258	2.4116	2.3915	2.4356	2.4012	2.3945
2	2.4586	2.4216	2.4089	2.4484	2.4351	2.4333
0.2	2.4673	2.4428	2.4392	2.4451	2.4338	2.4435
0.02	2.5194	2.4957	2.4680	2.4533	2.4882	2.4826

Table 829 showing interaction of block, stimulus intensity and session (LSCORE).

c) The interaction of block, session, neuroticism and time is significant at the 1% level (two tail). See discussion.

d) The interaction of noise, block, introversion, neuroticism and time of day is significant at the 5% level (two tail). See discussion.

e) The interaction of block, stimulus intensity, introversion and time of day is significant at the 5% level (two tail). See discussion.

f) The quadratic component associated with the interaction of noise, block, stimulus intensity, session and time of day is significant at the 5% level (two tail). See discussion.

g) The quadratic component associated with the interaction of noise, block, stimulus intensity, session, neuroticism and time of day is significant at the 1% level (two tail). See discussion.

h) The cubic component associated with the interaction between noise, block, stimulus intensity, session, introversion, neuroticism and time of day is significant at the 2.5% level (two tail). See discussion.

Planned comparisons between the two highest intensities which involve the 'block' factor (simple visual reaction time):

a) The planned comparison associated with the interaction between block and stimulus intensity is significant at the 5% level (two tail). See discussion.

Stimulus Intensity mx	2000	200	20	2	0.2	0.02
Block 1	2.4096	2.3962	2.4307	2.4535	2.4562	2.4863
Block 2	2.3790	2.3821	2.4064	2.4283	2.4383	2.4919
Block 3	2.3599	2.3883	2.3930	2.4061	2.4414	2.4753

⁸³⁰
Table showing the interaction of block and stimulus intensity (LSCORE).

The planned comparisons associated with the following comparisons were also significant (see discussion), in each case at the 5% level (two tail).

- b) Noise x block x stimulus intensity
- c) Noise x block x stimulus intensity x session x time of day
- d) Noise x block x stimulus intensity x session x neuroticism x time of day.

Results for the slope of the reaction time/intensity curve
derived from the simple visual reaction time task.

a) The interaction of block, neuroticism and time of day is significant at the 5% level (two tail). See discussion.

b) The interaction of noise, block, session and time of day is significant at the 1% level (two tail). See discussion.

b) DISCUSSION

The first effect we will consider is the main effect for block which shows that speed of reaction increases from block 1 to block 2 and from block 2 to block 3. The most likely explanation for this effect is one in terms of learning. We argued earlier (see pp. 607-9) that where a stimulus is presented at a constant interval after a warning signal (as it was in the experiment in question), subjects may learn when to expect the stimulus. This could lead to an increase in response speed in a number of different ways. The most obvious is pure anticipation - i.e. subjects may actually have initiated their response before the stimulus was presented. We saw examples of this in the simple auditory reactions time task. However, compared to the latter the number of anticipatory false alarms in the visual task were negligible, and certainly too few to make any meaningful analysis possible. This is in line with similar differences between the visual and auditory modalities found by other workers (Nissen 1977).

An alternative explanation, therefore, is that either the criterion of the subject is lowered and/or the sensory growth functions are raised at the point of stimulus expectancy. Finally, it is possible that the slopes of the sensory growth functions may be increased at this point. We have argued already that both the criterion and the slopes of the sensory growth functions may be influenced by the determinants. Here we have a situation in which these factors may be affected by the expectancy of the subject - i.e. the subjective probability of the occurrence of the

response stimulus. We saw earlier that one of the theories of vigilance decrement was an expectancy theory, and though (like the other theories) the evidence in its favour was equivocal, we will see later that it is highly relevant to one particular aspect of vigilance performance: i.e. the influence of the preceding training period (see pp. 783-98).

If, however, subjective probability does affect the criterion and/or the sensory growth functions, does this mean that it is a determinant? To draw such a conclusion, one would have to show that subjective probability produced the kind of effects that are predictable on the basis of the inverted 'U'. A number of studies have investigated the effect of the duration of the interval between the warning signal and the response stimulus. Some of these have employed tasks in which this duration was constant within a given condition, but varied between conditions. In other words, subjects were presented with sets of reactions time trials and within each set the duration (i.e. the 'foreperiod') was constant.

The influence of this duration was investigated by comparing the results from different sets of trials. Under these conditions, it is generally found that as the length of the foreperiod increases, response speed decreases.

The objective probability of a stimulus in all constant foreperiod tasks is equal to 1.0 at the time of stimulus occurrence and zero at all other times, regardless of the absolute length of the foreperiod. The decrease in response speed resulting from an increase in the latter between sets of trials is likely to be due to the greater difficulty in

estimating the exact point of stimulus occurrence when the foreperiod is relatively long. In other words, the area of uncertainty surrounding this point would be expected to be larger and the function relating subjective probability to time would coincide less exactly with the function relating objective probability to time (see p. 743).

However, other experiments have looked at the effect of varying the length of the foreperiod on a random basis within a given set of trials. Under these conditions it is found that there is an inverted 'U' relationship between the length of the foreperiod on a given trial and the speed of response. This is usually explained in the following way. On any given trial, once the warning signal has been presented, the conditional probability of the response stimulus steadily increases as the trial progresses. In other words, assuming that a stimulus is presented on every trial, the likelihood that it will occur at a given moment in time following the warning signal will gradually increase as the interval since the warning signal onset increases.

This is used to explain the fact that response speed tends to be relatively fast on trials on which the response stimulus is presented after a medium interval compared to trials on which it is presented after a relatively short interval. On the basis of what has been said, one would expect that at the time of stimulus occurrence the conditional probability is higher in the case of the medium interval trial than the short interval trial. Assuming that once the subject has been presented with a number of trials he realises that the foreperiod is random, subjective

probability should follow conditional probability fairly closely. Furthermore, theorists in this area argue that when subjective probability is relatively high the degree of motor 'set' or 'preparedness' of the subject is high - hence a faster response speed.

However, they still have to explain the fact that response speed is lower in trials with long foreperiod intervals than in trials with medium intervals, despite the fact that the conditional probability - and presumably, therefore, the subjective probability - is higher in the former than in the latter at the point of stimulus occurrence. Theorists usually meet this difficulty by referring to the 'Cost of preparation': they assume that a preparatory set can only be maintained for a limited period of time, and that at very long foreperiod durations the subject is unable to keep his level of preparation at a high level throughout - hence a decrease in response speed.

However, since the time periods that we are considering are of the order of a few seconds only, this argument would seem dubious. Furthermore, although we have seen evidence already that a motor or preparatory set can increase response speed (see p. 445); the results of studies in this area are conflicting. For instance, McGown (1976) has found that instructions which encourage a 'motor set' do not significantly influence simple reaction time. Also, Freeman (1937, op. cit.) has shown that even where a motor set does increase response speed, it does so by means of the sensory feedback from the associated muscle tension rather than directly.

Earlier we argued that this feedback could exert its effect on the sensory growth function and/or the criterion. The present author would like, therefore, to propose that the inverted 'U' relationship between the duration of the foreperiod and speed of response in studies where this duration is varied randomly from trial to trial, is evidence that subjective probability may be a determinant. This is because, as we have already stated, in such studies the conditional probability (and, therefore, presumably the subjective probability) of the stimulus increases as the time since warning signal onset increases.

There is quite a lot of evidence to support this view. Firstly, in our review of the studies of the relationship between personality and vigilance, we mentioned the study by Kishimoto (1978) which showed an interaction between signal frequency and introversion which was in line with the inverted 'U' hypothesis. Kishimoto interpreted his result purely in terms of signal frequency. In other words, he assumes that introverts show a relative decrement in the overall level of performance at the high frequency because of 'overarousal'. It is unlikely that such 'overarousal' would be due to the larger number of signals per se, since they differed from the neutral, background stimuli only in terms of stimulus duration. The signals lasted for 0.8 seconds whilst the non-signal stimuli lasted for 0.5 seconds. The marginally greater stimulation associated with the longer duration signals is unlikely to have produced 'overarousal' by itself.

It is possible, though, that such an effect could

have been produced by the greater stimulus feedback resulting from the greater opportunity to respond in the high signal frequency condition. We discussed such effects at length when we considered Brebner and Cooper's model of introversion-extraversion (see pp. 386-91). Although the introverts detected a lower percentage of signals in the high frequency condition than in the low frequency condition, the absolute number of correct responses was greater in the former than the latter. Kishimoto makes no mention of false alarms, so if we ignore this factor we can assume that the stimulus feedback from responding was greater in the high signal frequency condition than in the low signal frequency condition. This would have the effect of moving the subjects to the right along the 'X' axis of the inverted 'U' and could result in a relative decrement in the introvert group.

However, it will be remembered that signal frequency was completely confounded with signal probability in Kishimoto's study since the frequency of background, neutral stimuli was constant. As signal frequency was increased, signal probability increased by proportionately the same amount. This means that the results of Kishimoto's study could be interpreted as support for our view that subjective probability is a determinant.

It is possible, of course, that both signal ^{frequency} and signal probability have an effect, and in a normal vigilance task it is not possible to separate the two effects whilst keeping the frequency of background stimuli constant.

However, our analysis of the effect of foreperiod duration on response speed suggests that it may be signal probability that is the key factor since the frequency of the stimulus is not a relevant variable during the foreperiod of a simple reaction time task. Furthermore, there is other evidence in support of the view that signal probability is a determinant (see p 1054).

Let us now return to a consideration of the effect of the 'block' factor on our simple visual reaction time task. We found that speed of response increased from one block to the next, and we suggested that this may have been due to the subjects learning when to expect the response stimulus. It will be remembered that the foreperiod in this task was constant in length. This means that the effect of increasing time blocks is analogous to the effect of decreasing ^{the} foreperiod interval: in each case the subject is better able to judge when the stimulus will occur, and so we would expect the subjective probability to coincide more exactly with objective probability as in Fig C below.

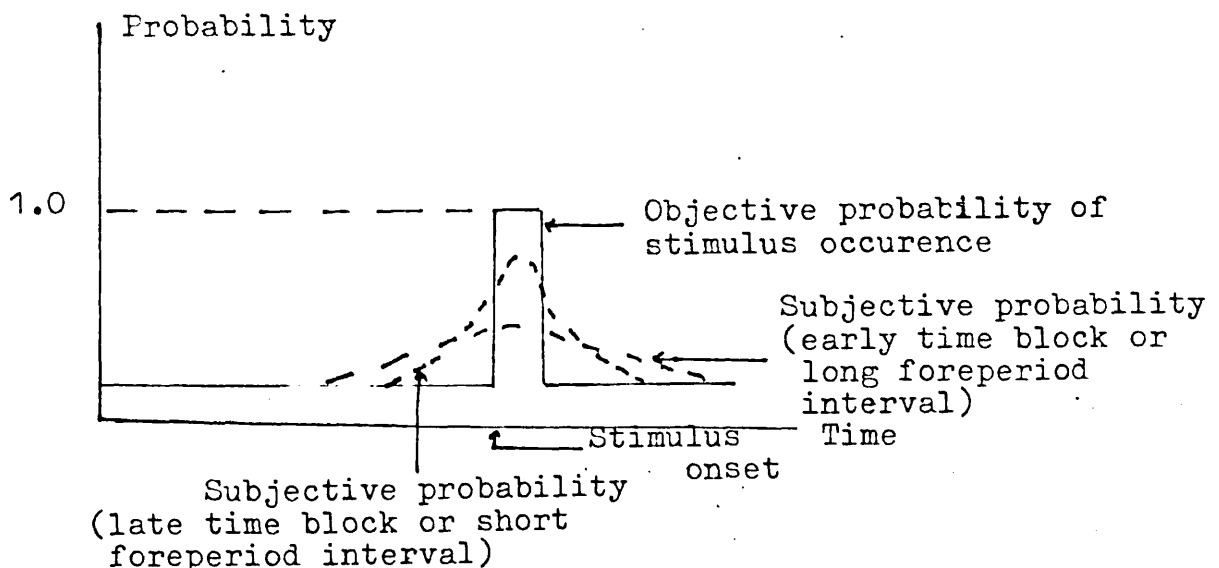


Fig. C Simple reaction time, subjective and objective probability

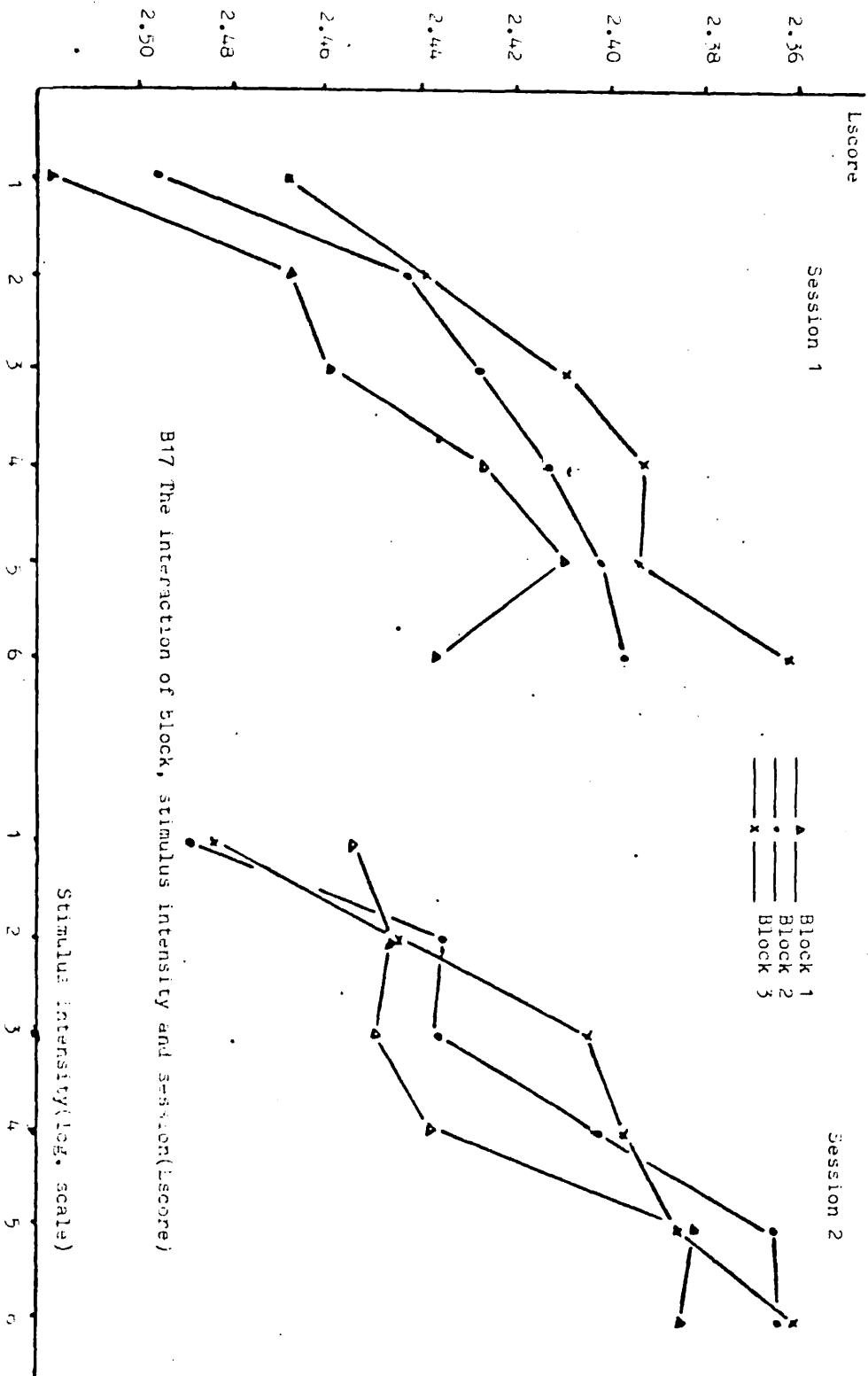
This shows that the height of the subjective probability curve at the point of actual stimulus occurrence will be greater if the subject is better able to estimate this point. One could, therefore, suggest that an inverted 'U' relationship might be found between response speed and the level of any factor which raised the height of the subjective probability curve at the point of stimulus occurrence. We have seen that the duration of the foreperiod may be one such factor, though to the author's knowledge there are no studies which have found a decrease in response speed at very short foreperiod durations, where the latter is constant within a given set of trials and comparisons are made across ^{sets of} trials.

In our simple visual reaction time task, it is the block factors which might be expected to affect the height of the subjective probability curve at the point of stimulus occurrence, due to the effect of learning. Is there any evidence for interactions between this factor and the other proposed determinants which would be consistent with the inverted 'U' hypothesis?

Let us consider the remaining results involving block.

The quadratic component associated with the interaction of block, stimulus intensity and session is significant at the 2.5% level (2 tail). This is depicted in graph B17 .

If we consider only the shapes of the curves, we see that the interaction would be fairly consistent with the view that both session and block move the subjects to the left of the inverted 'U', whilst stimulus intensity moves



B17 The interaction of block, stimulus intensity and session(Lscore)

Stimulus Intensity(log. scale)

subjects to the right. In session 1, there is a marked fall in response speed between the second highest and the highest stimulus intensity in block 1, which is consistent with the inverted 'U' model.

Such an effect is absent in blocks 2 and 3, however, and the shapes of the curves indicate that subjects are operating further to the left along the axis of the inverted 'U' in block 3 than in block 2, since the curve for the latter shows greater convexity upwards than the former.

Similar relationships are found in session 2, though if we compare the results for session 1 for corresponding curves, we find that they suggest that subjects are operating further to the right along the 'X' axis of the inverted 'U' in session 1 than in session 2. For instance, the fall in response speed between the second highest and highest intensities in block 1 is much less in session 2 than in session 1.

Our argument regarding the effect of learning on the subjective probability at the time of stimulus occurrence applies equally well to the session factor as to the block factor (we mentioned its possible role with respect to the former in connection with other simple reaction time results - see pp. 607-9). So in both cases we might have predicted that if subjective probability were a determinant, the block and session factors would have moved the subject to the right along the 'X' axis of the inverted 'U' (i.e. in the same direction as stimulus intensity), whereas the reverse seems to be true.

There are several possible explanations for this. The first is that our analysis of the changes in subjective probability during the foreperiod of a reaction time task is incorrect. It is possible that subjective probability at the point of stimulus occurrence does not increase from block 1 to 3. But if this were so, we would have to find some other mechanism to explain the clear learning effect that is apparent in the data. Despite the fact that the shapes of the curves conform to the inverted 'U' predictions, their absolute heights do not. One would have expected the overall mean response speed to decrease from block 1 to block 3, and from session 1 to session 2, if both factors move subjects to the left of the 'X' axis of the inverted 'U'. In fact, the reverse seems to be true so learning must be taking place although in session 2 its effect appears to be reaching an asymptote, since the curve for block 3 is not clearly above the curves for blocks 1 and 2.

What the mechanism for such a learning effect might be is not entirely clear. It is possible though that it is mediated via an increase in subjective probability, but that the latter is not a determinant and simply has the effect of raising the overall level of performance without affecting the shapes of the curves. As stated earlier, the author knows of no evidence that in studies employing a constant foreperiod (as in the present project), a very short duration foreperiod is associated with a fall in response speed.

This contrasts, however, with the results of the studies

employing variable foreperiods, which show clear evidence of an inverted 'U' relationship between foreperiod duration and response speed. It would be interesting to investigate the effects of the determinants in such a task.

It is difficult to decide from the present set of results whether or not subjective probability is a determinant since we have no direct measure of it. Also, what the results do indicate very clearly is that even if it is a determinant, its effect is unlikely to be demonstrated in a study which manipulates it by means of the time on task factor. This brings us back to our original point regarding the latter: there are a great many variables which will jointly determine the effect of time on task, and it is therefore very difficult to predict in which direction it will move the subjects along the 'X' axis of the inverted 'U'. These are summarised below:

<u>Factors which may move subjects to the right as time proceeds.</u>	<u>Factors which may move subjects to the left as time proceeds.</u>
Stimulus duration	Reduction in novelty due to:
Stimulus frequency (via summation of excitations)	(i) The unchanging aspects of the stimulus situation (stimulus duration)
Learning (via subjective probability)	(ii) Repetition of stimuli (stimulus frequency)
Diurnal rhythm	

In the present experiment summation of excitation is unlikely to have occurred since a fairly long interval (15 seconds)

separated the trials, and an even longer interval separated the blocks (2 minutes).

The diurnal rhythm is also unlikely to have had a major effect since the task was a relatively short one.

On the other hand the long intervals between trials and blocks would have reduced the rate of decrease in novelty due to the repetition of the stimuli. These were also of differing intensities presented in a random order, which would be expected to keep the rate of habituation down.

Nevertheless, overall the novelty factor seems to have been more powerful, since the graphs indicate that both block and session move subjects to the left along the inverted 'U' X axis. This does not mean, however, that in different situations the reverse might not be true.

What we are trying to demonstrate is that the effects of time on task are unpredictable, and for this reason the simple reaction time tasks in which the foreperiod is constant may not be the best way to test the hypothesis that subjective probability is a determinant. Fortunately, there may be other ways to do this. Before we discuss them, however, we must briefly consider the remaining results from the simple visual reaction time task involving block.

The planned comparison associated with the interaction between block and stimulus intensity is significant at the 5% level and is depicted in Graph 618. In block 1, response speed is faster at the second highest intensity than at the highest intensity, whereas the reverse is true in block 3. In block 2 there is very little difference between the two intensities. This is not inconsistent with the view that the



block factor moves subjects to the left along the 'X' axis of the inverted 'U' in the present study and the overall heights of the curves are consonant with the assumption that learning produces a general increase in response speed from block 1 to block 3.

There are a number of other significant effects involving the block factors both in terms of the main analysis of variable, the planned comparison and the analysis of Nelylitsyn's measure of the gradient of the reaction time/intensity curve. However, in none of these cases does the author have an adequate explanation of the result so they will not be discussed any further.

Results for the simple visual reaction time task involving the block factor and based on the subjects' E.P.C. scores.

- a) The quadratic component associated with the interaction between block, introversion, time of day and stimulus intensity is significant at the 2.5% level (two tail).
- b) The cubic component associated with the interaction between noise, block, introversion and stimulus intensity is significant at the 5% level (two tail).
- c) The linear component associated with the interaction between block, session, neuroticism and stimulus intensity is significant at the 5% level (two tail).
- d) The interaction between noise, block, introversion, neuroticism and stimulus intensity has a cubic component which is significant at the 2.5 % level (two tail).
- e) The interaction between noise, block, session, introversion neuroticism, time of day and stimulus intensity is significant at the 5 % level , as is the associated cubic component (two tail).

None of the planned comparisons (between the highest and the second highest intensities) involving the block factor were significant.

There were also no significant effects involving the 'block' factor for the analysis of Nebylitsyn's index of the gradient of the reaction time/ stimulus intensity curve.

Discussion.

None of the above results conform to prediction, nor has the author any adequate explanation for them. Furthermore, in only one case do they overlap with the results based on the subjects' E.P.I. scores, namely in the case of (e), and here too the two results have a different level of statistical reliability.

Results for simple visual reaction time involving
'block' and psychoticism:

This analysis was identical to the previous ones except that a bimodal split on the E.P.Q. P scores was used to define a psychoticism factor which replaced the introversion and neuroticism factors.

a) The interaction of noise, block and psychoticism is significant at the 0.5% level (two tail). See discussion.

b) The cubic component associated with the interaction between block, stimulus intensity and psychoticism is significant at the 1% level (two tail). See discussion.

c) The interaction of noise, block, session and psychoticism is significant at the 5% level (two tail). See discussion.

d) The cubic component associated with the interaction between block, session, stimulus intensity and psychoticism is significant at the 5% level (two tail). See discussion.

Discussion:

None of the above interactions involving block and psychoticism are in line with prediction so they will not be considered further.

4. OUTLINE OF A VIGILANCE STUDY

i) The Choice of factors

We must now consider how to test the inverted 'U' model in the context of vigilance. We have already argued that measures of overall performance level seem to provide the clearest support for the theory. Furthermore, if we look back to our review of the relationship of the determinants to vigilance, we see that signal frequency/probability, accessory stimulation in the form of noise, introversion and time of day seem the most promising of the factors which are practicable, though again there is considerable conflict within the literature and very few studies have manipulated even two factors jointly.

In addition to these, neuroticism is of great theoretical interest and is a variable which we have seen has emerged very strongly earlier in the present project, although it has been neglected by many other workers. As before we can investigate the effect of novelty without any extra manipulation simply by looking at the 'session' factor (though we will see that in the present instance there are certain limitations on such an endeavour). We will also argue shortly that it is possible to investigate the influence of stimulus duration in the sense of the duration of a single stimulus, by using this factor to differentiate the signals and the non-signals in our vigilance task.

Finally, although we have seen that stimulus duration interpreted as 'time on task' has yielded highly equivocal results, we have presented an explanation of this. Furthermore, we have suggested that though it is not really possible to predict the effect of this variable in advance, we can still

explain its interactions with other factors on a post hoc basis in terms of our inverted 'U' model. For this reason and since time on task has been the main interest of workers in the field of vigilance, we will include it.

ii) A partial solution of the problem of time on task

We emphasise again though that a shift to the left or a shift to the right along the 'X' axis of the inverted 'U' are both predictable for the time on task factor. Neither would be inconsistent with the model since either could occur depending on the circumstances of the particular study and the relative importance of the opposing factors which moderate its effect (see page 748).

In the past the general consensus has been that the effect of time on task is to move subjects to the left along the 'X' axis of the inverted 'U' due to a reduction in novelty and associated habituation effects - Gray (1967) has pointed out that it is likely to be difficult to produce movement in the opposite direction because of such effects, though he cites a suggestion by Rachman that this could be achieved by administering a gradually increasing dose of a stimulant drug. For practical reasons we are unable to take up this idea, but we intend to approach the problem from a slightly different angle.

Although it is generally assumed that time on task moves subjects to the left along the 'X' axis of the inverted 'U', most studies have tended to employ one or two other factors and were, therefore, largely concerned with overall effects of time on task on their group of subjects treated as a whole. We have consistently argued that this is not the way to test the inverted 'U' hypothesis since such main

effects for factors tell us very little about its validity or otherwise. We have been concerned with interactions between two or more factors and as a result we have deliberately designed multifactorial experiments. If we look at our final list of proposed factors for the vigilance task, we see that we have no less than eight:

- Introversion
- Neuroticism
- Signal frequency/probability
- Stimulus duration
- Accessory Sensory Stimulation
- Time of day
- Novelty
- Time on task

If we assume that the probability of moving to the left versus the right along the 'X' axis of the inverted 'U' as time on task increases depends partly on a subject's initial position, then we see that this multitude of variables is indeed highly desirable. We suggested earlier that one of the factors which would tend to produce movement to the right was summation of excitations from successive stimuli. This assumes that a given stimulus produces an excitation which rises to some maximum point and then gradually decreases, and Killeen et al (1978) have presented a theoretical model to support this interpretation. Summation will occur if the excitation is at a non-zero value when the excitation due to the next stimulus starts to rise. This itself will depend on a number of factors.

The first of these is the maximum value reached by the excitation to the first stimulus. This maximum value can be

considered to be equivalent to the value of the 'excitatory process' at the corresponding point on the inverted 'U'. This will depend on factors such as the intensity and the duration of the stimulus, but also on the levels of the other determinants.

Secondly, the likelihood of summation will depend on the rate at which the excitation from the first stimulus 'decays' with time. This may be a function partly of the maximum level reached, due for instance to the law of initial values, but it may also be an independent function of the levels of some or all of the determinants. It has been shown (Christie, personal communication) that subjects who are low and high on the dimension of 'ego strength' do not differ in the amplitude (i.e. the maximal level) of their physiological response to stimuli but in their rate of recovery - subjects who are relatively low on the dimension recover more slowly. Furthermore 'ego strength' has been shown to be negatively related to both introversion and neuroticism, which are included in our list of proposed determinants and which we are intending to employ in our vigilance task. Eysenck (1967) has also reviewed studies which suggest that the rate of recovery of physiological measures may be lower in subjects who are high on these dimensions. It is not, therefore, unreasonable to suggest that summation of excitation is more likely to occur in these subjects.

It should also be noted that a low rate of recovery following stimulation has been shown to lead to summation in studies on blood pressure. Chronic hypertension has been explained by some workers in terms of a failure of the cardiovascular system to return to normal resting levels

following a stressful event leading to a gradual increase in the blood pressure as a result of the continued action of successive 'stressors' (Christie, personal communication).

The third factor which would be expected to determine whether or not summation will occur is the interval between the stimuli. An increase in stimulus frequency must necessarily reduce the interval between stimuli and will therefore promote summation. Furthermore, signal frequency (/probability) is one of the factors we intend to employ in our vigilance task. Other things, being equal, an increase in signal frequency would be expected to decrease the interval between successive responses made by the subject, and therefore make it more likely that the excitations associated with these responses will summate.

Finally, the rate at which the excitation due to the second of two successive stimuli rises will help to determine whether or not summation occurs. In the section on reaction time and signal detection theory we suggested that, at initially low levels, at least, an increase in the levels of the determinants resulted in an increase in the slope of the sensory growth functions (see p. 479) - i.e the rate at which the level of neural activity due to a stimulus rises following stimulus onset. We showed, for instance, that the assumption that introverts have steeper sensory growth function than extraverts could be used to explain the findings of a number of studies (e.g. Brebner and Flavel, 1978 - see page 428) and that it received empirical support from studies of the signal detection index 'd' (e.g. Stelmack and Campbell, 1974).

We see therefore, that there is considerable evidence to support the view that summation of excitation is more likely

to occur if the levels of the determinants are relatively high than if they are relatively low, particularly where factors such as introversion are concerned. Shigehisa et al (1973) have shown that the effect of a preceding visual stimulus is more likely to persist and influence the response to a subsequent auditory stimulus in introverts than in extraverts. This result is in line with the above analysis.

We would, therefore, like to suggest that when the levels of the determinants are relatively high, the probability that time on task will result in a movement to the right along the 'X' axis of the inverted 'U' will be relatively high. We can therefore predict that if any subjects do show movement in this direction they are more likely to do so in conditions corresponding to a combination of high levels of the determinants than in conditions corresponding to a low combination of the determinants.

This itself could lead to interactions between time on task and the other determinants due to movement in different directions under different combinations. The nature of the interactions involving time on task that emerge from our vigilance experiment will, therefore, tell us whether the above analysis is correct. Furthermore, we see now the advantage of employing a large number of factors since the probability that in the highest combination group, at least, subjects will move to the right will be greater the larger the number of factors included.

However, since we are still talking in terms of probabilities our interpretation of the time on task factor will necessarily still be post hoc. We can predict that if movement to the right occurs it is more likely to occur when the levels of the

determinants are relatively high, but we cannot be sure that such movement will occur. Moreover, if instead, movement to the left occurs, we may still get interactions, but they will be of the opposite kind (see page 89). So we still are forced to the conclusion that, where time on task is concerned the inverted 'U' model is better able to explain than to predict. We can, however, generate fairly unambiguous predictions for the overall level of performance (i.e excluding the time on task factor) and we will address ourselves to this shortly.

iii) Signal frequency and Signal probability

Before we do so a brief word should be said about another of the factors we are proposing to employ in our vigilance task: signal frequency/probability. We discovered that attempts to test the hypothesis that subjective probability is a determinant using the 'block' factor of our simple visual reaction time task were unsuccessful (see pages 737-51). We suggested that this was because the block factor is equivalent to time on task, and as we have seen there are several variables confounded in this particular determinant, of which signal probability was only one in the experiment in question.

We also argued that a better test of the hypotheses might involve manipulating the duration of the foreperiod of a simple reaction time experiment in conjunction with some of the other determinants (e.g personality). Such a study would have the advantage that subjective probability would be unconfounded with other factors such as novelty. As we have seen, in vigilance tasks signal probability (and therefore, presumably, subjective probability - see later) is inevitably confounded with either the frequency of the signals or the

frequency of the background, neutral stimuli ('stimulus frequency').

It could be objected, therefore, that it would have been better to conduct a study on foreperiod duration in simple reaction time rather than a study on vigilance. There are a number of reasons why this procedure was not adopted. Firstly, the relationship between foreperiod duration and subjective probability has been very little studied, and the associated hypotheses which are presented were somewhat tentative. Secondly, subjective probability is only one of a number of determinants that we wish to study, and the review of the work on vigilance suggests that an experiment on the latter employing several of these would be very worthwhile. Thirdly, the study of vigilance has greater practical significance than the study of the foreperiod of a simple reaction time task. For these reasons it was decided to conduct a study on vigilance even though signal probability would be confounded with one other factor.

iv) Signal frequency and Stimulus frequency

The decision to keep stimulus frequency constant and to vary signal frequency and signal probability together as a joint factor was made on the basis of previous work. Our review of the determinants and vigilance showed that the evidence that signal frequency is a determinant was far clearer than the evidence that stimulus frequency is a determinant. This is particularly apparent in the case of studies on personality, ^{and} table V summarises the studies which have looked at the joint effect of introversion, on the one hand, and two or more of the three stimulus variables: stimulus

Parameter that

was manipulated :	Stimulus frequency	Signal probability	Signal frequency
Blakeslee(1979)	Blakeslee(1979)	Blakeslee(1979)	
	<u>Bakan(1959)</u>	<u>Bakan(1959)</u>	
	<u>Davies and Hockey(1966)</u>	<u>Davies and Hockey(1966)</u>	
	<u>Kennedy (1972)</u>	<u>Kennedy(1972)</u>	
	<u>Kishimoto(1978)</u>	<u>Kishimoto(1978)</u>	
Stroh(1971)	Stroh(1971)	Stroh(1971)	Stroh(1971)

Table V • Summary of studies which have manipulated stimulus frequency, Signal probability or signal frequency in vigilance tasks.

frequency, signal frequency and signal probability, on the other. It will be remembered that it is not possible to manipulate one of these variables by itself, so each study is entered in at least two columns. Studies which provided evidence in favour of the inverted 'U' are underlined.

Part of the reason why the evidence for stimulus frequency and introversion as joint determinants is less clear than for the other stimulus variables, is that stimulus frequency has been less often studied. However, the proportion of studies favouring the inverted 'U' is clearly greater for signal frequency (and signal probability) than for stimulus frequency

It is not difficult to see why this should be so. We argued earlier that an increase in the frequency of any kind of stimuli (whether signals or non-signals) would be likely to increase the rate of habituation - i.e the rate of reduction in novelty - and hence tend to oppose any movement to the right along the 'X' axis of the inverted 'U' due to an increase in the frequency, per se. Habituation is thought to occur when the characteristics of a stimulus match the internal 'model' derived from previous stimuli which the organism has encountered (e.g Sokolov, 1963), and amongst these characteristics we would include the spatial features of the stimulus - e.g its size, intensity, duration, position etc.

However, if the internal model also includes information about the temporal features of the stimulus, then we would expect habituation to occur more rapidly to a stimulus which occurs regularly than to a stimulus which occurs irregularly. It will be remembered that the background, neutral stimuli in a vigilance task are presented at regular intervals whilst

the signals are presented at irregular intervals. Furthermore even where signal frequency has been manipulated, it is rare for it to equal the frequency of the background, neutral stimuli. Thus the signals will be less frequent and more irregular than the background stimuli and we would expect both factors to retard the rate of habituation of the former relative to the latter. Finally, the subject is required to respond to the signals but not to the background stimuli, and it is a cardinal principle of most theories of habituation of the orienting response that habituation will occur more slowly to 'significant' than to irrelevant stimuli.

For all these reasons we would expect habituation to be more relevant to the stimulus frequency factor than to the signal frequency factor - i.e an increase in signal frequency is more likely to produce a movement to the right along the 'X' axis of the inverted 'U' despite any tendency for the rate of habituation to increase at the same time. This is especially so since the excitation associated with signals will include not only excitation due to the signal itself but also the stimulus feedback from the response the subject makes to it.

It is not surprising, therefore, that the effects of signal frequency have been more clearly in line with the inverted 'U' hypothesis than ^{those of} the stimulus frequency. It is for this reason that it was chosen to vary the former along with signal probability rather than the latter.

It might be thought that this argument is inconsistent with our professed aim to test the inverted 'U' model at its weakest points. However, this applies only in cases where

the apparent failure of the model to explain the results

in question was: due to an inadequate analysis of the processes involved. This applies, for example, to the findings relating personality to the gradient of the reaction time/intensity curve.

We believe that there has been a similarly inadequate account of the processes mediating 'time on task' effects and we have tried to make good this omission. However, the equivocal^{al} findings with respect to this factor are probably a direct consequence of the ambiguity inherent in the factor itself: namely, that its effect depends on the interplay of several opposing factors. This ambiguity cannot be eradicated, it can only be minimised, for instance by choosing^{to} manipulate signal frequency rather than stimulus frequency. Such a choice is completely consistent with the general policy which we have adopted throughout the present project - i.e to employ determinants whose influence on the subject's position on the 'X' axis on the inverted 'U' is fairly clear so that they would provide a relatively unequivocal test of the general model. Conversely, we have deliberately excluded factors such as drive where we felt that they could not provide such a clear-cut test (see page 116).

We have included time on task, nevertheless, because although it is a problematic determinant, our previous analysis suggests that its net effect is likely to be related in a systematic way to the levels of the determinants - i.e it is most likely to produce movement to the right when the levels of these are high.

v) Predictions for the overall level of performance

We have argued already that signal detection measures can be used to analyse the results of vigilance tasks, so that in this respect our proposed vigilance experiment is equivalent to the signal detection task we employed earlier, since that also was concerned with the overall level of performance. By combining the inverted 'U' hypothesis and the signal detection model we generated a number of predictions for the probability of a hit, the probability of a false alarm, the discrimination index, the criterion and the disjunctive reaction time (see pp. 516-35).

When considering the results of the signal detection task, one of our main contentions was that stimulus intensity did not seem to be interacting with the other proposed determinants as the inverted 'U' model in its original, most general form would predict. Stimulus intensity was not itself included as a factor in the analysis of variances, but we were able to make inferences about its effects because the signal and non-signal stimuli in the signal detection task differed only in intensity.

In our proposed vigilance task, we will be attempting to replicate to a reasonable extent the general experimental set-up employed by Kishimoto (1978). We are fortunate in that the latter used stimulus duration to define the difference between the signals in his task and the background, non-signal stimuli, since this provides us with the opportunity to test whether stimulus duration is a determinant or whether, like stimulus in-

tensity, it is special in some way. We have already pointed out that stimulus duration is thought to act in an analogous fashion to stimulus intensity within the Russian model, and workers in the West have shown experimentally, that it often acts in a similar way (e.g. Sanford, 1972). There is, therefore, a very real possibility that stimulus duration, interpreted as measuring the duration of a single stimulus rather than 'time on task', may also fail to interact with the other determinants in predictable ways. We intend to put this to the test.

Consider figures 46 and 47 below.

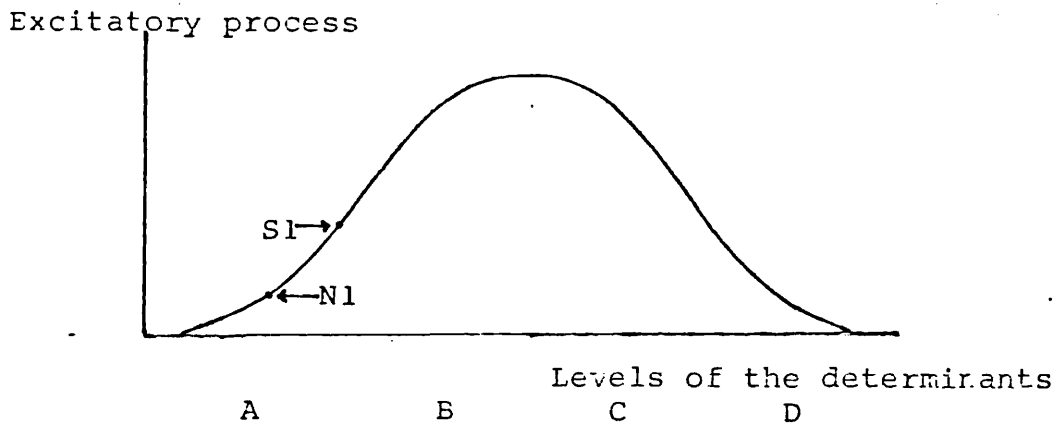


Fig.46 .The inverted 'U' hypothesis

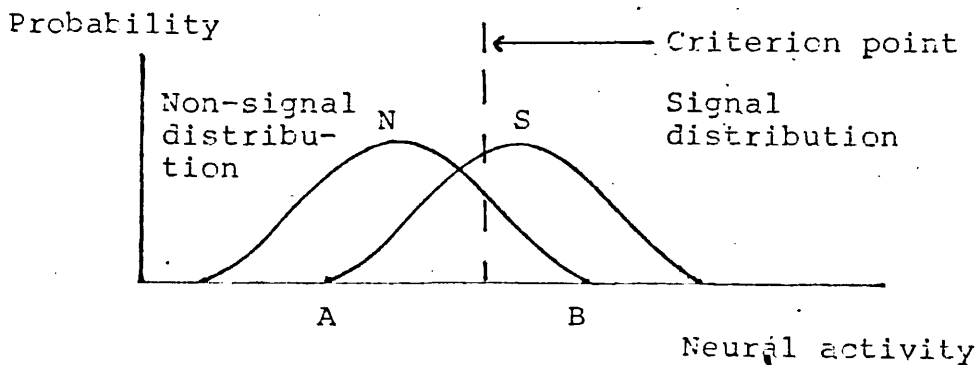


Fig.47 . The postulates of signal detection theory

These duplicate the diagrams which we used to generate our predictions for the signal detection task (see p.). The diagram in figure 46 is our hypothesised inverted 'U' relationship between the levels of the determinants and the level of the 'excitatory process'. The diagram in figure 47 depicts the essential postulates of signal detection theory showing the probability distributions of 'signal' and 'noise'. As in the signal detection task we can regard the 'noise' distribution as equivalent to the distribution for the non-signal stimulus. In the case of our proposed vigilance task this will be a background, neutral stimulus which differs from the signal in that it will be of shorter duration (in the signal detection task, it differed from the signal in that it was of lower intensity than the latter). Again the reader is reminded that the 'y' axis in figure 46 ('excitatory process') is functionally equivalent to the 'x' axis of figure 47 ('neural activity').

If we assume that stimulus duration is a determinant, points N1 and S1 in figure 46 can be treated as representing the non-signal and signal stimuli respectively, when the levels of the determinants are relatively low, and these correspond to the means of the non-signal and signal distributions in figure 47. Again the reader is cautioned that these distributions bear only a chance resemblance to the inverted 'U' function depicted in figure 46.

We can generate identical predictions for the overall level of performance in the vigilance task as for the

signal detection task, by assuming that as the levels of the Determinants are increased, the level of the 'excitatory process' corresponding to the points N_1 and S_1 changes as predicted by the inverted 'U' function in figure 46, and the non-signal and signal distribution alter their position on the 'x' axis of figure 47 accordingly.

The argument is exactly the same as for the signal detection task (see pp. 516-35), so we will not repeat it in detail here, instead we will simply summarise the predictions:

- 1) An inverted 'U' relationship between the levels of the determinants and
 - a) The probability of a hit
 - b) The probability of a false alarm
 - c) The disjunctive reaction time
- 2) A 'U' relationship between the levels of the determinants and the measured criterion
- 3) A complex relationship between the levels of the determinants and the discrimination index as described by the function in figure 48 below.

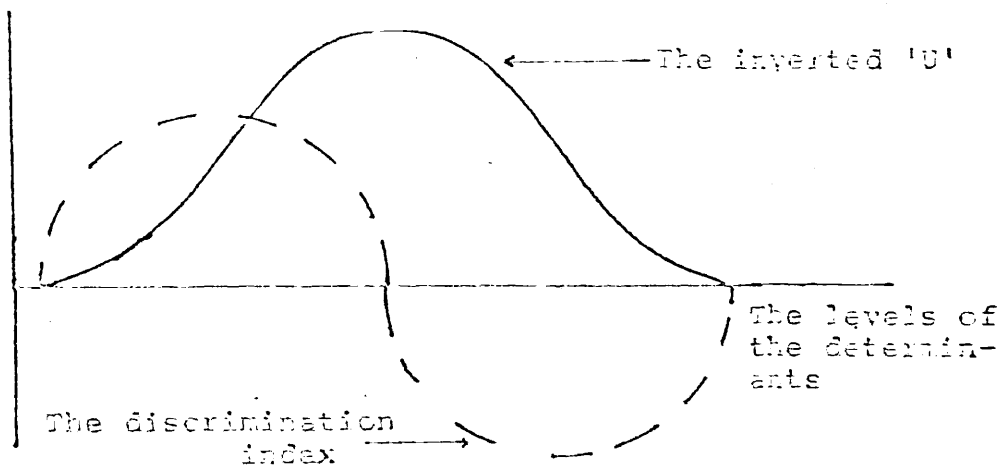


Fig. 48. Predictions for the discrimination index

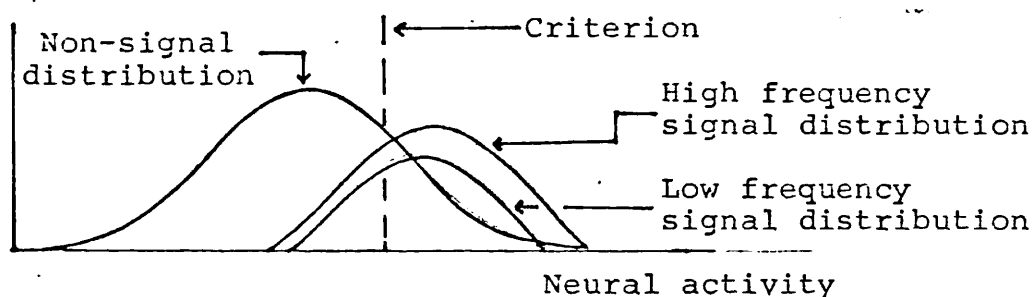
A few words of qualification must be added, however. Firstly to our list of proposed determinants we must add signal frequency/probability. For convenience, we will refer to this henceforth as signal frequency, but this variable is completely confounded with signal probability, and it is possible that either one or both may be a determinant.

Secondly, as in the signal detection task, our predictions refer to the probabilities of hits and false alarms. In the signal detection task, such probabilities are an accurate guide to the absolute numbers of hits and false alarms, since the total number of signals was equal to the total number of non-signals. In our proposed vigilance task, however, the total number of signals will be much less than the total number of non-signals. Furthermore, the ratio of the two will be different in the two signal frequency conditions.

The distributions shown in figure 47 are probability distributions. Furthermore, the signal distribution has been shown as having the same size as the non-signal distribution, since this representation enables us to predict what will happen to the measured criterion if the levels of the determinants alter. The reason for this is that the formula for the measured criterion does not take into account differences in the a priori probabilities of the signals and non-signals. It is defined as the ratio of the ^{heights of the} signal and noise distributions, and essentially assumes that these have the same overall shape and size as shown in figure 47 .

The measured criterion, therefore, provides an inverse index of the absolute tendency to respond only if the signal and non-signal probabilities are equal, as in the signal detection task. Our diagram in figure 47 will not, however, tell us about the absolute number of hits or false alarms, since in the proposed vigilance task the probability of a signal and of a non-signal will be different and will also vary from one frequency condition to another. Consider, though, figure 49 below.

Fig.49 .Signal frequency and the postulates of signal detection theory



In this diagram the size of the non-signal distribution is shown as being larger than the two signal distributions representing the high and the low frequency conditions. Such a diagram would enable us to make predictions regarding the absolute number of hits and false alarms should we wish to do so. If we consider each one separately, we would still predict an inverted 'U' relationship with the levels of all the determinants except signal frequency. The reason for this is that although we are proposing that signal frequency is a determinant, and will therefore move the signal distri-

butions along the 'x' axis of figure 49 in accordance with the inverted 'U' function in figure 46 we have two separate distributions for the two signal frequency conditions.

Let us consider the case in which the levels of the determinants were relatively low, and we were, therefore, operating on the left hand side of the inverted 'U'. An increase in signal frequency would raise the level of the 'excitatory process' and therefore move the signal distributions to the right along the 'x' axis of figure 49. But it would also cause a jump from the low signal frequency to the high signal frequency distribution. The absolute number of hits would, therefore, increase for both these reasons.

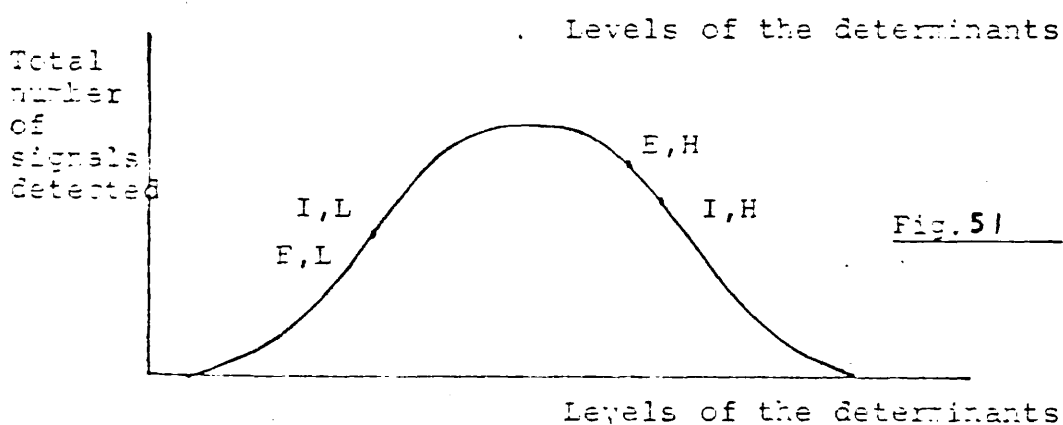
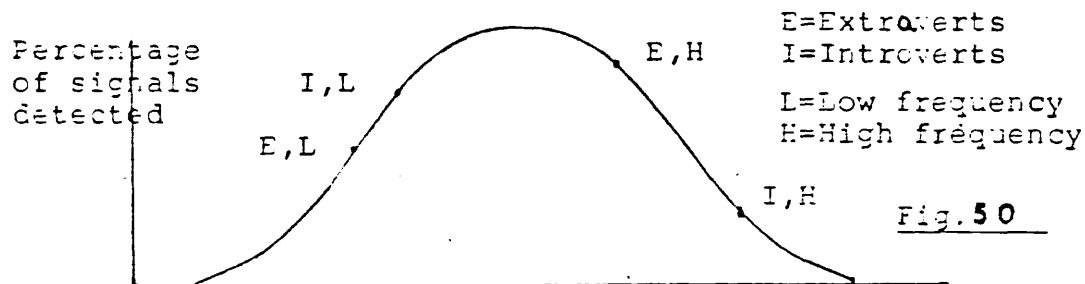
If, however, the levels of the determinants were relatively high, and we were operating on the right hand side of the inverted 'U', an increase in signal frequency would result in a fall in the level of the 'excitatory process' and, therefore, a shift to the left of the distributions in figure 49. This by itself would tend to reduce the absolute number of hits. However, again we would also have to change from considering the low signal frequency distribution to the high signal frequency distribution. Since the latter is larger than the former, this would tend to increase the absolute number of hits and would work in opposition to the shift in the positions of the distributions.

It is for this reason very difficult to predict what the effect of an increase in signal frequency upon the absolute number of hits will be.

The greater the difference between the signal frequency conditions, the greater the difference between the sizes of the two signal distributions. However, all other things being equal, the size of the shift in the positions of the distributions will also be greater. Of course, all other things may not be equal, and the size of this shift will also depend on which part of the inverted 'U' one is operating upon. We have argued many times that there is an inevitable element of indeterminacy involved in the inverted 'U' function, and though we may often be able to predict differences in the direction of changes, and sometimes differences in the size of changes, exact quantitative predictions are not really possible. For this reason, we cannot predict with certainty what the effect of a change in signal frequency will have upon the absolute number of hits.

However, if we look back to Kishimoto's study, we find that although the introverts detected a lower percentage of signals in the high signal frequency condition than in the low signal frequency condition, the absolute number of detections was greater in the former than in the latter. So in this case the effect of the size of the distributions seems to have outweighed the effect of their positions relative to the criterion.

If, therefore, we wish to explain the fall in the percentage of correct detections in the introverts at high frequency in terms of an inverted 'U' relationship between the tendency to respond and the determinants, it is the measured criterion which would be the relevant parameter - i.e. one would have expected a 'U' shaped relationship between the determinants and the measured criterion. The absolute tendency to respond only shows a 'partial' interaction effect (see p.41). To make this clearer consider figures 50 ^{and 51} below.



The inverted 'U' and Kishimoto's study : percentage of signals detected(Fig. 50) and total number detected(Fig.51)

We see that in the case of the percentage detection measure, the interaction works both ways. In other words, the effect of an increase in either introversion or signal frequency is opposite at the two levels of the other determinant. On the other hand, if we consider the absolute or total number of signals detected, we see that the

interaction only works one way. The effect of an increase in level of introversion is opposite at the two signal frequencies, but the effect of an increase in signal frequency is to increase the total number of signals detected in both the introvert and the extravert groups.

In both cases the introvert group under high frequency is shown as having passed the T.T.I. - i.e. the peak of the curve, but clearly the degree to which it has surpassed this point is greater in figure 50 than in figure 51 .

This reflects the fact that in the case of the absolute measure any tendency for the signal distribution in figure 49 to move to the left along the 'x' axis under conditions of high signal frequency will be mitigated by the fact that the distribution for this frequency level is relatively large, so the area to the right of the criterion point, which represents the total number of hits, will also be relatively large, all other things being equal.

This means that the effective threshold of trans-marginal inhibition will be lower for the percentage detection measure than for the absolute (total) measure. As for the discrimination index (see p. 525), this by itself does not contradict the view that transmarginal inhibition is a general phenomenon, since the two measures are qualitatively different, but it does illustrate the fact that the apparent or empirical threshold of trans-marginal inhibition will depend on the index employed.

It also shows that the indices couched in terms of probabilities of detection such as the measured criterion are likely to be more sensitive and less ambiguous than indices couched in terms of the absolute number of hits or absolute tendency to respond.

There is a further complication, though. When we considered the predictions for the signal detection task, we pointed out that with the exception of the discrimination index, they could be generated either by assuming that the position of the actual criterion on a dimension of neural activity (i.e. the 'x' axis in figure 49) altered, or that the absolute positions of the distributions on this dimension altered. We chose to adopt the latter view because we were able to explain such alterations solely in terms of changes in the level of the 'excitatory process', without the need to introduce any extra postulates regarding the effect of the determinants on the actual criterion. We also pointed out that this choice did not matter in operational terms, because the effects on the measured criterion would be the same whether it was the actual criterion or the distributions that moved.

However, we are now considering the hypothesis that signal frequency is a determinant, and it is at this point that the inability to disentangle signal frequency from signal probability effects becomes important. The reason for this is that signal detection theory predicts that as signal probability increases, the value of the measured criterion will decrease, and this has been cor-

roborated experimentally (see Green and Swets, 1974). Whether this is due to a shift to the right of signal and noise distributions, or to a shift to the left of the actual criterion in figure 49 is a matter for speculation, since the distributions and the criterion are hypothetical.

But if it is due to a shift to the left of the actual criterion, then this effect would be superimposed upon any changes in the positions of the distributions due to the effect of signal frequency/probability on the 'excitatory process'.

What we are suggesting here is that, unlike the signal detection task, alterations in the position of the actual criterion and the distributions are no longer entirely equivalent interpretations. It is possible that both may occur when we are considering signal frequency/probability.

This might have been the case even in the signal detection task, but we had no reason to suppose so, since signal detection theory has nothing to say about the relationship between the proposed determinants and the criterion. It is, however, quite explicit about the effect of signal probability. We will not go into the details of the prediction here (see Green and Swets, op. cit.), but we can summarise the matter by saying that signal detection theory argues that the subject behaves like an 'ideal observer' - i.e. one who tries to maximise certain 'values' associated with responding correctly, and to minimise certain 'costs' associated with responding

incorrectly. On this basis it can be shown that if an increase in signal probability occurs, an ideal observer will lower his criterion.

Furthermore, the author knows of no studies in the signal detection literature which show that at very high signal probabilities a rise in the criterion occurs. However, if we assume that signal probability is a determinant, this is what we might predict. Kishimoto's results could be explained by just such a 'U' shaped relationship between the criterion and the determinants, but it will be remembered that he manipulated the joint effect of introversion and signal frequency/probability. This illustrates the fact that curvilinear relationships of the kind we are considering here are more likely to be revealed by two factors acting together rather than by considering several levels of a single factor.

It is possible, therefore, that the lowering of the actual criterion at the high signal frequency/probability in Kishimoto's study is outweighed by the effect of the movement to the left of the signal distribution in figure 49. This movement would be explicable if we assumed that signal frequency and/or signal probability is a determinant. If signal probability is a determinant, the above analysis illustrates the fact that the effect of a given determinant operating within the framework of the inverted 'U', may be modified by its effect on some other factor. We saw an example of this in the taste experiment, when we suggested that the effect of neuroticism on salivation in its capacity as a determin-

ant, might be moderated by the influence of the neuro-
ticism on salivation via the autonomic nervous system
(see pp. 316-8). In the present instance, the effect
of signal probability on the measured criterion (and the
percentage of correct detections), in its capacity as a
determinant, may be moderated by its effect on the actual
criterion, in accordance with signal detection theory
postulates.

Even if it is signal frequency and not signal prob-
ability that is the determinant, one would expect the
latter to influence the effect of the former because in
Kishimoto's study (and in our proposed vigilance task) the
two are completely confounded. Since an interaction is
nevertheless, obtained in Kishimoto's experiment, it is
possible that the effect of signal probability on the
actual criterion has not been sufficiently great to out-
weigh the operation of the inverted 'U'. However,
Kishimoto did not employ any signal detection measures,
so it is difficult to clarify any of these ideas, a state
of affairs we hope to remedy.

Furthermore, we must take into account the possible
effect of signal probability on the actual criterion when
making our predictions for our proposed task.

Fortunately this is not difficult to do. In the
case of all of the measures except the discrimination
index, the effect of a decrease in the actual criterion
at the high signal frequency/probability would be simply
to delay the appearance of transmarginal inhibition
effects. For instance, if the signal distribution be-

gan to move to the left in Fig. 49 at the high frequency, this might be expected to reduce the probability of a hit. However, if the lowering of the actual criterion (i.e. a shift to the left) was sufficiently great, such an effect might not appear, and one might still get an increase in the probability of a hit. It should be noted, though, that this would only apply to the signal frequency/probability factor- i.e. to comparisons made between the two frequency/probability conditions. It is possible that the other determinants may affect the position of the actual criterion as well as the positions of the distributions, but we have no reason to suppose that this is so at present, and we will, therefore, make the simplifying assumption that this is not the case.

In the case of the discrimination index, the situation is even simpler, since signal detection theory, by itself, does not predict any change in this measure as signal probability is altered.

CHAPTER THIRTEEN- VIGILANCE : THE DESIGN

AND EXECUTION OF A STUDY

1. ISSUES IN THE DESIGN OF THE STUDY

We must now consider certain methodological issues associated with the design of our vigilance task.

i) PRETASK TRAINING

The first of these relates to the nature of the pre-task training which the subject receives. We have already pointed out that in a number of studies the decline in the probability of detection of a signal with time on task was associated not with a decline in 'd' (i.e. the degree of discriminability of the signals) but with an increase in the subject's criterion. As Williges (1969) has pointed out, the increase in the criterion may represent a move towards a level of responding which maximises 'expected value'. We have seen that signal detection theory predicts that the criterion depends to a large extent on the subject's assessment of the relative probability of signals and non-signals. If the relative probability of a signal is high then it 'pays' the subject to adopt a relatively low criterion, whereas if it is low it pays the subject to adopt a relatively high criterion. If the subject is acting as an 'ideal observer' - i.e. in accordance with the predictions of signal detection theory - then he should adjust his criterion should it seem to him that the relative probability of a signal and a non-signal has altered.

Vickers et al (1977) have reviewed a number of studies which have shown that the criterion increased during a vigilance session which followed a training or practice

period in which the probability of a signal (relative to that of a non-signal) was greater than the probability of the signal during the test session itself. Conversely, when the probability of a signal was lower in the practice period than in the following test session, the criterion fell during the course of the latter (e.g. Colquhoun and Baddeley, 1967). This indicates that changes in the criterion during the test session may have occurred as a result of a discrepancy between the probability of a signal in the practice and test periods.

Further support for this idea has come from the finding that where the relative probability of a signal is fairly high, no significant decline in the number of hits occurs during the session so long as there is no discrepancy between the probability of a signal in the practice and test sessions (Baddeley and Colquhoun, 1969). These findings all suggest that the vigilance decrement in the number of hits could be due to the fact that in most vigilance tasks the probability of a signal is greater in the practice than in the test periods. It therefore 'pays' the subject to raise his criterion during the test session to adjust to the altered signal probability.

There are, however, problems with this view, as Vickers et al have pointed out. Firstly, Baddeley and Colquhoun (1969) found that at relatively low signal probabilities a vigilance decrement, in terms of the number of hits, occurred even if there was no discrepancy between the signal probability in the practice and test periods.

Clearly, therefore, factors other than adjustment of the subject's criterion to the current signal probability may be affecting performance. Williges (op. cit.) has shown that if subjects are given misleading instructions which lead them to expect a signal probability of 0.5 in the test session, they do not in fact adjust their criterion during the course of the session so as to bring it in line with the actual signal probability. Instead, they adopt a criterion which produces a hit rate which is implied by the signal probability they had been led to expect (i.e. 0.5).

In an attempt to elucidate the source of this discrepancy, Vickers et al (1977) conducted an experiment in which the signal probability, relative to that of a non-signal, was gradually reduced during the course of the session according to a predetermined schedule, which was not known to the subjects. They found that although the number of hits and false alarms did decline during the test, the course of the decline did not follow the course of the decline in the actual signal probability at any one time, but the cumulative signal probability. In other words, subjects were carrying out a continual averaging process in which they were calculating a measure of the mean signal probability up to that moment in time.

The authors have developed a complex theoretical model to try to incorporate their findings and those of previous workers into a single framework. We will not describe it in detail here, but simply summarise their main conclusion which is that the underlying general

process which is involved in tasks of this kind is not an attempt by the subject to adjust his level of responding to the actual or cumulative signal probability, but rather to minimise the discrepancy between his actual level of responding at any one moment in time and his cumulative level of responding, whether in the form of a hit or a false alarm. The actual and cumulative levels of signal probability are important in as much as they help to determine the actual and cumulative levels of responding.

We can illustrate this by reference to the situation in which the probability of a signal is greater in the practice period than in the test period, resulting in a rise in the subject's criterion during the course of the latter. Vickers et al's explanation of this phenomenon is that the transition from the practice period results in an initial very sharp discrepancy between the subject's actual level of responding, which is low due to the relatively low signal probability in the test period, and his cumulative level of responding, which is high due to the relatively high signal probability in the practice period. The subject attempts to minimise this discrepancy by lowering his criterion very sharply at the beginning of the test session in order to raise the level of responding back towards the cumulative level of responding. The subsequent rise in the criterion during the course of the remainder of the session is interpreted as a gradual process of recovery as the situation appears to stabilise.

According to Vickers et al, the initial fall in the criterion is too rapid to be detected in an ordinary

vigilance task and can only be revealed if the fall in signal probability occurs gradually, as in their experiment, rather than abruptly, as in the transition from the practice to test period of a traditional vigilance task. If the theory is correct, we have a highly complex cognitive mechanism which comes into operation in situations where changes in signal probability induce discrepancies between the subject's actual and cumulative level of responding.

In addition to being able to account for a number of disparate findings (see Vickers et al for a detailed account) this theory is intuitively reasonable. The previous explanation for the adjustment of the subject's criterion in accordance with his subjective assessment of changes in the signal probability ignored the obvious fact that where no feedback is given to the subject during the test session, as is normally the case, his assessment of signal probability is based on his own level of responding. In other words, since he does not know whether he is right or wrong it is not unlikely that he assumes that every response he makes is made to a signal, and it is not surprising, therefore, that his own level of responding is the primary factor.

It is reasonable to propose on the basis of the preceding account that the discrepancy between a subject's actual and cumulative level of responding may produce changes in his criterion level which can account for the vigilance decrement in experiments where a change in the signal

probability occurs. What is crucial from the point of view of the present thesis is that though such a change in the signal probability may set in motion a train of events which lead to a change in the criterion and hence a change in the hit rate, it is not the only relevant factor.

Vickers et al also showed that the rate at which the subject's response rate gradually adjusted as the signal probability decreased varied widely from subject to subject. Furthermore, the rate of adjustment was significantly and positively correlated with the level of extraversion of the subjects (no mention of neuroticism is made). In other words, extraverts adjusted to the change in signal probability faster than introverts. The authors suggest a number of possible reasons for this. For example, introverts may tolerate a larger discrepancy between actual and cumulative measures. Alternatively, they may make smaller corrective adjustments, or perhaps base their estimates of the probability at a given moment in time ('total probability') on a larger number of trials, so that they are confronted with a smaller discrepancy between this value and the cumulative probability.

Whatever the reason, the finding itself has important implications for the present considerations since, as the authors themselves point out, it could explain the fact that the vigilance decrement in hit rate has been shown in a number of studies to be greater in extraverts than in introverts (e.g. Bakan et al 1963).

The finding that extroverts adapt to a change in signal probability more quickly than introverts is an interesting and important one. It is, however, difficult to incorporate directly into the other theoretical framework that we have been considering - for example, the hypothesis of an inverted 'U' relationship between the determinants and performance. Any attempt, therefore, to test such a hypothesis in the context of vigilance and personality should attempt to preclude the possibility that for any given subject the probability of a signal occurring would change during the experimental period.

It has been seen already that using the same signal probability in training and test periods prevents a significant vigilance decrement from occurring, at least at high signal probabilities (Baddeley and Colquhoun 1969). Vickers et al have also pointed out that the fact that a vigilance decrement was found in the same studies where the signal probability was low, despite the fact that it was the same in both the practice and test periods, can be explained by the use of an initial pre-practice period during which the signal probability was higher than during the later test period. Since Vickers et al showed that it was cumulative and not actual probability that is the relevant factor, changes in the subject's criterion during the test period as a result of their having undergone the pre-practice period could still be expected. Furthermore, the authors show that their model can predict the fact that this affects the low probability condition more than

the high probability condition.

The need to consider cumulative rather than actual probability can also explain why a more recent attempt to eliminate the vigilance decrement by training subjects on the same probability as they would encounter in the test period, was only partially successful (Craig, 1978). The aim of this study was to test the idea that vigilance decrement is due to a discrepancy between the initial level of responding of the subjects and the actual signal probability. Half of the subjects were informed of the signal probability in the test period prior to the commencement of the latter, the other half were not.

As predicted, the degree to which subjects responded more frequently (in terms of the total number of responses - i.e. hits plus false alarms) at the beginning of the task than the actual signal probability would warrant, was lower in the informed than in the uninformed group. Furthermore, the informed subjects showed much less of a vigilance decrement than the non-informed subjects.

The fact that the informed subjects tended to over-respond at all at the start of the test is explicable since at the beginning of the experimental period both groups underwent an introductory task in which the subject was required to respond and in which the probability of a signal was higher than in the later test period.

Despite the fact that the introductory task was followed by a practice period in which the signal probability was the same as in the test period, and despite the fact that the informed subjects were told this, Vickers et al's

theory would predict that the initial rate of responding would be higher than the actual signal probability. This is because the introductory task would have influenced the subject's cumulative level of responding, and the information provided to the informed subjects was able to mitigate but not completely eradicate the effects of this.

The general conclusion that can be drawn from the preceding analysis is that the procedures which the subject undergoes prior to the actual test period are crucial to the subject's performance in the latter and must be carefully controlled.

This is, therefore, one of the main tasks facing the present author in designing a study to clarify the relationship between vigilance performance and the various determinants. In other words, we must try to minimise the possibility that the results could be due to within-subject changes in situational variables - for example, signal probability interacting with other variables such as personality to produce within-subject changes in performance due to the kind of cognitive adaptive process outlined by Vickers et al.

We say 'minimised' because if Vickers et al are correct in their contention that it is ^{the} discrepancy between the actual and cumulative levels of responding that brings the adaptive mechanism into operation, then one cannot hope to eradicate the possible influence of such a mechanism in an ordinary vigilance task. This is because even if one controlled within-subject changes in signal probability, changes in the subject's level of responding could easily

occur for other reasons. In fact it is precisely such changes and their relationship to the determinants that would be the subject of investigation.

Thus we are faced with the problem that the very alterations in subject performance which could help to elucidate the relationships under consideration could also bring into operation a mechanism the action of which would be such as to counteract these changes. This is inevitable since the model that Vickers et al are proposing is a negative-feedback system: the subject is hypothesised to be trying to maintain a steady level of responding.

We can hope to control the effect of extraneous irrelevant variables (e.g. within subject changes in signal probability) on this level of responding, but the effects of relevant variables on the latter will immediately initiate a series of adaptive mechanisms to compensate for the change, since this is the fundamental process in negative feedback. This would be damaging since it would reduce the chance of showing the effects of relevant variables on levels of responding (though it would not eliminate the effect of the variables completely, since a change in the output of the adaptive negative feedback system would not occur or persist unless there were a discrepancy between the cumulative and actual level of responding).

A reduction in the sensitivity of the experiment would not be the only problem. If the gain of the adaptive system - i.e. the degree to which adaptation occurs as a result of a given discrepancy - is itself related to one of the relevant variables, as has been shown to be the case

for introversion/extraversion, then this would have the effect of either enhancing or diminishing the effect of the relevant variable, depending on the direction of its influence on the level of responding. For example, if even in the absence of a within-subject change in signal probability, extraverts had a greater tendency to show a decline in hit rate than introverts, this difference between the two groups would be partially mitigated by the fact that extraverts show greater adaptation than introverts.

This may seem paradoxical in view of the earlier argument that the greater decline in hit rate found amongst extraverts in some studies was also due to their more sensitive adaptive mechanism. But it will be remembered that Vickers et al's explanation for such a decline in hit rate was that it was not the direct result of the adaptation itself, but a rebound effect due to gradual recovery of the criterion following an initial sharp fall at the start of the test period. In this situation the adaptation precedes the decline in hit rate and the extent of decline (i.e. the extent of rebound) is positively related to the degree of adaptation. In the situation which we are envisaging, in which the adaptation mechanism would mask the difference between introverts and extraverts, the adaptation would be an effect rather than a cause of the decline in hit rate, and it would act in opposition to it, especially in the case of the extraverts.

The only way round this problem would be to ensure that the subject's level of responding did not change.

There are vigilance experiments in which the level of a given factor - e.g. the degree of discriminability of the signal from the non-signal - is made contingent on the subject's responses. If the subject's performance falls, the signal is made easier to detect, for example, and conversely, if the subject's performance improves. The aim of this is to keep the subject's level of responding reasonably steady, and changes in the subject's sensitivity are indexed by the changes in ^{the} level of the signal discriminability that are necessary to compensate for these changes.

Results using such methods (e.g. Wiener 1973) have been shown to produce similar findings to those of more conventional vigilance tasks. However, the technique requires the ability to automatically control factors such as stimulus discriminability on a moment to moment basis as determined by the subject's response, and the necessary equipment and technical expertise were not available to the present author. It is suggested that this would be a promising avenue of research for other workers.

We are, therefore, left with the less than ideal alternative of ensuring that changes in level of responding do not occur as a result of extraneous variables such as within-subject changes in signal probability. The situation is not as bad as it sounds since the effect of the adaptive mechanism on the interaction between time on task and a variable such as introversion would be simply to enhance or reduce an effect which already existed. Furthermore, it will be remembered that the important thing as far as the adaptive mechanism is concerned is the total level of

responding (i.e. hits plus false alarms) as reflected in the criterion measure. Changes in the discrimination ability of the subject influence the ratios of hits to false alarms and could take place in the absence of changes in the criterion and the subject's overall level of responding. This point illustrates the importance of using signal detection indices in vigilance tasks, since although the discrimination measure and the criterion are independent of each other, the hit rate (which is the usual measure employed) is a function of both.

There is another reason why it is desirable to have a pretask period in which the signal probability is the same as in the subsequent test session. We suggested earlier that 'subjective probability' may be a ^{de}terminant (see p.738). We showed how the foreperiod of a simple reaction time task might be used to manipulate this factor since the objective probability of a signal alters during the course of the latter. If we wish our vigilance task to investigate the effect of subjective probability by altering the objective probability, we must ensure that the former accurately reflects the latter. In other words we must ensure that subjects develop accurate expectancies of the probability of a signal before the test session begins. Our proposed pre-test period clearly would be one way to meet this requirement.

There is one problem, however, which remains. If the pre-test session trains the subjects on the signal probability which they are due to experience in the subsequent test, subjects in the different frequency/probability

conditions will have encountered a different number of signals prior to the start of the latter. Furthermore, since it is intended to inform the subjects as to which of the pre-test stimuli are signals and which are not, this might induce differential learning effects in the two conditions prior to the test and this might even interact with some of the other variables employed - e.g. personality.

Previous workers have attempted to get round this problem by 'compromising' between the need to generate accurate expectancies in the different signal probability conditions, and the need to ensure that the total number of signals presented prior to the test session is the same in these conditions to prevent differential learning of signal characteristics. Kishimoto (1978), for example, trained all his subjects at a signal frequency/probability which was midway between those corresponding to those presented during the main test in the two frequency/probability conditions. However, such a compromise was not really very satisfactory since it meant that subjects in the high frequency/probability condition were trained at a level below that which they encountered in the test period, whereas the reverse was true for subjects in the low frequency/probability condition. The results for this study which relate to changes with time on task are, therefore, suspect and the same applies to most other work in this area.

One way round this problem is suggested by a study by McFarland and Halcomb (1970). This showed that if

subjects were asked to sit and listen to auditory stimuli whose frequency was the same as that of visual signals in a subsequent vigilance task, the auditory stimuli could influence behaviour on this task in a manner that was consistent with the view that they helped to shape the subjects' expectancies of the frequency of the visual signals.

Furthermore, this was true even though the subjects were not told that the frequency of the auditory stimuli had any relationship to the frequency of these signals.

It is not, therefore, unreasonable to suggest that we could generate accurate expectancies in our vigilance task (which like that of Kishimoto will be a visual one) by simply presenting subjects in the pre-test period with auditory stimuli at the same frequency as the visual signals in the subsequent vigilance task. If in addition subjects were actually informed of this congruence, we would expect them to have developed fairly accurate assessments of objective signal probability by the start of the vigilance test.

This procedure has a number of advantages. Firstly, since the auditory stimuli would bear no resemblance to the visual signals, other than in terms of temporal frequency, the pre-task period could not induce differential learning of signal characteristics between the two frequency conditions. Secondly, if the subjects were not actually asked to respond to any of these stimuli the pre-task period would not induce any differential values of cumulative responding between these conditions, either. The same cannot be said of other studies in this area, such as that of

Kishimoto, in which the subjects were actually asked to respond to the pre-test signals in the same way as they would in the subsequent test period.

It is true that all subjects would have undergone the signal detection task before the vigilance task so the discrepancy between the total cumulative responses made prior to the latter and the level of responding during the vigilance task itself would be different at the two frequency conditions. However, the two tasks would be separated by several months, and would be of different kinds. It is possible that despite this fact, despite instructions to the subjects to treat the two tasks as being entirely distinct, and despite the pre-test period some degree of generalisation might occur. If so, however, the problem could not be entirely circumvented by using completely fresh subjects since they too might be influenced by their activities during the preceding months (or even years if we wish to employ a reductio ad absurdum argument), which might include, for example, psychological experiments carried out for other researches in the author's university. In any case, we have enumerated elsewhere other reasons why the use of fresh subjects for each set of experiments is undesirable in the present project.

THE CHOICE OF SIGNAL FREQUENCIES

One other methodological issue that we must consider is which values of signal frequency to employ in our study. It will be remembered that the study which has shown the clearest evidence for a predictable interaction between personality and signal frequency/probability is that of Kishimoto (1978), and for this reason we have decided to try to replicate to a reasonable extent the general experimental set up employed by the latter. However, in Kishimoto's study, although the interaction of signal frequency and introversion was significant there were no differences between introverts and extraverts in the effect of time on task at either frequency and no significant interaction between introversion, frequency and time on task. There was also no significant difference between introverts and extraverts at the low frequency, or between the two frequencies amongst introverts. It is possible that such effects might appear with a more judicious choice of signal frequencies.

We have already argued, though, that where an inverted 'U' is thought to be relevant and where the subject's position on the 'X' axis is dependant on the conjoint action of a large number of factors, it is very difficult to decide what particular operational values of a given factor are likely to produce a given effect. In this situation it was decided that the best approach would be to look at those studies which have shown clear evidence of a difference in the level of performance between introverts and extraverts

(either in terms of the overall level of performance or in terms of resistance to a decline with time on task) and to use these as a guide to the signal frequencies to employ. Not all of these studies provided the necessary details, but from those which did (or on the basis of personal communications from the authors) an average value of signal frequency was calculated and this was used as a rough guide to the frequency level to be employed in one of the two planned conditions.

When we look for studies which have shown clear evidence of a superiority of extraverts over introverts in vigilance we have a problem since there is only one: Kishimoto (1978) at high frequency. However, it will be remembered that two studies have shown clear evidence of superiority of extraverts over introverts in simple reaction time tasks: Buckalew (1973) and our own simple auditory reaction time task (see pp. 408 and 418). There are of course many differences between simple reaction time tasks and vigilance tasks, but one possible reason why the proportion of studies which have shown evidence for extravert superiority is greater in the former than the latter type of task, is that simple reaction time tasks generally employ higher signal frequencies than vigilance tasks and also the signal probability (i.e. 1.0) is much higher. Furthermore, Lisper et al (1977) have argued that it ought to be possible to develop a joint theory to explain performance in simple reaction time and vigilance tasks.

For these reasons the two reaction time studies mentioned above plus the high signal frequency condition in

Kishimoto's study were used to calculate an average signal frequency at which we hoped the chances of producing a significant superiority in the extraverts might be maximised. This average value was then used as a guide to the number of signals per unit time to employ in our second signal frequency condition.

It could be objected that this procedure is inconsistent with our earlier contention that comparisons across studies are less satisfactory than comparisons within studies. However, we are not here using cross-study comparisons to help us to decide which factors to employ; that choice has already been made. We are simply using them to help us to decide which particular frequencies to employ in the absence of acceptable values from individual studies such as that of Kishimoto. Furthermore, our objections to cross-study comparisons were based on the fact that the number of extraneous variables which differ from one study to another is very large. However, we might expect the effect of such variables to cancel each other out in the averaging process described above. This is less likely to be true at the high frequency since only three studies were involved, but to have chosen our signal frequencies completely without regard to the findings of other workers would have been very arbitrary.

2. METHOD

i) Subjects

Of the original 36 subjects who had taken part in the taste experiment, 31 were still available to take part in the vigilance task. We have seen that one 'stable introvert' had left the university prior to the start of the reaction time/signal detection task. A second one left prior to the start of the vigilance experiment, leaving a total of seven subjects in this quadrant. During the course of the vigilance task one of these seven failed to turn up for the second session so he was eliminated leaving six 'original' subjects for whom results were available.

All of the original nine 'neurotic introverts' took part in the vigilance task but one was eliminated because of equipment failure during the experimental session and another asked for the experiment to be terminated in the middle of the first session.

This left seven 'original subjects' for whom results were available.

Of the original nine 'stable extraverts', eight participated (one had left college). Of these, one failed to show up for the second session and was, therefore, eliminated, leaving a total of seven 'original' subjects for whom data were available.

Of the original nine 'neurotic extraverts', seven participated in the vigilance task (two left the college prior to the start of the latter).

We will see that a balanced design required eight subjects in each personality quadrant. The experimenter had foreseen the possibility that some subjects might drop out prior to the start of the vigilance task and that the extra subject per quadrant in the taste experiment might not be enough to make up for this. As a precaution, therefore, he had recruited some extra subjects to take part in the simple visual reaction time/signal detection task at the same time as the original subjects were tested on the latter.

Nearly all of these extra subjects had provided E.P.I. scores at the time of the taste experiment but had not been tested on the latter for one reason or another. Which of them took part in the reaction time/signal detection task depended partly on their availability and partly on the need to choose a few subjects from each quadrant.

To meet this latter need it was also necessary to include two subjects (one 'stable introvert' and one 'neurotic extravert') who had not provided E.P.I. scores at the time of the taste experiment but who became available on the occasion of the reaction time/signal detection task (at which time their E.P.I. scores were obtained). All of these extra subjects were informed that they might be asked to take part in a further experiment (i.e. the vigilance task) at a later date.

Of those extra subjects who were available at the time of the vigilance experiment, two 'stable introverts'

and one subject from each of the other three personality quadrants were chosen at random to make up the shortfall and to bring the total number of subjects in each quadrant up to the required eight.

All of the extra subjects were recruited on the basis of the same criteria as the original subjects had been (i.e. all were male, none were on drugs etc.; see pp. 248-60). Furthermore, all took part in the reaction time/signal detection task as well as the vigilance task so that not only were values of the gradient of the reaction time/intensity curve available for them all, but their experimental experience prior to the vigilance task was more comparable to that of the original subjects than it would have been had they only completed the vigilance experiment.

It is true that they did not take part in the taste experiment and their familiarity with the experimenter within an experimental situation, per se, was less than that of the original subjects at the time they participated in the other two tasks (also in two cases the E.P.I. scores were obtained at a somewhat later date than for the original subjects). However, as already stated, most of them were originally contacted at the time of the taste experiment and the experimenter maintained his acquaintance with them from this period onwards, so they knew him reasonably well by the time of the reaction time/signal detection task.

Also, of the three experiments the last two bear the greatest similarity to each other so that if any direct generalisation or 'carry over' regarding the task itself occurred, it is likely that it would have taken place between these two to a much greater extent than between the taste experiment, on the one hand, and the last two experiments, on the other. Such carry over, in any case, is likely to have been considerably reduced by the fairly lengthy period separating the various sets of experiments.

Furthermore, the number of extra subjects that it was necessary to include in the vigilance task was fairly small compared to the total sample size. Moreover it affected all of the personality quadrants and not just one or two (though the 'stable introvert' quadrant had two extra subjects whereas the others only had one); and it is, of course, comparisons between the various quadrants that are the important thing.

It is probable, therefore, that the inclusion of these extra subjects did not exert any major distorting effect on the results. It was considered that any slight bias that did persist was preferable to the much greater bias that would have resulted from an unbalanced design.

ii) Design

The design was in some ways very similar to that of the reaction time/signal detection task except that the extra factor of signal frequency was included.

Each subject completed two sessions separated by exactly one week. Each session was divided into a pre-task period and a task period. During the first part of the pre-task period subjects were presented with auditory stimuli at random intervals, but at an average frequency which was the same as the average frequency of the signals they were to receive in the task period. During the second (and much shorter) part of the pre-task period subjects were given alternate presentations of the signal and the non-signal stimuli which they were to receive during the task period, with prior knowledge of which of the two categories each stimulus belonged to.

The task period - i.e. the vigilance task itself - lasted for forty minutes. It was divided into four ten-minute blocks and in each block 200 stimuli were presented. In the low frequency condition seven of these stimuli were signals; in the high frequency condition twenty-nine of them were signals. These values, therefore, determined what the average intersignal interval was to be for each frequency condition within each time block. The actual intersignal intervals were chosen randomly except that they were arranged symmetrically about the average value. The order of the intervals within each time block was determined randomly and was different for the two experimental sessions to preclude the possibility that subjects might be helped in the second session by memory of the pattern of the signals in the first session.

The only exception to this was the position of the first signal in the first time block which was the same for each session, since Baddeley and Colquhoun (1964) have argued that the position of the first signal in a vigilance task can sometimes be important in determining later vigilance performance, presumably due to the development of some form of expectancy. The objection that this concordance between sessions might have helped some subjects more than others due to differential forgetting between the two sessions does not apply since pilot experiments showed that subjects almost invariably detected the first signal in each session.

Davies and Tune (1970) have reviewed evidence that the temporal structure of the presentation of signals may be an important determinant of vigilance performance, so the pattern of intersignal intervals was the same for all subjects within each frequency condition. These patterns are given in ^Appendix C.

Subjects were not told that the test period was divided into time blocks.

Between the pre-task period and the beginning of the task itself subjects were administered the Spielberger inventory of trait anxiety (which was also used in the taste experiment, see p. 240) and a modified version of Thayer's adjective checklist developed recently by Mackay et al. (1978) - see below.

The subject's deep core body temperature was also measured.

The two inventories were again administered after the end of the vigilance task, at which time the subject's body temperature was remeasured.

One of the two experimental sessions was carried out under 'quiet' conditions (55dB white noise to mask ext^raneous sounds) and the other under 'noise' conditions (90dB white noise).

The factors introversion, neuroticism, time of day and frequency each had two levels and were crossed to produce sixteen cells with two subjects in each cell. One subject in each cell performed under 'quiet' in the first session (Group 1) and the other under 'noise' in the first session (Group 2). Within each personality quadrant, separately, subjects were assigned at random to the frequency and the group conditions unless a particular combination was already full.

The assignment of subjects to the time of day condition was not random. This is because it has been shown in a number of studies (including some within the present project) that the effects of some of the determinants may be different at different times of the day. For this reason, as far as possible, subjects were tested at exactly the same time of day as they were tested during the reaction time/signal detection task. This was to maximise the likelihood that the index of the gradient of the reaction time/intensity curve derived from the latter would show the predicted relationships with the measures derived from the vigilance task.

iii) Materials

The same control and experimental rooms that were employed in the reaction time/signal detection task were used (see p. 543). The shutters were, however, closed over the exposure panel between the two rooms, and the stimuli were produced by a small neon bulb mounted on the wall opposite the subject's chair at eye level.

As before, the subject sat at a table in the experimental room on which a morse key was placed, but there was no tactile warning signal this time. Again, the two rooms were connected by intercom.

The neon bulb flashed on and off at regular intervals with an overall cycle time of three seconds (the same as that employed by Kishimoto (1978)). The signals consisted of flashes of 0.75 seconds duration, whilst the non-signals were of 0.5 seconds duration. The latter value was the same as in Kishimoto's study but the value of 0.75 for the signal is slightly shorter than the 0.8 seconds duration employed by Kishimoto. This is because pilot experiments showed that the 0.75 second duration produced a better spread of performance across individuals and also an average level of detectibility that was more comparable to that in Kishimoto's study.

The latter study was not carried out in darkness, and for this reason, and also because it was intended to administer paper and pencil tests, the present study was also carried out with the light in the experimental room kept on. This provided an ambient illumination of 450 lux which was checked regularly.

The experimenter himself presented the signals (i.e. increased the duration of the neon bulb flash) by pressing a switch on a relay in the control room. This was done at predetermined times measured by a digital clock on the experimenter's table. The overall time sequence was, however, controlled electronically, and reaction times to signals were measured by standard apparatus. For technical reasons it was not possible to measure reaction times to non-signals (i.e. reaction time associated with false alarms).

White noise was produced by playing a standard broad band white noise tape to the subject binaurally over ear-phones.

Measures of subjective state were the Spielberger inventory of state anxiety and a modified version of Thayer's activation checklist (Mackay et al. 1978). This differs from the original checklist in that it substitutes British equivalents for certain American words which the authors considered are too American in operation (e.g. 'clutched up') and which may be unfamiliar to subjects in this country. It yields two scales: subjective 'stress' and subjective 'arousal'. For convenience we will refer to it as the Thayer checklist.

Body temperature was measured using a standard deep core body temperature thermometer placed on a bench beside the subject.

iv) Procedure

When the subject arrived he was seated in the experimental room. If he was wearing a watch this was removed. He was then told:

'Please lift up your shirt on the right hand side.'

The deep core body temperature pad (which had been warmed up prior to the subject's arrival by placing the thermometer on 'standby') was attached using special tape to the subject's trunk on the right hand side. The thermometer was then switched to 'Read' and left to equilibrate with the subject's body.

'Are you right- or left-handed?'

Depending on the subject's reply, the morse key was placed so that it was adjacent to his preferred hand.

'Please put these earphones on. Can you hear me? Forget all previous experiments. Treat this one as something completely new and follow the instructions which I'm going to give you now.'

'A light is going to flash on and off at regular intervals inside that bulb. Every now and then the light will stay on for slightly longer than usual. Such a light is called a signal. As soon as you think that a signal has come on, I want you to press this key down as fast as you can. Please do it once to show me that you understand.'

'Use the forefinger of your right/left hand [the subject's preferred hand] and keep it lightly touching the top of the key throughout in readiness. You must press the key before the next light comes on.'

'I assure you that I have taken every possible precaution to make sure that you cannot predict whether a light is going to be a signal or not before it comes on. In other words, the signals will be occurring at completely random, irregular intervals, so just rely on what the lights look like and don't try to guess beforehand whether it's going to be a signal or not. Also, remember that once a signal has occurred, the next signal could come at any time. Don't think that once a signal has occurred the next one isn't likely for some time. I repeat, don't use guesswork, just rely on what the lights look like.

'So remember, press the key as fast as possible as soon as you think that the light is a signal, in other words as soon as you think it has stayed on for longer than normal.

'Throughout the experiment there will be some noise in your ears which will sound like this.'

The experimenter then entered the control room and played the white noise for five seconds. He then re-entered the experimental room.

'I'll tell you before I'm going to switch it on. If at any time you can't hear it, tell me.

'If you do need to speak to me, for any reason, you just have to talk, the intercom picks it up and I hear you next door. But please, once we start the actual test, don't talk unless it's an emergency.

'Please sit back in your chair throughout, don't lean forwards.

'Before we start the actual test we're going to do two things,

'Firstly, for a short period of time I want you just to sit in this room and not press anything. Every now and then you will hear a buzzer. The purpose of this period is to give you a rough idea of how often the signals will occur during the actual test, later. In other words, how often the buzzer occurs will give you a rough idea of how often the slightly longer-duration lights will occur during the actual test. But please note that it is a guide to the frequency of the signals - i.e. the number of signals per unit time. It is also only a guide to the average number of signals in the test. Both the buzzes and the light signals will be occurring at completely irregular, random intervals.

'Also there will be no buzzes during the actual test. Don't confuse the buzzer with the light signals which are the actual ones you'll have to respond to in the main test. Apart from the fact that their average frequency will be the same, they have got nothing to do with each other. For instance, the duration of the buzzer has got nothing to do with the duration of the light signals. Do you understand?'

Any misunderstandings were corrected. These were rare.

'Once this buzzer period is over, I'm going to show you the signal lights (i.e. the slightly longer lights) and the non-signal lights (i.e. the slightly shorter lights) twenty times each alternately, just to show you the difference between them. Each time I will say either 'signal next' or 'non-signal next' before the light is actually presented.

'I emphasise that this is just to show you the difference between the two types of light. The alternating pattern and the fact that half the lights will be signals and half non-signals is not meant to be a guide to the pattern or the frequency of the signals in the actual test. During this period also just sit, don't press the key. Do you understand?'

The experimenter then left the experimental room and entered the control room. He pressed the intercom switch and said:

'Now just sit and listen. Every now and then a buzzer will occur and the average frequency of the buzzer is meant to be a rough guide to how often the light signals will occur in the actual test later. Both the buzzes and the light signals will occur at completely random, irregular intervals and the pattern of these intervals is not related to each other.'

The experimenter then started the digital clock and pressed a buzzer switch for one second at predetermined intervals for a ten minute period (i.e. the duration of one block in the actual test). The average frequency of the buzzes was the same as the average frequency of the light signals which the subject was to be presented with later. The intersignal intervals were also the same, though the actual pattern of these intervals was determined randomly except for the fact that the temporal position of the first 'buzz' was the same as the temporal position of the first light signal in the actual test, for reasons which were stated earlier (see p. 807). Apart from this, the pattern of the intervals was dif-

ferent for the two sessions, but it was the same for all subjects within a particular frequency condition (see Appendix C). At the end of the ten minute period, the experimenter said:

'That is the end of the buzzer period. Now I'm going to show you the signal and the non-signal lights twenty times each alternately, just to show you the difference between them. Before each light I will tell you which one it is going to be.'

The experimenter then activated the automatic time sequence and presented the signals and non-signals alternately twenty times each, informing the subject each time beforehand which category the stimulus belonged to. Which one was presented first was determined randomly.

'That is the end of that period. Remember that the alternating pattern and the fact that half of the lights were signals is not meant to be any guide to the pattern or the frequency of the signals in the actual test.

'Remember, during the latter, press as fast as you can as soon as you think that a signal has come on, in other words a slightly longer-duration light. Also remember that the signals will be occurring at completely irregular intervals and that the overall frequency is roughly the same as the overall frequency of the buzzes which you had earlier on.

'I'd also like to remind you that this experiment has got nothing whatsoever to do with any of the other experiments you have done for me.

'Please could you describe briefly what is going to

happen and what you are required to do, so that I can be sure you understand.'

Any misunderstandings were then corrected.

The experimenter then entered the experimental room and placed a copy of the Spielberger inventory and the Thayer checklist on the table in front of the subject, along with a pencil.

'Before we start, please could you fill in these questionnaires. They are meant to test how you are feeling right now. I'm going to play you some noise at the same time. Don't start until I've switched it on. Tell me when you have finished.'

The experimenter then left the experimental room and entered the control room, where he switched on the white noise tape set at the same level that the subject was to receive during the actual test. When the subject stated that he had finished, the experimenter re-entered the experimental room. He removed the completed questionnaires and placed a new, uncompleted set face down on the table. He also placed an instruction sheet (see below) face upwards on the table in front of the subject. He then noted the subject's body temperature, left the experimental room and entered the control room. Pressing the intercom switch, he said:

'We're going to start the actual test now. When the test is over the lights will stop flashing. As soon as that happens, I want you to turn over the questionnaires on your table and fill them in to tell me how you are

feeling at that moment in time. Remember to tell me once you've completed the questionnaires.

'As you can see, I've put these instructions on the sheet in front of you as a reminder.'

(The instruction sheet said,

"When the lights stop flashing, turn over the questionnaires and fill them in to tell me how you are feeling at that particular moment in time. Remember to tell me when you have finished.")

The experimenter then said,

'I'm going to turn on the noise and then we'll begin.'

He then switched on the white noise tape and ten seconds later activated the time sequence and the digital clock at the same time.

At predetermined intervals he pressed the switch on the relay to present a signal and recorded whether or not the subject responded before the next light came on and, if so, the response time. Any responses which did not occur between the presentation of a signal and the presentation of the next light were recorded as false alarms.

At the end of the forty minutes (i.e. at the end of the fourth block) the experimenter switched off the digital timer, thus suspending the time sequence, but he did not switch off the white noise until the subject stated that he had completed the questionnaires. He then re-entered the experimental room and gave back the subject's watch. He also recorded the subject's body temperature.

If it was the subject's first session he was reminded of the second session and given a copy of the Eysenck Personality Questionnaire to take away and complete in his own time. He was asked to return it on the occasion of the second session, and all subjects did this.

If it was the subject's second session he was thanked, paid at the rate of \$1.00 per hour, and given a copy of the Spielberger inventory of trait anxiety, the E.P.I. and Strelau's temperament inventory, to complete in his own time and to return to the experimenter in a sealed envelope within a few days. However, not all of the subjects did this so the results from these questionnaires will not be presented.

CHAPTER FOURTEEN:

VIGILANCE

RESULTS AND DISCUSSION

1. E.P.I. ANALYSES

i) State and physiological measures

We will discuss the results of the state and physiological measures before the behavioural measures because, in the present instance, the former may help us to elucidate **the latter**. Also, the order in which the various results are presented and discussed will again be governed by considerations of overall clarity.

a) Results for state and physiological measures

The following results are based on an analysis of variance employing introversion (2 levels), neuroticism (2 levels), time of day (2 levels), frequency (2 levels), accessory stimulation - noise (2 levels), and position (2 levels).

The 'position' factor represents the measurements before and after the vigilance task and is, therefore, roughly equivalent to 'time on task'. The introversion and neuroticism factors are based on the subjects' E.P.I. scores obtained prior to the taste experiment (see p.250).

In these results, and in subsequent results for the vigilance task, the session factor has been excluded because of insufficient degrees of freedom.

The following indices were involved:

i) Thayer's subjective 'arousal' scale.

The values for this were skewed and so a square root transformation was carried out initially. The resulting measure will be referred to as 'TAROUSAL'.

ii) Thayer's subjective 'stress' scale.

The results for this were also skewed and a similar square root transformation was carried out. The resulting measure will be referred to as 'TSTRESS'.

iii) Spielberger's state anxiety scale ('ANX').

iv) Deep core body temperature ('TEMP').

All results were analysed using a standard Genstat computer package.

Because the direction in which 'time on task' moves the subjects along the 'x' axis of the inverted 'U' cannot be predicted in advance, all of the effects involving 'position' will be two tailed ones.

Results for subjective 'arousal' (vigilance task):

Effects involving 'position' factor

a) The main effect for position is significant at the 0.5% level (two tail). Overall, subjects reported a higher degree of 'arousal' before the task than after it.

Before	After
1.617	1.260

Table C1. The main effect for position (TAROUSAL).

b) The interaction of position and frequency is significant at the 5% level (two tail). Before the task, subjects reported a higher degree of 'arousal' at high frequency than at low frequency, whereas the reverse was true after the end of the task. Also, although under both frequency

conditions, the reported level of 'arousal' was higher before the task than after it, the difference is much greater in the high frequency condition than in the low frequency condition.

	Low Frequency	High Frequency
Before	1.489	1.746
After	1.387	1.133

Table C2. The interaction of position and frequency (TAROUSAL).

c) The interaction of noise, position and introversion is significant at the 2.5% level (two tail). See discussion.

	Before		After	
	Introverts	Extraverts	Introverts	Extraverts
No Noise	1.505	1.765	1.120	1.395
Noise	1.704	1.495	0.992	1.532

Table C3. The interaction of noise, position and introversion (TAROUSAL).

Effects not involving position factor

a) The interaction of neuroticism and frequency is significant at the 2.5% level (2 tail). At low frequency, low N subjects report a higher level of 'arousal' than high N subjects, whereas the reverse is true at high frequency. Also, amongst low N subjects, a higher degree of 'arousal' is reported at low frequency than at high frequency, whereas the reverse is true for high N subjects.

	Low Frequency	High Frequency
High N	0.865	1.512
Low N	2.011	1.367

Table C4. The interaction of neuroticism and frequency (TAROUSAL).

b) The interaction of introversion and frequency is significant at the 5% level (2 tail). At low frequency, extraverts report a higher degree of 'arousal' than introverts, whereas the reverse is true at high frequency. Also, amongst introverts, a higher degree of 'arousal' is reported at high frequency than at low frequency, whereas the reverse is true for extraverts.

	Low Frequency	High Frequency
Introverts	1.080	1.581
Extraverts	1.796	1.298

Table C5. The interaction of introversion and frequency (TAROUSAL).

c) The interaction of noise and neuroticism is significant at the 2.5% level (one tail). Amongst low N subjects, a higher degree of 'arousal' was reported under 'noise' than under 'no noise', whereas the reverse was true for high N subjects. Also, although low N subjects reported a higher level of 'arousal' than high N subjects under both noise conditions, the difference was much greater in the noise condition.

	High N	Low N
No Noise	1.413	1.480
Noise	0.964	1.898

Table C6. The interaction of noise and neuroticism (TAROUSAL).

d) The interaction of introversion, neuroticism, time of day and frequency is significant at the 0.1% level (2 tail). See discussion.

		Morning		Afternoon	
		Low Frequency	High Frequency	Low Frequency	High Frequency
Introverts	High N	0.217	2.251	0.643	1.497
	Low N	1.912	0.125	1.547	2.450
Extraverts	High N	1.539	0.677	1.059	1.624
	Low N	1.214	2.084	3.371	0.809

Table C7. The interaction of introversion, neuroticism, time of day and frequency (TAROUSAL).

e) The main effect for neuroticism is significant at the 5% level (2 tail). Overall low N subjects report a higher degree of 'arousal' than high N subjects.

High N	Low N
1.188	1.689

Table C8. The main effect for neuroticism (TAROUSAL).

Results for subjective 'stress' (vigilance task)

Effects involving 'position' factor

a) The main effect of position is significant at the 0.5% level (2 tail). Overall, subjects reported a higher degree of 'stress' after the end of the task than before it.

Before	After
1.647	2.047

Table C9. The main effect for position.

b) The interaction of noise, position and frequency is significant at the 1% level (2 tail). See discussion.

c) The interaction of noise, position and time of day is significant at the 5% level (2 tail). See discussion.

Effects not involving 'position' factor

a) The interaction of neuroticism and frequency is significant at the 1% level (1 tail). At low frequency, high N subjects report a higher level of 'stress' than low N subjects, whereas the reverse is true at high frequency. Also, amongst low N subjects, a greater degree of 'stress' was reported at the high frequency than at the low frequency, whereas the reverse was true for high N subjects.

	Low Frequency	High Frequency
High N	2.324	1.749
Low N	1.180	2.134

Table C10. The interaction of neuroticism and frequency (TSTRESS).

b) The interaction of noise and introversion is significant at the 1% level (one tail). In introverts, a higher degree of 'stress' was reported under 'no noise' than under 'noise', whereas the reverse was true for extraverts. Also, under 'no noise', introverts reported a higher degree of 'stress' than extraverts, whereas the reverse was true under 'noise'.

	Introverts	Extraverts
No Noise	2.095	1.508
Noise	1.873	1.912

Table C11. The interaction of noise and introversion (TSTRESS).

c) The interaction of noise and neuroticism is significant at the 1% level (one tail). Amongst low N subjects, a higher degree of 'stress' was reported under 'noise' than under 'no noise', whereas the reverse was true for high N subjects.

	High N	Low N
No Noise	2.149	1.454
Noise	1.924	1.861

Table C12. The interaction of noise and neuroticism (TSTRESS).

d) The interaction of introversion and neuroticism is significant at the 2.5% level (one tail). Amongst introverts, low N subjects reported a higher degree of 'stress' than high N subjects, whereas the reverse was true amongst extraverts. Also, amongst low N subjects, a higher degree of stress was reported by introverts than by extraverts, whereas the reverse was true of high N subjects.

	High N	Low N
Introverts	1.876	2.091
Extraverts	2.197	1.223

Table C13. The interaction of introversion and neuroticism (TSTRES)

e) The interaction of noise, introversion and frequency is significant at the 5% level (one tail). See discussion.

	Introverts		Extraverts	
	Low Frequency	High Frequency	Low Frequency	High Frequency
No Noise	1.855	2.335	1.491	1.525
Noise	1.944	1.801	1.719	2.106

Table C14. The interaction of noise, introversion and frequency (TSTRESS).

f) The interaction of noise and time of day is significant at the 5% level (two tail).

In the morning, subjects report a higher degree of 'stress' under 'no noise' than under 'noise', whereas the reverse is true in the afternoon. Also, under 'no noise' subjects report a higher degree of 'stress' in the morning than in the afternoon, whereas the reverse is true under 'noise'.

	Morning	Afternoon
No Noise	1.995	1.603
Noise	1.827	1.957

Table C15. The interaction of noise and time of day (DSTRESS).

g) The interaction of noise, neuroticism, time of day and frequency is significant at the 5% level (2 tail). See discussion.

Results for Spielberger's state anxiety measure (vigilance task):
Effects involving the 'position' factor

The main effect for position is significant at the 0.5% level (2 tail). Overall, subjects reported a higher level of 'anxiety' after the end of the task than before the task.

Before	After
37.69	40.95

Table C16. The main effect for position (ANX).

Effects not involving 'position' factor

The interaction of neuroticism and frequency is significant at the 2.5% level (one tail). At low frequency, high N subjects reported a higher level of 'anxiety' than low N subjects, whereas the reverse was true at high frequency. Also, amongst high N subjects, a higher level of 'anxiety' was reported under low frequency than under high frequency, whereas the reverse was true amongst low N subjects.

	Low Frequency	High Frequency
High N	41.88	39.34
Low N	34.44	41.63

Table C17. The interaction of neuroticism and frequency (ANX).

Results for deep core body temperature (vigilance task)

Effects involving 'position' factor

The main effect for position is significant at the 0.1% level (2 tail). Overall, body temperature was higher after the end of the task than before it.

Before	After
35.945	36.366

Table C18: The main effect for position (TEMP).

Effects not involving 'position' factor

The interaction of noise, introversion and time of day is significant at the 0.5% level (2 tail). See discussion.

	Introverts		Extraverts	
	Morning	Afternoon	Morning	Afternoon
No Noise	35.606	35.431	36.369	36.181
Noise	36.106	36.006	36.163	36.351

Table C19. The interaction of noise, introversion and time of day (TEMP).

c) The interaction of noise, introversion, time of day and frequency is significant at the 5% level (2 tail). See discussion.

b) DISCUSSION OF STATE AND PHYSIOLOGICAL MEASURES

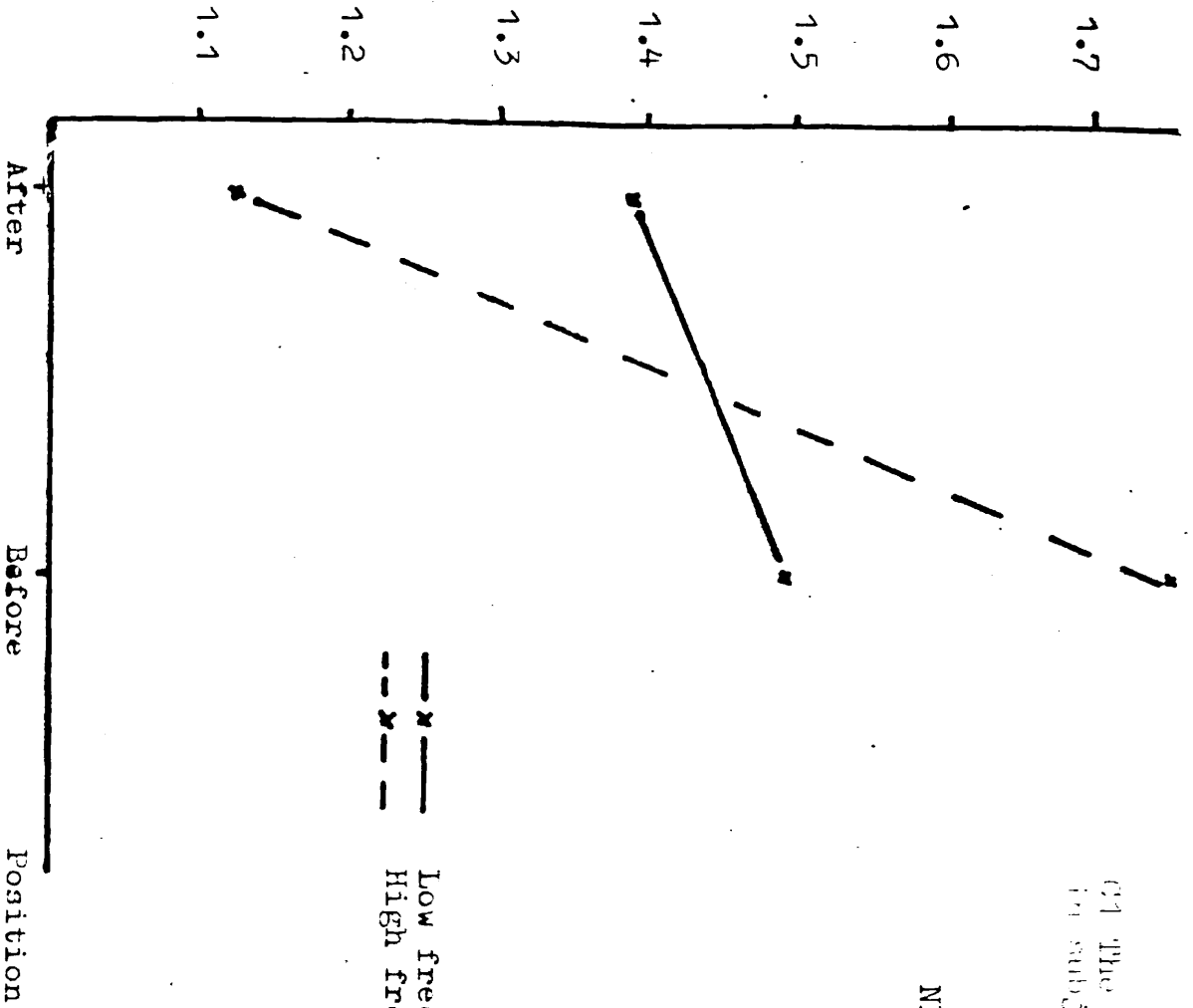
Subjective 'arousal'

The first thing to note is that the main effect for position is highly significant : a higher degree of 'arousal' is reported before the task than after it. This is in line with the general consensus of opinion that when subjects are considered as a whole, at least, the level of 'arousal' decreases during the course of a vigilance task. What is less expected is the nature of the interaction between position and signal frequency. As Graph ⁽¹⁾ shows, before the start of the task, subjective 'arousal' was greater at high frequency than at low frequency. This could be explained by the larger number of auditory stimuli (buzzes) per se that the subject had received during the pre-task period and by the greater level of expectancy generated by this period in subjects in the high frequency/probability condition.

However, by the end of the task, subjective 'arousal' is higher at the low frequency than at the high frequency, indicating that the decline in 'arousal' is greater in the latter than in the former. Furthermore, since the two lines in Graph ⁽¹⁾ actually cross, one cannot explain the greater decline at the high frequency simply in terms of the 'law of initial values' - i.e. by the fact that 'arousal' is higher than at the low frequency before the start of the task. Let us see if we can explain this somewhat surprising result.

In the introduction to the present experiment we argued that an increase in the frequency of a stimulus would

ZAAOUSALI



01 The interaction of position and frequency in subjective 'ZAAOUSALI'.

NB. Because one would expect movement to the right along the 'X' axis of the inverted 'U' to occur only at high levels of the determinants, the 'X' axis has been reversed for the sake of clarity in this graph and in all others in which this axis represents time on task.

have unpredictable effects on the relationship between response indices and 'time on task'. The reason for this is that such an increase would be expected to both promote the summation of the excitations due to successive stimuli and, at the same time, increase the rate at which the novelty of the stimuli decreased (see pp. 728-9). These two factors would tend to work in opposition to each other. We also suggested that the reduction in novelty aspect was likely to be less important where an increase in signal frequency was concerned than where an increase in stimulus frequency was involved.

There were several reasons for this: firstly the signals in a vigilance task are presented at irregular intervals, whereas the background, neutral stimuli (non-signals) are presented at regular intervals. Secondly, the signals are less frequent than the non-signals. Thirdly, the subject is required to respond to the signals, but not to the non-signals. All these factors would tend to result in a slower habituation rate for signals than for non-signals. However, the crucial comparison is between the effect of habituation and the effect of summation of excitation (assuming that the latter occurs). If the effect of the former is greater than the effect of the latter, then time on task will move the subject to the left along the 'X' axis of the inverted 'U', whereas if the latter is greater than the former the reverse will be true.

Because habituation effects are overall likely to be lower in magnitude for signals than for non-signals we suggested that an increase in signal frequency is

more likely to lead to movement to the right than an increase in non-signal or stimulus frequency, and it was for this reason that we chose to manipulate the former rather than the latter. We were supported in this choice by the results of a number of studies which indicated that signal frequency interacted more often with other proposed determinants in a manner that was predictable from the inverted 'U' than did stimulus frequency. Principal amongst these was the study by Kishimoto (1978).

However, in our present study the absolute signal frequencies and the ratios of signal frequency to stimulus frequency are somewhat higher than in Kishimoto's study. Also the subjects in the present study were old hands. This was their third experiment and they may have become somewhat blasé, especially since no performance contingent reward or punishment was administered. It is possible, therefore, that the 'significance' of signals may not have been particularly great for them.

All of these factors may have conspired together to make habituation to signals more important than in other studies such as that of Kishimoto. If so, it is possible that the effect of an increase in signal frequency on habituation rate may have been greater than its effect on the degree of summation of excitation. Consequently, the net effect of this increase may have been to produce a movement to the left along the 'X' axis of the inverted 'U' as time on task increased.

There is an alternative explanation of the findings, however. This would be to assume, firstly, that with time on task subjects are moved to the right along the 'X' axis

of the inverted 'U' rather than to the left, (as we implied when we discussed the main effect for 'position' : see earlier). We would also have to assume that subjective 'arousal', as measured by Thayer's checklist, was a direct index of the 'excitatory process', and that the Russian model was the correct one. If we make these two assumptions we can accommodate the finding as follows:

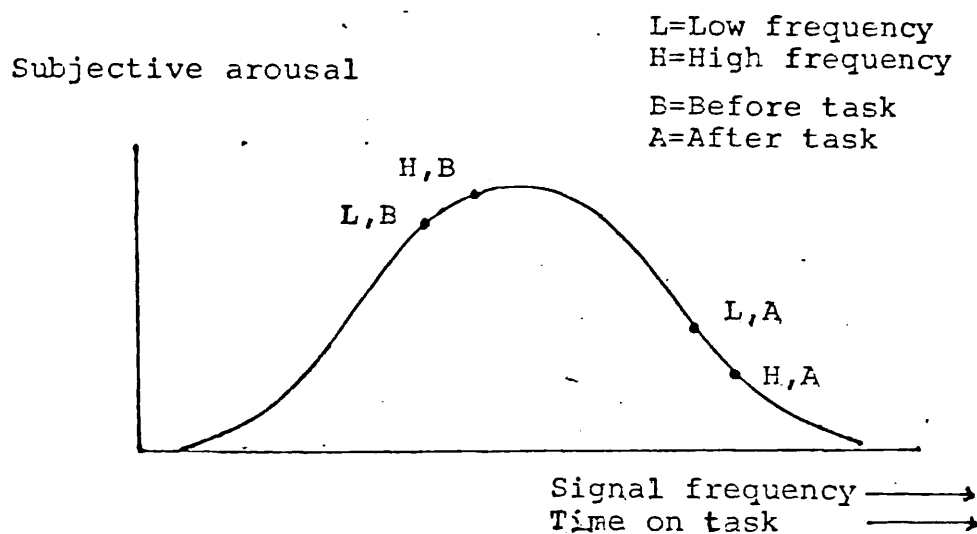


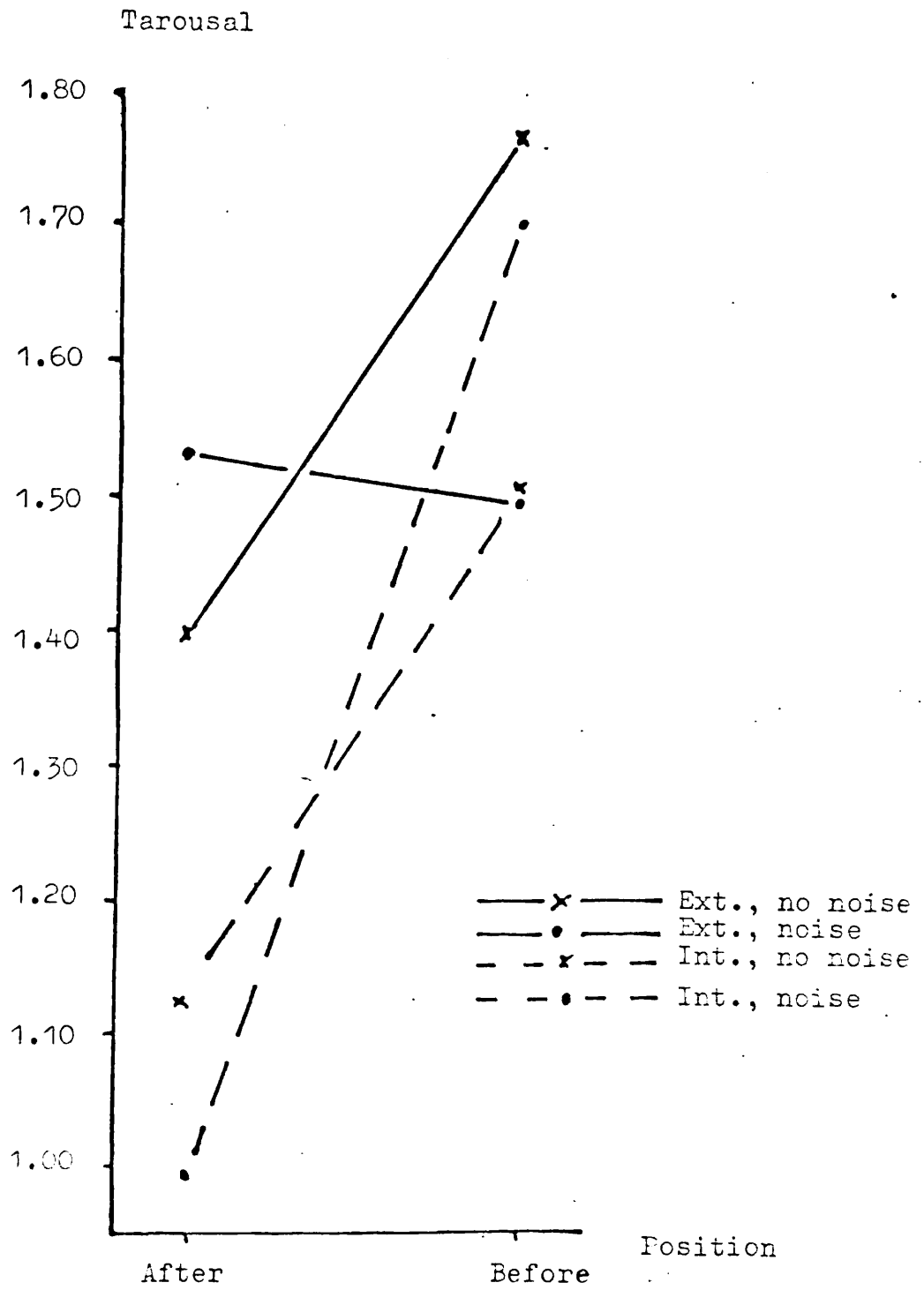
Fig. 52. An alternative explanation for the interaction between frequency and position in the subjective 'arousal' measure.

However, in the absence of independent evidence to support these assumptions, the explanation embodied in Figure 52 above, must remain highly speculative. Furthermore, we will see later that the alternative assumption that habituation rate is greater at the high signal frequency will help us to explain other apparently discrepant findings. The above analysis does, however, illustrate the difficulty of explaining, unambiguously, effects involving time on task even where 'state' measures are employed.

There is one other significant effect for subjective 'arousal' involving time on task which must be considered. This is the interaction between noise, position and introversion, depicted in Graph (2). The graph for the introverts bears some resemblance to the interaction between position and frequency described above (see Graph (1) p. 834), if we substitute the factor of noise for the factor of frequency. However, there is no reason to suppose that a reduction in novelty (due for instance to habituation) should be greater under 'noise' than under 'no noise'.

The relationship for the introverts is somewhat reminiscent of Broadbent's (1971) suggestion that the trend during the course of a vigilance task might be different under 'noise' than under 'no noise', and might correspond to a higher value initially under 'noise', but a lower value at the end (compared to 'no noise'). However, the measure which he was referring to at that time was not subjective 'arousal', but the subjects 'tendency to respond' - i.e. the reciprocal of the criterion (although we have suggested that this may be related to 'arousal').

Furthermore, this would not explain the relationship found in the extraverts. We might be able to explain the findings for introverts by a relationship such as that shown in Figure 52 (again substituting noise for frequency) and the findings for extraverts by assuming that time on task moves these subjects to the right along the 'X' axis under 'noise', but to the left under 'no noise'. This would be consistent with our analysis of time on task effects, but it is again very speculative.



C2 The interaction of noise, position and introversion in subjective 'arousal'

Let us now consider the significant effects for subjective 'arousal' which do not involve position (i.e. time on task). We have two interactions involving signal frequency, both of which are exactly opposite to prediction. The first is between neuroticism and signal frequency. At low frequency, low N subjects report a higher level of 'arousal' than high N subjects, whereas the reverse is true at high frequency. Also, amongst low N subjects, a higher degree of 'arousal' is reported at low frequency than at high frequency, whereas the reverse is true amongst high N subjects.

The second interaction is of an analagous kind between introversion and signal frequency. At low frequency, extraverts report a higher degree of 'arousal' than introverts, whereas the reverse is true at high frequency. Also, amongst introverts, a higher degree of 'arousal' is reported at high frequency than at low frequency, whereas the reverse is true for extraverts.

Both of these interactions are quite opposite to what we would expect if the Russian model were correct and if subjective 'arousal' provided an index of the 'excitatory process'. However, an explanation may become apparent if we consider again what was said about signal frequency earlier. We suggested that we could explain the interaction between signal frequency and position by assuming that the reduction in novelty (due to habituation) with time on task was greater at the high signal frequency than at the low signal frequency, and that both an increase in frequency and time on task move subjects to the left along the 'X' axis of the inverted 'U', in our particular

experiment, at least:

Subjective arousal

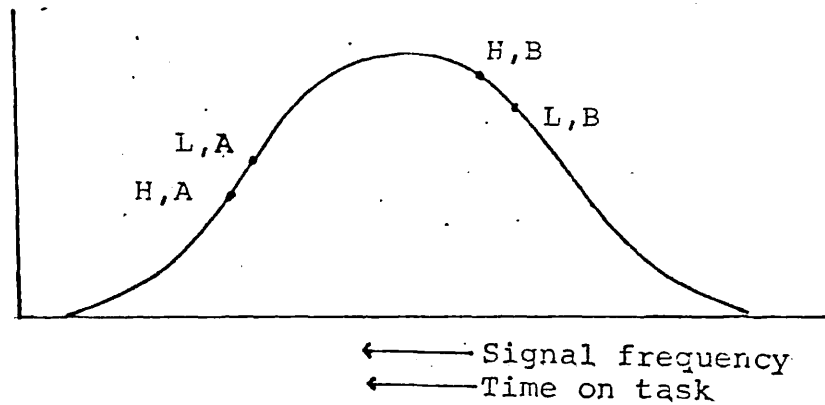


Fig. 53. Hypothesised relationship between signal frequency and time on task for subjective 'arousal'

If this is true and if introversion and neuroticism move subjects to the right, as we would expect, it would explain why the interactions between neuroticism and frequency, and introversion and frequency are in the opposite directions to prediction.

On the other hand, the interaction between noise and neuroticism is in the predicted direction. Amongst low N subjects, a higher degree of 'arousal' was reported under 'noise' than under 'no noise', whereas the reverse was true for high N subjects. Also, although low N subjects reported a higher level of 'arousal' than high N subjects under both noise conditions, the difference is greater in the 'noise' condition. This is in line with our view that neuroticism and noise both move the subjects to the right along the 'X' axis of the inverted 'U'.

The last interaction which we must mention is for introversion, neuroticism, time of day and frequency.

However, this does not conform either to the view that signal frequency moves subjects to the left or to the view that it moves subjects to the right. The author has no explanation for this result and we will, therefore, not discuss it any further.

It should also be noted that the main effect for neuroticism is significant: low N subjects report a higher level of 'arousal' overall than high N subjects. It will be remembered that Carr (1971) found that extraverts have a higher level of 'arousal' (as measured by skin conductance) than introverts in a vigilance task. Since our hypothesis predicts that introversion and neuroticism act in an analogous fashion to each other, the two sets of results could be regarded as similar, since in each case the subjects who are low on the personality dimension in question show a higher level of 'arousal' than those high on the dimension. The fact that in the present study the effect appears for neuroticism rather than introversion is in line with the general pre-eminence of the former in the present project, though, as we have stated before, main effects are of less value to us than interactions.

One final point should be made and that is that despite the transformation (see p. 821), the values for the subjective 'arousal' measure which were used were still slightly skewed. However, Meddis (1973) has pointed out that under these circumstances one can get round the problem by adopting the next most stringent significance level (i.e. 2.5% in this case). If we did this, very few effects we have reported would become suspect. Those that might include the interaction between

introversion and frequency and the interaction between position and frequency. However, the theoretical interpretation of these two results is supported by a number of the other interactions which are significant at the 2.5% level or beyond (e.g. the interaction between neuroticism and frequency). Furthermore, we will see that this interpretation is in line with the results for the behavioral measures. It is, therefore, not unreasonable to suggest that the two interactions represent genuine effects rather than spurious false positives.

The only other effect which is only significant at the 5% level is the main effect for neuroticism. However, as we have argued already, main effects are not very important in the context of the present project.

Subjective stress

We must now discuss the significant effects involving the second of the two scales derived from Thayer's checklist: subjective 'stress'. If we consider firstly interactions involving two factors we find that there are four such interactions which are in line with prediction - i.e. which indicate that the two factors involved move subjects in the same direction along the 'X' axis of an inverted 'U' curve. The interactions are between:

- i) Neuroticism and frequency
- ii) Noise and introversion
- iii) Noise and neuroticism
- and iv) Introversion and neuroticism

We will not describe them all here, since this has been done already in the results section (see pp. 826-8). But we must note certain points of interest. We have stated that the interactions are in line with prediction. By this we mean that they would be expected if we assume that the Russian model is correct, and that subjective 'stress' as measured by Thayer's checklist is an index of the 'excitatory process'. However, on this basis the interaction between neuroticism and frequency is out of line with our earlier suggestion that signal frequency moves subjects to the left along the 'X' axis in our present experiment, whilst neuroticism moves subjects to the right. There is a way out of this difficulty, though. Consider Figures 55 and 55 overleaf:

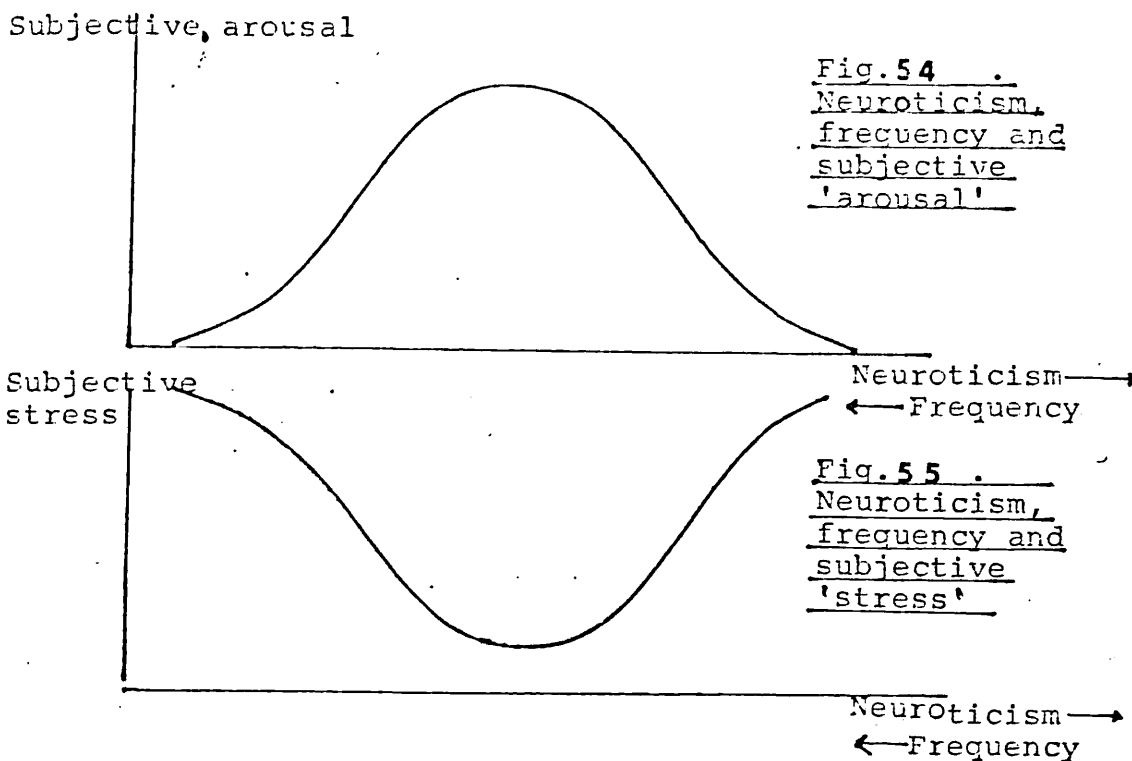


Figure 54 shows our hypothesised relationship between neuroticism and frequency for subjective 'arousal'. Figure 55 shows what would happen if we assumed that a 'U' function were operating rather than an inverted 'U' for the 'stress' measure: we could retain our suggestion that neuroticism and frequency move subjects in opposite directions along a single 'X' axis. Furthermore, the 'U' function depicted in Figure 55 is predictable if we assumed that 'stress' is a direct index not of the 'excitatory process', but an inverse measure of the level of hedonic tone. It will be remembered that we have suggested that an inverted 'U' relationship exists between the levels of the determinants and the level of hedonic tone. If so, and if 'stress' is an inverse measure of the latter, we would predict a 'U' shaped relationship between the determinants and 'stress'. Furthermore, if

signal frequency is acting like a determinant in reverse in the present experiment, the relationships depicted in Figure 55 are in line with the above suggestions.

There are, however, certain problems with this view. The first is that it is out of line with the hypothesis implicit in the theories of workers such as Gray (e.g. 1976) that the level of 'arousal' and the level of 'anxiety' are related in a positive fashion to each other. We will see later that the interaction between neuroticism and frequency for Spielberger's state 'anxiety' measure is similar to that for subjective 'stress'. Furthermore, the correlations between the two measures calculated separately for each noise condition and for each position (i.e. 'before' and 'after' the task) are all positive, high and significant at the 0.5% level (they range from 0.60 to 0.72). On the other hand, the correlations between subjective 'arousal', on the one hand, and subjective 'stress' and state 'anxiety', on the other, are either non-significant or negative (in some cases significantly so. See Appendix C).

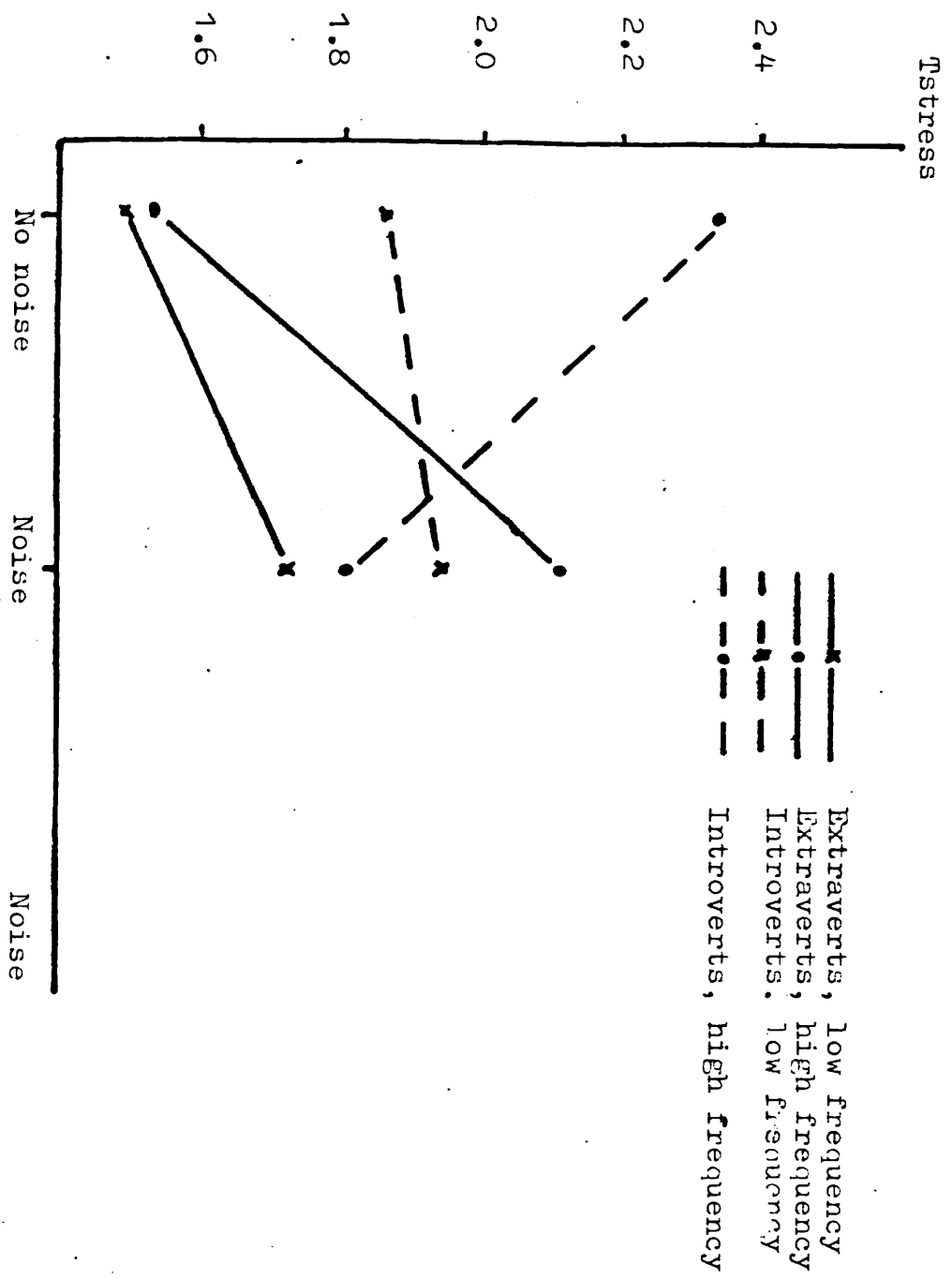
Since Gray's 'behavioural inhibition system' contains an 'arousal' mechanism and is also thought to control anxiety level, one might have expected the latter set of correlations to be positive also. This, of course, assumes that the 'state' measures employed do in fact correspond to the physiological mechanism discussed by Gray. We have been led simply by the names given to the scales by their creators, and this illustrates the problem with the use of such indices.

There is, however, a second problem with the hypothesis depicted in Figure 55. The remaining three interactions for subjective 'stress' are also in line with the view that this scale indexes the 'excitatory process'. Furthermore, since the determinants involved do not include signal frequency, but rather factors which are all thought to move the subject to the right along the 'X' axis, if we assumed that subjective 'stress' was an inverse measure of hedonic tone, we would have to abandon this view and assume that they moved subjects in opposite directions.

The same applies to one of the higher order interactions which is in many ways in line with the hypothesis that there is an inverted 'U' relationship between the determinants and subjective 'stress' - namely that between noise, introversion and frequency (see Graph C3). In this interaction we have an effect which could be interpreted as due to trans-marginal inhibition: i.e. the effect of noise on the 'introvert high frequency group'.

However, it should be noted that since the frequency factor is involved it might be possible to accommodate the finding within a 'U' shaped function in which frequency moved subjects in the opposite direction to the other two proposed determinants (noise and introversion).

C3 The interaction of noise, introversion and frequency in subjective 'stress'.



There is one other effect which we have not mentioned which would support the view that subjective 'stress' may be an inverse measure of hedonic tone. The interaction between noise and time of day (see p. 829) apparently contradicts the view that these two factors move subjects in the same direction along the 'X' axis of an inverted 'U'. We could rescue this hypothesis, though, if we supposed that a 'U' function such as that shown in Figure 55 is operating.

There is one other significant interaction for subjective 'stress' (of those not involving 'position', which we will consider below) - i.e. between noise, neuroticism, time of day and frequency. It does not, however, conform to any of the hypotheses suggested above and the author has no explanation for it.

Let us now look at the effect of time on task on the subjective 'stress' measure. The main effect of position is highly significant and indicates that subjects report a higher level of 'stress' after the task than before it. This is again the opposite of the result for the subjective 'arousal' measure, supporting the view that the two scales may be negatively related to each other.

There are two other significant interactions: between noise, position and frequency and between noise, position and time of day. However, the author has no explanation for these and they will, therefore, not be discussed.

As for the 'arousal' measure, the 'stress' values were still slightly skewed despite the transformation. However, the only results which are significant at the 5% level are the interaction between noise and time of day and the interaction between noise, neuroticism, time of day and frequency. Neither of these are in the predicted direction so even if we assumed that they were false positives this would not alter any of the preceding arguments.

State anxiety

Let us now consider the results for Spielberger's 'state anxiety' measure.

The interaction between neuroticism and frequency is significant and in the predicted direction, if we assume that 'anxiety' is an index of the 'excitatory process'. At low frequency, high N subjects reported a higher level of 'anxiety' than low N subjects, whereas the reverse was true at high frequency. Also, amongst high N subjects, a higher level of 'anxiety' was reported under low frequency than under high frequency, whereas the reverse was true amongst low N subjects.

We have already pointed out the similarity between this interaction and the corresponding interaction for subjective 'stress' (see p.846). Furthermore, we have suggested that this could alternatively be explained by assuming that 'anxiety' and 'stress' are inverse measures of hedonic tone. We pointed out that in the case of 'stress' there were several other interactions which posed problems for this view, but this does not apply to 'anxiety', so the idea would seem to be more tenable for this measure.

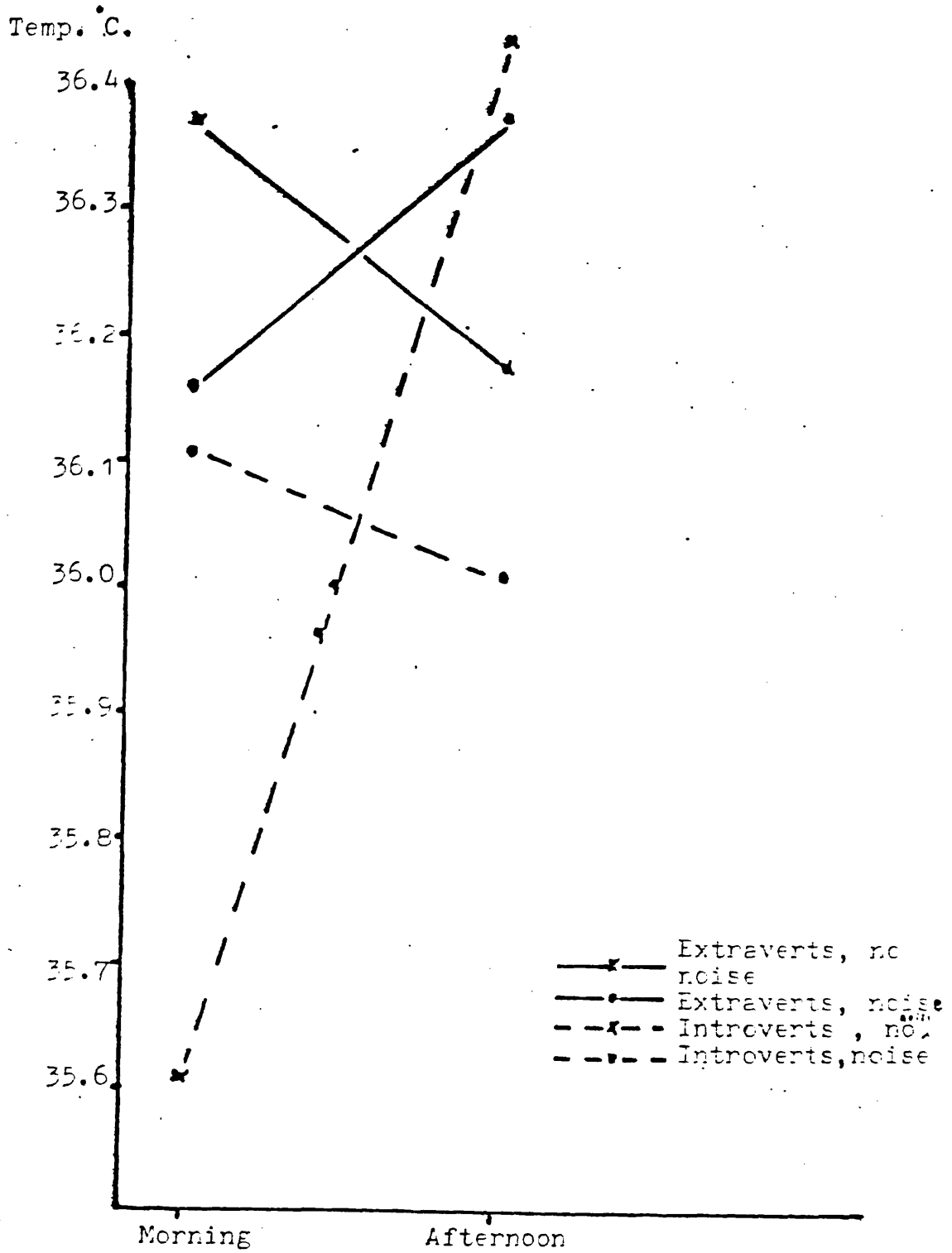
There is, in fact, only one other significant effect involving 'anxiety': the main effect for position which indicates that subjects are more 'anxious' after the end of the task than before it. This is in line with a similar finding for the 'stress' measure.

Deep core body temperature

We must finally discuss the results for the only physiological measure employed in the present task: body temperature.

There are two interactions which are significant but in neither case does the author have an explanation for them. However, because of the theoretical interest surrounding body temperature measures (especially after Blake's (1971) work - see p. 369) and because one of these interactions is highly significant (0.5%), we have depicted it in Graph C4 . The interaction is between noise, introversion and time of day and the graph shows that amongst introverts, body temperature increases between the morning and afternoon under 'no noise', but decreases under 'noise'. This by itself might be predictable if we assumed that body temperature was an index of the 'excitatory process'. However, the exact opposite relationship is found amongst extraverts, and the author has no explanation for this.

The same applies to the interaction between noise, introversion, time of day and frequency. This is significant at ^{the} 5% level, but is not in line with prediction and we will make no attempt to describe or discuss it.



C4 The interaction of noise, introversion and time of day (TEMP)

The failure to confirm Blake's findings, specifically, and the inverted 'U' model, more generally, using deep core temperature is, however, in line with a similar failure in the taste experiment (see pp. 368-371).

One last result should be mentioned, and that is the highly significant effect for position. Overall, body temperature is higher after the end of the task than before it. This is at variance with the finding that subjective 'arousal' is lower after the task than before it, but it is consonant with the previous findings that due to the diurnal rhythm, body temperature rises during the course of the day. If this interpretation is correct it would support the view that the diurnal rhythm may be relevant to changes associated with time on task (see p. 748) even when the time scale being considered is a fairly short one (in this case forty minutes).

ii) BEHAVIOURAL MEASURES

The following results are based on an analysis of variance involving introversion (2 levels), neuroticism (2 levels), time of day (2 levels), frequency (2 levels), **accessory stimulation - noise** (2 levels), block (4 levels).

The introversion and neuroticism factors are based on the subjects' E.P.I. scores obtained prior to the taste experiment.

When discussing the predictions for the signal detection task, we pointed out that if the probability of a hit was equal to 1, the value of the criterion would be infinitely low. Conversely, if the probability of a false alarm was zero the value of the criterion would be infinitely high (see p. 516). However, we mentioned the fact that it is possible to get round this problem if we make an **assumption**. This assumption is that the criterion in fact is never placed exactly at point A or point B in Fig. 44 which is reproduced below.

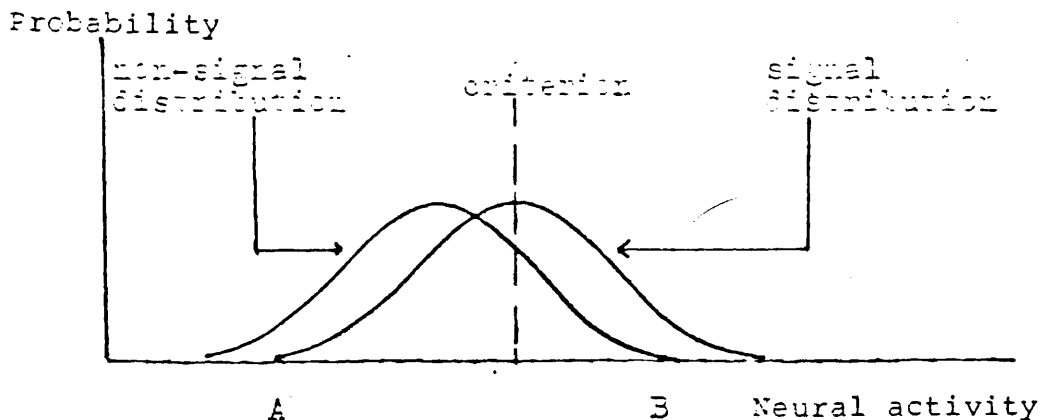


Fig. 44. The postulates of signal detection theory

If it were located at A, the subject would be making an extremely large number of false alarms, whereas if it were at B, the subject would be making an extremely large number of omissions. Both of these (false alarms and omission) are forms of error and the subject was instructed to avoid both kinds. If the subject was acting as an 'ideal' observer - i.e. one who tries to optimise his performance - then one would not expect him to place his criterion at such extreme points. Furthermore, the concept of an ideal observer is central to signal detection theory, which is one of the two main pillars on which the present hypotheses are based, the other being the inverted 'U'.

If this is true, though, the following question arises: why does the probability of a hit ever equal 1, and why does the probability of a false alarm ever equal zero? The answer is that since the distributions in Fig. 44 are probability distributions one can only hope to obtain an approximate idea of their positions relative to each other and to the actual criterion by experimental means. Furthermore, Grice (1968) has pointed out that the criterion itself may fluctuate around a mean value - i.e. may have an associated probability distribution. Under these conditions, if the criterion lies close to, but not actually coincident with, points A or B, one may obtain a value of unity for the probability of a hit or a value of zero for the probability of a false alarm simply due to chance. This is particularly plausible where the number of trials employed is relatively limited (as they inevitably were in the present task).

Valentine (personal communication) has suggested that one can correct for this on the basis of the following argument which is originally derived from a theoretical paper by Cohen (1967):

If 'K' out of N trials produce an event E, the best estimate of the probability of E is that it falls in the interval $(K - 1/2)/N$ to $(K + 1/2)/N$, the mean of which is equal to K/N . When $K = 0$ the best estimate is that E falls between $0/N$ and $(0 + 1/2)/N$ the mean of which is equal to $1/4 N$.

Valentine therefore suggests that where the probability of a false alarm empirically is found to be zero, the true probability (based on the above assumptions) is equal to $\frac{1}{4N}$ where N is the number of non-signal trials. By a similar argument, he suggests that where the probability of a hit empirically is found to be equal to 1, the true probability is equal to: $1 - \frac{1}{4N}$, where N is equal to the number of signal trials.

This correction procedure has been used by other workers, e.g. Wilding (personal communication), and was adopted by the present author on the basis of a joint recommendation from Wilding and Valentine.

What it means operationally is that where the probability of a hit was equal to one, in any one block of the vigilance task, a value of $\frac{1}{4N}$ was subtracted from 1, where N is equal to the number of signals presented in that block (7 at low frequency and 29 at high frequency).

If the probability of a false alarm was equal to zero in any one block, a value of $\frac{1}{4N}$ was substituted, where N is equal to the number of non-signals presented in that block (193 at low frequency, 171 at high frequency).

Otherwise the probability of a hit and the probability of a false alarm were calculated in the normal way (separately for each block within each noise condition):

probability of a hit = $\frac{\text{Total number of responses made to signals}}{\text{Total number of signals per block}}$

probability of a false alarm = $\frac{\text{Total number of responses made to non-signals}}{\text{Total number of non-signals per block}}$

These probabilities were then used to calculate the signal detection indices as described previously (see pp. 555-8). As before, where the probability of a false alarm exceeded the probability of a hit, these probabilities were 'swapped' before substitution in the formula for the criterion (see p.555) and the non-parametric discrimination index.

It should also be pointed out that where a subject failed to respond to any of the signals in a given block, the entry for that block in the computer program for the reaction time to signals was recorded as a 'missing value'. The Genstat program incorporates a facility which estimates what the missing value would have been had the subject responded, on the basis of the blocks for which data are available.

All of the resulting indices were skewed and so the following transformations were carried out, based on recommendations by Valentine (personal communication) and McNicol (1973):

- 1) Transformed non-parametric criterion measure (TBE)

$$= 2 \times \text{ARCSIN} \sqrt{\frac{\text{Untransformed value (BE)} + 1}{2}}$$
- 2) Transformed non-parametric discrimination index (TDY)

$$= 2 \times \text{ARCSIN} \sqrt{\text{Untransformed value (DY)}}$$
- Transformed parametric discrimination index (SPR)

$$= \sqrt{\text{Untransformed value (PR)} + .482}$$

The figure of 0.482 was added to the untransformed value of the parametric discrimination index since this had the effect of rendering all the values positive (three values out of a total of 256 were negative to start off with). This was necessary if the transformation was to be carried out.

- 3) Transformed probability of a hit (IPH)

$$= 2 \times \text{ARCSIN} \sqrt{\text{Untransformed value (PH)}}$$
- 4) Transformed probability of a false alarm (IPF)

$$= 2 \times \text{ARCSIN} \sqrt{\text{Untransformed value (PF)}}$$
- 5) Transformed reaction time to signals (LSIG)

$$= \text{Log}_{10} (\text{untransformed value (SIG)})$$

For convenience, the results for the overall level of performance, i.e. excluding the 'block' or 'time on task' factor, will be presented first.

a) Results for behavioural measures relating to overall performance (i.e. excluding the 'block' factor).

Results for the non-parametric criterion (vigilance task)

The reader is reminded that the criterion is an inverse measure of the tendency to respond.

a) The interaction of neuroticism and frequency is significant at the 5% level (2 tail). At low frequency, low N subjects respond more readily than high N subjects, whereas the reverse was true at high frequency. Also, low N subjects respond more readily at low than at high frequency, whereas the reverse is true for high N subjects.

	Low Frequency	High Frequency
High N	2.617	2.541
Low N	2.372	2.742

Table C20. The interaction of neuroticism and frequency (TBE).

b) The interaction of neuroticism and time of day is significant at the 2.5% level (one tail). In the morning, high N subjects responded more readily than low N subjects, whereas the reverse was true in the afternoon. Also, low N subjects responded more readily in the afternoon than in the morning, whereas the reverse was true for high N subjects.

	Morning	Afternoon
High N	2.492	2.666
Low N	2.693	2.421

Table C21. The interaction of neuroticism and time of day (TBE).

c) The interaction of introversion, neuroticism and frequency is significant at the 0.5% level (2 tail). See discussion.

	High N		Low N	
	Low Frequency	High Frequency	Low Frequency	High Frequency
Introverts	2.873	2.292	2.141	2.656
Extroverts	2.362	2.790	2.603	2.798

Table C22. The interaction of introversion, neuroticism and frequency (TBB).

d) The interaction of introversion, time of day and frequency is significant at the 2.5% level (2 tail). See discussion.

Results for the non-parametric discrimination index
(vigilance task):

- a) The interaction of neuroticism and frequency is significant at the 5% level (2 tail). At low frequency, low N subjects discriminated better than high N subjects, whereas the reverse was true at high frequency. Also, low N subjects discriminated better at low frequency than at high frequency, whereas the reverse was true for high N subjects.

	Low Frequency	High Frequency
High N	2.3257	2.5033
Low N	2.5393	2.5003

Table C23. The interaction of neuroticism and frequency (TDY).

- b) The main effect for neuroticism is significant at the 5% level (2 tail). Overall low N subjects discriminated better than high N subjects.

High N	Low N
2.4145	2.5201

C24. The main effect for neuroticism (TDY).

- c) The interaction of neuroticism, time of day and frequency is significant at the 0.5% level (2 tail). See discussion.

- d) The interaction of introversion, neuroticism and time of day is significant at the 2.5% level (2 tail). See discussion.

Results for the parametric discrimination index:
(vigilance task).

a) The interaction of introversion and frequency is significant at the 2.5% level (one tail). Introverts discriminated better at low frequency than at high frequency, whereas the reverse was true for extraverts. Also, at low frequency, introverts discriminated better than extraverts, whereas the reverse was true at high frequency.

	Low Frequency	High Frequency
Introverts	1.7475	1.7178
Extraverts	1.6427	1.8741

Table C25. The interaction between introversion and frequency (SPR).

b) The interaction of introversion and neuroticism is significant at the 5% level (2 tail). Amongst introverts, high N subjects discriminated better than low N subjects, whereas the reverse was true amongst extraverts. Also, amongst low N subjects, extraverts discriminated better than introverts, whereas the reverse was true amongst high N subjects.

	High N	Low N
Introverts	1.7500	1.7153
Extraverts	1.6389	1.8779

Table C16. The interaction of introversion and neuroticism (SPR).

c) The interaction of neuroticism, time of day and frequency is significant at the 0.5% level (2 tail).
See discussion.

d) The interaction of introversion, neuroticism and time of day is significant at the 5% level (2 tail).
See discussion.

Results for the probability of a hit (vigilance task)

a) The interaction of neuroticism and frequency is significant at the 2.5% level (2 tail). Under low frequency, low N subjects were more likely to detect signals than high N subjects, whereas the reverse was true under high frequency. Also, high N subjects detected a larger proportion of signals under high frequency than under low frequency, whereas the reverse was true for low N subjects.

	Low Frequency	High Frequency
High N	1.539	1.873
Low N	2.034	1.783

Table C17. The interaction of neuroticism and frequency (TPH).

b) The main effect for noise is significant at the 0.5% level (2 tail). Overall, subjects detected more signals under 'noise' than under 'no noise'.

No Noise	Noise
1.665	1.950

Table C18. The main effect for noise (TPH).

c) The interaction of introversion, neuroticism and time of day is significant at the 1% level (2 tail). See discussion.

d) The interaction of neuroticism, time of day and frequency is significant at the 2.5% level (2 tail). See discussion.

Results for the probability of a false alarm (vigilance task)

a) The interaction of neuroticism and time of day is significant at the 2.5% level (one tail). In the morning, high N subjects recorded more false alarms than low N subjects, but the reverse was true in the afternoon. Also, high N subjects recorded more false alarms in the morning than in the afternoon, whereas the reverse was true for low N subjects.

	Morning	Afternoon
High N	0.3413	0.2123
Low N	0.1764	0.3330

Table C31. The interaction of neuroticism and time of day (TFP).

b) The interaction of introversion, neuroticism and frequency is significant at the 1% level (2 tail). See discussion.

	High N		Low N	
	Low Frequency	High Frequency	Low Frequency	High Frequency
Introverts	0.1163	0.3830	0.4680	0.1905
Extraverts	0.4530	0.1577	0.2282	0.1319

Table C30. The interaction of introversion, neuroticism and frequency (TPF).

c) The interaction of introversion, time of day and frequency is significant at the 5% level (2 tail). See discussion.

d) The interaction of neuroticism, time of day and frequency is significant at the 5% level (2 tail). See discussion.

Results for speed of response to signals (vigilance task) relating to overall performance level:

a) The interaction of neuroticism and time of day is significant at the 2.5% level (one tail). In the morning high N subjects were faster than low N subjects whereas the reverse was true in the afternoon. Also, amongst high N subjects, speed of response was faster in the morning than in the afternoon whereas the reverse was true amongst low N subjects.

	Morning	Afternoon
High N	0.0638	0.0659
Low N	0.0701	-0.0182

Table C31. The interaction of neuroticism and time of day (LSIG).

b) The interaction of noise and introversion is significant at the 2.5% level (one tail).

Amongst extraverts, speed of response is greater under 'noise' than under 'no noise' whereas the reverse is true amongst introverts.

	Introverts	Extraverts
No Noise	0.0581	0.0417
Noise	0.0629	0.0189

Table C32. The interaction of noise and introversion (LSIG).

c) The main effect for frequency is significant at the 2.5% level (two tail). Overall speed of response is faster at high frequency than at low frequency.

low frequency	high frequency
0.0714	0.0193

Table C33. The main effect for frequency (LSTG).

d) The main effect for time of day is significant at the 5% level (two tail). Overall speed of response is faster in the afternoon than in the morning.

Morning	Afternoon
0.0669	0.0239

Table C34. The main effect for time of day (LSTG).

e) The interaction of noise, neuroticism and frequency is significant at the 1% level (two tail). See discussion.

b) Discussion of Behavioural Measures (overall performance)

In this section we propose, initially at least, to depart from our general policy of discussing each index separately since in this particular case we will see that a more coherent account can be provided by considering them together.

The most striking group of results relate to the factor of signal frequency and its interactions with the other proposed determinants, particularly neuroticism. If we look at the behavioural measures we find three cases in which the interaction of neuroticism and signal frequency is opposite to that predicted. The first of these corresponds to the non-parametric discrimination index (TDY). At low frequency, low N. subjects discriminate better than high N subjects, whereas the reverse is true at high frequency. Also, low N subjects discriminate better at low frequency than at high frequency, whereas the reverse is true for high N subjects. If we look at the parametric index of discrimination ability (SPR), however, we find that there is no such interaction between neuroticism and frequency. It will be remembered that the non-parametric index may sometimes fail to give an accurate representation of the difference in discriminability between two or more conditions if these also differ markedly on the criterion measure (McNicol 1973). Since there is also an interaction between neuroticism and frequency for this measure, it is possible that the corresponding

interaction for the non-parametric measure of sensitivity may have been an artefact.

The interaction between neuroticism and frequency for the criterion is, however, not subject to such strictures and is again opposite to that predicted. At low frequency, low N subjects respond more readily than high N subjects, whereas the reverse is true at high frequency. Also, low N subjects respond more readily at low than at high frequency, whereas the reverse is true for high N subjects. The corresponding interaction for the 'probability of a hit' measure is also significant and in the same direction. At low frequency, low N subjects were more likely to detect signals than high N subjects, whereas the reverse is true at high frequency. Also, high N subjects detected a larger proportion of signals under high frequency than under low frequency, whereas the reverse is true for low N subjects.

In the absence of an unequivocal interaction between neuroticism and frequency for the discrimination index, it is likely that the above interaction is related to the conjoint effect of neuroticism and frequency on the measured criterion which was described earlier, so we will consider the implications of this joint effect in terms of the criterion measure.

It should be clear that the interaction of neuroticism and frequency for the criterion measure is in line with the suggestion we made when discussing the state measures, that in the present study signal frequency moves subjects to the left along the 'X' axis of the inverted 'U'.

If we look at the other interactions involving signal frequency amongst the behavioural measures, we get a somewhat different picture. There are two such interactions, and both refer to the same measure - the discrimination index. The interaction between introversion and frequency for the parametric measure of the latter is significant at the 2.5% level. At low frequency, introverts discriminated better than extroverts, whereas the reverse is true at high frequency. Also, introverts discriminated better at low than at high frequency, whereas the reverse is true for extroverts. This would suggest that both introversion and signal frequency are moving subjects in the same direction (which we will call to the 'right' for convenience).

We saw that the interactions between neuroticism and frequency for the criterion and subjective 'arousal' measures corresponded very closely. However, we now have the situation that the interactions between introversion and frequency for the discrimination and subjective 'arousal' measures are contradictory. The latter suggests that the two factors (introversion and frequency) move subjects in the opposite direction, whilst the latter suggests that the two factors move subjects in the same direction.

One possible reason for the discrepancy is that in the case of the introversion dimension, it is the discrimination index that is involved. We have argued

already that the stimulus duration factor is 'concealed' within this measure, since the signals and the non-signals differed only in terms of duration. In discussing the results of the signal detection task in which the signals and non-signals were distinguished by their intensity, we came to the conclusion that stimulus intensity was special and that the assumption that it could be included with the other determinants along the 'X' axis of the same inverted 'U' curve was invalid. It is possible that stimulus duration is also special, and this is supported by the fact that it is thought to act in analogous fashion to stimulus intensity within the Russian model, and we have already mentioned the fact that this has been confirmed experimentally in the West (e.g. Sanford, 1972). It is not, therefore, surprising that a measure which is based upon stimulus duration (such as the discrimination index in the present experiment) should yield different results to other measures.

The idea that stimulus duration may be special receives support from the fact that although transmarginal inhibition is evident in the criterion and probability of a hit measures, as evidenced by the interaction between neuroticism and frequency, the group which appears to have passed its T.T.I. (the high N group at low frequency) shows no sign that they were more likely to respond to non-signals than to signals. In other words, their average discrimination index indicated that they still perceived the signals as being longer than the non-signals. If stimulus duration could be represented along the same 'X' axis as the other determinants (such as neuroticism and frequency), one would

have predicted that beyond the T.T.I. the level of the 'excitatory process' would be lower for a long duration stimulus. It will be remembered that a similar argument led to the conclusion that stimulus intensity was special in our discussion of the signal detection task.

Another piece of evidence in support of this view is the fact that there is a significant interaction for the parametric discrimination index between introversion and neuroticism which is also out of line with prediction. Amongst introverts, high N subjects discriminated better than low N subjects, whereas the reverse is true amongst extroverts. Also, amongst low N subjects, extroverts discriminated better than introverts, whereas the reverse is true amongst high N subjects. This would suggest that introversion and neuroticism move subjects in opposite directions along the 'X' axis of the inverted 'U'. Such a relationship is not only in conflict with the theories of personality presented by Gray, Eysenck and others, but it is also in direct contrast to the interaction between introversion and neuroticism obtained in our simple auditory reaction time task. It will be remembered that this provided powerful evidence in favour of the view that introversion and neuroticism move subjects in the same direction (see p. 498). In view of this fact, the present finding for the discrimination index provides indirect support for the view that the interaction in the reaction time task was due to criterial rather than to sensory factors.

Let us now consider the results for the probability of a false alarm.

There is an interaction between neuroticism and time of day for the false alarm measure. In the morning, high N subjects record more false alarms than low N subjects, but the reverse is true in the afternoon. Also, high N subjects record more false alarms in the morning than in the afternoon, whereas the reverse is true for low N subjects. This interaction is significant at the 2.5% level and indicates that neuroticism and time of day move subjects in the same direction along the 'X' axis of an inverted 'U'.

It might seem then that our suggestion in the discussion of the signal detection task that there is a 'U' shaped relationship between the false alarm rate and the determinants is invalid. Moreover, in that discussion we argued that such a 'U' relationship indicated that stimulus intensity was special. By analogy, if we had found such a 'U' relationship in the present task it would have supported our suggestion that stimulus duration is special (see pp. 875-7). It might seem, therefore, that the absence of such a relationship runs counter to this suggestion.

However, there is one crucial difference between the present set of results and those of the signal detection task. In the latter, the 'U' relationship for the false alarm rate was consistent with the view that stimulus intensity was special because the corresponding interaction (between noise and introversion) for the discrimination index indicated that the true T.T.I. had not been passed, so no interaction between noise and introversion for the

false alarm measure was expected. The fact that one did exist produced a contradiction within our general model, and the fact that it was of a 'U' form suggested that the false alarm rate was an inverse measure of 'performance'. There was, moreover, no corresponding interaction for the criterion measure.

In the present study, however, there is no interaction between neuroticism and time of day for the discrimination index. Furthermore, the interaction for the false alarm measure has a corresponding interaction for the criterion measure. The interaction between neuroticism and time of day is related to the fact that in the morning high N subjects respond more readily than low N subjects, whereas the reverse is true in the afternoon. Also, low N subjects respond more readily in the afternoon than in the morning, whereas the reverse is true for high N subjects. This interaction, like the corresponding interaction for the false alarm measure, is significant at the 2.5% level.

We see that the joint effect of these two factors for the false alarm measure is completely explicable in terms of the subject's criterion. Since the latter, unlike the discrimination index, does not contain the factor of stimulus duration concealed within it, this interaction has no bearing on the question of whether or not stimulus

duration is special. It, therefore, in no way contradicts the other evidence from this study which supports this view (see p. 876).

We must also consider the fact that the interaction suggests that an inverted 'U' relationship exists between the determinants and the false alarm rate. It would appear that evidence for such a relationship emerges when it is the criterion that is involved. In contrast, in the signal detection task the interaction between introversion and neuroticism did indicate that there was a 'U' shaped relationship between the determinants and the false alarm rate, but this was related to a corresponding interaction for the discrimination index.

The fact that the false alarm rate (like the hit rate measure) is dependent jointly on criterial and sensory factors, is a cardinal tenet of signal detection theory, and it is the main reason why studies which do not employ signal detection indices are inadequate. Furthermore, the fact that the false alarm rate may be more closely tied to sensory factors in one study, but to criterial factors in another, should also come as no surprise, since vigilance tasks and signal detection tasks do differ in many ways. Moreover, the factors that were involved were quite different (neuroticism and time of day in one case, and noise and introversion in the other).

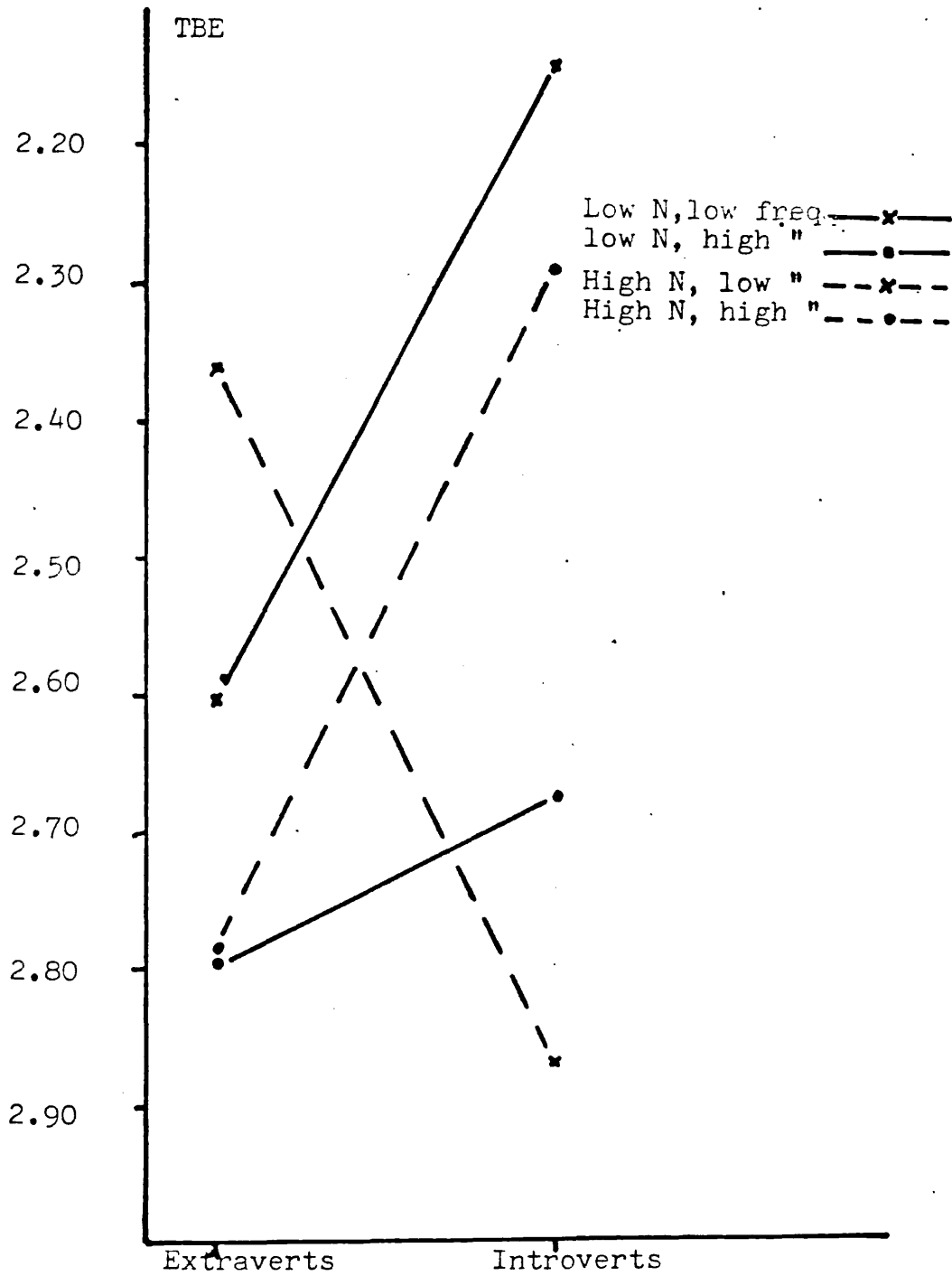
We will now address ourselves to the remaining significant results relating to overall measures of performance. For this we will revert to our previous policy of discussing each index separately.

Let us consider first the results for the criterion measure.

The interaction between introversion, neuroticism and frequency is highly significant (0.5% level), and is depicted in Graph C7. If we look at the results for the two signal frequencies separately, we see that the interaction is very much in line with what we would expect on the basis of what has already been said. At high frequency, introverts have a higher tendency to respond than extroverts amongst both low and high N subjects. On the other hand, at low frequency we would expect subjects to be operating further to the right along the 'X' axis if an increase in signal frequency moves subjects to the left. In line with this, we find that although introverts have a higher tendency to respond than extroverts amongst low N subjects, the reverse is true amongst high N subjects and we could attribute this latter effect to transmarginal inhibition.

It might seem that there are other features of the results which the inverted 'U' is less successful in explaining: for example, the fact that 'stable' and 'neurotic' extraverts have almost identical tendencies to respond at high frequency, but the difference between these and the corresponding introvert groups at high frequency is far greater amongst high N subjects than amongst low N subjects. However, this would be explicable

C5 The interaction of introversion, neuroticism and frequency in the non-parametric criterion.



NB. Because the criterion is an inverse measure of the tendency to respond the 'Y' axis has been reversed.

if we assumed that the extravert groups were both operating on the extreme left-hand portion of the inverted 'U' (portion A. See p. 83), which is relatively flat and which, therefore, might yield little difference between two groups placed on different parts of it.

The interaction of introversion, time of day and frequency is significant at the 2.5% level (2 tail). This is not in line with prediction, nor has the author any explanation for it, so it will not be discussed further.

The main effect for neuroticism is significant at the 5% level. Overall low N subjects discriminate better than high N subjects.

There are also two interactions involving three factors each, which are significant for both the parametric and the non-parametric index. The first is between neuroticism, time of day and frequency, and the second is between introversion, neuroticism and time of day. In neither case are the results in line with prediction, nor has the author any explanation for them. They will, therefore, not be discussed any further.

When we come to the probability of a hit measure, we find that the main effect for noise is significant at the 0.5% level. Overall, subjects detected more signals under 'noise' than under 'no noise'. From a theoretical point of view this does not tell us a great deal, since main effects are not very informative. However, it is possible that it may have practical implications, since it shows that under certain conditions at least, performance may be improved rather than worsened by high levels of ambient noise.

There are two other significant effects and in both cases these are inexplicable and correspond to the equally baffling interactions for the discrimination measures: introversion x neuroticism x time of day and neuroticism x time of day x frequency.

We must also consider the probability of a false alarm. The interaction of introversion, neuroticism and frequency is significant at the 5% level. It is virtually identical to the corresponding interaction for the 'tendency to respond' (see the discussion of the criterion measure). It is likely, therefore, that the two interactions have the same underlying basis, and we suggested that this conformed fairly closely to the inverted 'U' on the assumption that an increase in signal frequency moves subjects to the left along the 'X' axis.

There is also an interaction between introversion, time of day and frequency, and this is also very similar to the corresponding interaction for the tendency to respond though in this case the author has no explanation for either result.

Finally, there is an interaction between neuroticism, time of day and frequency. Here again the underlying mechanisms are unclear and we will, therefore, not discuss it further.

Let us now consider the results relating to overall level of performance in the speed of response to signals.

The interaction of neuroticism and time of day is significant at the 2.5% level. In the morning, high N subjects were faster than low N subjects, whereas the reverse was true in the afternoon. Also, amongst high N subjects speed of response was faster in the morning than in the afternoon, whereas the reverse was true amongst low N subjects. This is both in line with prediction and consonant with corresponding interactions for the 'tendency to respond' and 'probability of a false alarm' measures.

The interaction of noise and introversion is significant at the 2.5% level, also. Amongst extraverts, speed of response is greater under 'noise' than under 'no noise', whereas the reverse is true amongst introverts. This too is in line with prediction, though in this case there is no corresponding interaction for any of the other behavioural measures.

There are two main effects which are significant: overall speed of response is faster at high frequency than at low frequency. Also speed of response is faster in the afternoon than in the morning.

Finally, the interaction between noise, neuroticism and frequency is significant. However, this is not in line with the view that frequency moves subjects to the left, or with the view that it moves subjects to the right, and the author has no explanation for this particular result.

c) Results for behavioural measures from vigilance task involving time on task:

The non-parametric criterion.

a) The main effect for block is significant at the 0.1% level (two tail) and the associated linear and quadratic components are significant at the 0.1% and 1% levels (two tail), respectively. See discussion.

Block	1	2	3	4
TBE	2.378	2.601	2.617	2.676

Table C35. The main effect for block (TBE).

b) The linear component associated with the interaction between noise and block is significant at the 5% level (two tail). See discussion.

Block	1	2	3	4
No Noise	2.493	2.648	2.655	2.680
Noise	2.263	2.555	2.580	2.672

Table C36. The interaction between noise and block (TBE).

c) The interaction between block, introversion, neuroticism and time of day and its linear component are both significant at the 0.5% level (two tail). See discussion.

		High N		Low N		
		Block	Morning	Afternoon	Morning	Afternoon
Introverts	1		2.218	2.485	2.624	1.761
	2		2.556	2.698	2.633	2.317
	3		2.493	2.743	2.717	2.269
	4		2.680	2.784	2.609	2.379
Extraverts	1		2.409	2.368	2.582	2.576
	2		2.479	2.714	2.711	2.702
	3		2.472	2.735	2.787	2.721
	4		2.625	2.805	2.879	2.645

Table C37. The interaction between block, introversion, neuroticism and time of day (TBE).

d) The interaction between block, introversion, neuroticism and frequency is significant at the 5% level (two tail) and the linear component is significant at the 1% level (two tail). See discussion.

		High N		Low N	
Block		low frequency	high frequency	low frequency	high frequency
Introverts	1	2.810	1.893	1.871	2.513
	2	2.879	2.375	2.229	2.720
	3	2.890	2.345	2.246	2.741
	4	2.911	2.559	2.220	2.768
Extraverts	1	2.155	2.622	2.496	2.662
	2	2.325	2.869	2.626	2.786
	3	2.382	2.825	2.679	2.829
	4	2.585	2.846	2.608	2.916

Table C38. The interaction between block, introversion, neuroticism and frequency (TBE).

The non-parametric discrimination index.

a) The main effect for block is significant at the 0.1% level (two tail) and the linear and quadratic components are significant at the 0.1% and 5% levels (two tail), respectively. See discussion.

Block	1	2	3	4
TDY	2.5991	2.4512	2.4272	2.3915

Table C39. The main effect for block (TDY).

b) The linear component associated with the interaction between noise and block is significant at the 2.5% level (two tail). See discussion.

Block	1	2	3	4
No Noise	2.5711	2.3953	2.3819	2.3123
Noise	2.6271	2.5072	2.4725	2.4708

Table C40. The interaction of noise and block (TDY).

c) The interaction between noise, block and neuroticism is significant at the 2.5% level (two tail) and the linear component is significant at the 0.5% level (two tail). See discussion.

Block		1	2	3	4
High N	No noise	2.5202	2.3184	2.3441	2.3253
	Noise	2.5974	2.4370	2.3781	2.3953
Low N	No noise	2.6220	2.4721	2.4196	2.2994
	Noise	2.6568	2.5774	2.5670	2.5462

Table C4/. The interaction between noise, block and neuroticism (TDY).

d) The interaction between noise, block, introversion and neuroticism is significant at the 5% level (two tail) and the linear component is significant at the 2.5% level (two tail). See discussion.

e) The interaction of noise, block, introversion and time of day is significant at the 0.1% level (two tail) and the linear and quadratic components are significant at the 1% and 0.5% levels (two tail), respectively. See discussion.

f) The interaction of noise, block, neuroticism and time of day is significant at the 2.5% level (two tail) and the quadratic component is significant at the 1% level (two tail). See discussion.

g) The interaction between noise, block, neuroticism and frequency is significant at the 2.5% level (two tail) and the linear component is significant at the 0.5% level (two tail). See discussion.

h) The interaction between noise, block, introversion, time of day and frequency and its quadratic component are significant at the 0.1% level (two tail). See discussion.

i) The interaction between noise, block, introversion, neuroticism, time of day and frequency and its linear

component are significant at the 2.5% and 0.5% levels (two tail), respectively.

The parametric discrimination index.

a) The main effect for block and its linear component are significant at the 0.5% and 0.1% levels (two tail), respectively.

b) The interaction of noise and block and its linear component are significant at the 1% and 0.1% levels (two tail), respectively.

c) The interaction between noise, block and neuroticism and its linear component are significant at the 5% and 0.5% levels (two tail), respectively.

d) The interaction between noise, block, introversion and neuroticism and its linear component are significant at the 2.5% and 1% levels (two tail), respectively.

e) The interaction between noise, block, introversion and time of day and its linear and quadratic components are significant at the 0.1%, 0.5% and 0.5% levels (two tail), respectively.

f) The interaction between noise, block, neuroticism and time of day and its quadratic component are significant at the 5% and 2.5% levels (two tail), respectively.

g) The interaction between noise, block, neuroticism and frequency and its linear component are significant at the 0.5% and 0.1% levels (two tail), respectively.

h) The interaction between noise, block, introversion, time of day and frequency and its quadratic component are significant at the 0.1% level (two tail).

i) The linear component associated with the interaction

between noise, block, introversion, neuroticism, time of day and frequency is significant at the 5% level (two tail). See discussion for consideration of these results.

The probability of a hit.

a) The main effect for block and its linear and quadratic components are significant at the 0.1%, 0.1% and 2.5% levels (two tail), respectively.

Block	1	2	3	4
TPH	2.166	1.790	1.700	1.573

Table C42. The main effect for block (TPH).

b) The interaction between noise and block and its linear component are significant at the 5% and 2.5% levels (two tail), respectively.

Block	1	2	3	4
No noise	2.068	1.669	1.579	1.343
Noise	2.264	1.911	1.821	1.803

Table C43. The interaction between noise and block (TPH).

c) The linear component associated with the interaction between noise, block and neuroticism is significant at the 2.5% level (two tail).

d) The interaction between noise, block, introversion and time of day and its quadratic component are significant at the 5% and 2.5% levels (two tail), respectively.

e) The linear component associated with the interaction between noise, block, neuroticism and frequency is significant

at the 2.5% level (two tail).

f) The cubic component associated with the interaction between noise, block, time of day and frequency is significant at the 5% level (two tail).

g) The linear component associated with the interaction between noise, block, introversion, neuroticism and frequency is significant at the 2.5% level (two tail).

h) The interaction between noise, block, introversion, time of day and frequency and its quadratic component are significant at the 0.1% level (two tail).

i) The linear component associated with the interaction between noise, block, introversion, neuroticism, time of day and frequency is significant at the 2.5% level (two tail).

See discussion for consideration of these results.

The probability of a false alarm

a) The main effect for block and its linear component are significant at the 0.1% level (two tail).

Block	1	2	3	4
TPF	0.3290	0.2723	0.2450	0.2166

Table C44. The main effect for block (TPF).

b) The linear component associated with the interaction between block, introversion and frequency is significant at the 2.5% level (two tail).

Block	Introverts		Extraverts	
	low frequency	high frequency	low frequency	high frequency
1	0.3220	0.3833	0.4254	0.1854
2	0.3198	0.2879	0.3541	0.1275
3	0.2813	0.2517	0.3029	0.1442
4	0.2456	0.2186	0.2801	0.1220

Table C45. The interaction of block, introversion and frequency (TPF).

c) The quadratic component associated with the interaction between noise, block and introversion is significant at the 5% level (two tail).

Block	Introverts		Extraverts	
	No noise	Noise	No noise	Noise
1	0.3395	0.3657	0.2393	0.3714
2	0.3676	0.2401	0.1676	0.3140
3	0.3052	0.2279	0.1734	0.2737
4	0.2482	0.2160	0.1626	0.2395

Table C46. The interaction of noise, block and introversion (TPF).

d) The linear component associated with the interaction between block, introversion, neuroticism and time of day is significant at the 2.5% level (two tail).

e) The linear component associated with the interaction between block, introversion, neuroticism and frequency is significant at the 5% level (two tail).

See discussion for consideration of these results.

Results involving time on task for the speed of response to signals (vigilance task):

a) The main effect for block and the associated linear component are significant at the 0.5% and 0.1% levels (two tail), respectively.

Block	1	2	3	4
	0.0279	0.0482	0.0506	0.0549

Table 47 . The main effect for block (LSIG).

The following effects were also significant:

b) The cubic component associated with the interaction between block and introversion (1%, two tail).

c) The interaction of block, introversion and neuroticism (1%, two tail) and the associated cubic component (1%, two tail).

d) The quadratic component associated with the interaction between block, neuroticism and time of day (5%, two tail).

e) The interaction between block, introversion and frequency (5%, two tail) and the associated cubic component (1%, two tail).

f) The linear component associated with the interaction between block, introversion, neuroticism and time of day (5%, two tail).

g) The interaction between block, introversion, neuroticism and frequency and the associated linear and cubic components (all at the 5% level, two tail).

h) The interaction between noise, block and introversion (0.1%, two tail) and the associated quadratic (0.5%, two tail) and cubic (1%, two tail) components.

i) The interaction between noise, block, introversion and frequency and the associated quadratic and cubic components (all at the 0.1% level, two tail).

j) The cubic component associated with the interaction between noise, block, introversion, time of day and frequency (2.5%, two tail).

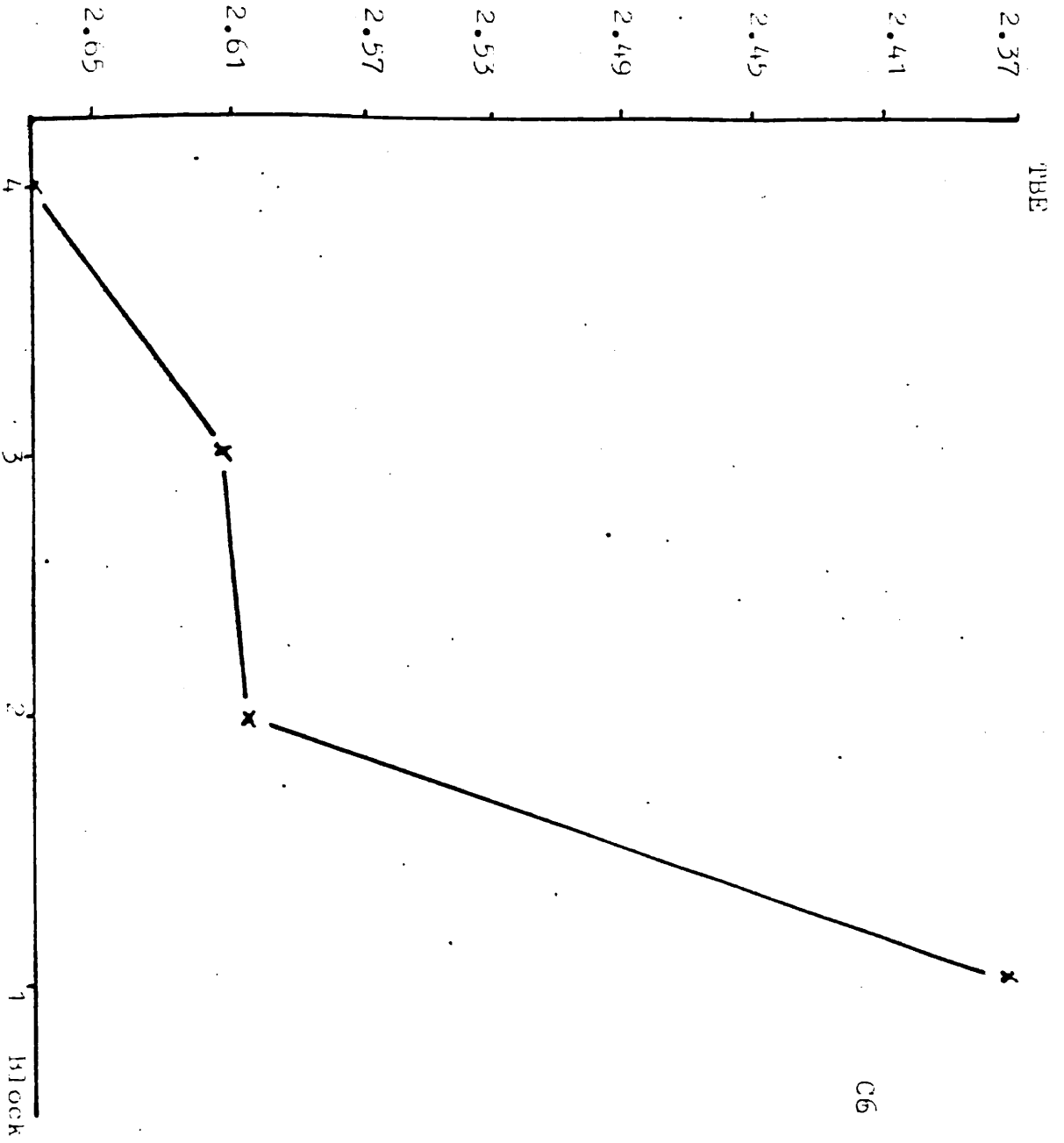
k) The interaction between noise, block, introversion, neuroticism, time of day and frequency (0.1%, two tail) and the associated linear component (2.5%, two tail).

Further consideration of (b) to (k) will be postponed until the discussion.

The reader is reminded that in graphs presented in the discussion, any that have time on task represented on the 'X' axis have had this axis reversed in the interests of clarity.

d) Discussion of significant effects involving time on task for behavioural measures:

The first index that we will consider is the non-parametric criterion (TBE). The main effect for block and the associated linear and quadratic components are all significant, due to the fact that with time on task, the tendency to respond steadily decreased (see Graph (6)). There is some indication that the initial concavity upwards of the graph is followed by a slight convexity upwards. But since the cubic component is not significant, it is reasonable to assume that the overall trend is for the rate of decrease to decrease with time on task. This would be consistent either with the view that time on task moves subjects to the left along the 'X' axis of the inverted 'U' and that we are operating on portion 'A', or that it moves subjects to the right and that we are operating on portion 'D'. We have argued already that there is no way of resolving this issue unequivocally where simple main effects are concerned. The main effect for 'position' in the subjective 'arousal' measure would support the view that time on task overall moves subjects to the left along the 'X' axis of the inverted 'U', whilst the main effect for position for the subjective 'stress' and state 'anxiety' measures would suggest the reverse. However, all this assumes that there is a linear, monotonic relationship between the determinants and the intervening construct - i.e. that the Western model is the correct one. We have seen already that there is evidence for the Russian model in the present study, and if this is so, main effects for state measures are as ambiguous as main



C6 The main effect for block (TBE)

effects for behavioural measures.

There are, however, one or two other points to be made about the main effect for block. It can be shown from inspection of the total number of responses made by the subjects that the value for block 1 overall is 19.46.

The value we would have expected if subjects had responded to all the signals but not to any of the non-signals is 18, since this is the average of the number of signals per block for the high and low frequency conditions (29 and 7, respectively). Since these two values are very close to each other and since the total number of responses quickly falls below the expected value, one cannot explain the fall in the tendency to respond with time on task by any adjustment of subjective signal probability to actual signal probability. Our pre-task 'buzzer period' seems to have been quite successful in establishing a fairly accurate overall subjective probability at the start of the task. Overall, subjects seem to have developed fairly accurate expectancies about signal probability, so the decline in the tendency to respond must be due to other factors. What these factors are may become clearer when we consider interactions between time on task and other factors. At present the important point is that we can safely assume that overall changes with time are not due to any perceived discrepancy between the pre-test and the test periods, and that the adaptive mechanism proposed by Vickers *et al* (see pp. 783-98) to maintain the subject's level of responding

has not been powerful enough to prevent the influence of other factors from becoming apparent. If we look at the total number of responses in block 1 for the two frequency conditions separately, the values are 13.8 and 26.1, respectively, for the low and the high condition. The value for the low frequency, in particular, departs considerably from the expected value (7), indicating that the initial setting of the criterion may not depend entirely on subjective probability. But this is, of course, exactly what we would predict. We have argued all along that the dictates of signal detection theory by itself may conflict with the dictates of the hedonic tone model, for example. In the case of Brebner and Flavel's study on reaction time (see pp. 422-38), signal detection theory seemed to be paramount. However, in this instance it is possible that when the opportunities to respond provided by the experimenter were very slight, as in the low signal frequency condition, the need to maximise hedonic tone may have overridden the need to optimise performance, with the result that subjects responded more frequently than the objective signal probability would require. Equally, it is possible that at the high frequency, responding at the expected level of 29 times per ten minute period might have provided too much stimulation so subjects responded at a slightly lower level.

There is, therefore, no need to believe that the pre-task period did not establish accurate expectancies. Initial discrepancies between expected and actual levels of responding could be explained by hedonic tone considerations. The subsequent changes with time are a different matter. The fact that the level of responding decreases markedly with

time on task could be due to changes in the discrepancy between actual and desired levels of hedonic tone. But it is more likely that they are a reflection of other factors such as habituation, summation of excitation, etc. which we will consider below. It is worth, though, mentioning one interesting point. In the low frequency condition, the total number of responses made by the subjects decreased from a value of 13.8 in block 1 to a value of 7.17 in block 4. This latter value is close to the actual signal frequency in the 'low' condition - i.e. 7. It is possible, therefore, that in this condition the subjects may still have been learning about the signal probability during the course of the test session. Why this should be so is not clear, though it may be that at low frequency a pre-test period does not give the subject a sufficient number of stimuli to develop accurate expectancies. If so, this poses a problem for the design of experiments in the vigilance area, since it may mean that very lengthy training sessions are necessary before subjective probability becomes matched to actual probability. But if such training sessions were employed it might mask many interesting phenomena in vigilance which could be expected to show up when the novelty of the task was higher.

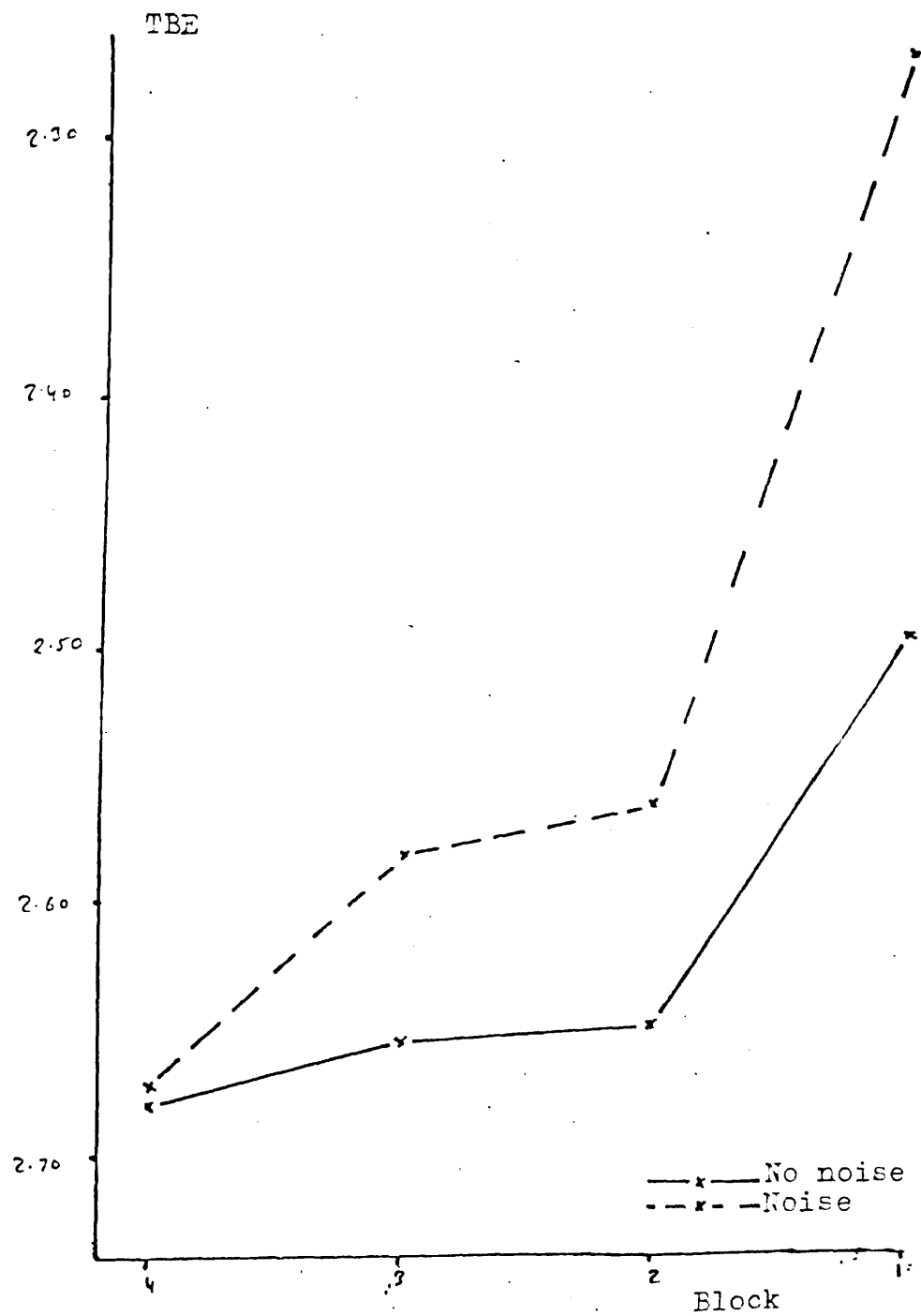
However, it is possible that the correspondence between the actual and expected level of responding in block 4 in the low frequency group is simply coincidental. Furthermore, the fact that the level of responding in the high frequency condition falls from 26.1 in block 1 to 15.8 in block 4, which is well below the expected value, indicates that in this group at least factors other than matching of subjective to

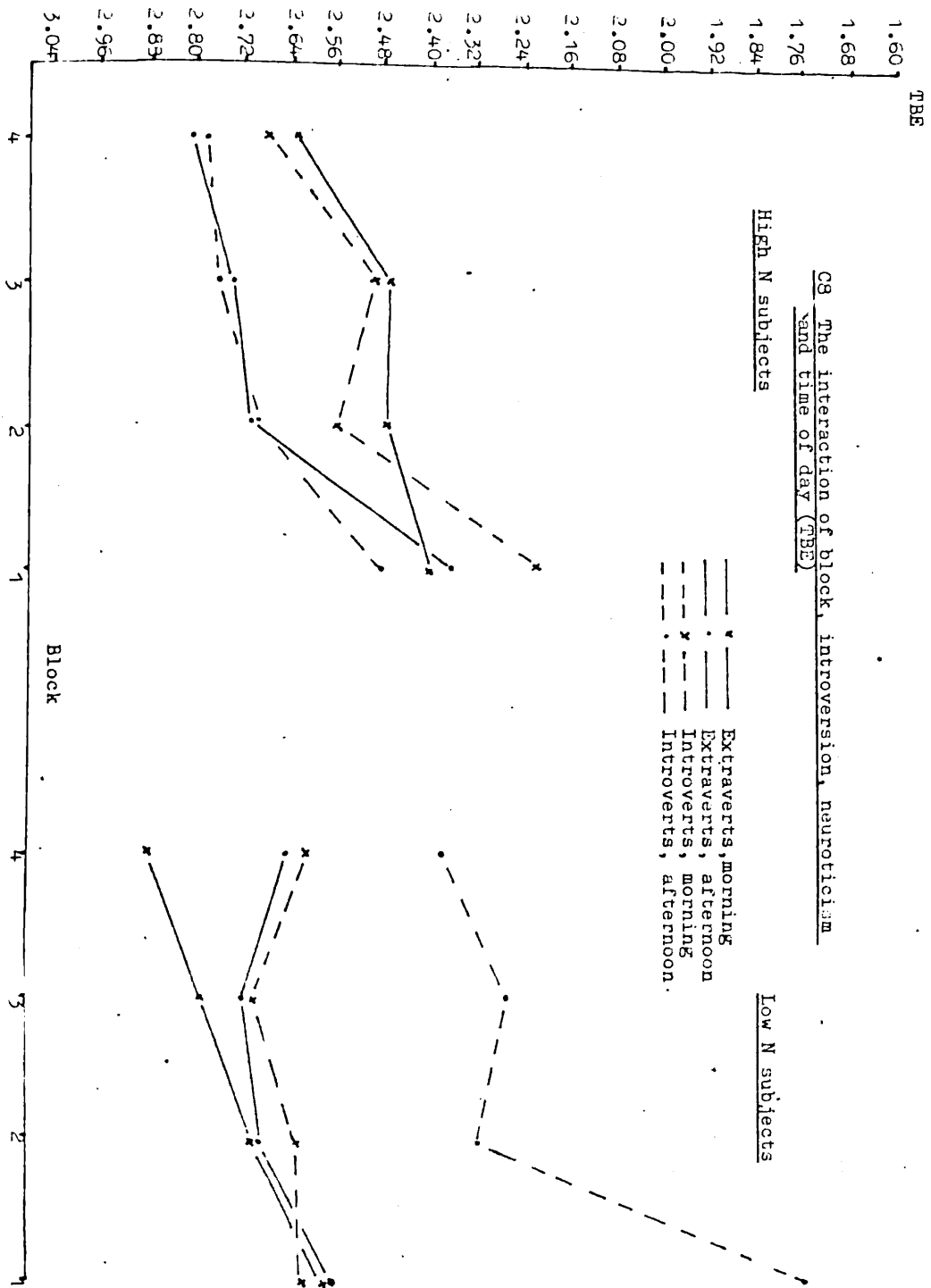
objective probability must be at work. The much larger fall at high frequency could be interpreted as support for our earlier suggestion that in the present study the rate of habituation may be greater at high than at low signal frequency. However, the difference may simply be a reflection of the law of initial values, and in any case the interaction between block and frequency is not significant for any of the behavioural measures.

The same does not apply to the interaction between noise and block. This is significant for the criterion measure as is the associated linear component. Graph C7 shows that with time on task the tendency to respond falls under both noise conditions, but does so more markedly under 'noise' than under 'no noise'. This may be due to the law of initial values, especially since the curves do not actually cross. It may be possible, therefore, to explain this interaction simply by assuming that the subjects are operating on portion 'A' of the inverted 'U', but further to the right in the 'noise' condition than in the 'no noise' condition. If so, then movement to the left with time on task would produce the kind of relationship depicted in Graph C7.

The interaction between block, introversion, neuroticism and time of day and its linear component are significant, and the relevant means are plotted in Graph C8. If we look at the curves for the high N subjects, we see that the relationships may be explicable on the basis of our model. The fact that the functions for the morning condition are by and large higher than the corresponding functions for the afternoon condition might be explicable if we assumed that time on

C7 The interaction of noise and block in the
non-parametric criterion





task moved high N subjects to the right along the 'X' axis of the inverted 'U' in the afternoon. The reasoning behind this statement is as follows: The overall heights of the curves can only be explained by assuming that the 'afternoon groups' were operating beyond the T.T.I. If so, then the negative, monotonic relationship between the tendency to respond and block in these groups can only be explained if we assume that time on task moved them further past the T.T.I. If it did not, then one would have expected, at least, an initial increase in the tendency to respond as time on task moved subjects to the left and hence back towards the T.T.I. It could be argued that such an initial increase might have been masked by the fact that the measures are averaged over a ten minute time period. However, to have split up the block factor to provide a finer degree of resolution would have been difficult, especially at the low frequency, since it would have meant that the number of signals per time period would have been extremely low. Furthermore, it is an unlikely explanation of the results in the present case, since the gap between the morning and afternoon groups does not narrow with time on task as one would expect it to, if this factor increased the tendency to respond of the afternoon groups initially. If anything the gap increases, at least for the extravert group.

If we, therefore, assumed that time on task moves the high N afternoon groups to the right, we are still left with the question of its effect on the high N morning groups. We could assume that it moved both groups to the left, but this would not explain why the 'introvert morning' group has a

lower tendency to respond than the 'extrovert morning' group in blocks 2, 3 and 4. One might be able to explain the relationship between these two groups, though, if we assumed that they moved to the right and to the left, respectively, with time on task. However, this would not explain why the 'introvert morning' group has a higher tendency to respond in Block 1 and yet shows a steeper fall than the 'extrovert morning' group. The latter group would seem to be operating on portion B of the curve, but if this is so, then one must assume that the 'introvert morning' group in block 1 must also be operating on portion B or portion C, but at a higher level - i.e. closer to the T.T.I. If so, one would expect a given movement along the 'X' axis to produce less of a change in this group, since both portions B and C are negatively accelerated - i.e. ^Aconvex upwards. Of course, since the net movement along the 'X' axis as a result of time on task depends on the direction and size of the combined vector of several opposing factors (see p. 748), it may not be valid to assume that a given change in time on task (as represented, for instance, by movement from block 1 to block 2) produces the same size of change in position on the 'X' axis in different groups, let alone the same direction of change. It is possible, therefore, that the results for the high N subjects may be consonant with the inverted 'U' model as we have presented it.

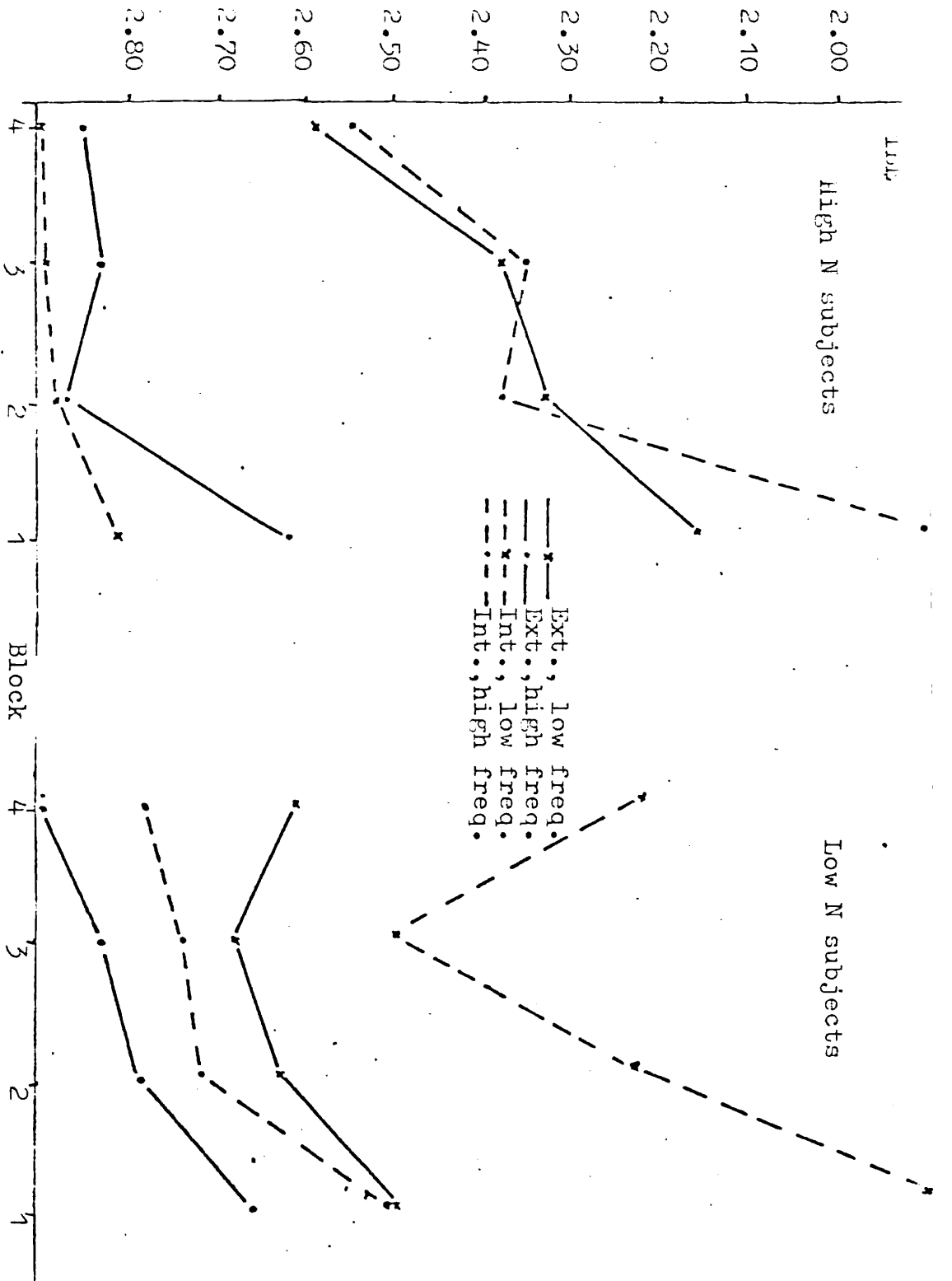
However, when we come to consider the results for the low N subjects in this interaction, this concordance breaks down. We see that the curves for the 'extrovert afternoon' group and the 'introvert morning' group are fairly flat

compared to the other groups. The inverted 'U' has three such flattened areas: the two extreme ends and the region around the T.T.I. The overall heights of the curves suggest that these two groups are not operating near the T.T.I. However, if they are operating on one of the flattened extreme ends of the curve it is difficult to explain why the 'extrovert morning' group, which would be expected to be operating further to the left than the 'extrovert afternoon' group, shows a steady decline in tendency to respond with time on task. It is, of course, possible that if the various opposing factors which govern the effect of time on task were fairly equally balanced it might result in little change in the position of subjects on the inverted 'U' and a relatively flat curve might result. This would, perhaps, be most likely in intermediate groups who were high on the levels of some but not all of the factors involved. The two groups in question would fall into this category. However, such an explanation is highly speculative, and in any case their overall height relative to the other groups would suggest that they were operating near one of the extreme ends of the inverted 'U', so the problem of explaining their relationship to the 'extrovert morning' group for instance, still remains. For these reasons, we cannot state unequivocally that the interaction between block, introversion, neuroticism and time of day is consistent with the inverted 'U' hypothesis, especially since complex interactions are difficult to interpret by eye.

The final interaction we must consider for the criterion measure is that between block, introversion, neuroticism and frequency. This is significant at the 5% level and the associated linear component is significant at the 1% level.

Graph C9 shows that our earlier suggestion that the reduction in novelty at high frequency may be greater than at low frequency has some foundation. If we look at the curves for the low N subjects we see that in both introverts and extraverts the curves for the high frequency condition are lower overall than the corresponding curves for the low frequency condition. The fact that this relationship holds good in block 1 and not just in the later blocks is explicable if we remember that prior to the start of the task subjects underwent an initial period during which they were subjected to auditory stimuli at the same frequency as the signals in the subsequent test period. It is, therefore, not out of line with expectation that the rate of decline of the tendency to respond during the test period itself is less at the high frequency than at the low frequency in introverts. One can explain this by postulating a 'floor effect', in the former case. But if this is the case, it is surprising that a similar floor effect is not apparent in the 'extravert high frequency' group despite their lower overall level. The author also has no explanation for the sharp rise in the tendency to respond between blocks 3 and 4 in the 'introvert high frequency' group.

If we now look at the curves for the high N subjects we see that the 'extravert, low frequency' group is higher than the 'extravert high frequency' group, as before, but **the relative** positions of the two frequency conditions is reversed amongst introverts. However, this is explicable on the basis of our analysis of the effect of time on task. We suggested that the effect of an increase in frequency would both enhance the



C9 The interaction of block, introversion, neuroticism and frequency in the non-parametric criterion.

reduction in novelty associated with increasing time on task, but also promote summation^{of} the excitations of successive stimuli. We also argued that the latter effect would be relatively more pronounced when the levels of the determinants were relatively high than when they were relatively low. It is possible, therefore, that in the high N introverts, the effect of an increase in signal frequency is opposite to that in the other groups. If this effect operates during the pre-task period it could explain why the tendency to respond in block 1 is greater at high frequency than at low frequency in this group. The fact that the tendency to respond nevertheless declines more at high frequency than at low frequency could be explained by the law of initial values: i.e. by the fact that the overall tendency to respond in the 'introvert, low frequency' group is very low.

This latter phenomenon does, however, pose a problem for our hypothesis. Up till now we have considered the relative positions of the corresponding curves for the low and high frequency conditions. If we now compare the relative positions of the corresponding curves for introverts and extraverts, we find that in nearly all cases the introvert curve is higher than the extravert curve as we would expect. The relative rates of decline of the curves for the introvert and extravert groups would also by and large be explicable on the basis of the assumption that the rate of decline will be greater in the extraverts (due to a greater predominance of the reduction in novelty factor over the summation of excitations factor), though in some cases this effect seems to be moderated by the law of initial values. However, the

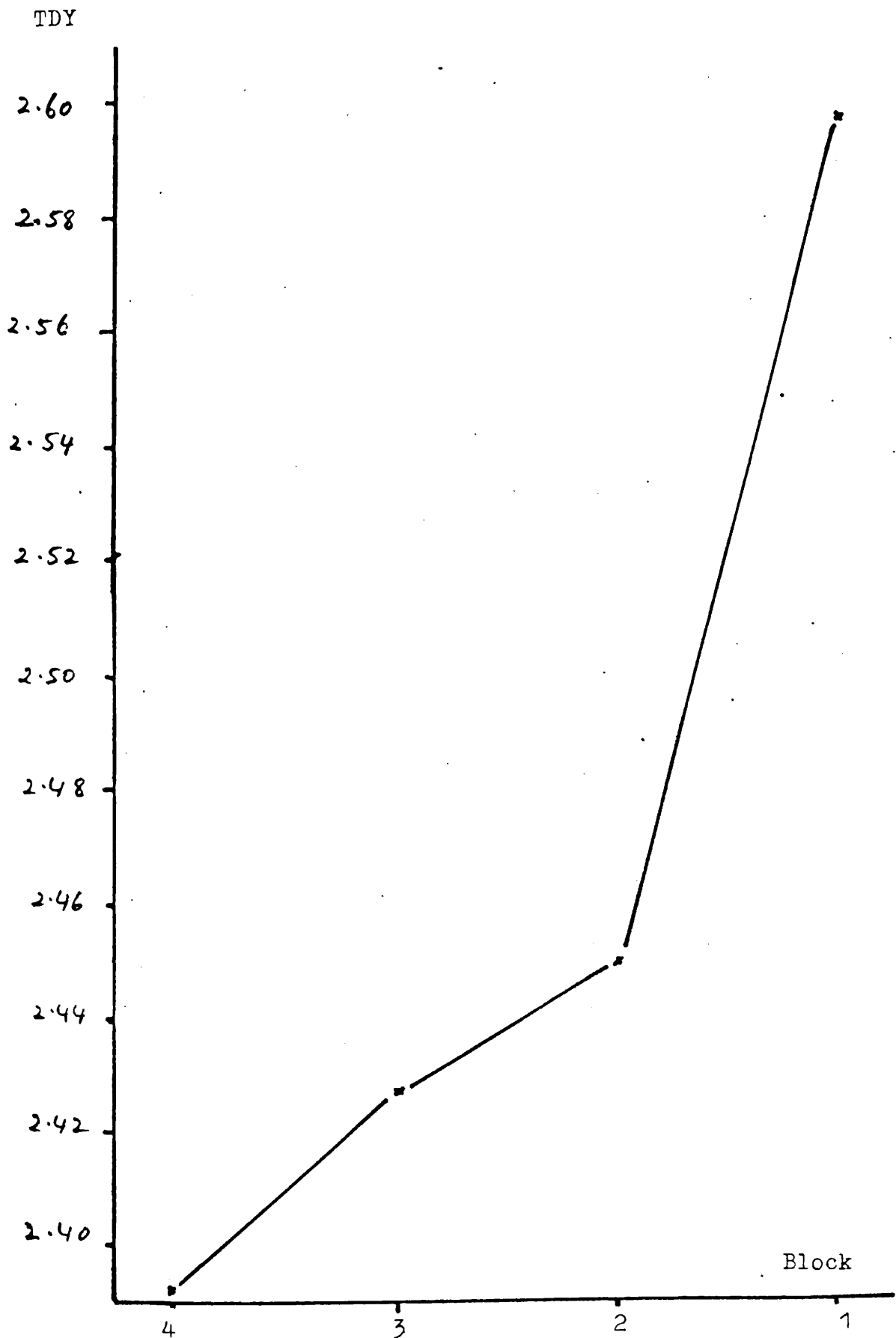
one thing that such an assumption cannot explain is the fact that the curve for the 'high N introverts' at low frequency is much lower than the corresponding curve for the 'high N extraverts'. The author has no satisfactory explanation for this relationship and so this interaction again provides only partial support for our hypotheses.

We have considered the results for the criterion measure at some length in order to illustrate the kind of reasoning that is necessary when the time on task factor is involved. In discussing the remaining results we will not devote as much attention to interactions which provide, at best, equivocal support for the hypothesis.

Let us now consider the results for the discrimination index. The non-parametric and parametric measures of the latter yield essentially similar results differing, by and large, only on the significance level at which a given effect is found to be reliable, or occasionally in the fact that one particular component of a given interaction is significant for one measure but not for another. There are no instances, however, where a given interaction yields one or more significant components for one index but no significant components for the other. For this reason in our treatment of the results we will confine our account to the non-parametric measure, since the latter is based on fewer assumptions than the parametric measure.

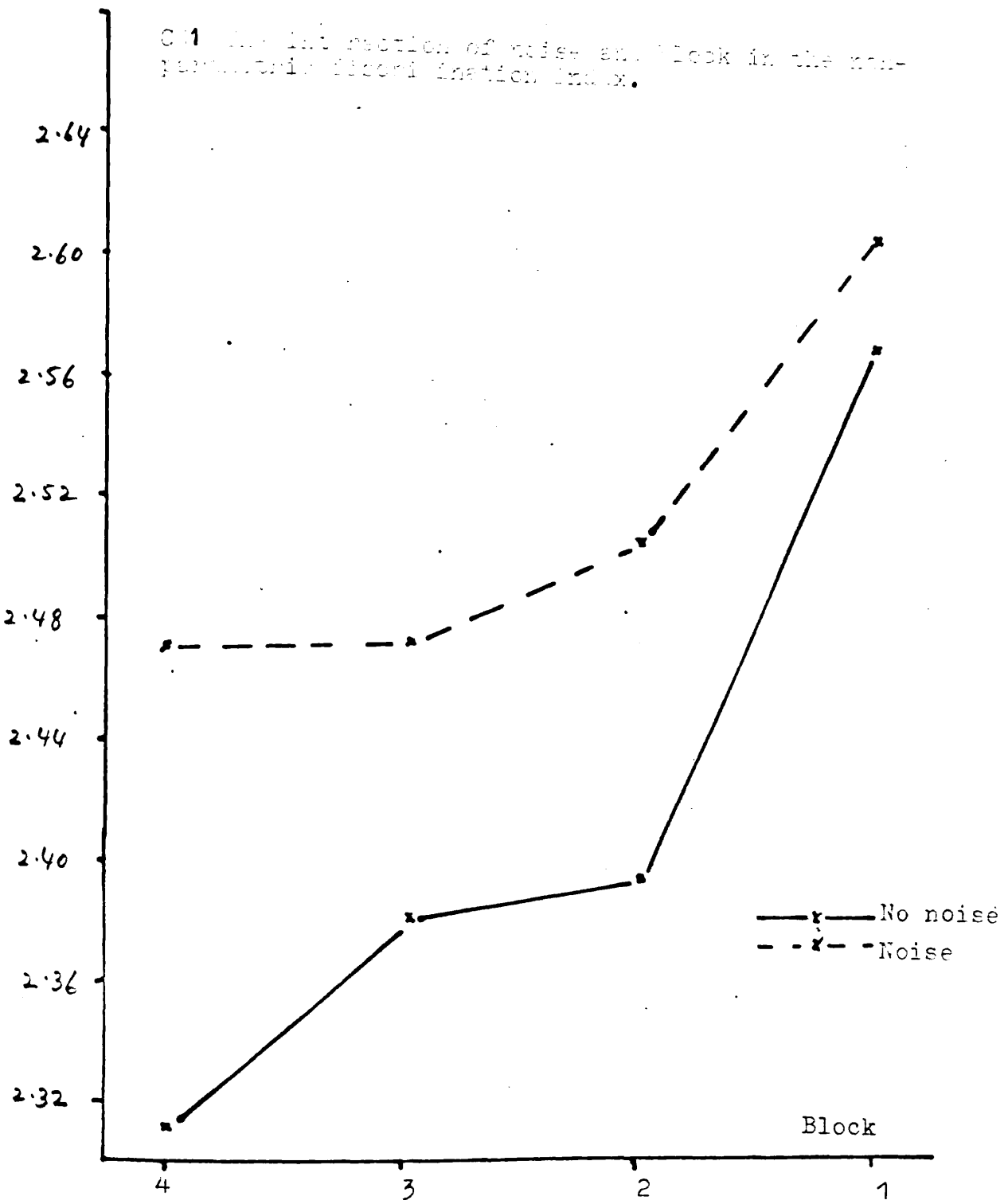
The main effect for block is significant as are its linear and quadratic components. Graph C10 shows that with time on task the discrimination ability of the subject decreases but the rate of decrease also decreases. This certainly cannot be due to any adjustment of subjective to objective probability and must be due to the influence of other factors, though because we are considering a main effect it is not easy to discern what these factors are. If we now look at the interaction between noise and block we find that the linear component is significant. Graph C11 shows that in both noise conditions discrimination ability falls with time on task, but it falls more steeply under 'no noise' than under 'noise'. This could be explained by assuming that time on task moves subjects to the left under both noise conditions and that the differential fall off is due to the fact that both groups are operating on portion B. The slight concavity

910 Effect of block in the non-parametric
discrimination index.



TDY

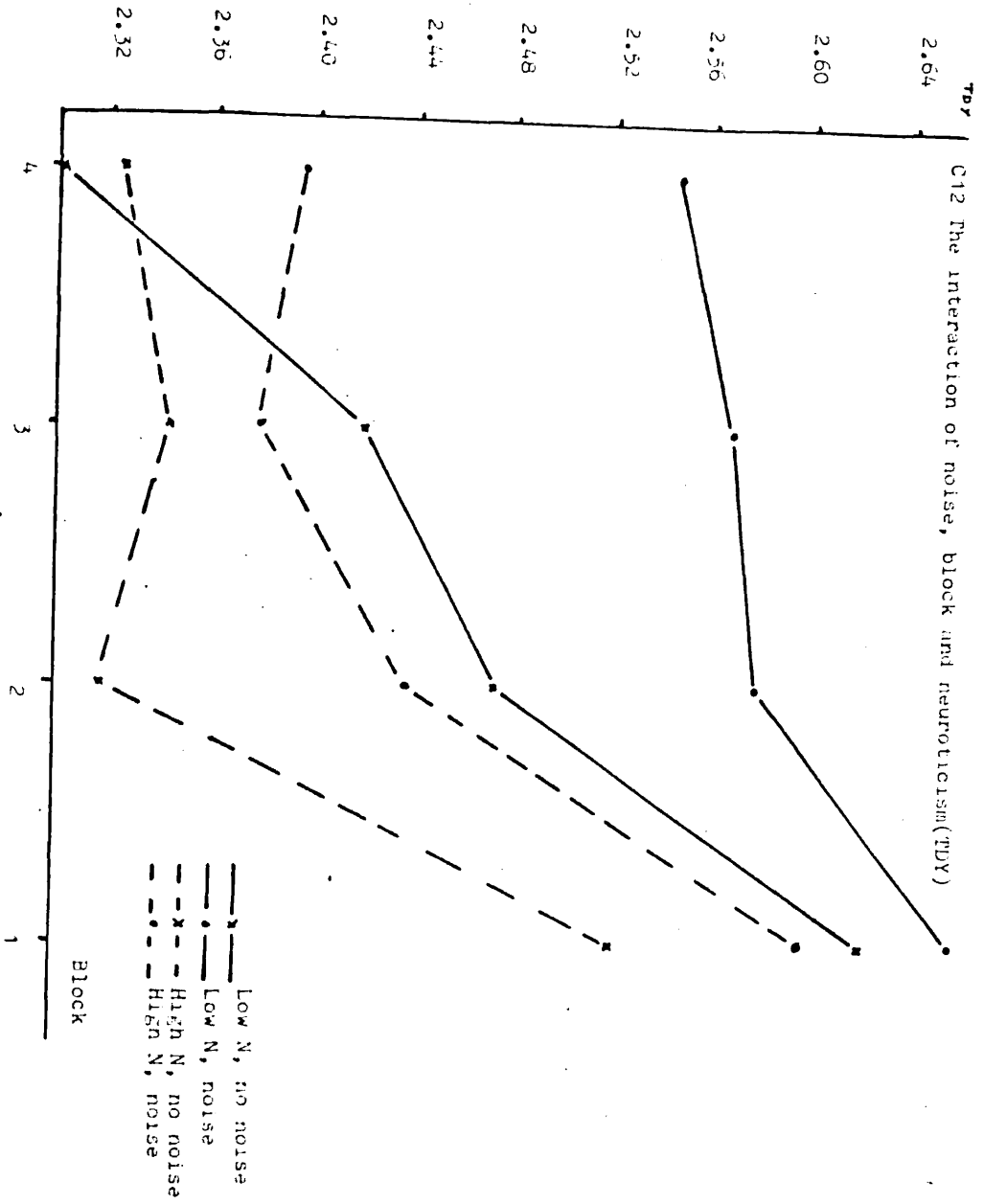
GM1 The last section of noise on Block in the non-parametric fiberoptic index.



upwards in both groups is not consistent with this view, so it is possible that the differences between the two conditions are not explicable in terms of differences in the initial positions on the inverted 'U' curve alone, but also in terms of the differential importance of the reduction in novelty and the summation of excitations factors. It is possible that the summation of excitations factor is more important in the 'noise' condition than in the 'no noise' condition and hence retards the rate of decline in the former relative to the latter.

Let us now consider the interaction between noise, block and neuroticism which is significant at the 2.5% level and which is depicted in Graph (12). The interaction is due to the fact that whereas under 'noise' conditions, the low N subjects show greater discrimination ability than the high N subjects throughout the task, especially towards the end, the difference is greatest in the second block under 'no noise' and, in fact, in block 4 the relative positions of the two groups are reversed. Also, the linear component is significant due to the fact that under 'no noise', low N subjects show a greater decline than high N subjects, whereas the reverse is true under 'noise'.

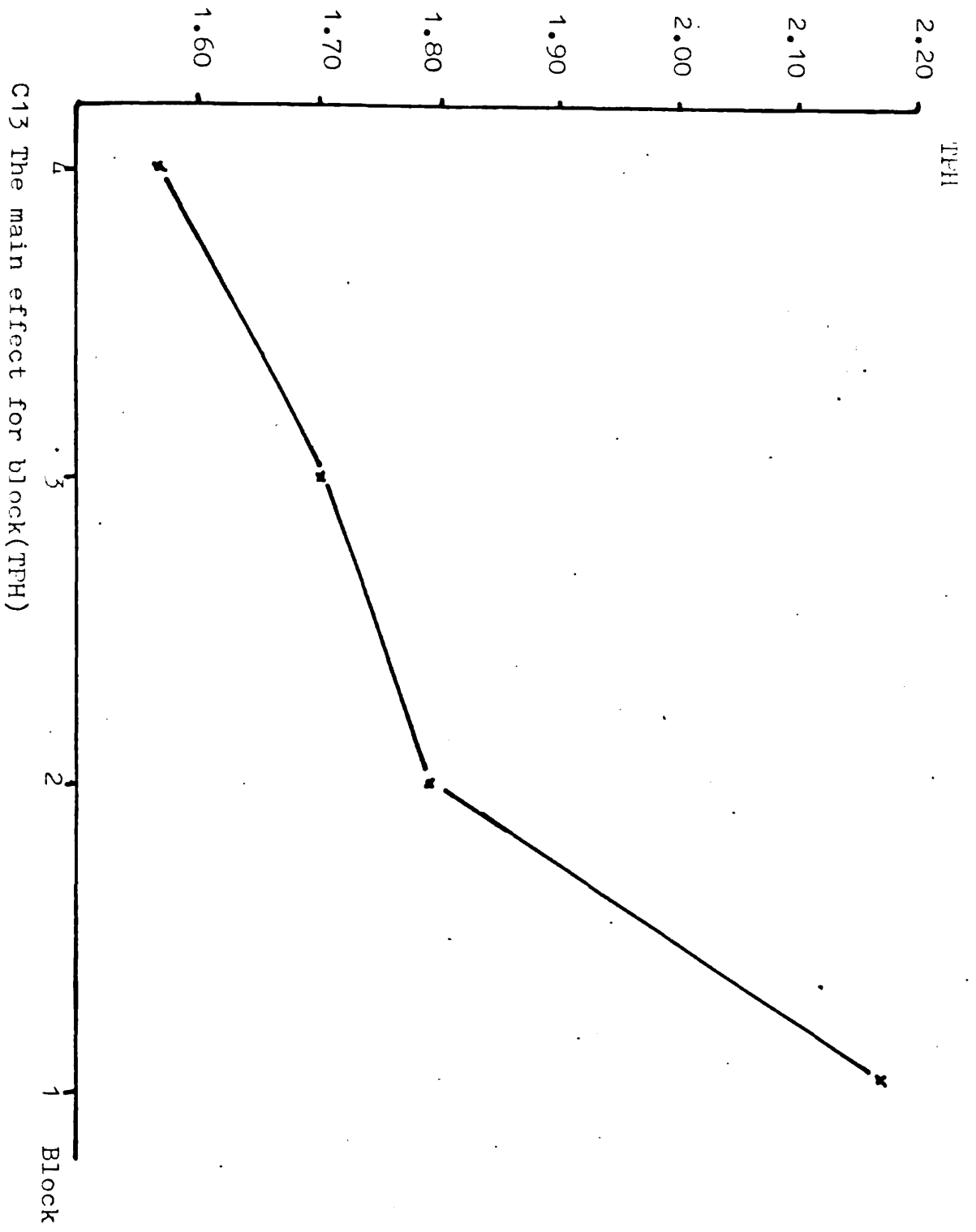
The curves for the low N subjects could be explained if we assumed that time on task moved subjects to the left under both noise conditions, but that under 'noise' subjects were operating further to the right overall, on portion B, than under 'no noise'. However, the curves for the high N subjects do not conform to the model, whether we consider the possibility of movement to the left or to the right.

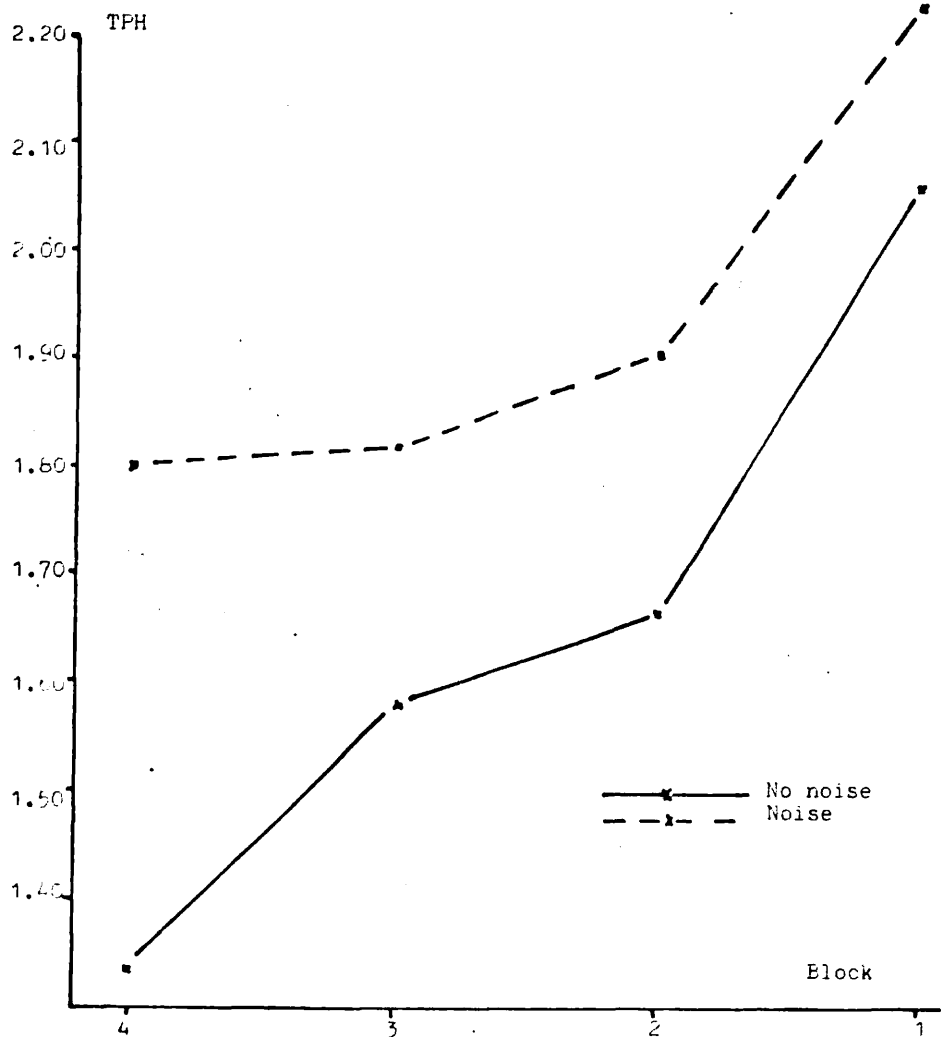


There are a number of other interactions for the discrimination index, but none of these are in line with the hypothesis so they will not be considered. The reader is referred to the results section for a list of them (see pp. 890-3).

Let us now consider the findings for the probability of a hit. This is the most widely used measure in the field of vigilance and in line with previous findings the main effect for block is significant, as are its linear and quadratic components, due to the fact that the probability of detecting a signal decreases with time on task, with the rate of decrease also decreasing (see Graph C13). The fact that there is no interaction between introversion and time on task provides indirect support for the view that high frequency pre-task training sessions may have been responsible for such an interaction in other studies (e.g. Bakan, Belton and Toth, 1963).

On the other hand, the interaction of noise and block is significant at the 5% level, as is its linear component (2.5% level). Graph C14 shows that the probability of detecting a signal decreases with time on task but more so under 'no noise' than under 'noise'. The corresponding ^{interactions for both the criterion and the} discrimination index are also significant, but the form of the latter corresponds more closely to the present one. Since it is likely, therefore, that the interaction between noise and block for the probability of a hit is related to the same interaction for the discrimination index, we will not discuss it further. A glance at the results shows that a similar correspondence exists for the most of the remaining interactions. The only exceptions are the interaction between noise, block, introversion, neuroticism and frequency, for which the linear component is significant and the interaction between noise, block, time of day and frequency for which the cubic component is significant. In neither case is there a





C14 The interaction of noise and block (TPH)

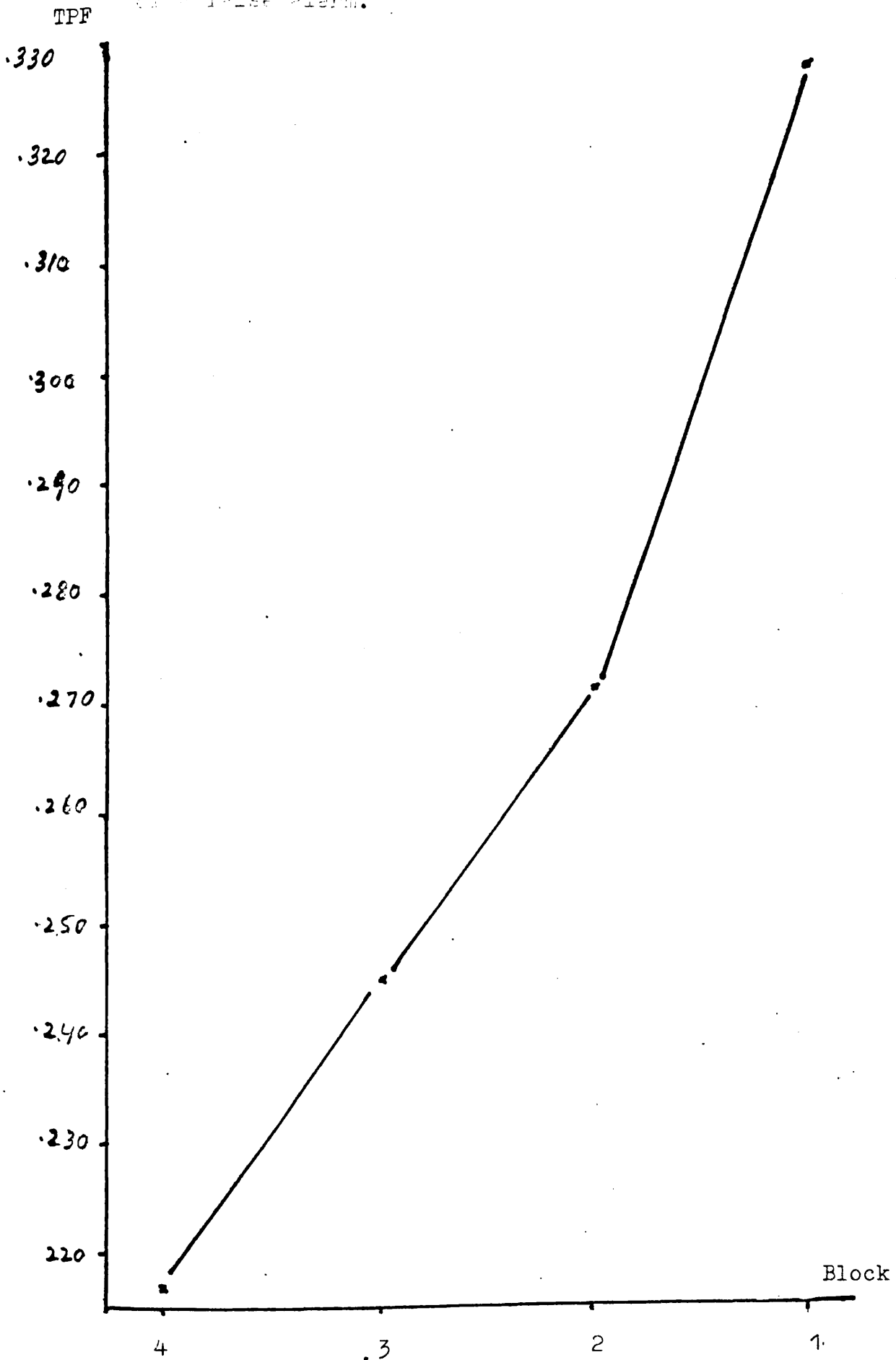
corresponding interaction for the discrimination index. However, like the other interactions, in neither case is the result in line with the model so will not consider them any further.

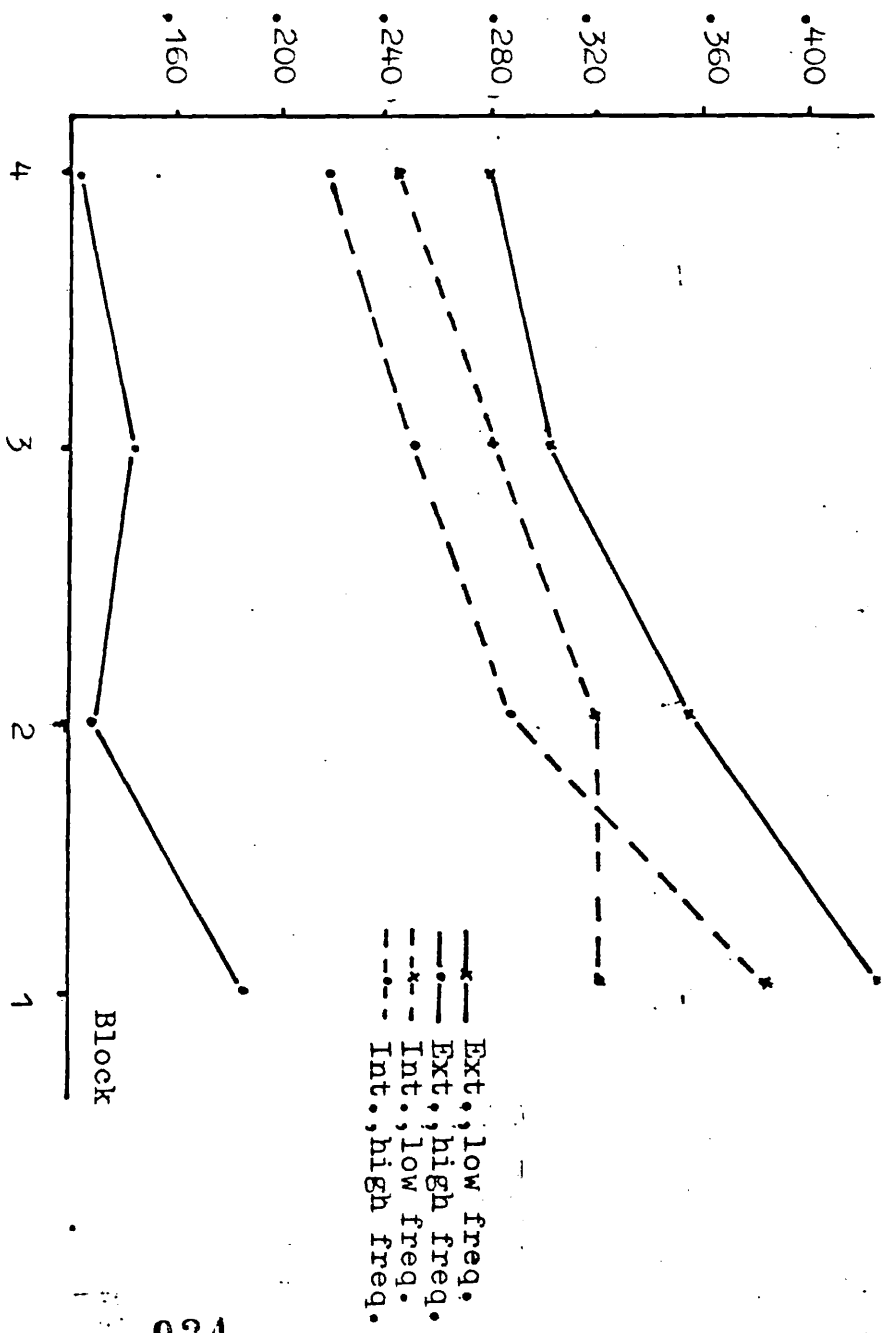
If we now look at the results for the probability of a false alarm we find that the main effect for block and its linear component are significant, due to a decrease with time (see Graph C15). This is in line with the results for both the criterion and the discrimination index. This, too, is consonant with previous findings though in the present case it is unlikely to be due to the gradual adjustment of subjective to actual probability.

The linear component associated with the interaction between block, introversion and frequency is also significant and is depicted in Graph C16. We see that amongst extraverts a greater decline is found at low frequency than at high frequency. This could be due to a floor effect combined with greater habituation at the high frequency during the pre-task period. Amongst introverts, on the other hand, the probability of a false alarm declines more steeply at high frequency possibly due to greater habituation - this time unbridled by proximity to some imaginary baseline. However, it is difficult to explain why both introvert groups have curves which are lower overall than that of the extrovert, low frequency group.

We must also consider the interaction between noise, block and introversion for which the quadratic component is significant. Graph C17 shows that this is due mainly to the fact that the introverts under 'no noise' show an initial increase and then a decrease, whereas in the other conditions

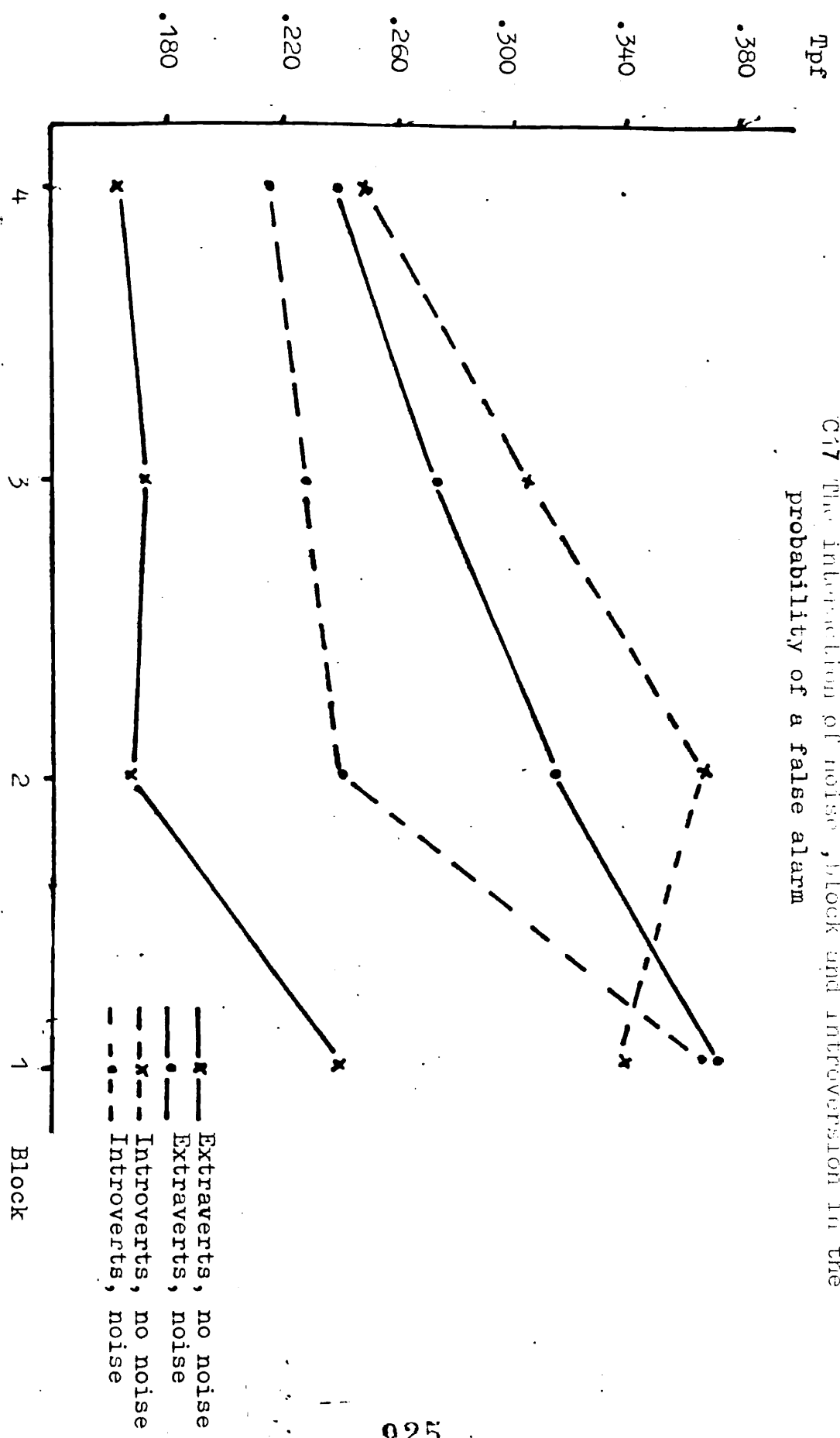
C15 The main effect of block in the probability of a false alarm.





C16 The interaction of Block, introversion and frequency in the probability of a false alarm.

C17 The interaction of noise, block and introversion in the probability of a false alarm



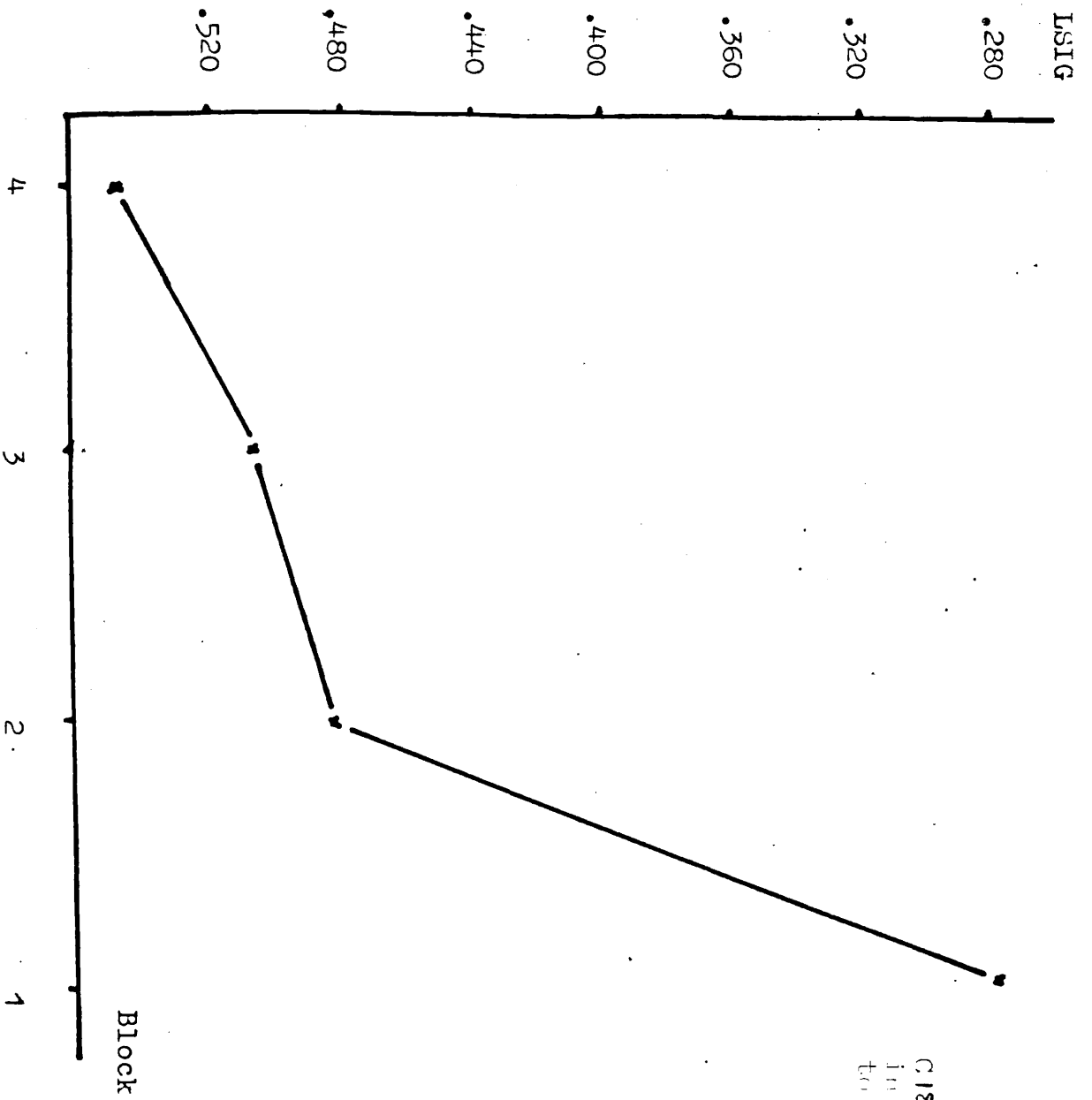
there is a monotonic decrease with time on task. The results might seem explicable if we assumed that time on task moves the introvert groups to the right, but the extrovert groups to the left. However, this would necessitate the assumption that under 'noise' the introverts are operating on portion D of the inverted 'U' and the corresponding curve is higher than would be expected on this basis.

There are two other interactions which should be mentioned, both of which have significant linear components: block x introversion x neuroticism x time of day and block x introversion x neuroticism x frequency. These are associated with corresponding interactions for the criterion measure which we have already discussed.

Let us now consider the results for the final measure, namely the speed of response to signals.

The main effect for block and the associated linear component are highly significant, and as Graph C18 shows this is due to the fact that speed of response decreases with time on task. This is in line with Buck's (1966) conclusion that this index usually parallels the decline in performance with time found using more conventional measures such as the probability of a hit.

However, the author has no adequate explanation for any of the remaining significant effects (listed in the results section) so these will not be discussed.



C18 Therman effector block
in the speed of response
to signals.

2. E.P.Q. ANALYSES

As for the joint simple visual reaction time/signal detection task we must consider the subjects' scores on the extraversion and neuroticism dimensions based on the E.P.Q.s given at the time of the experiment as well as the scores based on the E.P.I.s given at initial recruitment. We find that the correlations between the two sets of scores (for the 23 subjects who participated throughout) are 0.7268 and 0.7472 for extraversion and neuroticism, respectively. These are both significant beyond the 0.5% level (one tail). The correlation for neuroticism is somewhat smaller than the corresponding correlation between the E.P.I. and the first E.P.Q. (given at the time of the joint task) - see p. 637. This could be due to the greater length of time that had elapsed but surprisingly the correlation for the extraversion dimension is much higher than the corresponding E.P.I./first E.P.Q. correlation. It is possible that some form of long term cyclical process is involved but its exact nature is very difficult to discern, nor is it clear why the two dimensions should show such a different pattern of results.

This difference is further reflected in the correlation between the scores for the first and second administration of the E.P.Q. (i.e. at the time of the joint task and the vigilance task respectively). The correlation for extraversion is 0.4793 (2.5%, one tail) which is lower than the

corresponding E.P.I./second E.P.Q. correlation despite the fact that the relevant time interval was shorter and the same questionnaire was employed (again militating against the view that differences in the sociability/impulsivity item contents of the E.P.I. and E.P.Q. are playing an important part here). This lends support to the view that some cyclical process may be governing the extraversion dimension, and this congruence is not of course surprising since correlations between three variables are not entirely independent of each other (full matrices are given in Appendix C).

When we look at the neuroticism factor we see that the first E.P.Q./second E.P.Q. correlation is 0.749 (0.5% one tail) which is higher than the corresponding E.P.I./second E.P.Q. correlation. This underlines the previously noted disparity between the two personality dimensions.

Let us now consider the relationship between the E.P.Q. scores and the measures derived from the vigilance task. As before there was a significant negative correlation between the lie scale score and the extraversion score (-0.3629: 5% two tail), but no significant correlation between the lie score and either neuroticism or psychotism. It was decided for reasons stated earlier (see pp. 637-9) not to correct the extraversion scores for dissimulation.

Results (vigilance task: E.P.Q. scores):

Two bimodal splits on the E and N scores resulted in an introversion/extraversion and a neuroticism/stability factor. All analysis procedures were identical to those

carried out before except that the introversion and neuro-
ticism factors were defined in terms of the E.P.Q. scores
and not the original E.P.I. scores.

i) State and physiological measures

a) Results

These results are based on analyses which are identical to the previous ones except that the subjects EPQ scores were subjected to a biocodal split to define the introversion and neuroticism factors. Unfortunately, the nature of the resulting non-orthogonal analyses of variance was such that it was not possible to investigate interactions involving more than two factors (McManus, personal communication).

Results for subjective 'arousal' (E.P.Q.):

The interaction of introversion and frequency is significant at the 5% level (two tail). At low frequency, extraverts report a higher level of 'arousal' than introverts, whereas the reverse is true at high frequency. Also, amongst extraverts a higher level of 'arousal' is reported at low frequency than at high frequency, whereas the reverse is true amongst introverts.

	low frequency	high frequency
Introverts	1.136	1.725
Extraverts	1.745	0.979

Table C48 . The interaction of introversion (EPQ) and frequency (TAROUSAL).

Results for subjective stress (EPQ):

The main effect for neuroticism is significant at the 5% level (two tail). Overall, high N subjects report a higher level of 'stress' than low N subjects.

Low N	High N
1.526	2.168

Table C49 . The main effect for neuroticism (EPQ) - (TSTRESS).

Results for state anxiety (EPQ):

The interaction of noise and introversion is significant at the 2.5% level (two tail). Amongst introverts, a higher level of 'anxiety' is reported under 'noise' than under 'no

noise', whereas the reverse is true amongst extraverts. Also, under 'no noise', extraverts report a higher level of anxiety than introverts, whereas the reverse is true under 'noise'.

	Introverts	Extraverts
No noise	38.75	39.41
Noise	42.78	36.34

Table C50 . The interaction of noise and introversion (EPQ) - (ANX).

Results for deep core body temperature (EPQ):

a) The interaction of neuroticism and frequency is significant at the 5% level (one tail). At low frequency, high N subjects have a higher temperature than low N subjects, whereas the reverse is true at high frequency. Also, amongst low N subjects, body temperature is higher at high frequency than at low frequency, whereas the reverse is true amongst high N subjects.

	low frequency	high frequency
Low N	35.894	36.173
High N	36.414	36.063

Table C51 . The interaction of neuroticism (EPQ) and frequency (TEMP).

b) The main effect for introversion is significant at the 2.5% level (two tail). Overall, extraverts have a higher body temperature than introverts.

Introverts	Extroverts
35.928	36.383

Table C52 . The main effect for introversion (EPQ) - (TEMP).

b) Discussion (state and physiological measures from vigilance task E.P.Q. scores):

If we look at the results for the subjective 'arousal' measure we find that only one of the effects involving two factors or less (since higher order interactions could not be investigated - see p. 932) which was significant for the E.P.I. analysis is also significant for the E.P.Q. analysis. This is the interaction between introversion and frequency which is due to the fact that at low frequency, extraverts report a higher level of 'arousal' than introverts, whereas the reverse is true at high frequency. Also amongst extraverts a higher level of 'arousal' is reported at low frequency than at high frequency, whereas the reverse is true amongst introverts. This corresponds to the interaction derived from the E.P.I. analysis and thus supports our earlier contention that in the present study, an increase in signal frequency results in movement to the left along the 'X' axis of the inverted 'U'.

The only result that is significant for the subjective 'stress' measure is the main effect for neuroticism due to the fact that overall high N subjects report a higher level of 'stress' than low N subjects. In view of the high correlation between the 'stress' and 'anxiety' scores in the present study, and the positive relationship between neuroticism and 'anxiety' found by Spence and Spence (1966), this result is intuitively reasonable. However, there is no corresponding main effect for the 'state anxiety' measure in the present set of results.

There is, however, an interaction between noise and introversion that supports our earlier contention that this

index may be an inverse measure of hedonic tone. Amongst introverts, a higher level of anxiety is reported under 'noise' than under 'no noise'; whereas the reverse is true amongst extraverts. Also, under 'no noise', extraverts report a higher level of anxiety than introverts, whereas the reverse is true under 'noise'. This is contrary to prediction if we assume that state anxiety is an index of the 'excitatory process' since it indicates that there is a 'U' shaped relationship between anxiety and the determinants (in this case introversion and noise). However, if anxiety is an inverse measure of hedonic tone, the result supports the idea that there is an inverted 'U' relationship between the latter and the determinants.

The final measure we must consider is deep core body temperature. We have, firstly, an interaction between neuroticism and frequency which is in line with our original prediction but which does not support our later suggestion that in the present context, signal frequency moves subjects to the left along the inverted 'U'. At low frequency, high N subjects have a higher body temperature than low N subjects, whereas the reverse is true at high frequency. Also, amongst low N subjects, body temperature is higher at high frequency than at low frequency, whereas the reverse is true amongst high N subjects. There is also a main effect for introversion due to the fact that overall, extraverts have a higher body temperature than introverts. This is somewhat surprising in view of Blake's (1971) finding that over the time of day range that was covered by the present study, body temperature tends to be somewhat higher in introverts than in extraverts,

but it tells us little about the applicability or otherwise of the inverted 'U' model to the body temperature measure.

ii) BEHAVIOURAL MEASURES

a) Results relating to overall performance

Results for the non-parametric criterion (EPQ)

No significant effects.

Results for the non-parametric discrimination index

(E.P.O.):

a) The main effect for neuroticism is significant at the 5% level (two tail). Overall, low N subjects discriminate better than high N subjects.

Low N	High N
2.5413	2.3932

Table C24. The main effect for neuroticism (EPQ) - (TDY).

b) The interaction of neuroticism, time of day and

frequency is significant at the 5% level (two tail). See discussion.

Results for the parametric discrimination index (EPQ):

The interaction of neuroticism, time of day and frequency is significant at the 5% level (two tail). See discussion.

Results for the probability of a hit (EPQ):

No significant effects.

Results for the probability of a false alarm (EPQ):

No significant effects.

Results for the speed of response to signals (EPQ):

The interaction of neuroticism and time of day is significant at the 2.5% level (one tail). In the morning, high N subjects are faster than low N subjects, whereas the reverse is true in the afternoon. Also, amongst low N subjects speed of response is greater in the afternoon than in the morning, whereas the reverse is true amongst high N subjects.

	Morning	Afternoon
Low N	0.0653	-0.0195
High N	0.0464	0.0580

Table C54. The interaction of neuroticism (EPQ) and time of day (IS16).

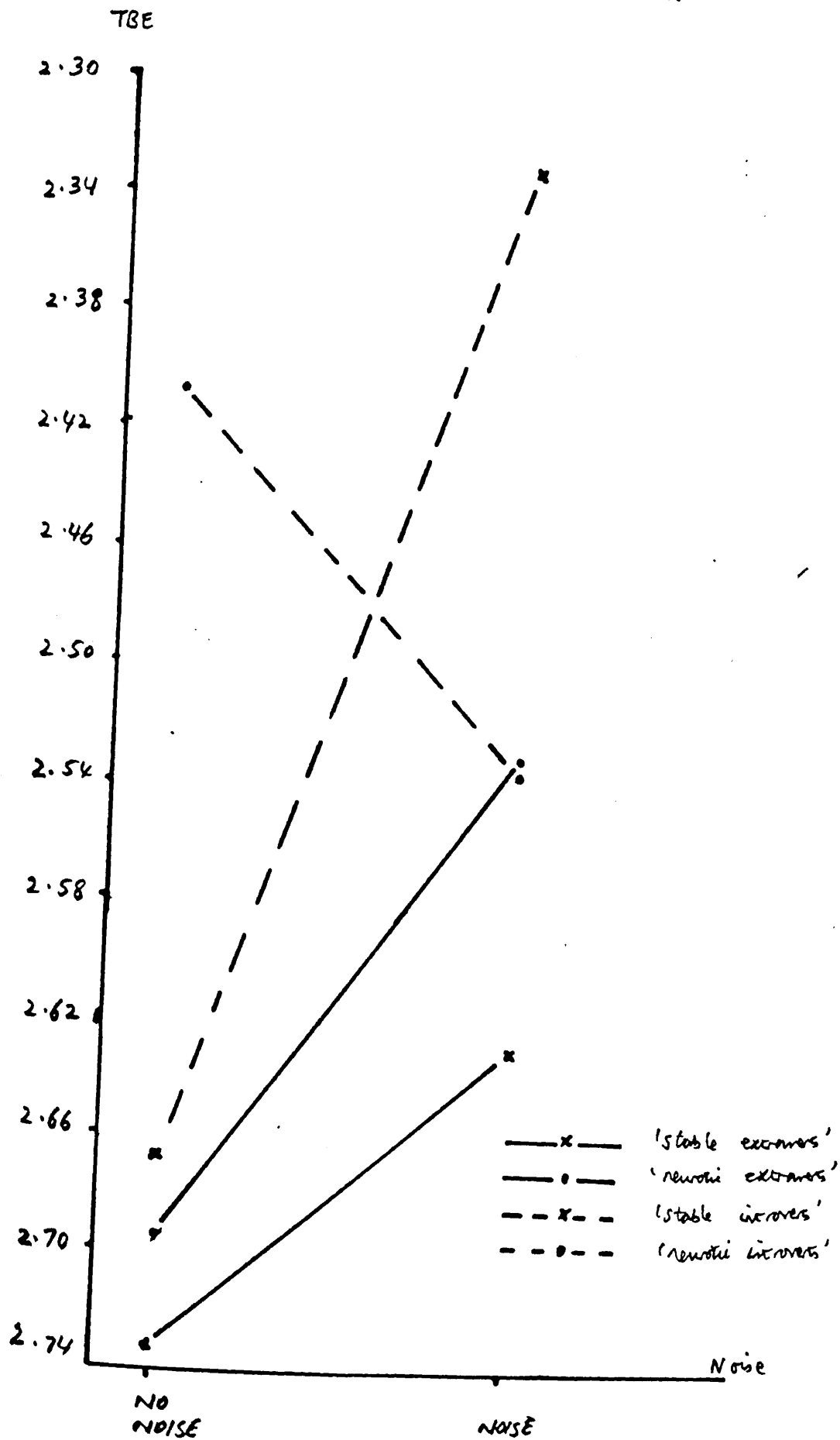
b) Discussion (behavioural measures from vigilance task relating to overall performance; EPO scores)

When we look at the results for the behavioural measures which relate to the overall level of performance, we find that none of the effects which appeared in the E.P.I. analysis of the non-parametric criterion appear in the E.P.Q. analysis. In the former analysis there were significant interactions between neuroticism and frequency, between neuroticism and time of day, and between introversion, neuroticism and frequency, for example. However, there are no significant effects for the non-parametric criterion in the E.P.Q. analysis.

There is a similar dearth of significant results for the discrimination index. The interaction of neuroticism, time of day and frequency is significant for both the parametric and non-parametric measures and is very similar in form to the corresponding interaction for the E.P.I. analysis so we will not discuss it here. The main effect for neuroticism is significant for the non-parametric measure with low N subjects showing better discrimination ability overall than high N subjects, but, as for the E.P.I. analysis, the parametric measure does not show this effect at a statistically reliable level.

There are no significant effects for the probability-of-a-hit and probability-of-a-false-alarm measures, but there is one significant result for the speed-of-response-to-signals index. This is the highly significant interaction between neuroticism and time of day. In the morning, high

G21 III- interaction of noise, introversion and neuroticism (EPA) in the non-parametric criterion.



N subjects are faster than low N subjects, whereas the reverse is true in the afternoon. Also, amongst low N subjects, speed of response is greater in the afternoon than in the morning, whereas the reverse is true amongst high N subjects. This is completely in line with prediction and is also corroborated by a similar result for the E.P.I. analysis.

c) Results for behavioural measures (vigilance task) involving time on task and based on E.P.O. scores:

Results for the non-parametric criterion (EPQ):

a) The interaction of block, introversion and time of day, is significant at the 5% level (two tail). As is the associated linear component. See discussion.

Block	Introverts		Extraverts	
	Morning	Afternoon	Morning	Afternoon
1	2.414	2.126	2.501	2.471
2	2.460	2.589	2.721	2.635
3	2.468	2.585	2.758	2.657
4	2.607	2.648	2.785	2.661

Table 555 . The interaction of block, introversion (EPQ) and time of day (TEE).

b) The quadratic component associated with the interaction of noise, block and neuroticism is significant at the 2.5% level (two tail). See discussion.

c) The linear component associated with the interaction of block, introversion, neuroticism and time of day is significant at the 2.5% level (two tail). See discussion.

d) The linear component associated with the interaction between noise, block, introversion, time of day and frequency is significant at the 5% level (two tail). See discussion.

Results for the non-parametric discrimination index

(EPQ):

a) The quadratic component associated with the interaction between block and neuroticism is significant at the 2.5% level (two tail). See discussion.

Block	Low N	High N
1	2.6527	2.5455
2	2.5536	2.3489
3	2.5259	2.3285
4	2.4331	2.3499

Table C56 . The interaction of block and neuroticism (EPQ) - (TDY).

b) The linear component ^{associated} with the interaction between noise, block and neuroticism is significant at the 2.5% level (two tail). See discussion.

Block	No noise		Noise	
	Low N	High N	Low N	High N
1	2.6623	2.4799	2.6432	2.6110
2	2.5034	2.2871	2.6038	2.4107
3	2.4640	2.2997	2.5878	2.3572
4	2.3223	2.3023	2.5440	2.3975

Table C57 . The interaction of noise, block and neuroticism (EPQ) - (TDY).

c) The quadratic component associated with the interaction between block, introversion and neuroticism is significant at the 5% level (two tail). See discussion.

d) The cubic component associated with the interaction between block, introversion and time of day is significant

at the 5% level (two tail). See discussion.

e) The quadratic component associated with the interaction between block, neuroticism and frequency is significant at the 5% level (two tail). See discussion.

Results for the parametric discrimination index (EPO):

a) The quadratic component associated with the interaction between block and neuroticism is significant at the 2.5% level (two tail). See discussion.

b) The linear component associated with the interaction between noise, block and neuroticism is significant at the 5% level (two tail). See discussion.

c) The quadratic component associated with the interaction of block, introversion and neuroticism is significant at the 5% level (two tail). See discussion.

d) The quadratic component associated with the interaction between block, neuroticism and frequency is significant at the 5% level (two tail). See discussion.

e) The quadratic component associated with the interaction between noise, block, neuroticism and time of day is significant at the 5% level (two tail). See discussion.

f) The quadratic component associated with the interaction between noise, block, introversion, time of day and frequency is significant at the 5% level (two tail). See discussion.

Results for the probability of a hit (EPQ):

a) The quadratic component associated with the interaction between block and introversion is significant at the 5% level (two tail).

Block	Introverts	Extraverts
1	2.168	2.164
2	1.888	1.691
3	1.774	1.626
4	1.567	1.579

Table C58 . The interaction of block and introversion (EPQ) - (TPH).

b) The quadratic component associated with the interaction between block and neuroticism is significant at the 2.5% level (two tail). See discussion.

c) The quadratic component associated with the interaction between block, introversion and neuroticism is significant at the 5% level (two tail).

d) The cubic component associated with the interaction between block, introversion and time of day is significant at the 5% level (two tail).

e) The quadratic component associated with the interaction between block, neuroticism and frequency is significant at the 2.5% level (two tail).

f) The quadratic component associated with the interaction between noise, block, neuroticism and frequency is significant at the 5% level (two tail).

g) The linear component associated with the interaction between noise, block and neuroticism is significant at the 5% level (two tail).

Results for the probability of a false alarm (EPQ):

The linear component associated with the interaction between noise, block, introversion and frequency is significant at the 5% level (two tail). See discussion.

Results for the speed of response to signals (EPQ):

a) The quadratic component associated with the interaction between block, neuroticism and time of day is significant at the 2.5% level (two tail). See discussion.

b) The interaction between noise, block, neuroticism and time of day is significant at the 5% level (two tail) and the associated quadratic component is significant at the 1% level (two tail). See discussion.

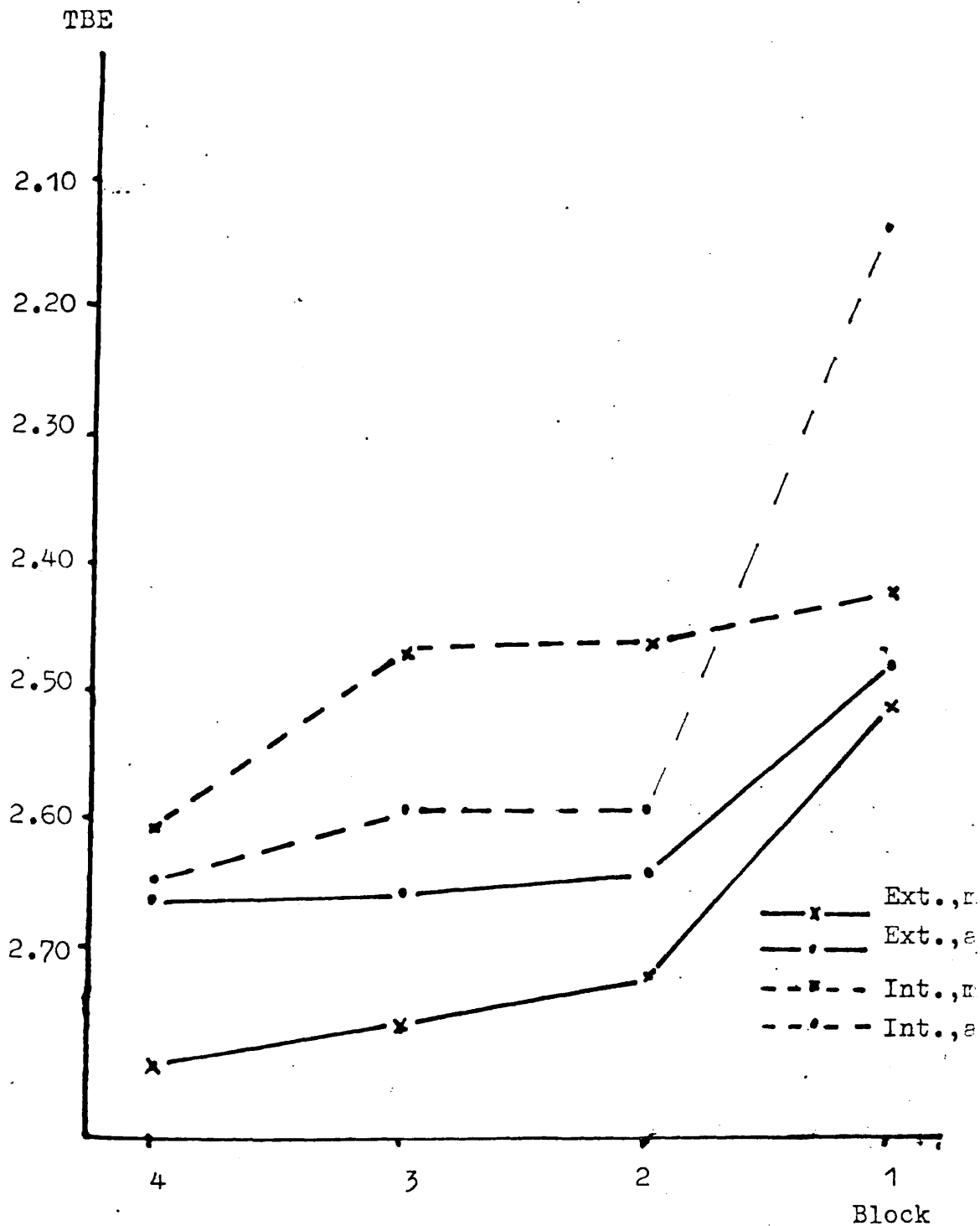
c) The interaction between noise, block, introversion and frequency is significant at the 5% level (two tail). See discussion.

d) Discussion (behavioural measures from vigilance task involving time on task: E.P.Q. scores):

Let us first consider the results for the non-parametric criterion. We have one effect in common with the E.P.I. analysis namely the interaction between block, introversion, neuroticism and time of day and the associated linear component (though the significance levels differ between the analyses). Furthermore the form of the result is very similar in the two analyses though in both cases it is out of line with expectation and not amenable to explanation.

A somewhat more promising effect is perhaps the interaction between block, introversion and time of day (and its linear component) depicted in Graph C19. We see that amongst extroverts, the afternoon curve is higher than the morning curve and declines less steeply, whereas amongst introverts the afternoon curve is higher in block 1 but lower in blocks 2, 3 and 4 than the morning curve, and overall shows a steeper decline. The result is possibly explicable if we assumed that the 'introverts, afternoon' group moved to the right along the inverted 'U' with time and the other groups to the left, with the 'introvert, morning' group operating on portion B and the extrovert groups on portion A. This would be in line with the hypotheses developed earlier. There are certain recalcitrant features of the results though. For instance, the very steep fall between blocks 1 and 2 for the introvert, afternoon group and the very shallow portion of the curve for

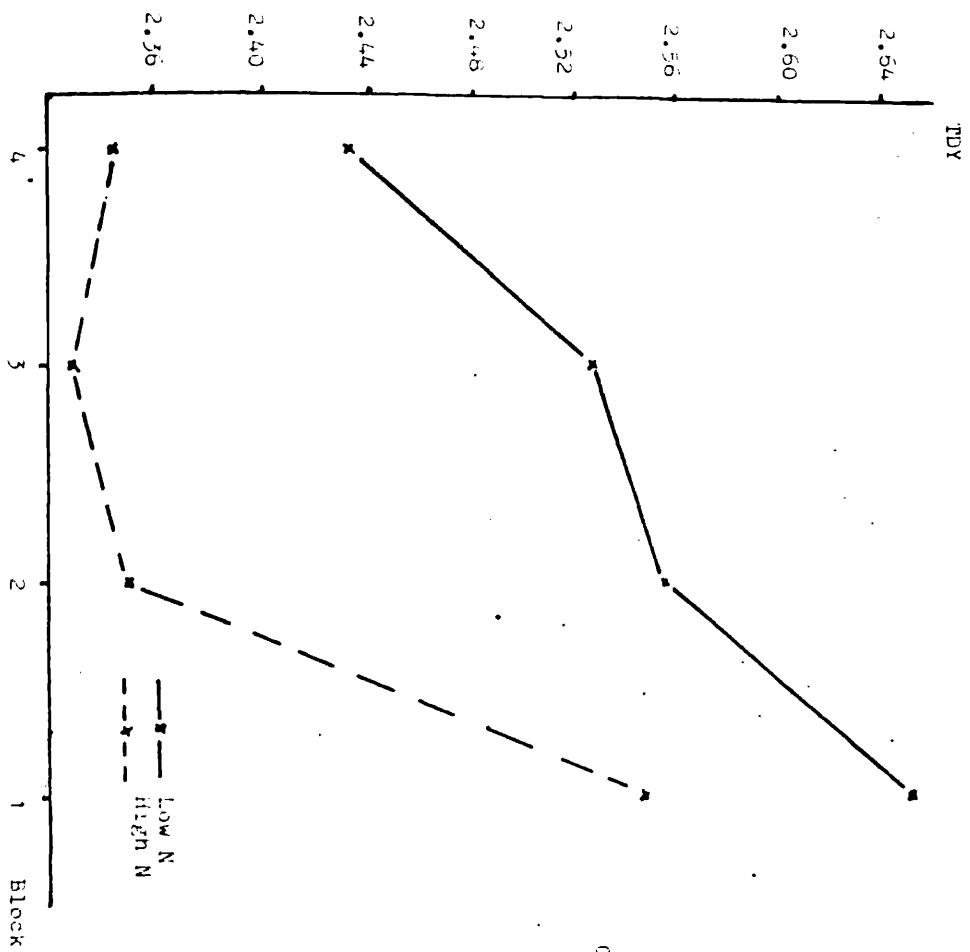
C19 The interaction of block, introversion (EPQ) and time of day in the non-parametric criterion.



the 'extrovert, afternoon' group are both somewhat surprising. The same applies to the height of the 'introvert, afternoon' curve: if one assumed that these subjects were operating on portion D of the inverted 'U' one would have expected the curve to be lower. Of the remaining significant effects, none are in line with the model or explicable so they will not be considered any further.

If we now consider the results for the discrimination index, we find that there are four results which are common to both the parametric and non-parametric measures, (in both cases they are verified at a more stringent level for the latter). The first of these is the quadratic component associated with the interaction between block and neuroticism, depicted in Graph C23 . We see that whilst the low N subjects show a fairly linear decrease with time, the high N subjects show a very sharp fall between blocks 1 and 2 and a much flatter function subsequently. It might be possible to accommodate the present result if we assumed that the high N subjects moved to the right of the inverted 'U' with time and this would be consistent with our hypothesis, if true, but it is of course difficult to substantiate such a claim.

Another effect which appears for both the parametric and non-parametric measures is the linear component associated with the interaction between noise, block and neuroticism. Since the corresponding effect for the E.P.I. analysis was also significant and since the two sets of results are also very similar in form we will not discuss



C20 The interaction of block and neuroplasm(EPC)-FLY.

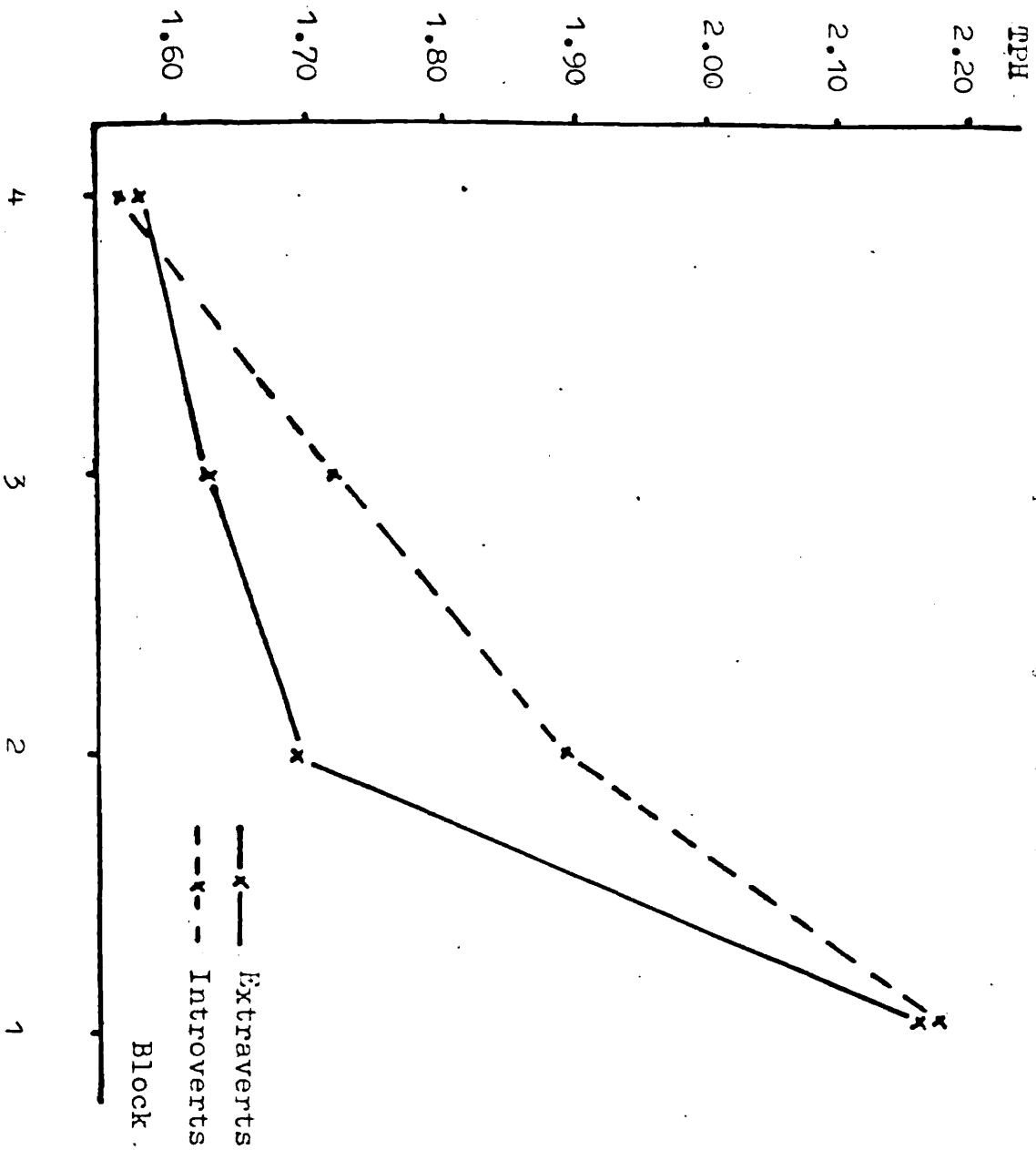
the present finding in detail.

Of the remaining results which are significant for both measures, none have exact counterparts in the E.P.I. analysis nor are they explicable in terms of our present hypotheses and the same applies to the results which are significant for only one measure.

We now come to the results relating to the probability of a hit. Of these, none have their exact counterpart in the E.P.I. analysis, but nearly all of them are associated with corresponding effects for the criterion and for the discrimination index which we have already discussed. There are two exceptions to this, though. The first is the quadratic component associated with the interaction between block and introversion and depicted in Graph (21). This shows that whereas the introverts show a fairly linear decrease with time, the extroverts show an initial sharp decrease followed by a much shallower function. We could suppose that the extroverts were operating on portion A of the inverted 'U' curve, but the fact that the slope of the introvert curve is both less than that of the extrovert curve between blocks 1 and 2 and also at approximately the same level is inexplicable. The second result which is not associated with a corresponding result for a signal detection index is the interaction between noise, block, neuroticism and frequency, but the author has no explanation for this.

There is only one significant effect for the probability of a false alarm measure and that is the linear component associated with the interaction between noise, block,

Q21 The interaction of block A and introversion (IQ) in the probability of a hit.



introversion and frequency. This did not appear in the E.P.I. analysis nor does the author have any adequate explanation for it.

The final measure that we must consider is the speed of response to signals. There is only one effect - the quadratic component associated with the interaction between block, neuroticism and time of day - which is common to both the E.P.Q. and the E.P.I. analysis, and even here the forms of the two results are different. Furthermore, neither this nor any of the other results are in line with the theory or amenable to explanation so we will not consider them further.

3. PSYCHOTICISM ANALYSES

These results are based on analyses which are identical to the previous ones except that the subjects' E.P.Q. P scores were subjected to a bimodal split resulting in a psychoticism factor which was substituted for the introversion and neuroticism factors.

i) Physiological and state measures: results

No significant effects.

ii) Behavioural measures: results

Results relating to overall performance:

No significant effects

Results involving time on task:

The non-parametric criterion:

The interaction of block, psychoticism and frequency is significant at the 5% level (two tail) and the associated linear component is significant at the 0.5% level (two tail). See discussion.

The non-parametric discrimination index:

The linear component associated with the interaction between block and psychoticism is significant at the 2.5% level (two tail). Overall, low P subjects show a steeper decline in discrimination ability between blocks 1 and 4 than high P subjects.

Block	Low P	High P
1	2.5952	2.6030
2	2.4484	2.4540
3	2.4014	2.4530
4	2.3129	2.4702

Table C59 . The interaction of block and psychoticism (TDY).

The parametric discrimination index:

a) The linear component associated with the interaction between block and psychoticism is significant at the 5% level (two tail). Overall, low P subjects show a steeper fall in discrimination ability between block 1 and 4 than high P subjects.

Block	Low P	High P
1	1.835	1.844
2	1.755	1.717
3	1.698	1.735
4	1.613	1.766

Table C60 . The interaction between block and psychoticism (SPR).

b) The quadratic component associated with the interaction between block, psychoticism and frequency is significant at the 2.5% level (two tail). See discussion.

The probability of a hit:

No significant effects.

The probability of a false alarm:

a) The linear component associated with the interaction between block and psychoticism is significant at the 5% level (two tail). Overall, high P subjects show a steeper decline between blocks 1 and 4 than high P subjects.

Block	Low P	High P
1	0.3057	0.3523
2	0.2466	0.2980
3	0.2403	0.2498
4	0.2208	0.2124

Table C61. The interaction of block and psychoticism (TPF).

b) The interaction between block, psychoticism and frequency is significant at the 0.5% level (two tail) and the associated linear component is significant at the 0.5% level (two tail). See discussion.

The speed of response to signals.

a) The interaction between block and psychoticism is significant at the 5% level (two tail) and the associated quadratic component is significant at the 1% level (two tail). In both low and high P groups, speed of response falls between block 1 and block 4, but the fall is steepest between blocks 1 and 2 for low P subjects, and between blocks 3 and 4 for high P subjects.

Block	Low P	High P
1	0.0362	0.0111
2	0.0622	0.0198
3	0.0665	0.0273
4	0.0615	0.0421

Table C62. The interaction between block and psychoticism (LSIG).

b) The linear component associated with the interaction between noise, block, psychoticism and frequency is significant at the 2.5% level (two tail). See discussion.

iii) Discussion:

The only significant effects involving psychoticism that emerge from the vigilance task relate to the time on task measure. There are significant interactions between block, psychoticism and frequency for the non-parametric criterion and the probability of a false alarm, and in both cases the linear components are also significant. The two interactions are fairly similar, but in neither case are they in line with prediction or amenable to adequate explanation. The same applies to the significant quadratic component associated with the interaction between block, psychoticism and frequency for the parametric discrimination index, and the significant linear component associated with the interaction between noise, block, psychoticism and frequency for the speed of response to signals measure.

For both the parametric and non-parametric discrimination indices and also for the probability of a false alarm there is a significant linear component associated with the interaction between block and psychoticism. For d' , low P subjects show a steeper decline than high P subjects. The reverse is true for the false alarm measure. It might be possible to accommodate ^{these} within our present framework, but interactions involving only two factors are of relatively little value when time on task is involved and this is doubly so when psychoticism is also involved, since to show a reversal of the inverted 'U' relationship amongst high P subjects one really requires a minimum of three factors. For the same reason, the significant quadratic component associated with the interaction between block and psychoticism for the speed of response to signals measure is also not very informative.

4. SUMMARIES

Summary of results relating to overall performance

We will now briefly summarise the main conclusions arising out of a consideration of overall measures of performance in the vigilance task. Firstly, we have support for our suggestion (based on the results of state measures) that in the present study, signal frequency moves subjects to the left along the 'X' axis of the inverted 'U', whilst the other determinants (e.g. neuroticism) move subjects to the right. We find that the results for the discrimination index are not in line with this view, and that they also contradict certain other findings, for instance the results of the simple auditory reaction time experiment showing that introversion and neuroticism move subjects in the same direction. However, we suggested that these discrepant results could be due to a dissociation between stimulus duration and the other determinants, and we adduced further evidence to support this view.

We also discovered that in the present task the false alarm measure seemed to have an inverted 'U' relationship with some of the determinants. We suggested that this was due to its association with the criterion measure, and that in situations where it was associated with the discrimination measure, a 'U' shaped relationship could be expected.

One finding which might have some practical significance was the discovery that high level ambient noise resulted in an increase in the overall probability of detection of a signal.

Summary of results involving time on task.

It should be clear that there is some degree of support for our analysis of the effect of time on task and for our suggestion that movement to the right along the 'X' axis of the inverted 'U' due to summation of excitations is more likely to occur when the levels of the other determinants are relatively high. By its very nature, though, this suggestion is most amenable to test when we are considering the conjoint action of several factors (see p. 756), and it must be admitted that in such situations the degree of support for our analysis has been rather equivocal. This is in fact in line with the relative dearth of higher order interactions which are explicable in terms of the inverted 'U' model in the project as a whole.

Conversely, results involving two factors have frequently been consistent with our analysis of time on task. In other areas of the project most of the conclusions we have deduced have been based on such interactions, but where time on task is involved they provide relatively little hard information because we have argued that this factor can move subjects either to the left or to the right of the inverted 'U'. As a result, where only two factors are involved the general model is capable of accommodating all possible outcomes and is, therefore, unfalsifiable. It is only through the higher order interactions that we have a chance to really test the theory with respect to time on task, and as we have seen the results have provided it with only partial support.

It should be noted that there are relatively few significant results for the E.P.Q. analysis, though those that do exist are by and large in line with the E.P.I. analysis and with the above conclusions. One possible reason for this is the fact that because of changes in the subject's neuroticism and extraversion scores, we no longer have exactly eight subjects in each quadrant. As a result some of the interactions which include these variables contain non-orthogonal factors. The Genstat analysis of variance computer package incorporates a correction for such non-orthogonality, but Valentine (personal communication) has pointed out that the chances of obtaining significant results are somewhat smaller with non-orthogonal analyses as compared to orthogonal ones.

Finally, although neuroticism still seems to be the major dimension, the proportion of results, ^{involving introversion} which are consistent with an inverted 'U' interpretation is much higher in the vigilance task than in the earlier experiments, particularly the taste study. This supports our earlier contention that noxious stimuli and novelty will tend to 'favour' neuroticism, possibly through their action on Gray's proposed 'behavioural inhibition system'.

CHAPTER FIFTEEN: THE OPERATIONAL DEFINITION OF 'STRENGTH'

We must now consider the relationship between our results and the operational measure of 'strength' employed in the present project: namely Nebylitsyn's index ($\Sigma t/t_{min}$) of the gradient of the reaction time/intensity curve (see p. 136). Since the analysis of variance described earlier (see p. 544) failed to show any significant effect of accessory stimulation on Nebylitsyn's index it was considered valid to combine the measures obtained from the two noise conditions. The two values obtained for the index under 'no noise' and 'noise' were, therefore, averaged. A bimodal split was then carried out on the resulting values yielding two groups: a 'strong' group (high values) and a 'weak' group (low values). We thus have defined a factor of 'strength' and for each set of results the same analyses of variance were carried out substituting this factor for the variables of introversion and neuroticism.

1. THE TASTE EXPERIMENT

i) Main indices

a) Results

All of the subjects who took part in the taste experiment also took part in the later joint simple reaction time/signal detection task (and, therefore, yielded values for Nebylitsyn's index) except one stable introvert who left college between the two sets of experiments. For this reason, in the analysis of the taste experiment measures, this subject's results were excluded and instead the results for the stable introvert who had been excluded from the analysis based on the subject's introversion and neuroticism scores were substituted. Otherwise the data for the two sets of analyses are identical.

Results for salivation

No significant main effects or interactions involving 'strength'.

Results for magnitude estimation

Session 1

The linear component associated with the interaction between noise, stimulus intensity and 'strength' is significant at the 0.5% level (two tail). See discussion.

Stimulus intensity		1	2	3	4	5
No noise	Weak	2.1517	2.3349	2.5358	2.7416	2.8175
	Strong	2.0879	2.3590	2.5739	2.6737	2.7625
Noise	Weak	2.2292	2.4761	2.6125	2.8144	2.8747
	Strong	1.9720	2.2654	2.5240	2.7458	2.8519

Table D1 The interaction of noise, stimulus intensity and neuroticism.

Session 2

a) The linear component associated with the interaction between stimulus intensity and 'strength' is significant at the 2.5% level (two tail). See discussion.

Stimulus Intensity	1	2	3	4	5
Weak	1.0255	1.1810	1.3535	1.5887	1.7249
Strong	0.9543	1.1380	1.3796	1.6190	1.7933

Table D2. The interaction of stimulus intensity and 'strength' (LME2).

b) The linear component associated with the interaction between noise, stimulus intensity and 'strength' is significant at the 2.5% level (two tail). See discussion.

Results for hedonic tone

Session 1

The linear component associated with the interaction between stimulus intensity and 'strength' is significant at the 2.5% level (two tail). See discussion.

	1	2	3	4	5
Weak	12.64	11.00	10.19	8.64	7.58
Strong	13.32	12.36	10.07	7.29	6.82

Table D3 . The interaction between stimulus intensity and 'strength' (HEDI).

Session 2

The linear component associated with the interaction between stimulus intensity and 'strength' is significant at the 5% level (two tail). See discussion.

	1	2	3	4	5
Weak	13.14	12.63	12.06	10.03	8.25
Strong	13.46	12.55	11.88	9.59	6.54

Table D4. The interaction between stimulus intensity and 'strength' (HED 2).

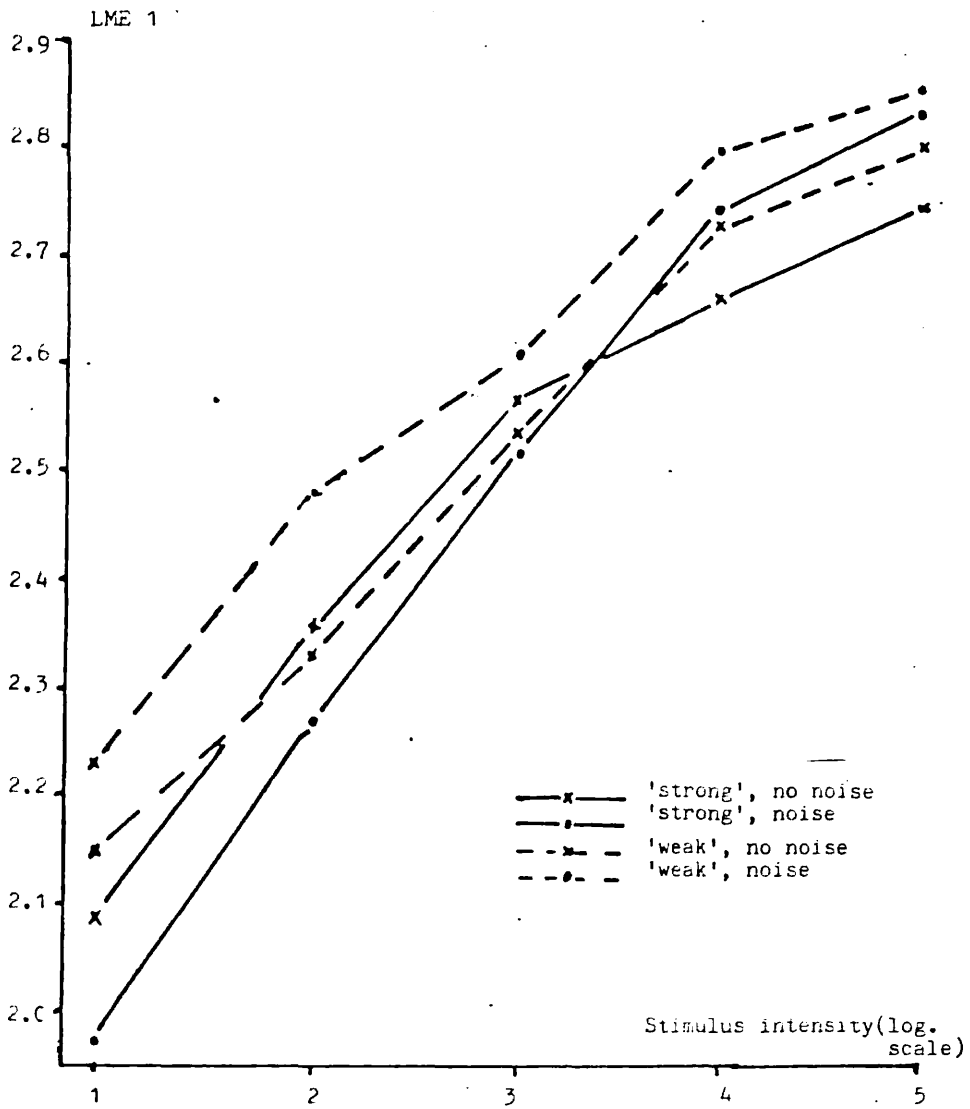
Results for the sensory threshold

No significant effects involving 'strength'.

Discussion of 'strength' results: main indices (taste
experiment)

Since there are no significant results for salivation we will consider only magnitude estimation and hedonic tone. The first effect for magnitude estimation which we must discuss is the interaction between noise, stimulus intensity and 'strength' for which the linear component is significant. This is depicted in Graph D1.

We see that the curve for the 'weak' subjects under noise is higher overall than the other curves, and since there is no evidence of transmarginal inhibition this is what we would expect since the inverted 'U' model predicts that before the T.T.I. is reached subjects operating relatively to the right will have higher values of the determinate than subjects operating relatively to the left. On the assumption that 'weak' subjects are operating further to the right than 'strong' subjects, one would expect the 'weak' subjects under noise to show the highest magnitude estimates at relatively low levels of the determinants. However, it is the linear component of the interaction which is significant and here we find less support for the hypothesis. Under 'noise' the curve for the 'strong' subjects is steeper overall than that of the 'weak' subjects, whereas

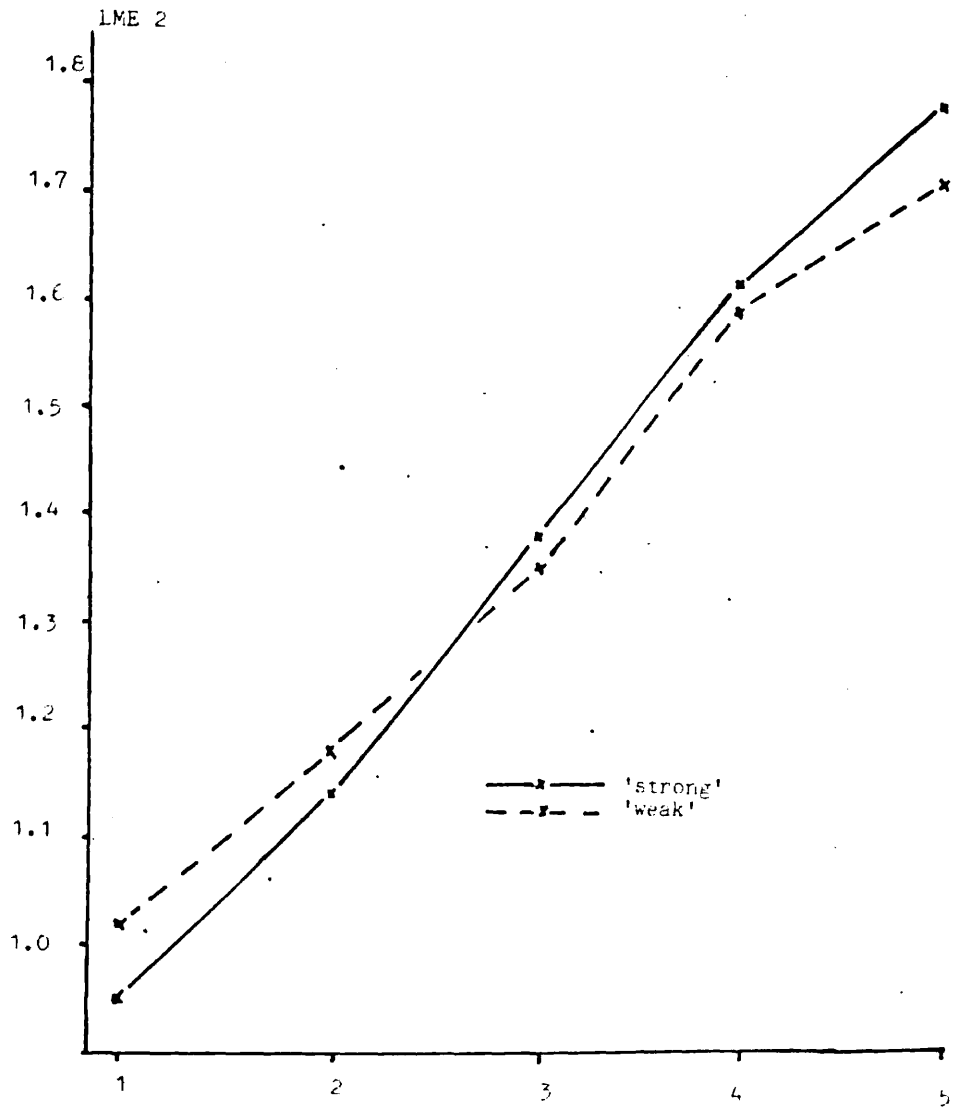


D1 The interaction of noise, stimulus intensity and 'strength' (LME 1)

there is much less of a difference in the slopes of the curves for the two groups under 'no noise'. Also, amongst 'strong' subjects, the curve under 'noise' is steeper than that under 'no noise' whereas there is much less of a difference amongst 'weak' subjects. These relationships are not as predicted and the author has no explanation for them. The corresponding interaction for Session 2 is also significant though it is not in line with prediction, nor is it of the same form as the interaction for Session 1.

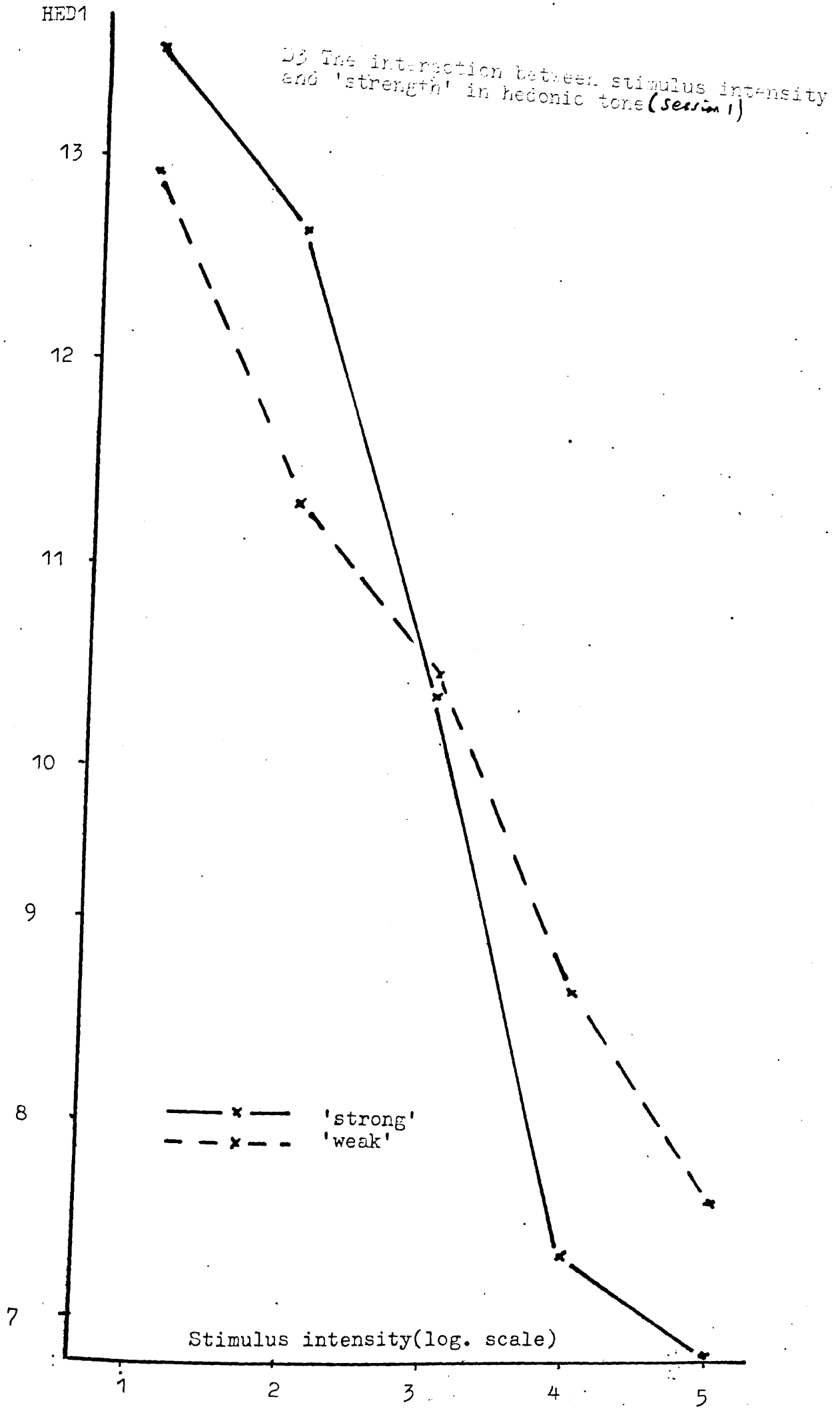
In Session 2, the linear component associated with the interaction between stimulus intensity and 'strength' is also significant, and this is depicted in Graph **D2**. We see that the curve for the 'weak' subjects is shallower than that for the 'strong' subjects, and this would be explicable if we assumed that both groups were operating on portion B of the inverted 'U'. However, the fact that the curves cross despite the absence of transmarginal inhibition effects is not in line with this view, though it is possible that some form of response bias is operating resulting in a shift upwards in the curve for the 'strong' subjects relative to the 'weak' ones. We have seen that 'strong' subjects show a greater tendency to take risks than weak subjects (e.g. Koslowski 1977) and that it is possible that there may be a relationship between this tendency and the tendency to display a positive response bias.

On the other hand the results for hedonic tone suggest rather the opposite, namely that 'weak' subjects may display greater positive response bias than 'strong' subjects and



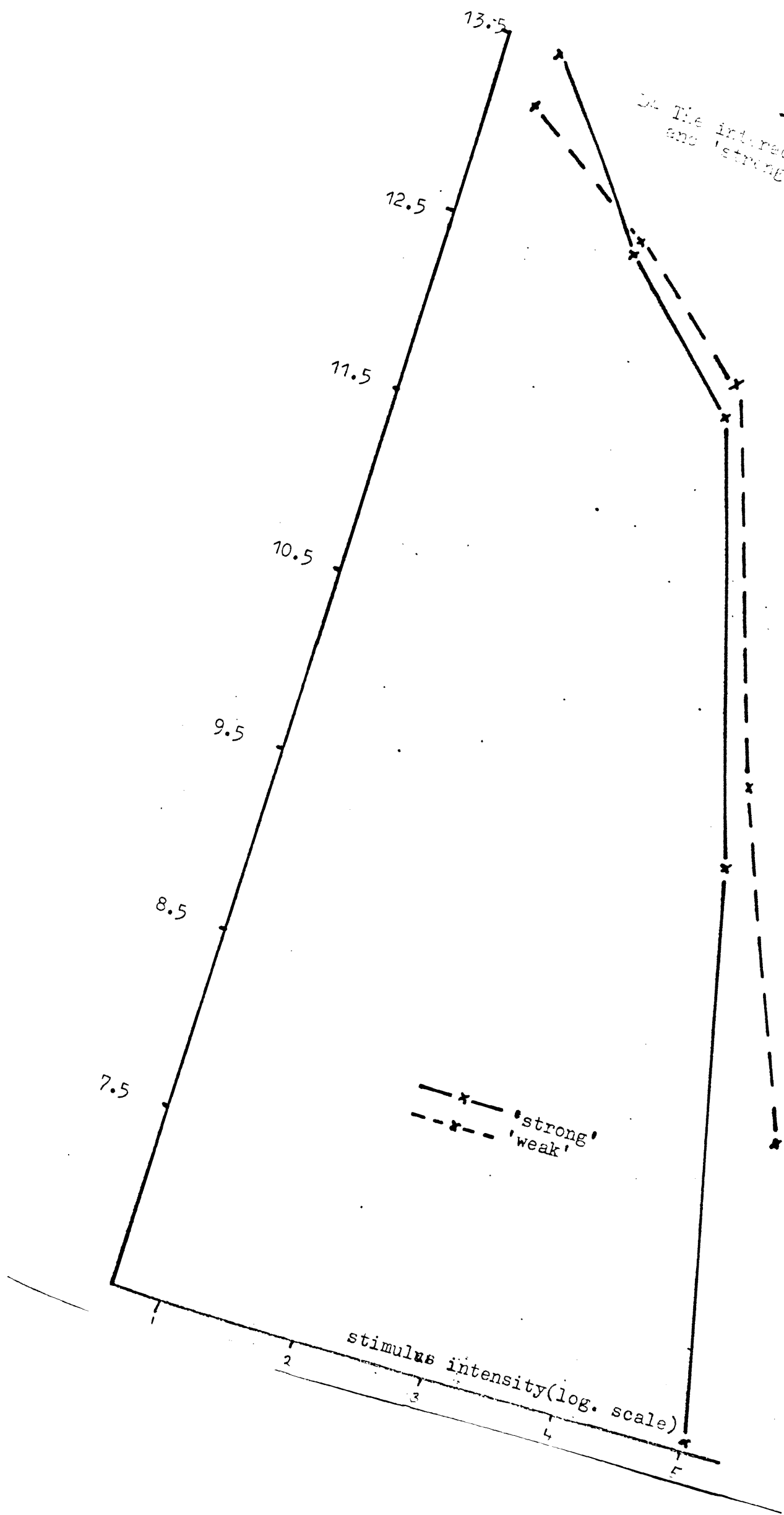
D2 The interaction of stimulus intensity and 'strength'(LME 2)

we saw that this could explain the relationship between 'strength' and the gradient of the reaction time/intensity curve (see p.454). Graph D3 shows that in Session 1, the function relating hedonic tone to stimulus intensity is shallower for the 'weak' subjects than for the 'strong' ones, hence the significant linear component associated with the interaction between stimulus intensity and 'strength'. We might be able to incorporate this into the inverted 'U' model if we assumed that the 'weak' subject's curve was shifted upwards relative to that of the 'strong' subjects due to some form of positive response bias. We will see evidence for such a difference in bias between 'strong' and 'weak' subjects when we come to consider the relationship of 'strength' to vigilance performance, but this evidence is not statistically reliable and in any case the hedonic tone results for Session 2 do not conform to this picture. As Graph D4 shows, although the linear component is again significant there is quite marked evidence of convexity upwards in the curve for 'weak' subjects. So it is unlikely that we could legitimately claim that they were operating further to the right along the 'X' axis of the inverted 'U' than the 'strong' subjects.



974

34 The interaction of stimulus intensity and 'strength' in hedonic tone (session 2)



ii) STATE AND PHYSIOLOGICAL MEASURES

a) Results

Results for heart rate

Session 1

No significant effects involving 'strength'.

Session 2

No significant effects involving 'strength'.

Results for deep core body temperature:

No significant effects involving 'strength'.

Results for pupil diameter:

No significant effects involving strength.

Results for blood pressure:

No significant effects involving 'strength'.

Results for the Nowlis mood adjective checklist:

a) The interaction of noise and strength is significant at the 5% level (one tail) for the activation scale. Amongst 'strong' subjects a higher level of activation is reported under 'noise' than under 'no noise', whereas the reverse is true amongst 'weak' subjects. Also under 'no noise' a higher level of activation is reported by 'weak' subjects than by 'strong' subjects, whereas the reverse is true under 'noise'.

	Weak	Strong
No noise	0.699	0.683
Noise	0.624	0.906

Table D5. The interaction of noise and 'strength' (Activation).

b) The interaction of session and 'strength' is significant at the 5% level (two tail) for the 'startle' scale. Amongst 'strong' subjects a higher degree of startle is reported in Session 1 than in Session 2, whereas the reverse is true amongst 'weak' subjects. Also, in Session 1 a higher degree of startle is reported by 'strong' subjects than by 'weak' subjects, whereas the reverse is true in Session 2.

	Weak	Strong
Session 1	0.134	0.306
Session 2	0.174	0.071

Table 06. The interaction of Session and 'strength' (startle).

Results for Spielberger's state anxiety measure:

No significant effects involving 'strength'.

b) Discussion of 'strength' results: physiological and state measures (taste experiment).

There are no significant effects for the physiological measures or for the Spielberger state anxiety inventory. There are, however, two significant effects involving 'strength' for the scales derived from the Nowlis Mood Adjective checklist. The first of these is the interaction between noise and 'strength' for the activation scale. This is due to the fact that a higher level of activation is reported by 'weak' subjects than by 'strong' subjects under 'no noise', but the positions of the two groups are reversed under 'noise'. Furthermore, 'strong' subjects report a higher level of activation under 'noise' than under 'no noise', whereas the reverse is true for 'weak' subjects. This is completely in line with prediction and supports the Russian model and the assumption that the activation scale provides a measure of the 'excitatory process'.

The remaining interaction is between session and 'strength' for the 'startle' scale. In Session 1 'strong' subjects report a higher degree of 'startle' than 'weak' subjects, but the positions are reversed in Session 2. Moreover, 'strong' subjects report a higher level of startle in Session 1 than in Session 2, whereas the reverse is true for 'weak' subjects. The relationship of the 'startle' scale to a hypothetical construct such as 'arousal' or the 'excitatory process' is perhaps less clear than for the activation scale (for which reason a two tailed test was employed), but if it can be considered to be analogous to

the latter the interaction also provides support for the Russian model.

2. THE SIGNAL DETECTION TASK

i) Results

There were no significant effects involving 'strength' on the non-parametric criterion, the discrimination index (parametric or non-parametric), the probabilities of a hit or a false alarm, or on the reaction time to non-signals.

However, there was a significant interaction between 'strength' and accessory stimulation (5%, one tail) in the reaction time to signals.

Amongst 'strong' subjects speed of response is faster under 'noise' than under 'no noise', whereas the reverse is true amongst 'weak' subjects.

	Weak	Strong
No noise	0.667	0.821
Noise	0.695	0.757

Table 07 The interaction of noise and 'strength' (SIG).

ii) Discussion of results involving 'strength': signal detection task

We see that the results for the reaction time to signals support the view that 'strength' of the nervous system, as defined by Nebylitsyn's index is a determinant. The interaction between 'strength' and noise is significant and isⁱⁿ the predicted direction: amongst 'strong' subjects

speed of response is faster under 'noise' than under 'no noise', whereas the reverse is true amongst 'weak' subjects. The fact that no such effects were found using the reaction time to non-signals is in line with previous findings that the reaction times associated with errors may show different relationships from reaction times associated with correct responses (see Vickers et al 1972). Also the failure to find any significant effects for the other measures derived from the signal detection task is in line with the suggestion made by a number of other authors that reaction time is often a more sensitive index than signal detection variables, the probability of a hit etc. (e.g. Buck 1966; Loeb and Alluisi 1977).

3. THE VIGILANCE TASK

We must now consider the relationship between 'strength', as defined by the slope of the reaction time/intensity curve and the measures derived from the vigilance task. It will be remembered that all of the subjects who had taken part in the latter, had also previously taken part in the joint simple visual reaction time/signal detection task, and, therefore, had yielded measures of the slope of the reaction time/intensity curve.

As before, the average value of this index (as defined by Nebylitsyn) for the 'no noise' and 'noise' conditions was calculated and a bimodal split used to form a 'strong' (high slope) and a 'weak' (low slope) group.

An analysis of variance involving 'strength' (2 levels), frequency (2 levels), time of day (2 levels), accessory stimulation - noise (2 levels), time on task (2 levels in the case of the state and physiological measures - i.e. 'position' - and 4 levels in the case of the behavioural measures - i.e. 'block') and session (2 levels) was, therefore, carried out. The inclusion of the 'session' factor was possible because only one individual differences factor - i.e. 'strength' - was involved so that an adequate number of degrees of freedom were available. However, another problem was encountered. The analysis of variance as described above was unbalanced in that there were some cells which contained no subjects, since the experiment had been designed so as to be balanced with respect to the introversion and neuroticism factors (as defined by the original

E.P.I. scores) and not the 'strength' factor (as defined by Nebylitsyn's index).

For this reason, it was decided to run two separate analyses of variance with one between subjects factor excluded from each. In the first analysis the 'time of day' factor was excluded and in the second the latter was included but the 'frequency' factor was excluded. This made it possible to investigate all possible interactions involving 'strength' except those involving 'strength', 'time of day' and 'frequency'.

In each case we will initially report any results from the first analysis of variance which involve the 'strength' factor, and then any results from the second analysis of variance which involve 'strength' and 'time of day'.

1. STATE AND PHYSIOLOGICAL MEASURES

a) Results

Results involving 'strength' for the state and physiological measures from the vigilance task: overall level (time on task excluded)

Subjective Arcousal

Results of analysis of variance ('time of day' excluded) involving 'strength'.

a) The interaction of noise, 'strength' and frequency is significant at the 5% level (two tail). See discussion.

	'Weak'		'Strong'	
	low frequency	high frequency	low frequency	high frequency
No noise	1.732	1.979	1.163	0.967
Noise	1.998	1.635	0.610	1.344

Table D8. The interaction of noise, 'strength' and frequency (TAPOUSAL).

b) The main effect for 'strength' is significant at the 2.5% level (two tail). Overall, 'weak' subjects report a higher level of 'arcousal' than 'strong' subjects.

Weak	Strong
1.846	1.031

Table D9. The main effect for 'strength' (TARCUSAL).

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

No significant effects.

Subjective stress:

No significant effects involving 'strength' for either analysis variance.

State anxiety:

No significant effects involving 'strength' for either analysis of variance.

Deep core body temperature:

Results of analysis of variance ('time of day' excluded) involving 'strength':

No significant effects.

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

The interaction of 'strength' and time of day is significant at the 5% level (one tail). In the morning, 'weak' subjects have a higher body temperature than 'strong' subjects whereas the reverse is true in the afternoon. Also, amongst 'weak' subjects body temperature is higher in the morning than in the afternoon, whereas the reverse is true for 'strong' subjects.

	Morning	Afternoon
Weak	36.227	36.107
Strong	35.950	36.506

Table 910. The interaction of 'strength' and time of day
(TEMP).

Results involving 'strength' for the state and physiological measures from the vigilance task: the effect of time on task.

Subjective 'arousal':

Results of analysis of variance ('time of day' excluded) involving 'strength':

No significant effects.

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

The interaction of position, 'strength' and time of day is significant at the 2.5% level (two tail). See discussion.

Position	Weak		Strong	
	Morning	Afternoon	Morning	Afternoon
Before	2.191	1.853	0.943	1.776
After	1.728	1.776	0.695	9.873

Table DII . The interaction of position, 'strength' and time of day (AROUSAL).

Subjective 'stress':

No significant effects for either analysis of variance.

State anxiety:

No significant effects for either analysis of variance.

Deep core body temperature:

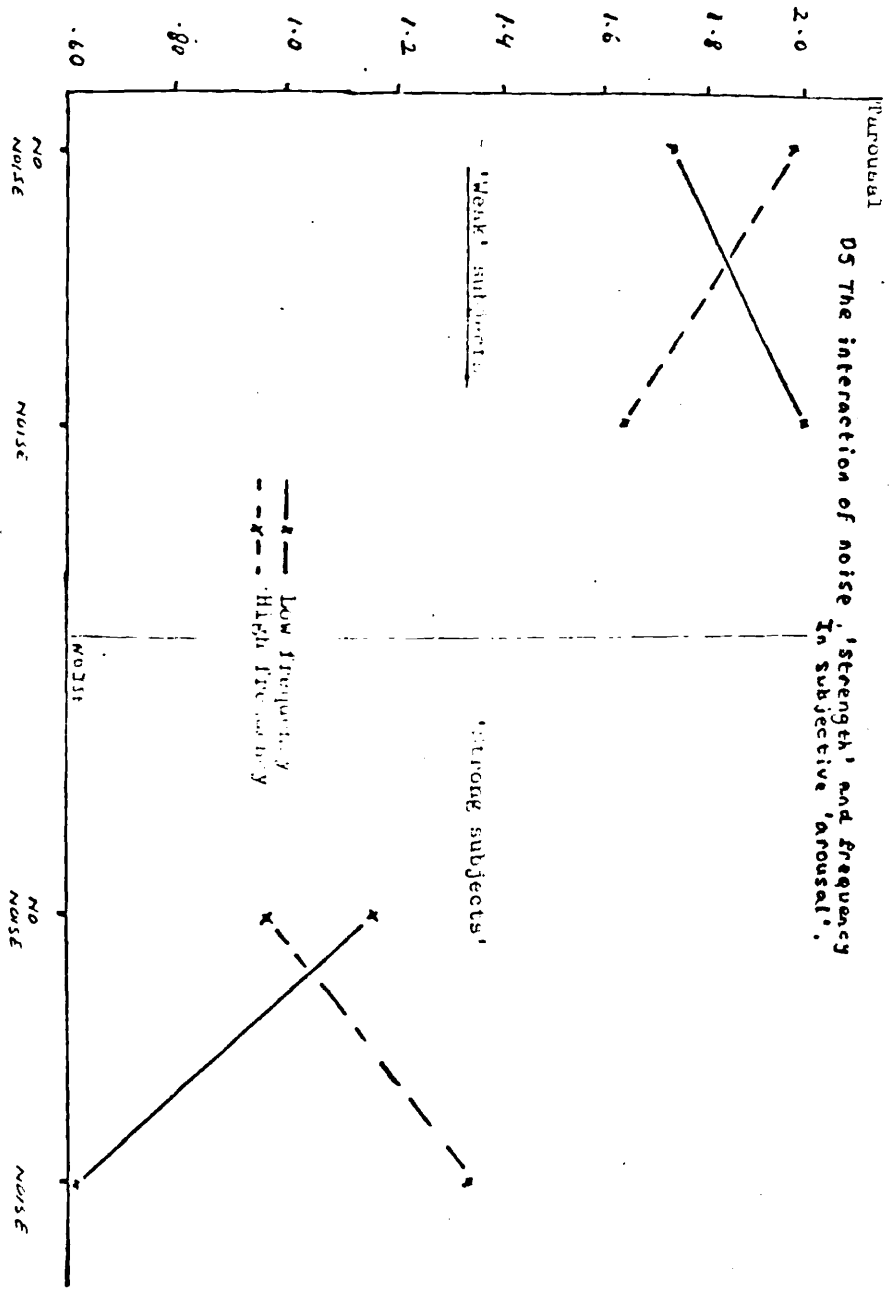
No significant effects for either analysis of variance.

b) Discussion

Discussion of state and physiological measures with respect to the overall level of 'performance':

The only significant effects not involving time on task for the state indices relate to the subjective 'arousal' measure. The interaction between noise, 'strength' and frequency is reliable at the 5% level and is depicted in Graph D5. We see that amongst 'weak' subjects a higher level of 'arousal' is reported under 'noise' than under 'no noise' at low frequency, but the reverse is true at high frequency. This by itself would be in line with the original predictions we made, but it is out of line with the suggestion made earlier that signal frequency moves subjects to the left along the 'X' axis of the inverted 'U'. It will be remembered that this viewpoint was based on the subjective 'arousal' measure, but also ^{on} a number of other measures and that this fact countered the possible objection that the reliability of the results for the 'arousal' measure were suspect due to the residual skewedness of the data values. In this instance, however, it is possible that this may account for the surprising nature of the present interaction, especially if we consider the 'strong' and 'weak' subjects together. This is because the relationships in the 'strong' group are exactly opposite to those in the 'weak' group (hence the interaction) and this is not explainable on the basis of our model whether we assume that signal frequency moves subjects to the left or to the right.

The main effect for 'strength' is also significant but this time at the 2.5% level, so that it is likely that



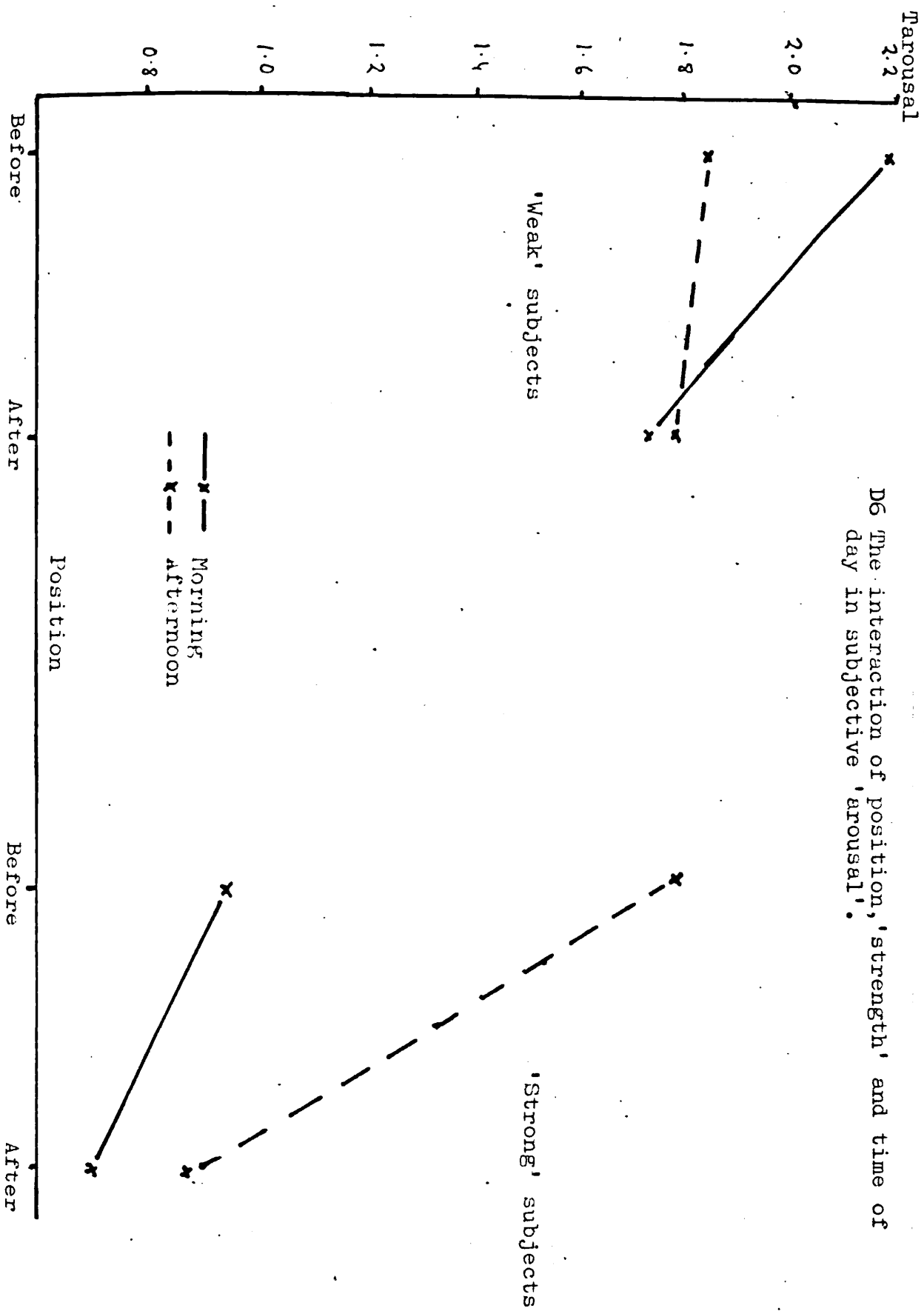
it represents a genuine result and not a false positive. It is due to the fact that, overall, 'weak' subjects report a higher level of 'arousal' than 'strong' subjects. This by itself would provide strong support for the Western model, which argues that there is a linear positive relationship between the determinants and 'arousal', and for the view that 'weak' subjects are operating further along the 'X' axis of the function depicting this relationship than 'strong' subjects. However, the results for the 'arousal' measure based on the introversion and neuroticism scores of the subjects did suggest that it was the Russian model which was applicable. Therefore, though, it is true that there are no interactions relating to overall performance involving 'strength' which support this interpretation, the exact meaning of the main effect for 'strength' must remain somewhat doubtful.

There is one significant effect for the deep core body temperature measure. This is the interaction between 'strength' and time of day. In the morning, 'weak' subjects have a higher body temperature than 'strong' subjects whereas the reverse is true in the afternoon. Also, amongst 'weak' subjects body temperature is higher in the morning than in the afternoon, whereas the reverse is true for 'strong' subjects. This is completely in line with prediction and supports the Russian model and the view that body temperature may be an index of the 'excitatory process'.

Discussion of state and physiological measures: the effect of time on task.

The only significant effect involving time on task and 'strength' is the interaction between position, 'strength' and time of day for the subjective 'arousal' measure. Graph D6 shows that in 'strong' subjects, 'arousal' falls more steeply between the beginning and the end of the task in the afternoon than in the morning, whereas the reverse is true amongst 'weak' subjects. We could accommodate these findings very nicely if we assumed that time on task moved all subjects to the left and that the 'weak' subjects in the afternoon are operating on portion 'B' whilst the 'strong' subjects in the morning are operating on portion 'A'. The other two groups could be considered to lie somewhere on the steep portion of the inverted 'U' curve which encompasses the boundary between portions 'A' and 'B'. The problem with this view is that the 'weak' subjects show a lower level of 'arousal' initially in the afternoon than in the morning. We could meet this difficulty, however, if we assumed that the 'weak' subjects were operating beyond the T.T.I. in the afternoon and that time on task moved them to the right - i.e. further beyond this threshold. If true then this would be very much in line with the hypotheses we developed earlier since it is this group in which summation of excitation is most likely to occur.

D6 The interaction of position, 'strength' and time of day in subjective 'arousal'.



ii) BEHAVIOURAL MEASURES (OVERALL PERFORMANCE)

a) Results involving 'strength' for the behavioural measures from the vigilance task: the overall level of performance (time on task excluded).

The non-parametric criterion:

Results of analysis of variance ('time of day' excluded) involving 'strength':

No significant effects.

Results of analysis of variance ('frequency' excluded) involving 'strength' and 'time of day':

No significant effects.

The non-parametric discrimination index:

Results of analysis of variance ('time of day' excluded) involving 'strength':

No significant effects.

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day.

No significant effects.

The parametric discrimination index.

Results of analysis of variance ('time of day' excluded) involving 'strength':

The interaction of session and 'strength' is significant at the 5% level (one tail). In Session 1, 'strong' subjects display a higher discrimination ability than 'weak' subjects, whereas the reverse is true in Session 2.

	Weak	Strong
Session 1	1.589	1.701
Session 2	1.881	1.811

Table 012. The interaction of session and 'strength' (SPR).

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

No significant effects.

Probability of a hit:

Results of analysis of variance ('time of day' excluded) involving 'strength'.

The interaction of 'strength' and frequency is significant at the 2.5% level (two tail). At low frequency, 'strong' subjects were more likely to detect signals than 'weak' subjects, whereas the reverse was true at high frequency. Also, 'weak' subjects had a higher probability of detecting signals at high frequency than at low frequency, whereas the reverse was true for 'strong' subjects.

	low frequency	high frequency
Weak	1.685	2.099
Strong	1.916	1.618

Table 013 The interaction of 'strength' and frequency (TPH).

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

No significant effects.

The probability of a false alarm:

No significant effects for either analysis of variance.

Speed of response to signals.

Results of analysis of variance ('time of day' excluded) involving 'strength':

The interaction of session, 'strength' and frequency is significant at the 2.5% level (two tail).

	Weak		Strong	
	low frequency	high frequency	low frequency	high frequency
Session 1	0.0737	-0.0031	0.0615	0.0310
Session 2	0.1016	-0.0005	0.0329	0.0407

Table 017. The interaction of session, 'strength' and frequency (LSIG).

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

No significant effects.

b) Discussion of behavioural measures: the overall level of performance

There are no significant effects involving 'strength' for the criterion measure which relate to the overall performance level, but the interaction between session and 'strength' is significant for the parametric discrimination index, (at the 5% level). This is due to the fact that in session 1, 'strong' subjects show greater discrimination ability than 'weak' subjects, whereas the reverse is true in session 2. This is very much in line with prediction.

If we now consider the results for the probability of a hit and of a false alarm we find that the only significant effects that can be found relate to the first of the two measures: namely the probability of a hit. The most striking finding in this connection is the highly significant interaction between 'strength' and frequency. 'Weak' subjects display a higher probability of detecting signals at high frequency than at low frequency, whereas the reverse is true for 'strong' subjects. Also, at low frequency, 'strong' subjects were more likely to detect signals than 'weak' subjects whereas the reverse is true at high frequency. This result is completely in line with the view that in the present experiment signal frequency moves subjects to the left along the 'X' axis of the inverted 'U', and that increasing 'weakness' of the nervous system moves subjects to the right.

There are two other interactions which also support the latter conclusion. The first is between noise and 'strength' and is based on the sizes of differences between conditions. 'Weak' subjects are more likely to detect signals than

'strong' subjects, but the difference is greater under 'no noise' than under 'noise'. Also, more signals were detected under 'noise' than under 'no noise' but the difference is greater for 'strong' subjects than for 'weak' subjects. This result can be explained if we assume that all groups are operating on portion 'B' of the inverted 'U' and that differences between groups presumed to be operating further to the right will be smaller than differences between groups presumed to be operating further to the left.

The second interaction between session and 'strength' - on the other hand, is based on the direction of differences between conditions. 'Weak' subjects are more likely to detect signals in session 2 than in session 1, whereas the reverse is true for 'strong' subjects.

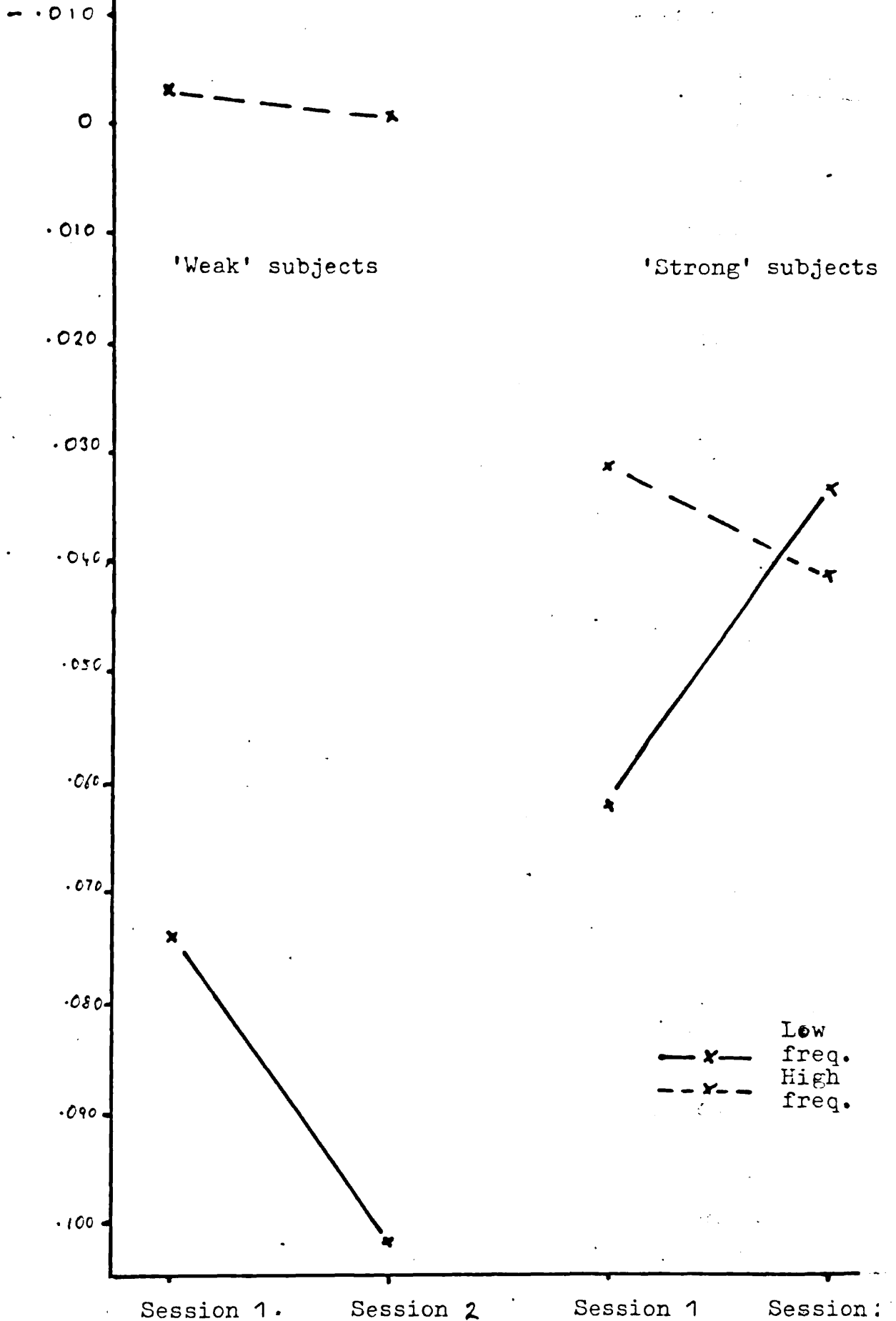
This too is in line with prediction.

There is only one significant effect for the speed of response to signals, relating to the overall level of performance and that is the interaction between session, 'strength' and frequency, depicted in Graph D7. Amongst 'weak' subjects and amongst 'strong' subjects at high frequency, speed of response is greater in session 1 than in session 2, whereas the reverse is true for 'strong' subjects at low frequency. Also, speed of response is greater at high frequency than at low frequency amongst 'weak' subjects and amongst 'strong' subjects in session 1, but the reverse is true for 'strong' subjects in session 2.

These relationships are not in line with expectation and the author has no explanation for them.

Lscore

D7 The interaction of session, 'strength' and frequency in the speed of response to signals.



iii) BEHAVIOURAL MEASURES (TIME ON TASK)

a) Results involving 'strength' for behavioural measures:
the effect of time on task.

Non-parametric criterion.

Results of analysis of variance ('time of day' excluded) involving 'strength'.

a) The quadratic component associated with the interaction between block and 'strength' is significant at the 5% level (two tail). 'Strong' subjects show a fairly linear decrease in tendency to respond with time on task whereas 'weak' subjects show a sharp fall from block 1 to 2 and thereafter a much smaller and more erratic fall.

Block	1	2	3	4
'Weak'	2.210	2.354	2.530	2.580
'Strong'	2.546	2.648	2.704	2.772

Table *DIS* . The interaction of block and 'strength' (TBE).

b) The linear component associated with the interaction between block, 'strength' and frequency is significant at the 2.5% level (two tail). See discussion.

Block	'Weak'		'Strong'	
	low frequency	high frequency	low frequency	high frequency
1	2.287	2.104	2.391	2.671
2	2.541	2.549	2.479	2.798
3	2.528	2.517	2.575	2.818
4	2.508	2.648	2.672	2.869

Table *016* . The interaction of block, 'strength' and frequency (TBE).

c) The interaction of block, session, 'strength' and frequency is significant at the 2.5% level (two tail) and the associated linear and quadratic coefficients are significant at the 5% level (two tail). See discussion.

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

No significant effects.

The non-parametric discrimination index.

Results of analysis of variance ('time of day' excluded) involving 'strength':

The quadratic component associated with the interaction between block, 'strength' and frequency is significant at the 5% level (two tail). See discussion.

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

No significant effects.

The parametric discrimination index.

Results of analysis of variance ('time of day' excluded) involving 'strength':

No significant effects.

Results of analysis of variance ('frequency' excluded) involving 'strength':

No significant effects.

The probability of a hit

Results of analysis of variance ('time of day' excluded) involving 'strength':

The quadratic component associated with the interaction between block, 'strength' and frequency is significant at the 5% level (two tail). See discussion.

Block	'Weak'		'Strong'	
	low frequency	high frequency	low frequency	high frequency
1	2.166	2.387	2.203	1.966
2	1.529	2.116	2.018	1.619
3	1.534	2.049	1.828	1.496
4	1.510	1.847	1.617	1.389

Table D17 The interaction between block, 'strength' and frequency (TPH).

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day.

No significant effects

Probability of a false alarm.

Results of analysis of variance ('time of day' excluded) involving 'strength'.

The linear component associated with the interaction between block and 'strength' is significant at the 2.5% level (two tail). The probability of a false alarm, declines more steeply in 'weak' subjects than in 'strong' subjects.

	'Weak'	'Strong'
Block		
1	0.3976	0.2605
2	0.3107	0.2339
3	0.2783	0.2118
4	0.2405	0.1926

Table 018. The interaction between block and 'strength' (TPF).

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

No significant effects.

Speed of response to signals

Results of analysis of variance ('time of day' excluded) involving 'strength':

a) The interaction of block, session and 'strength' is significant at the 0.1% level (two tail) and the associated linear, quadratic and cubic components are significant at the 2.5%, 1% and 2.5% levels, respectively (two tail). See discussion.

b) The linear component associated with the interaction between noise, block, 'strength' and frequency is significant at the 2.5% level (two tail). See discussion.

c) The interaction between block, session, 'strength' and frequency is significant at the 0.1% level (two tail) and the quadratic and cubic components are significant at the 0.5% and 1% levels respectively (two tail).

Results of analysis of variance ('frequency' excluded) involving 'strength' and time of day:

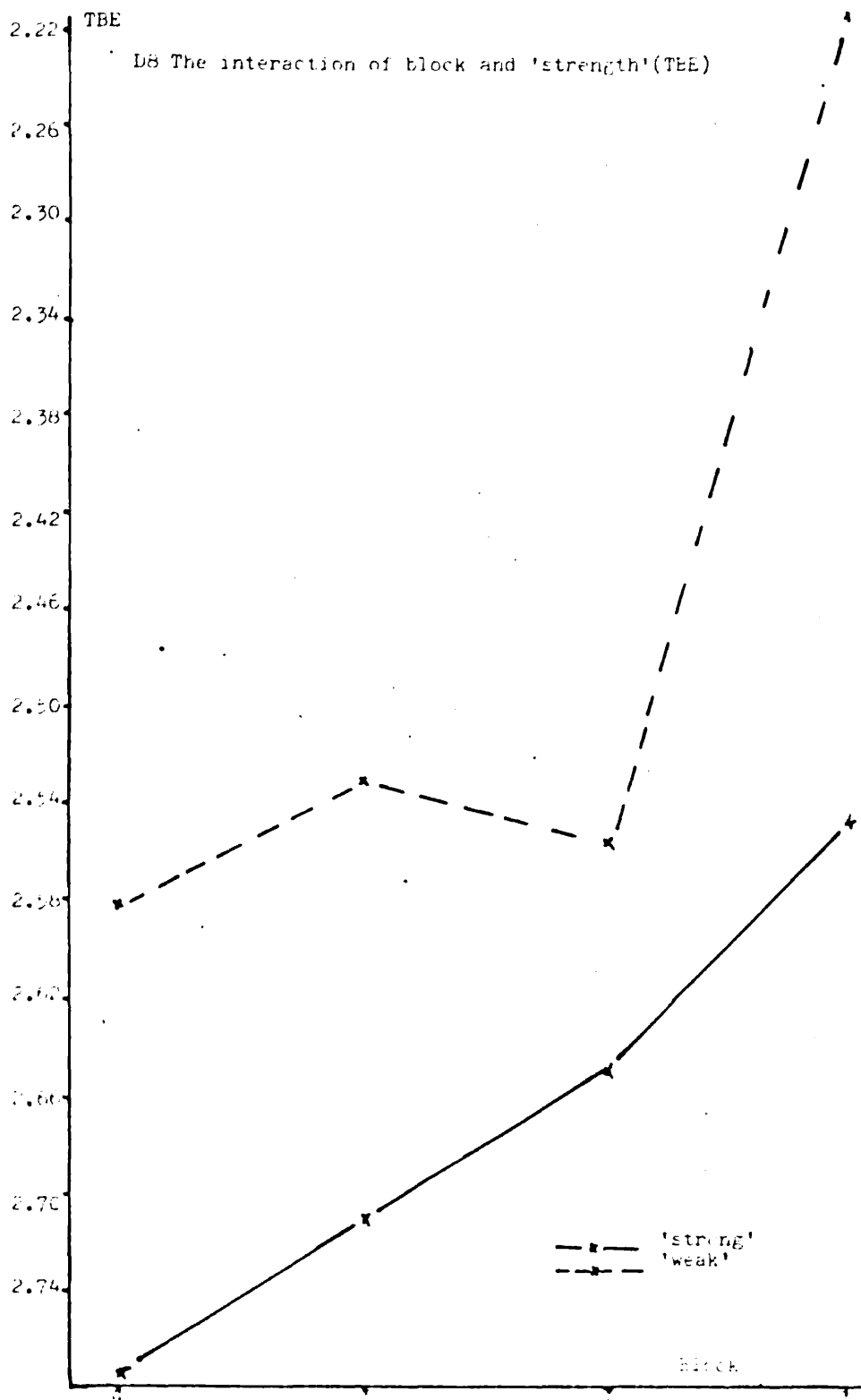
a) The cubic component associated with the interaction between block, 'strength' and time of day is significant at the 5% level (two tail). See discussion.

b) The interaction between block, session, 'strength' and time of day is significant at the 2.5% level (two tail) and the associated linear component is significant at the 5% level (two tail). See discussion.

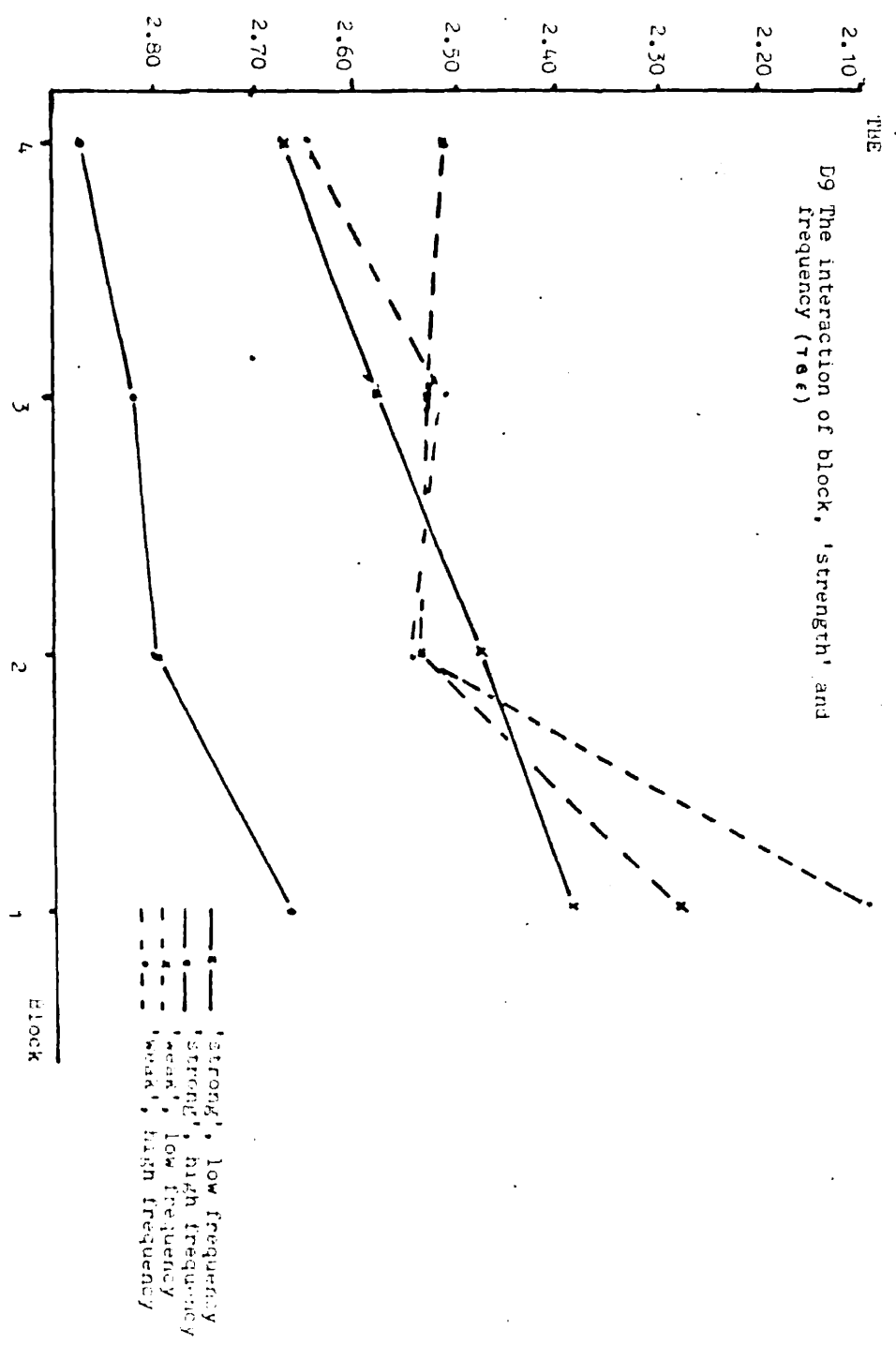
b) Discussion of results involving 'strength' for behavioural measures: the effect of time on task.

As before we will first consider the non-parametric criterion. The quadratic component associated with the interaction between block and 'strength' is significant and this is depicted in Graph D². The 'weak' subjects show a sharp decline in tendency to respond between the first and the second blocks and thereafter a slight increase followed by a slight decrease. The 'strong' subjects on the other hand show a fairly linear decrease in tendency to respond with time. It might be possible to accommodate the finding within the general model if we considered the shapes of the curves alone. We could suggest that the 'weak' subjects move to the right with time on task, whereas the 'strong' subjects move to the left, for instance. However, the relative heights of the two curves do not fit in with this view. They are, however, interesting from another point of view. The fact that the 'strong' curve overall is lower than the 'weak' curve fits in with the suggestion made elsewhere that 'strong' subjects may adopt a higher criterion than 'weak' subjects (see p. 454), and this is reflected in the main effect for 'strength', as well, which is in the predicted direction though it is not significant.

The linear component associated with the interaction between block, 'strength' and frequency is also significant and is depicted in Graph D¹. We see that at high frequency 'weak' subjects show a greater decline with time than 'strong' subjects, though this could be due simply to the law of initial values. The same cannot be said though for the



D9 The interaction of block, 'strength' and frequency (T₆ε)



result at low frequency which is the reverse and which is in line with previous suggestions that 'strong' subjects show a greater rate of habituation than 'weak' subjects (e.g. see Gray 1964). We also find that amongst 'strong' subjects, the rate of decline is greater at low frequency than at high frequency. Again this could be due to the law of initial values, and the fact that the curve for the low frequency condition is higher than that for the high frequency condition right from the start, is perhaps, explicable in terms of greater habituation in the latter condition during the pre-task period. We have already suggested that such a difference may be apparent in the present study between the two frequency conditions, and it could also explain why amongst 'weak' subjects, a greater decline is found at high frequency than at low frequency.

All in all then, the present result is in many ways in line with previous findings and the ideas we have developed earlier, though in terms of the general model there are some discrepancies - for instance, the very flat curve for the 'weak' subjects at low frequency between blocks 2 and 4.

There is one other significant effect and that is the interaction between block, session, 'strength' and frequency and its associated linear and quadratic components. However, this result is not in line with our hypothesis and the author has no explanation for it so it will not be considered further.

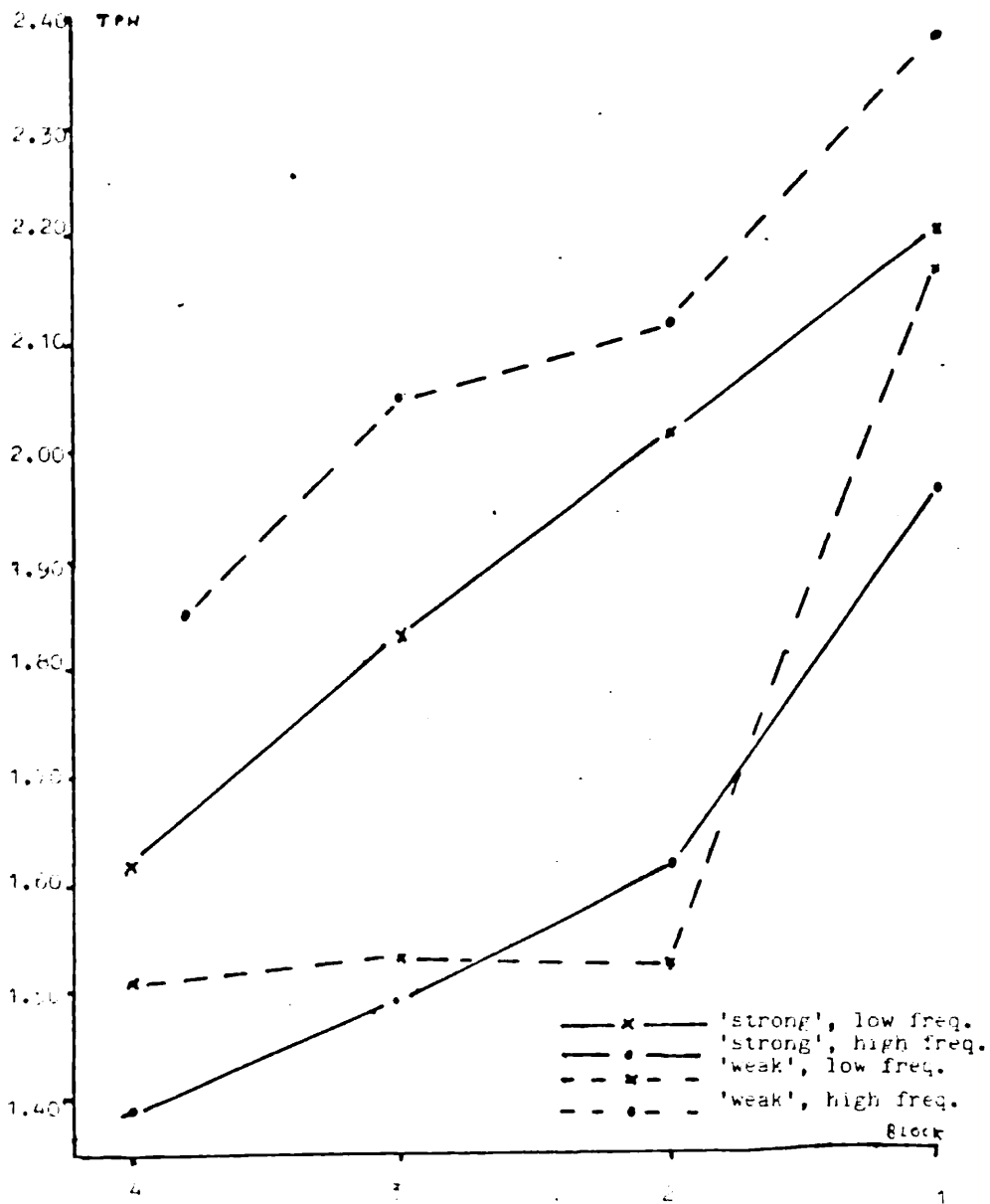
When we come to the results for the discrimination index we find that there is only one significant effect involving both time on task and 'strength'. This is the

quadratic component associated with the interaction between block, 'strength' and frequency for the non-parametric measure. The author has no explanation for this result and since the effect for the parametric measure is not significant, but the corresponding interaction for the criterion is significant it is possible that the result is an artefact.

The only significant effect for the probability of a hit measure is the quadratic component associated with the interaction between block, 'strength' and frequency which is depicted in Graph D10. We see that amongst 'strong' subjects there is a greater degree of upward concavity in the high frequency curve than in the low frequency curve, whereas the reverse is true amongst 'weak' subjects. Also, at low frequency the curve for 'weak' subjects shows much greater concavity than the corresponding curve for 'strong' subjects, whereas the reverse is true at high frequency, though in the latter case the difference is slight. It would be possible to accommodate the present findings if we assume that with time on task all subjects move to the left along the 'X' axis of the inverted 'U' except the 'weak' subjects at low frequency who begin beyond their T.T.I. and are moved further beyond it with time. The very flat portion of their curve between blocks 2 and 4 would then correspond to portion 'D' of the inverted 'U'.

This might seem very implausible but if we remember the earlier suggestion that in the present experiment habituation occurs to a lesser extent at low frequency than at high frequency then one might expect movement to the right to be most likely to occur in the 'weak', low frequency

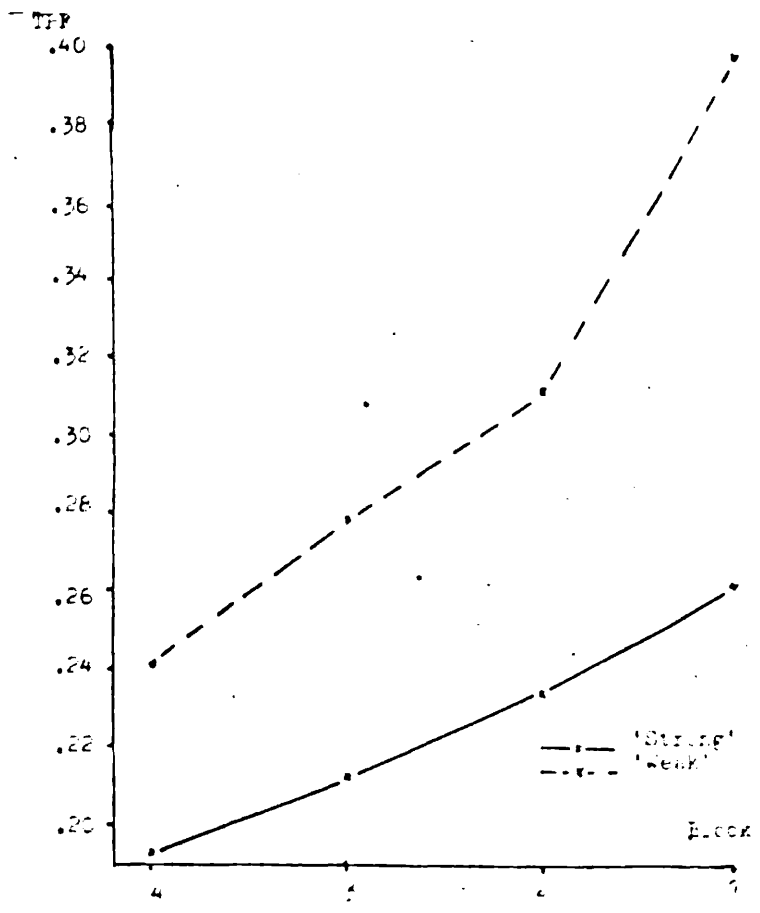
D10 The interaction of block, 'strength' and frequency (TPH)



group. Furthermore, the relative positions of the other groups would also be explicable on this basis since the 'strong', high frequency group would be expected to be operating furthest to the left along the 'X' axis of the inverted 'U' whereas the other two groups would be expected to occupy intermediate positions.

There is only one significant effect for the probability of a false alarm which involves 'strength' and time on task. This is the linear component associated with the interaction between block and 'strength' which is depicted in Graph 21. It is clear that 'weak' subjects show a greater decline than the 'strong' subjects but it is also clear that this could be due to the law of initial values since overall the curve for the 'strong' subjects is lower than for the 'weak' ones. We could accommodate the findings quite easily if we assumed that both groups are operating on portion 'A' of the inverted 'U' and that both groups move to the left with time on task.

There are a number of significant effects involving both 'strength' and time on task for the speed-of-response-to-signals measure, but they will not be considered here since none of them conform to expectation and the author has no explanation for them.



D41 The interaction between block and 'strength' in the probability of a false alarm.

4. Summary:

The results that we have presented do provide some degree of support for the hypothesis that the gradient of the reaction time/stimulus intensity curve can be used to define a factor of 'strength' and that this factor moves subjects to the left along the 'x' axis of the inverted 'U' resulting in predictable interactions with the other proposed determinants. However, it should also be clear that the number of results on which such a conclusion can be based is relatively small.

There are two fairly obvious reasons why this might be so. Firstly, the phenomenon of 'partial properties' (see p. 96) can explain why there are so few significant results involving 'strength' for the taste experiment since this was conducted in the gustatory modality, whereas the gradient of the reaction time/intensity curve was based on measurements in the visual modality. In line with this view is the fact that the interaction in the taste experiment results, which provides the clearest support for our hypotheses with respect to 'strength' relates to a measure of the general 'state' of the individual, and is not modality specific - i.e. the interaction between noise and 'strength' for the activation scale of the Nowlis Mood Adjective Checklist.

A second possible reason why so few results were obtained from the taste experiment is that this was widely separated in time from the simple visual reaction time task from which the operational measure of 'strength' was derived. Although this measure was designed as an index of 'temperament', which is regarded as a fairly fixed and stable

characteristic of the individual, it is recognised in the Soviet Union (e.g. Nebylitsyn 1972) that laboratory indices of temperament are subject to changes within the nervous system that take place over both a short time scale (e.g. seconds and minutes) and a long one (e.g. months and years).

If these two factors are relevant here, then one would expect that the vigilance task would yield more significant and explicable results involving 'strength' than the taste experiment, because although it too was widely separated in time from the simple visual reaction time task, it was at least conducted in the same sensory modality as the latter. This is in fact exactly what we find. There are several interactions in the results of the vigilance task data which support our hypothesis with respect to 'strength' and, moreover, these are not confined to non-modality-specific measures of the general 'state' of the organism.

However, if what we have said above is true we would expect the signal detection task to have shown the largest number of significant and explicable effects involving 'strength' since it was conducted in the same modality as the simple visual reaction time task, at almost exactly the same time and under almost exactly the same conditions. In fact, there is only one significant interaction from the signal detection task which provides support for our hypothesis, and that is the interaction between noise and 'strength' in the speed of response to signals. We have already discussed elsewhere certain inevitable differences that did exist between the simple visual reaction time and signal detection tasks and it is in addition possible that short term changes of

the kind referred to by Nebylitsyn may have obscured the relationship between the two tasks. Nevertheless, if so, it is not clear why these factors should have had such a marked effect.

One possible explanation for the dearth of significant results overall is the fact that, like the E.P.Q. analysis, non-orthogonal analyses of variance had to be employed and we have seen that this somewhat reduces the chance of obtaining significant F ratios.

CHAPTER SIXTEEN:

SUMMARY AND CONCLUDING COMMENTS

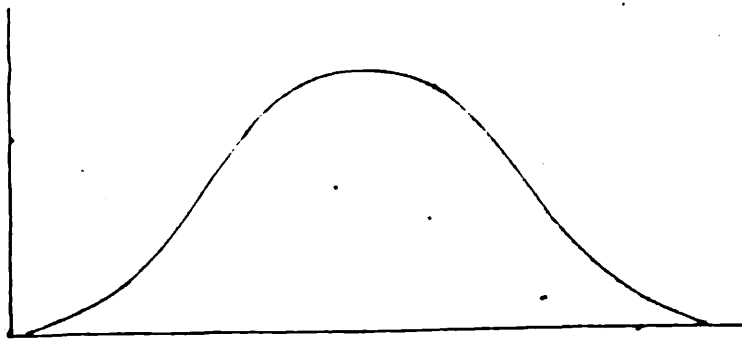
A) SUMMARY

i) Summary of aims of the project

At the start of this thesis we presented a description and analysis of the inverted 'U' model in its most general form as embodied in the theories of workers in the field of 'arousal' in the West, and workers in the field of 'strength of the excitatory process' in Eastern Europe. We pointed out that a principle feature of this model was the assumption that a number of stimulus factors or 'determinants' interacted with each other so as to produce certain types of empirical outcome (see Fig. 27, pp. 233-4) when certain response indices or 'determinates' were employed. We argued that this assumption implied that all of the determinants contributed to the level of some composite measure which in turn determined the level of a single intervening construct ('arousal' in the West, the 'excitatory process' in Eastern Europe), and that finally the level of the various determinates depended on the level of the intervening construct. The relevant relationships are summarised in figures 59a-c in idealised form. Note that the inverted 'U' diagrams in these figures differ from those usually presented in that they include two relatively flat portions at the extreme ends. Certain empirical and theoretical considerations argue in favour of this modification, and its validity was assessed in the results of the present investigation.

The determinants that have been employed by previous workers are stimulus intensity, stimulus duration, stimulus frequency, drugs, accessory stimulation of a non-relevant sensory modality, drive, novelty, fatigue and individual

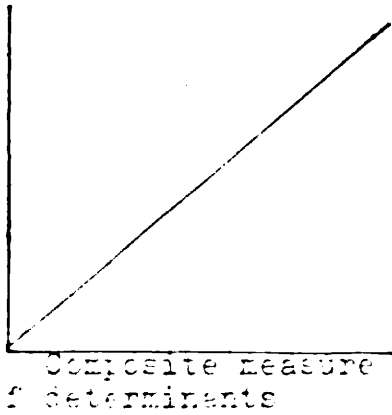
Determinate



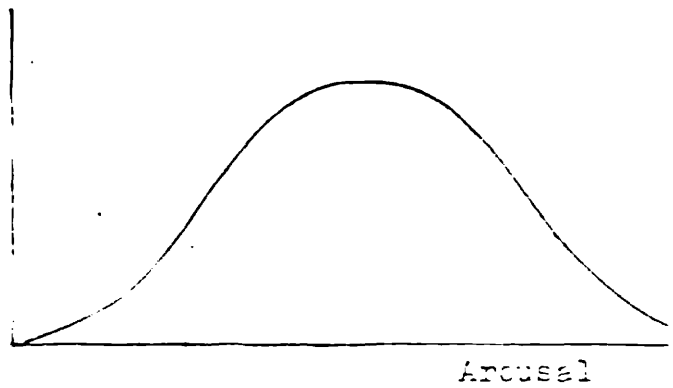
Composite measure of determinants

a) The empirical relationship between determinants and determinate.

Arousal

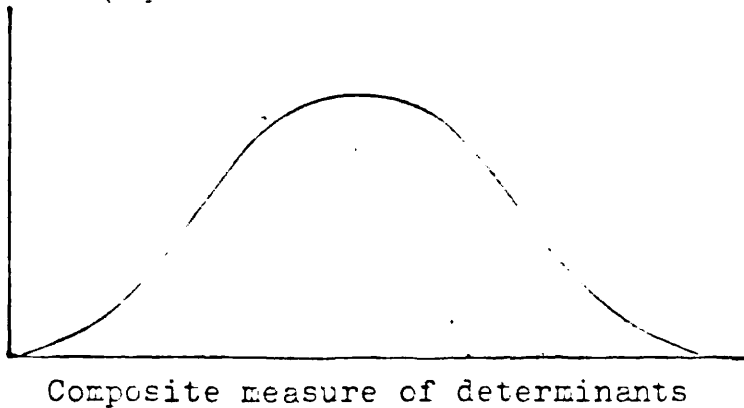


Determinate

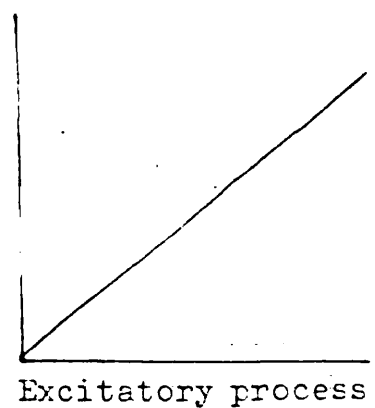


b) The Western model

Excitatory process



Determinate



c) The Russian model

Fig. 59 The inverted 'U' and the Western and Russian models

differences. We argued, however, that stimulus duration could be construed either as the duration of a single stimulus or as the length of time that had elapsed since the start of the task, and that stimulus frequency could be construed either as the frequency of a single stimulus or as the number of separate stimuli presented per unit time. Furthermore, we have suggested that there is evidence that time of day should be added to this list. Finally we pointed out that the factor of individual differences has been manipulated either by employing individuals who differed in their scores on certain personality dimensions such as introversion and neuroticism (in the West) or who differed in their scores on certain classical measures of 'strength of the excitatory process' or indices calibrated against these classical measures (in Eastern Europe).

The list of determinates consisted of certain broad categories of measures, namely: magnitude of response, alertness, efficiency of learning and efficiency of performance. However, within these categories we argued that there were a number of individual response indices that had posed problems for the inverted 'U' model in its most general form, because the various determinants had not interacted as predicted.

Our principle aim in the present project was to take a number of these problematic response indices and to try to present explanations for the discrepant results and to try to devise experimental means of testing these ideas to see whether the assumption of the 'conjoint action of the determinants' which underlies the inverted 'U' model could

be upheld after all. We argued that the best way to test this assumption was to employ as many of the proposed determinants as possible in the same study, though we were ourselves forced to exclude some of them on practical and/or theoretical grounds.

We also discussed the fact that previous work had cast doubt on the assumption that the levels of various determinates could be predicted from the value of a single intervening construct and we stated that in some cases this might have been due to the moderating effect of variables such as sensory modality. Though we did not intend to provide a rigorous test of this aspect of the model we did hope to cast some light upon it since we intended to employ several different response indices.

There were a number of other theoretical issues we also hoped to clarify including some associated with the relationship between the Western and the Russian models. Figs. 59b and c show that these differ in their theoretical postulates, and it has been suggested that physiological measures might be an index of the underlying intervening construct and that their use might, therefore, help to determine whether it was the Russian or the Western model that was applicable. We also ventured the possibility that measures of subjective 'state' might be additional or alternative candidates to fulfill this function.

It is also important to note that though the Russians and Western models differ in some respects, they are also very similar in others, and it has been suggested by other workers that Western personality dimensions such as

introversion and neuroticism are negatively related to the Russian dimension of 'strength of the excitatory process'. This could be tested firstly by determining whether these personality dimensions interact with the other proposed determinants as the 'theory of strength' (embodied in Fig. 59c) predicts, or by looking at their effect on an index such as the gradient of the function relating stimulus intensity to simple reaction time, which has been shown to be related to classical measures of 'strength'.

It has also been suggested, however, that in certain groups of psychiatric subjects, the inverted 'U' relationship described by the theory of 'strength' becomes a 'U' shaped relationship and that this is also reflected in the responses of non-psychiatric subjects scoring highly on the dimension of psychoticism.

It was intended to explore all these possibilities.

Finally, we presented both theoretical and practical reasons why it was desirable to use the same group of subjects throughout and this choice also afforded us the opportunity to test the idea that personality measures reflect a fairly stable and basic characteristic of an individual.

ii) Summary of experimental procedures and findings

1) Overview of the project

The project consisted essentially of three groups of experiments: a gustatory study, an investigation of simple reaction time and signal detection theory, and a vigilance task. 36 subjects took part in the first group and all yielded scores on the E.P.I. resulting in 9 subjects in each of the four personality quadrants produced by the crossing of introversion and neuroticism (2 levels each). For purposes of the analysis one subject was eliminated in each quadrant at random to produce a balanced design with 8 subjects in each quadrant.

A similar procedure was employed in the two later groups of analyses and unless otherwise stated the results that are described derive from these orthogonal analyses based on the initial E.P.I. scores. However, results from non-orthogonal analyses based on E.P.Q. scores obtained at the time of the later experiments themselves will sometimes be presented for comparison.

In the second group only 35 subjects completed the experiment, and in the third group only 27 of the original subjects took part, so that five additional subjects were included to achieve a balanced design. Although these subjects did not take part in the first group of experiments, they did take part in the second, so scores on the gradient of the simple reaction time/stimulus intensity function were available for at least 32 subjects in each of the three groups of experiments and the results relating to 'strength'

of the nervous system as a determinant were based on analyses using these scores.

In addition to these three main groups of experiments, an experiment on simple auditory reaction time was carried out prior to the second group. In contrast to the main experiments it was not possible to exclude subjects who scored highly on the 'L' scale of the E.P.I. before behavioural testing. But the analysis only included the results for the 42 subjects whose lie scores fell below the conventional cut-off point.

These subjects did not take part in the main groups of experiments and were recruited separately.

2) Discussion of the individual groups of experiments

a) The gustatory study

This consisted of two sessions which were essentially similar except that one of the four main indices - the unconditional salivary response to an acidic stimulus - was only measured in the first session. The relevant determinants for this measure and two of the other main indices: subjective estimate of the intensity ('magnitude estimate') of the acidic stimulus and degree of pleasantness or unpleasantness associated with the stimulus ('hedonic tone'), were the same, however. These were stimulus intensity, accessory stimulation (in the form of 'white noise'), introversion and neuroticism.

The most important finding that emerged from this set of measures was an interaction between introversion and noise for the magnitude estimation measure in session 1 suggesting an inverted 'U' relationship between these determinants and subjective stimulus intensity. However, it was also pointed out that the result could reflect the operation of response biases as well as or instead of sensory-perceptual mechanisms and that if the former were true it would be consistent with the hypothesis that there is an inverted 'U' relationship between the levels of the determinants and the degree of positive response bias. In certain contexts the latter can be considered to be positively related to the 'tendency to respond' and this will be of relevance when we come to consider reaction time and signal detection theory.

Secondly, the result apparently suggests that stimulus intensity does not interact with introversion and accessory

stimulation as predicted by the general model since even in those subjects who appeared to have surpassed the threshold of transmarginal inhibition (T.T.I.), subjective intensity was a positive, monotonic function of objective intensity.

This also applied to the results overall for magnitude estimation and as such it was similar to the results for salivation, but contrasted with the results for hedonic tone, for which the corresponding relationship was a negative, monotonic one. This suggested that the relationship between determinant and determinate may depend on the particular determinate involved, which is not what the general model would predict.

The second interaction which should be mentioned is that between neuroticism and stimulus intensity. Though it was the cubic component and not the interaction itself which was significant it is noteworthy that whereas high N subjects salivated more than low N subjects at low intensities, the reverse was true at high intensities, despite the fact that there was no evidence for transmarginal inhibition due to a rise in stimulus intensity. It was suggested that at high intensities the sympathetic nervous system is relatively more active than at low intensities resulting in inhibition of salivation, and that this effect is more marked in high N subjects.

The last main index that was employed was the forced choice gustatory threshold for acidic stimuli for which the factors introversion, neuroticism and novelty (in the form of a comparison between the results for the two sessions) were included in the analysis. The only significant finding was

that high N subjects had lower thresholds than low N subjects. The failure to find a corresponding result for introversion was in line with some negative findings for forced choice thresholds obtained by other workers, and the main effect for neuroticism did not tell us much about the validity of the inverted 'U' hypothesis.

This hypothesis also failed to derive support from the higher order interactions for the other main indices which were significant, since none of these conformed unequivocally to the model.

In addition to the main indices described above, two state measures (the Nowlis Mood Adjective Checklist and the Spielberger measure of State Anxiety), and four other physiological measures (heart rate, blood pressure, pupil diameter and deep core body temperature) were employed. Owing to the experimental design, the relevant determinants were not the same for all these measures, but we will summarise the main findings.

There was an interaction between noise and neuroticism for the Spielberger State Anxiety measure which supported the Russian model of the inverted 'U' and main effects for session for both the 'anxiety' and 'deactivation' scales of the Nowlis checklist which would have by themselves been consistent with either the Russian or the Western model. However, the main effect for neuroticism for the 'deactivation' scale contradicted the Western theory, whilst, interactions between session and neuroticism and noise and neuroticism for 'anxiety' and 'pleasantness', respectively, contradicted the Russian model.

Introverts also scored more highly on the 'concentration' scale of the Nowlis checklist than extraverts which is in line with results for behavioural measures. But the difficulty of interpreting the labels given to subjective scales was illustrated by the fact that the results for the 'activation' and 'deactivation' scales of the Nowlis checklist were not the obverse of one another.

It was hoped that the results for the physiological measures might also help as to compare the Western and Russian models as well as to clarify some other specific issues.

The results for the heart rate measure provided no support for the Russian model, and the Western model was upheld by main effects for noise in session 2 (heart rate being higher under 'noise' than under 'no noise') and for stimulus intensity in session 1 (heart rate tending to increase as stimulus intensity increased). The discrepancies between the sessions were *puzzling*, though habituation effects may have played a part. Habituation of orienting, defense or startle reflexes may also help explain why heart rate initially accelerated following stimulus onset in session 1 (the stimulus 'duration' factor) before decelerating, whilst it showed a monotonic fall with time in session 2. However, stimulus duration did not interact with stimulus intensity nor with any of the other factors in a predictable fashion, though it was suggested that where between subject factors were involved, physical fitness may have complicated the picture.

The heart rate measure certainly provided no support for the view that personality is related to differences in the

degree of 'balance' between the sympathetic and parasympathetic nervous systems and the same applied to the results for the other physiological measures. There were no significant effects for blood pressure, but there was an interaction between session and introversion for pupil diameter, however, which supported the Russian model of the inverted 'U'. The picture was more mixed for the temperature measure, though. The main effect for session, with body temperature being higher in session 2 than in session 1, contradicted the Western model, but the increase in body temperature with time of day was consistent with it and the interaction between time of day and introversion was at variance with the rival Russian model. It was also out of line with the results of Blake (1971) and Home and Ostberg (1977), though it was suggested that this may have been due to the use of deep core rather than oral temperature.

b) The simple auditory reaction time task

The factors employed in this study were stimulus intensity, introversion, neuroticism, time of day and accessory stimulation (no accessory stimulation - 'dark' - constant accessory stimulation and variable accessory stimulation).

The most important finding that emerged from this experiment was an interaction between introversion and neuroticism which was significant beyond the 0.1% level (one tail). This was due to the fact that firstly, amongst extraverts, high N subjects responded more quickly than low N subjects, whereas the reverse was true amongst introverts. Secondly, amongst low N subjects, introverts responded more quickly than extraverts, whereas the reverse was true amongst high N subjects. This supported the view that there is an inverted 'U' relationship between response speed and the position one occupies on an 'X' axis in which 'neurotic introverts' and 'stable extraverts' occupy extreme positions and 'stable introverts' and 'neurotic extraverts' an intermediate position. This is exactly what the inverted 'U' model would predict, and the latter was also supported by a highly significant interaction between introversion and time of day.

However, in the present study introversion did not interact significantly with stimulus intensity, and furthermore there was no evidence for a fall in response speed due to a rise in stimulus intensity in any of the groups of subjects who seemed to be operating beyond the T.T.I. Again this appeared to suggest that stimulus intensity does not interact with the other determinants as predicted by the general model alone.

c) Simple reaction time and signal detection theory

Our analysis of simple reaction time is based on the 'counting model' (summarised on pp. 464-6) which essentially assumes that following the onset of a stimulus the frequency of impulses in the relevant neural pathway rises (as described by a 'sensory growth function') until a certain critical value (the 'criterion') is reached at which point the response is triggered. It also assumes that the rate at which the frequency rises (i.e. the slope of the sensory growth function) is positively related to the intensity of the stimulus and that, therefore, the sensory growth functions for stimuli differing in intensity diverge with time-since-stimulus-onset.

We argued that if one assumes that there is an inverted U relationship between the determinants and the slope of the sensory growth function one can explain most of the data relating the determinants to simple reaction time. However, we also suggested that an alternative explanation is that there is 'U' relationship between the determinants (except stimulus intensity) and the subject's criterion.

Furthermore, although the criterion cannot explain the effect of stimulus intensity per se when the various intensities are randomised, the fact that the corresponding sensory growth functions diverge leads to the prediction that a higher criterion level will result in a higher value for the gradient of the function relating simple reaction time to stimulus intensity. In particular the finding that introverts adopt higher criteria than extraverts in signal detection tasks (Harkins and Geen 1975) can explain why they also show a larger value for this gradient in simple reaction time tasks

in the visual modality (Mangan and Farmer 1967), if we assume that the relative criteria of the two groups are the same in the two kinds of task.

Since the study by Mangan and Farmer has been taken as evidence against the view that introversion and stimulus intensity are determinants and the view that introversion is negatively related to 'strength of the excitatory process', it was decided to employ a visual simple reaction time task and a visual signal detection task side by side and to introduce the criterion values derived from the signal detection task as a covariate in the analysis of the simple reaction time results. It was hoped that this would reveal the influence of the sensory growth functions alone, although differences in 'motor time' might still affect the results.

The factors which were employed in the analysis of the simple reaction time results were introversion, neuroticism, accessory stimulation ('white noise'), time of day, stimulus intensity and novelty. Novelty was assessed both by between session and by within session comparisons, but discussion of the latter will be postponed until the section on vigilance.

The factors employed in the analysis of the signal detection task were the same as for the simple reaction time task except that within session changes were not assessed and the stimulus intensity factor was not included, although the two stimuli to be differentiated differed only in intensity.

In the results of the signal detection task we found an interaction between neuroticism and time of day for the

criterion which supports the criterion hypothesis (see p. 1036) However, this was only found in the case of the E.P.Q. analysis (see p. 1028); the E.P.I. analysis simply showed that high N subjects responded more readily than the low N subjects.

Conversely, there were interactions between neuroticism and time of day and between session and time of day for d^1 , which although not directly supportive of the sensory growth function hypothesis (see p. 1036) nevertheless suggested that there was an inverted 'U' relationship between these determinants and discrimination ability. However, there were no corresponding interactions for the E.P.Q. analysis and there was also no evidence for negative values of d^1 even in the groups who appeared to have passed the T.T.I. Since d^1 would be expected to be related to the gradient of the inverted 'U', this again seemed to suggest that the general model alone could not explain the effect of stimulus intensity.

Another discrepancy was the apparent 'U'-shaped relationship suggested by the noise x introversion interaction for the false alarm measure. However, since a false alarm is an error, this supported the view that there was an inverted 'U' between the determinants and 'performance', though again it was not corroborated by the E.P.Q. analysis.

There were no significant results in the E.P.I. analysis of the latency measures from the signal detection task, but there was a significant interaction in the E.P.Q. analysis between noise and neuroticism for the speed of response to signals which supported the inverted 'U' hypothesis.

There were a number of other significant effects for measures derived from the signal detection task, but they were either uninformative main effects or higher order interactions which were not amenable to explanation.

Let us now consider the results of the simple reaction time task. There was no evidence for transmarginal inhibition due to stimulus intensity where the main effect for this factor was concerned, but there was a significant planned comparison (between the two highest intensities) associated with the interaction between stimulus intensity and neuroticism. This was due to the fact that response speed increased for the low N subjects but decreased for the high N subjects between the two highest intensities. This was consistent overall with the model and the result for the high N subjects was consistent with a transmarginal inhibition interpretation. However, post hoc comparisons of the relevant means did not yield a significant result.

Nevertheless, there was other evidence to support the view that neuroticism is negatively related to 'strength of the excitatory process' as measured by the gradient of the simple reaction time/stimulus intensity curve. Nebylitsyn's $\Sigma t/t_{min}$ index of this gradient had a significantly lower value amongst high N subjects than amongst low N subjects.

All of the above results were derived from both the E.P.Q. and the E.P.I. analysis. There were, however, a number of other interactions (mostly involving three factors or more) which were either significant for only one analysis or which were not explicable on the basis of the inverted 'U' model (or both).

Furthermore, inclusion of the criterion as a covariate in the analysis of the simple reaction time results did not produce a significant result. The correlations between the criterion and Nebylitsyn's index of the gradient of the

reaction time/intensity curve were also non-significant. All in all there was little direct evidence for the influence of the criterion on simple reaction time per se.

There was, however, some evidence for the influence of the sensory growth functions since there was a significant positive correlation between Nebylitsyn's index and d^1 , though this was only found under 'noise'.

In contrast, under both noise conditions there were significant negative correlations between the criterion and d^1 indicating that when subjects found a discrimination difficult, they may have adopted a higher criterion to compensate.

We have noted above a number of differences between the E.P.I. and E.P.Q. analysis and these discrepancies in general were more apparent for results involving introversion than for those involving neuroticism. This was also reflected in the fact that the intercorrelations between the two sets of questionnaire scores (for the 23 subjects whose results were included in all the three main groups of analyses in the project) were 0.448 and 0.818 for introversion and neuroticism respectively. This may indicate that neuroticism is a more stable dimension than introversion or simply be a reflection of the relative success with which the questionnaires measure these two aspects of personality.

The use of the E.P.Q. also allowed psychoticism to be investigated, and interactions emerged between noise, psychoticism and time of day for the criterion and speed-of-response-to-non-signals measures which indicated that amongst high P subjects the inverted 'U' relationship found in low P subjects was reversed to form a 'U' shaped relationship.

d) Vigilance task

Let us now consider the third of the main studies in the present project: the vigilance task.

The following factors were employed: signal frequency/probability, ^{introversion,} neuroticism, time of day and time on task. The factor of signal probability was included despite the fact that no evidence for its role as a determinant had been found in the results for the simple visual reaction time task, since this failure may have been due to the moderating effect of within session changes. For convenience the joint factor of signal frequency/probability will be referred to simply as 'signal frequency'.

The signals and non-signals (both visual) were differentiated in terms of their duration and before the task itself, subjects were presented with auditory stimuli at an average frequency which was the same as those of the visual signals they were to later encounter. This was to establish accurate expectancies. Also Spielberger's state anxiety scale and a modified version of Thayer's checklist (yielding scales of 'arousal' and 'stress') were administered before and after the task, and measurements of deep core body temperature were also taken at these times. The behavioural measures employed were the tendency to respond (the reciprocal of the criterion), the discrimination index, the probabilities of a hit and false alarm and the speed of response to signals, for all of which an inverted 'U' relationship with the determinants was predicted.

We will first consider the results for the state and

physiological measures. The 'arousal' scale of the Thayer checklist yielded an interaction between time on task and signal frequency due to the fact that 'arousal' was initially greater under high than under low frequency but fell more steeply to an eventually lower level. This suggested that in the present study, contrary to prediction, an increase in signal frequency seemed to be moving subjects to the left along the 'X' axis of the inverted 'U', and this was supported by interactions between introversion and frequency, and between neuroticism and frequency which were also opposite to prediction.

The interaction involving neuroticism (unlike the one involving introversion) was not corroborated by the E.P.Q. analysis, but there were corresponding interactions for the 'stress' scale of Thayer's checklist and Spielberger's anxiety scale which also supported the above interpretation of signal frequency effects, if we assume that these two measures are inversely related to 'hedonic tone' (see p. 1030) since the latter is presumed to have an inverted 'U' relationship with the determinants.

There were interactions between noise and time of day, and between noise, introversion and frequency for the stress measure (E.P.I. analysis) and between noise and introversion for the anxiety measure (E.P.Q. analysis) which were also in line with such an assumption.

However, there were three interactions for the stress index (noise x introversion, noise x neuroticism and introversion x neuroticism) derived from the E.P.I. analysis, and one interaction (neuroticism x frequency) for the body

temperature measure, derived from the E.P.Q. analysis, which were inimical to these views.

For all four measures there were a number of higher order interactions and main effects which were significant but either uninformative and/or inexplicable. There was, however, an interaction between noise and neuroticism for the 'arousal' scale (E.P.I. analysis) that was in line with prediction.

If we now look at the results for the behavioural measures which relate to the overall level of performance, we find that there were interactions between neuroticism and frequency for the criterion and 'probability-of-a-hit' measures, and between introversion, neuroticism and frequency for the criterion and 'probability-of-a-false-alarm' measures that supported our above interpretation of signal frequency effects.

The same does not apply to the interaction between introversion and frequency for the parametric discrimination index, though it was argued that this was possibly because this measure is related to the stimulus duration factor. The view that this factor may be special apparently also received support from an interaction between introversion and neuroticism which was discrepant and from the fact that despite apparent transmarginal inhibition effects for other measures, in no condition were subjects more likely to respond to non-signals than to signals.

In the remaining results there were interactions between neuroticism and time of day for the criterion, 'probability-of-a-false-alarm' and 'speed-of-response-to-signals' measures, all of which supported the inverted 'U' model, as did an interaction between noise and introversion for the last of

the three indices. It was suggested that the failure to find any evidence for a 'U' relationship for the false alarm measure (unlike the signal detection task) may have been because in the vigilance experiment the corresponding interaction was for the criterion and not the discrimination index. Finally, there were a number of other higher order interactions and main effects which were either uninformative and/or inexplicable, except for the fact that subjects overall were more likely to detect signals under 'noise' than under 'no noise' which may have some practical significance.

It should be noted that of the results for the behavioural measures which have been mentioned, the only one involving personality which was corroborated by the E.P.Q. analysis was the interaction between neuroticism and time of day for the 'speed-of-response-to-signals' measure.

Let us now consider the results for the behavioural measures which relate to the effect of time on task. There was evidence that the pre-task training did establish fairly accurate expectancies in the high frequency condition at least, though the same may not have been true of the low frequency condition.

For all the behavioural measures, the effect of time on task overall was to produce a monotonic decline which was consistent with the inverted 'U' model, as were some of the lower interactions, for example between noise and block. However, the higher order interactions provided only equivocal support for the model.

It should also be pointed out that relatively few results overlapped between the E.P.I. and the E.P.Q. analyses though

those that did were often similar in form. The correlations between the personality scores for the two sets of questionnaires were 0.7268 and 0.7472 for extraversion and neuroticism respectively. The correlations between the vigilance task E.P.Q. scores and the joint simple reaction time/signal detection task E.P.Q. scores were 0.4793 and 0.749, respectively. Overall the various correlations derived from the present project suggested that though the personality dimensions showed some measure of stability, this was more marked for neuroticism than for extraversion, and that some form of cyclical process may have been affecting the latter.

The only results for psychoticism which were significant in the vigilance task, were ones involving time on task for the behavioural measures and none of these supported the view that a 'U' shaped relationship is operating in high P subjects.

e) The operational measure of 'strength'

The last set of results we must consider are those relating the operational measure of strength (Nebylitsyn's index of the gradient of the simple reaction time/stimulus intensity curve) to the various response indices which we have already considered.

The gustatory study yielded a number of interactions for the main indices but none of these were in line with prediction. The only significant results for the state and physiological measures were interactions between noise and 'strength' and session and 'strength' for the 'activation' and 'startle' scales of the Nowlis checklist, respectively. These could be regarded as supportive of the model but they were possibly suspect due to some residual skewedness in the data.

The signal detection task yielded only one significant result - an interaction between 'strength' and noise for the speed of response to signals - but it was in line with prediction.

A number of results from the vigilance task are worth considering. There was an interaction between session and 'strength' for the discrimination index and interactions between 'strength' and frequency, noise and 'strength', and session and 'strength' for the 'probability-of-a-hit' measure, all of which supported the ideas we have already presented in our discussion of earlier results. The remainder of the results for the behavioural measures, however, provided no more than partial support for the model. The same applied to the results for the state and physiological measures,

though 'weak' subjects had a significantly higher level of 'arousal' than 'strong' subjects, which by itself would have supported the Western model of the inverted 'U'. On the other hand, the interaction between 'strength' and time of day for body temperature, supported the Russian model.

Overall, greater evidence for our hypotheses was present in the vigilance study than in the gustatory study. This may have been due to the fact that the former (like the simple reaction time task from which Nebylitsyn's index was derived) was conducted in the visual modality. However, this would not explain why there were so few significant results for the signal detection task which was not only visual but also conducted at about the same time as the simple reaction time task.

B) CONCLUDING COMMENTS

i) Theoretical implications

a) Individual differences

The most notable finding that emerges from the results relating to the individual differences factors is the role of neuroticism as a prime variable, despite its previous neglect by other workers. This supports Gray's theory of the biological basis of personality (as its author himself has pointed out - personal communication) since, according to this theory, an increase in the activity of the 'behavioural inhibition system' leads to an increase in the activity of a non-specific 'arousal' mechanism. Furthermore, the B.I.S. is thought to be the physiological substrate of 'anxiety' which is more closely related to neuroticism than to introversion. (Spence and Spence 1966).

It should be mentioned that the interaction between introversion and neuroticism found by other workers was also demonstrated in the present project, most notably in the simple auditory reaction time task (though the corresponding interaction for the discrimination index in the vigilance task was of the opposite form). Such interactions also support Gray's theory since introversion is also thought to influence the B.I.S., though less so than neuroticism. Eysenck's mechanism for the spill over of activity from the autonomic nervous system into the cortico-reticular system provides, perhaps, a less plausible explanation for these interactions since such effects are presumed to take place only under conditions of strong emotion.

We should also briefly mention the fact that though the

operational measure of 'strength' - i.e. the gradient of the reaction time/intensity curve - showed some predictable interactions with the other proposed determinants, the number of these was relatively limited. We earlier suggested some reasons why this might have been so, but we acknowledged that these were not entirely satisfactory.

Finally, there is some indication that Claridge's (1972) suggestion that the normal homeostatic mechanisms based on the inverted 'U' are deranged in high P non-psychiatric subjects resulting in a 'U' relationship, may have been correct.

b) Time of day

One variable which merits particular attention is time of day. This was not included in our original list of determinants, but the present project has added to the growing body of evidence that it should be accorded a place.

Its interactions with introversion and neuroticism are of particular significance since the theories presented by Gray, Eysenck and others all tend to assume that personality dimensions are related in a fairly direct way to behavioural traits such as susceptibility to conditioning, and that these in turn interact with environmental factors to determine the behaviour of the subject. If, however, the relationship between personality and susceptibility to conditioning were to reverse between the morning and the afternoon, such theories would encounter grave difficulties. This is a point that has been made by Gray (personal communication) and he goes on to suggest a taxonomic classification of tasks into those which do display such reversals and those which do not. Clearly, many of the determinates employed in the present project fall into the former category. Later we will consider some of the clinical implications of the results of the present body of work, but the qualification with respect to time of day should be taken into account when assessing these.

Throughout the present project we have treated time of day as a determinant like the others, in other words we have tested the hypothesis that it moves subjects to the right along the 'X' axis of the inverted 'U'. However, recent work by Revelle et al (1980) has shown that if we consider the impulsivity subscale of the introversion dimension, there is

evidence that though low impulsives seem to be operating further to the right along this 'X' axis in the morning (as the above hypothesis would predict), the reverse is true in the evening. Revelle, et al (1980) suggest that this indicates that low and high impulsives differ in the phase of their diurnal rhythms, the former being relatively advanced compared to the latter.

This in fact does not contradict the hypothesis stated above, but is complementary to it. Since the diurnal rhythm is a cyclical phenomenon we would expect both low and high impulsives to initially move to the right along the 'X' axis of the inverted 'U', but we might also expect that at some point the groups would start to move in the opposite direction to bring them back to their original position at the start of the next diurnal cycle. Clearly, the group which was advanced in phase (the low impulsives) would begin to move to the left first, and one might, therefore, expect that at some point the two groups would cross on the 'X' axis resulting in a reversal of their relative positions. This may seem a speculative account, but the fact that none of the afternoon sessions in the present project went beyond 17.00 hours, whereas the study by Revelle et al which showed such reversals was carried out at the later time of 19.00 hours, provides support for it.

The fact that the above relationships seemed to hold for impulsivity but not for sociability or for the composite dimension of introversion in Revelle et al's study, might lead one to the conclusion that introversion is a less useful variable to employ than its component factors. Revelle et al's findings are certainly to some extent in line with the

suggestions made by other authors that impulsivity and sociability may yield useful information when considered separately. For example, Claridge (1967) has presented a theory of personality in which both impulsivity and sociability are negatively related to the level of activity in an 'arousal modulating system', but in which the former is related positively and the latter negatively to the level of activity of a 'tonic arousal system'.

However, it should also be noted that Craig et al (1979) did not find that the results for introversion, sociability and impulsivity were markedly discrepant in a study on memory.

c) Stimulus associated factors

One of the conclusions which seems at first glance to arise from the present project is that stimulus intensity and duration (construed as the duration of a single stimulus, as opposed to 'time on task') do not interact with the other determinants as predicted by the inverted 'U' model at its most general. The discrepancy can be explained, however, if we remember Hebb's (1955) suggestion that stimuli have both a 'cue function' to guide behaviour and an arousal function. Furthermore, Sokolov's model (1963) is in line with this view as are physiological data that suggest that information about stimuli relating to intensity, duration etc. will reach the cortex directly before they affect it more indirectly via an 'arousal' system such as the A.R.A.S. Such an arrangement would ensure that the 'cue' and 'arousal' functions of stimuli did not conflict and could explain many of our own data. For example, it could explain why subjective stimulus intensity continued to faithfully and accurately reflect objective stimulus intensity even in groups who by other accounts appeared to have passed their threshold of transmarginal inhibition.

A word should also be said about stimulus probability. Although in our vigilance task, signal probability was confounded with signal frequency and, therefore, affected by the ambiguity associated with the latter, there is evidence that subjective probability (as determined by signal probability) may be a determinant. For example, both Wer^{re}et al (1975) and Lolas and Andraca (1977) have indicated that there is an inverted 'U' relationship between the amplitude

of the 'contingent negative variation' (CNV) and 'arousal'. Here CNV is the electrical brain potential which occurs during the fore-period of a reaction time task as the level of expectancy (subjective probability) rises, and 'arousal' is either measured in terms of autonomic activity (heart rate) or manipulated by factors such as time on task or accessory stimulation. Furthermore CNV has been shown to be closely related to response speed which is itself related by an inverted 'U' function to the objective, conditional probability of the response stimulus in a reaction time task in which the foreperiod duration varies randomly from trial to trial (see pp. 737-44).

d) The inverted 'U' model and the normal distribution curve.

What are we then to conclude about the generality of the inverted 'U' model with respect to the conjoint action of the determinants which was one of the main issues under consideration in the present project? We find that where only two factors are involved there is usually some evidence to support the inverted 'U' model for most combinations. There are, however, exceptions such as the failure of introversion and stimulus intensity to show any such interactions. Furthermore, it is relatively rare for a particular combination to yield a significant and predictable interaction in all of the tasks in which it was investigated. Because of the danger of false positives in a project in which numerous large scale analyses of variance were employed, we have tried to base conclusions on sets of results of a similar kind rather than isolated findings. For this reason we cannot state for any one of the various combinations of factors that it provides unequivocal support for the model when the project is considered as a whole. One possible explanation is that the operation of the model is moderated by the particular determinate in question, and we have already seen evidence to support this suggestion.

Another fact that we must consider is the relative dearth of higher order interactions which support the theory. We argued at the outset that these provided the most stringent test of the assumption that the various proposed determinants can be combined on the 'X' axis of a single inverted 'U' curve. Since most of our conclusions have been based on interactions involving two factors, the inverted 'U' model

does not seem to have passed this test particularly well.

Nevertheless, let us for the moment assume that we can combine some factors at least into a composite measure. It must have struck the reader already that the modified inverted 'U' curve (see p. 1023) that we have taken as the basis for the present project, bears a striking resemblance to the statistical normal distribution curve. It should be noted that we cannot be sure that the data after transformation for statistical reasons are linearly related to the underlying variable in question, and empirical support for this modification is in any case not abundant within the present project, at least. However, let us consider what implications this modification, if true, might have.

If the determinants do interact as predicted by the general model then one might expect that the value of the composite measure of these determinants would have a normal distribution. This is because - with the exception of time of day - one might expect the levels of the individual determinants (e.g. introversion, neuroticism, accessory stimulation) to be normally distributed so that a composite measure derived from them should have the same form. If so, then it would make perfect teleological sense for the function relating the level of this composite measure to performance to be a normal distribution curve (such as our modified inverted 'U').

The reason is that the peak of a normal distribution curve is the point of maximum probability, and the peak of the inverted 'U' is the point of optimal performance. These two peaks would, therefore, coincide so that the probability

of the performance level of the organism being optimal would be maximal. It should be noted that this would apply whether we accept the modification or not. However, with the modification included the two curves not only would have coincidental peaks but would also be identical in form, the level of functioning exactly following the probability of obtaining a given value of the composite measure. Moreover, since some of the determinants which make up this measure are between subject factors this mechanism would operate across individuals as well as for a given individual.

Furthermore, we would be correct in concluding that the modified inverted 'U' is survival-oriented for a given individual if we assume that the level of activity within the nervous system corresponds to the 'excitatory process' and that it has a normal distribution. This latter assumption is of course a cardinal tenet of signal detection theory.

To conclude, then. Though the inverted 'U' model has not received overwhelming support from the project we see that it is still a useful conceptual tool and the view that it is a mechanism which promotes the survival of the organism may be worth considering.

2. CLINICAL IMPLICATIONS: HYPNOTIC SUSCEPTIBILITY, PERSONALITY AND BEHAVIOUR THERAPY.

The relationship between hypnotic susceptibility, introversion and neuroticism was first investigated by Furneaux and Gibson (1961), who found that susceptibility was highest in 'stable extraverts' and 'neurotic introverts', and lowest in 'neurotic extraverts', while 'stable introverts' had a low-average susceptibility. Some studies have failed to replicate these findings, for instance Hilgard and Bentler (1963), but Gibson and Curran (1974) pointed out certain procedural differences between the two investigations, and also produced findings which were essentially similar to those of the Furneaux and Gibson study. Moreover, the relationships that emerged from the latter have since received further confirmation (Fellows 1973; Gibson and Corcoran 1975).

A variety of explanations for the findings have been advanced. One of these (Gibson and Curran, op. cit.) assumes that neuroticism acts as a moderator variable of attitude, with high levels of neuroticism producing deferential behaviour in introverts, but tense, defensive behaviour in extraverts. This is in line with the discovery that 'fearful' or 'oversocialised' behaviour is more likely to be found in 'neurotic introverts' whereas behaviour disorders and symptoms of 'undersocialisation' are more common in 'neurotic extraverts' (Eysenck 1967). Both Eysenck (op. cit.) and Gray (1971) have put forward theories to explain these patterns, based on the idea that 'neurotic introverts' form conditioned fear responses more readily than

'neurotic extroverts'. It is possible that such concepts may indeed be relevant to the hypnotic setting in which a considerable degree of compliance is demanded of the subject. The moderate levels of hypnotic susceptibility of the 'stable introverts' in the Furneaux and Gibson (op. cit.) study and the 'stable extroverts' in the Gibson and Corcoran study (op. cit.) are also explicable on this basis, since both these groups would appear to occupy an intermediate position on a dimension of socialisation. However, the latter study showed that 'stable introverts' had a level of susceptibility comparable to that of the 'neurotic extroverts' (i.e. very low), which suggests that degree of socialisation may not be the only relevant variable.

Furneaux (1961) has invoked the Yerkes-Dodson law to provide an alternative explanation of these findings. The law assumes that there is an inverted 'U' relationship between drive and performance, of the form depicted in figure 57

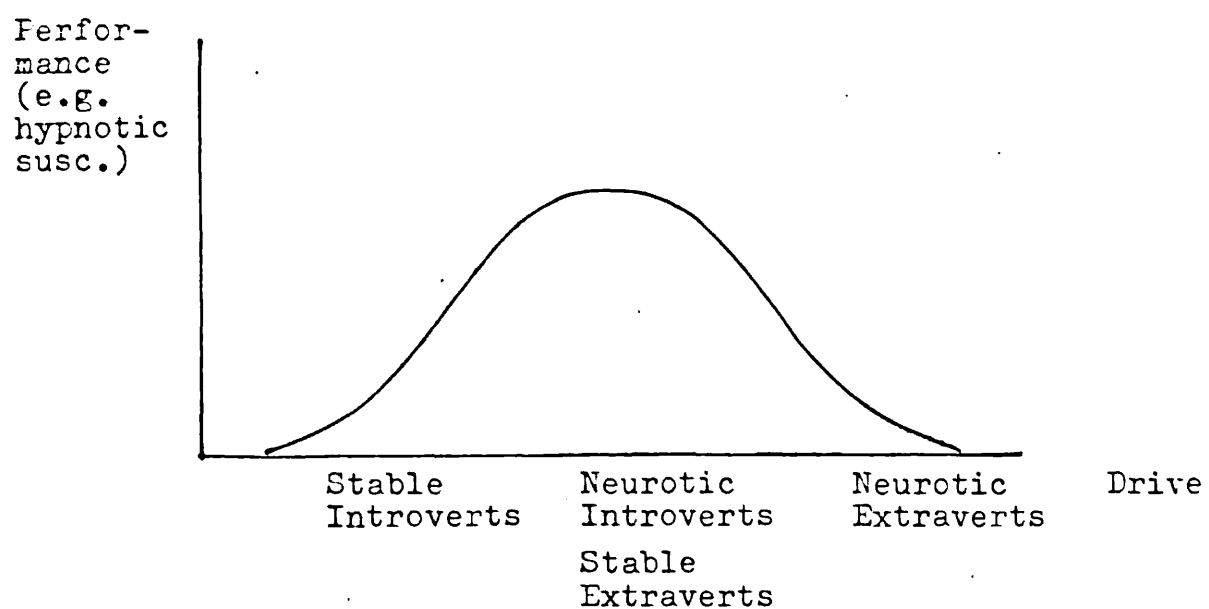


Fig. 57 Furneaux' theory of personality and hypnotic susceptibility

Furneau argues that high levels of drive are associated with high levels of neuroticism and also, in the interpersonal context of hypnosis, with low levels of introversion. On this basis, 'stable extraverts' and 'neurotic introverts' would occupy intermediate positions on the 'X' axis and would, therefore, have high levels of susceptibility (since Furneau regards hypnotic susceptibility as a performance measure), whereas 'neurotic extraverts' and 'stable introverts' would occupy the extreme right and left-hand ends of the axis, respectively, and would, therefore, have relatively low levels of susceptibility.

But there is a third way to explain the findings. This explanation also uses curvilinear relationships, such as those embodied in the Yerkes-Dodson law, as starting points, but it differs from the earlier explanations in a number of ways. Before presenting it in detail it is pertinent to consider the findings of a study carried out by Winter et al (1976). The study showed that the E.E.G. alpha amplitude was greater in extraverts than in introverts amongst subjects low on neuroticism, whereas the reverse was true amongst subjects high on neuroticism. This would suggest that E.E.G. alpha amplitude may be an inverse measure of the level of the 'excitatory process'. It is significant that high E.E.G. alpha amplitude is associated with high hypnotic susceptibility (e.g. London, Hart and Leibovitz, 1968). Also photic-driving of the E.E.G. alpha has been found to aid hypnotic induction (Shor and Cobb 1968), as has biofeedback training in E.E.G. alpha production

(Engstrom et al, 1970). Moreover, in the latter study it was found that subjects experienced the 'alpha-on' periods and hypnotic induction in very similar ways, as judged by subjective reports.

The relationships between personality and hypnotic susceptibility, described earlier, could be explained by a 'U' shaped function such as the one depicted in Fig. 58

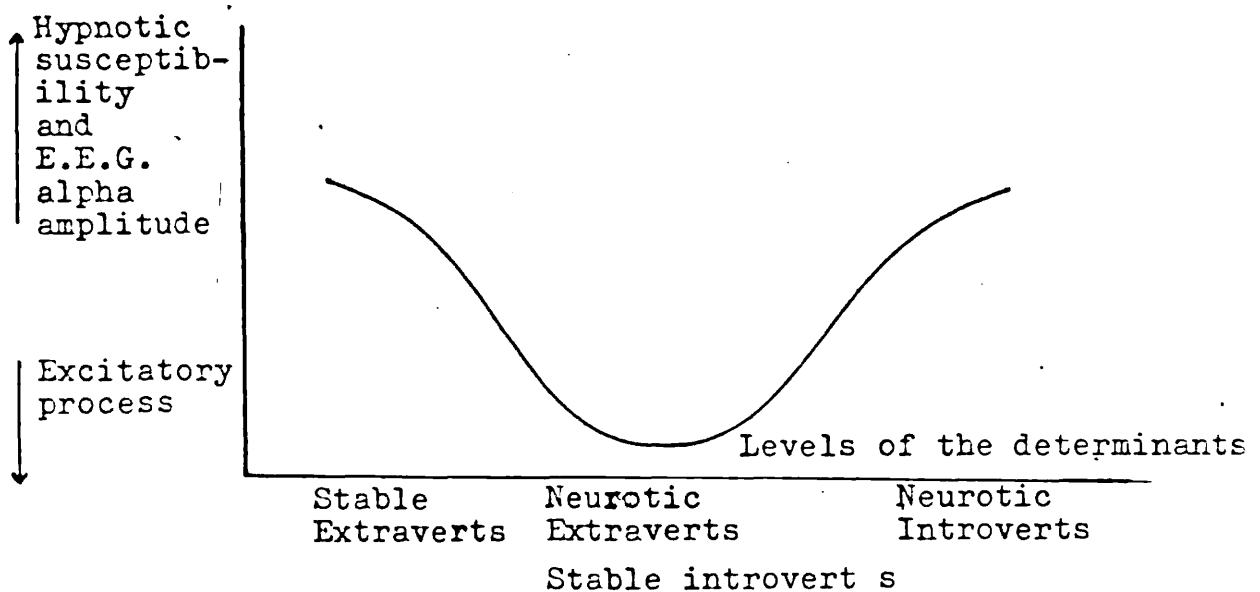


Fig. 58 A new theory of the relation between personality and hypnotic susceptibility

This predicts that 'stable extraverts' and 'neurotic introverts' will both have high hypnotic susceptibilities but for different reasons. The 'stable extraverts' because they are operating on the left of the 'X' axis; the 'neurotic introverts' because they are operating on the right of the 'X' axis. In both cases this results in a low value of the 'excitatory process' within the nervous system and a high value of E.E.G. alpha amplitude.

This explanation clearly differs from Furneaux' formulation, shown in Fig. 57 and may be preferable since the

general model supports the ordering of personality groups on the 'X' axis of fig.58 rather than the ordering in Fig.57. It is possible that the relative positions of the various personality groups in the kinds of situations employed in the present project and in hypnotic settings are different, but a more coherent theory would be obtained if one assumed that the relative positions of the personality groups remain unchanged, whilst the shape of the function governing the relationship between personality, on the one hand, and the determinates and hypnotic susceptibility, on the other, are different. This is partly because the present theory is also in line with a 'U' shaped relationship between hypnotic susceptibility and the difference between the standard scores for extraversion and neuroticism ('Ez-Nz'), found by Gibson and Curran (op. cit.). An increase in the value of ('Ez-Nz') would be expected to move one to the left along the 'X' axis of Fig.58 and would produce a 'U' Function. Our theory is also consonant with Gibson, Corcoran and Curran's (1977) finding that tranquillisers increase hypnotic susceptibility in 'neurotic extraverts'. This too is predictable from Fig.57 if we assume that tranquillisers move subjects to the left along the 'X' axis. It would be interesting to see if manipulations other than the administration of drugs (e.g. the use of accessory stimulation) also produced predictable effects.

The present theory obviously bears directly on the question of hypnotic induction procedure. If the theory is correct, it follows that the techniques adopted to induce hypnosis may need to be different for different individuals,

since the effect of a given manipulation will depend on which side of the 'U' one is operating. This is of considerable clinical relevance since hypnosis is used widely in a number of therapeutic procedures for psychiatric disorders (Gibson 1979, Kihlstrom 1979), and its possible role in the treatment of psychosomatic illnesses has also been discussed (e.g. Kline and Linder 1967). Furthermore, it is likely that even where overtly hypnotic procedures are not deliberately and consciously employed by the therapist, the mechanisms underlying therapy may in some cases be similar to the mechanisms underlying hypnosis. This is supported by the finding, for instance, that the efficacy of both relaxation training and self-hypnosis training in reducing anxiety is dependent on the hypnotic susceptibility of the subject (Benson et al 1978). The procedural similarities between hypnosis and the relaxation techniques used in systematic desensitisation, for example, are obvious. At the other extreme, it is also significant that the changes that take place in the later stages of flooding therapy have been attributed to transmarginal inhibition (Wolpe 1968; Astrup 1979). Furthermore, Horowitz (1970) has shown that the efficacy of 'fear arousal' - an integral component of flooding - in treating a snake phobia is positively correlated with hypnotic susceptibility.

The relationships between personality and the inverted 'U' would by themselves suggest that the effectiveness of a given therapeutic method might depend on the personality of the subject. It would not be unreasonable to suppose

that in both systematic desensitisation and flooding, for instance, success may depend partly on an eventual lowering of the level of the 'excitatory process' in the feared situation. Systematic desensitisation could be considered to move the individual to the left of the 'X' axis of the inverted 'U' and clearly the speed of reduction of the 'excitatory process' to a given level by this method will be greater in a patient who is already operating relatively to the left such as a 'stable extrovert'. (It should be remembered that neurotic disorders such as monosymptomatic phobias, though more common in neurotic introverts, are found in individuals of varying personality profiles.) Conversely flooding could be considered to move the individual to the right and eventually past his threshold of trans-marginal inhibition. This is in line with the finding (Watson and Marks 1971) that the induction of anxiety irrelevant to the phobia is therapeutic in flooding, and that the therapeutic effect is proportional to the degree of irrelevant anxiety induced. This does not apply to the degree of relevant anxiety induced, though, so clearly more than one factor is involved in flooding. However, the preceding account does suggest that the production of a trans-marginal inhibition effect may be one of these, and if so one would expect this process to occur more readily in subjects already operating relatively to the right such as 'neurotic introverts'.

Whatever the actual mechanisms involved in systematic desensitisation and flooding, there is empirical evidence to support the view that their relative effectiveness may

depend on the kind of subject factors outlined above. For instance, variables which predict a good prognosis for patients treated by systematic desensitisation also predict poor prognosis for patients treated by flooding (Marks et al 1971). Systematic desensitisation produced the best results in the least anxious subjects, i.e. those with the fewest phobias and the lowest level of physiological activity. This is in line with the theory presented by Rizley and Repucci (1974) according to which mild anxiety facilitates treatment by systematic desensitisation because the conditioned emotional responses (C.E.R. s) elicited by stimuli presented to the patient extinguish as they are not sufficiently intense to elicit the covert stimuli (internal nocive responses) which may reinforce the C.E.R. s under conditions of intense anxiety. Such anxiety, however, may be beneficial in flooding procedures since the study by Marks et al (op. cit.) also showed that this method produced the best results in patients suffering from severe phobias, i.e. those with the most symptoms and with the highest level of physiological 'arousal'. (This has been confirmed by Watson and Marks (1971).) Furthermore, Sipprelle et al (1977) have found that in a clinical setting, subjects high on trait anxiety displayed higher levels of physiological 'arousal' than subjects low on anxiety (which as stated earlier is positively related to both introversion and neuroticism).

The relative efficacy of flooding and systematic desensitisation in producing an improvement in the patients'

disorders' may not be the only factor to consider. Flooding procedures not only fail to work with some individuals but may actually worsen the complaint under certain conditions, for instance if the flooding session is not sufficiently prolonged (e.g. Rabavilas et al 1976). It is not unreasonable to suggest that this may have been partly because the subjects concerned were not taken past their threshold of transmarginal inhibition (since stimulus duration is one of the factors which is thought produces movement to the right along the 'X' axis of the inverted 'U') and clearly, all other things being equal, this situation is more likely to occur in a subject with a relatively high T.T.I.

Conversely, the theory presented by Rizley and Repucci (see above) would suggest that in very anxious subjects (who can be identified in the present context with subjects with 'weak' nervous systems) systematic desensitisation may produce a worsening of the symptoms (due to the reinforcement of the C.E.R. s by internal 'nocive' responses) rather than an amelioration.

The above account suggests that different therapeutic procedures may be differentially beneficial in different individuals. It is also possible that such differential effects may be due in part to their differential effects on hypnotic susceptibility. On the basis of Fig. 5⁸ one might predict that, for instance, systematic desensitisation may increase the hypnotic susceptibility of a 'stable extravert' to a given level more quickly than that of a 'neurotic

introvert¹. The reverse would be true for flooding.

Astrup (op. cit.) has pointed out that the choice of therapeutic procedure is one of the main ones that clinicians have to face. It is possible that factors such as personality and hypnotic susceptibility may be relevant to such a choice, and this possibility is worthy of investigation.

BIBLIOGRAFIY

- ADAMS, J.A. (Sp.Ed.). (1965) Vigilance. Human Factors, 7, 91-180.
- AHLERS, R.H. (1973) An analysis of the effects of acoustic noise upon sensory-motor task performance. Dissertation Abstracts International, 35(9-B) p.4672.
- AIKEN, L.C. (1974) Comparison of reaction time and magnitude estimation methods for scaling brightness and loudness. Dissertation Abstracts International, 34(9-B), p.4683.
- ASTRUP, C. (1978) Physiological mechanisms of flooding (implosion) therapy. Pavlovian Journal of Biological Science, 13, 195-8.
- BADDELEY, A.D. (1968) A three minute reasoning test based on grammatical transformation. Psychonomic Science, 10, 341-342.
- BADDELEY, A.D. & COLQUHOUN, W.P. (1969) Signal probability and vigilance: a reappraisal of the 'signal rate' effect. British Journal of Psychology, 60, 169-178.
- BAKAN, P. (1959) Extroversion-introversion and improvement in an auditory vigilance task. British Journal of Psychology, 50, 325-32.
- BAKAN, P., BELTON, J.A. & Toth, J.C. (1963) Extraversion-introversion and decrement in an auditory vigilance task. In Buckner, D.N. & McGrath, J.J. (Eds.), Vigilance: a Symposium, pp.22-33, New York, McGraw Hill.
- BAKER, C.H. (1958) Vigilance decrement as a function of regularity of intersignal intervals. Toronto: Defence Research Medical Laboratory, Memorandum February 1958.
- BARTHOLOMEW, A.A. & MARLEY, E. (1959) The temporal reliability of the Maudsley Personality Inventory. Journal of Mental Science, 105, 238-40.
- BARTLETT, W.R. & McLEOD, S. (1954) Effects of flash and field luminance upon human reaction time. Journal of The Optical Society of America, 44, 306-311.
- BARTOL, C.R. (1973) Extraversion, neuroticism, the orienting response and preference for stimulation. (Doctoral dissertation, Northern Illinois University) Ann Arbor: University Microfilms, No. 73-20533.
- BARTOL, C.R. (1975) The effects of chlorpromazine and dextroamphetamine sulfate on the visual stimulation preference of extraverts and introverts. Psychobiology, 12, 25-29.

- BENSON, H. et al (1978) Treatment of anxiety: A comparison of the usefulness of self-hypnosis and a meditational relaxation technique. *Psychotherapy and Psychosomatics*, 30, 299-242.
- BERGUM, B.O. (1966) A taxonomic analysis of continuous performance. *Perceptual and Motor Skills*, 23, 47-54.
- BERGUM, B.O. & LEHR, D.J. (1964) Monetary incentives and vigilance. *Journal of Experimental Psychology*, 67, 197-198.
- BERLYNE, D.E. (1960) Conflict, Arousal and Curiosity. New York, McGraw.
- BERNSTEIN, I.H., CHU, P.K. & BRIGGS, P. (1973) Stimulus intensity and foreperiod effects in intersensory facilitation. *Quarterly Journal of Experimental Psychology*, 25, 171-181.
- BERRY, R.N. (1962) Skin conductance levels and verbal recall. *Journal of Experimental Psychology*, 63, 275-277.
- BINFORD, J.R. & LOEB, M. (1966) Changes within and over repeated sessions in criterion and effective sensitivity in an auditory vigilance task. *Journal of Experimental Psychology*, 72, 339-345.
- BISHOP, D.V.M. (1977) The P Scale and psychosis. *Journal of Abnormal Psychology*, 86, 127-134.
- BLAKE, M.J.F. (1971) Relationship between circadian rhythm at body temperature and introversion-extroversion. *Nature, London*, 215, 896-897.
- BLAKESLEE, P. (1979) Attention and vigilance performance and skin conductance response changes. *Psychophysiology*, 16, 413-419.
- BLOCK, J. (1977) P Scale and psychosis: continued concerns. *Journal of Abnormal Psychology*, 86, 431-434.
- BLOCK, J. (1978) Claridge and Birchall, different forms of the P scale, and dependable moderators. *Journal of Abnormal Psychology*, 87, 669-672.
- BOIKO, E.I. (1961) Reaction time and the physiological law of 'strength', in Common Problems of Psychology and Physiology, Moscow, Izd. Akad. Pedagog. Nauk RSFSR.
- BOIKO, E.I. (1964) Human Reaction Time, Moscow, Izd. Medicsina.
- BONE, R.N. & MONTGOMERY, D.D. (1970) Extraversion, neuroticism and sensation seeking. *Psychological Reports*, 26, 974.

- BORISOVA, M.N. (1972) Concentration of nervous processes as an individual typological feature of higher nervous activity. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp.29-42, Academic Press, New York and London.
- BOWSER, J.M., JOHNSON, D.R. & ROBINSON, D.W. (1966) A further experiment on the judging of the noisiness of aircraft in flight. Acustica, 17, 245-67.
- BRENER, J. & COOPER, C. (1974) The effect of a low rate of regular signals upon the reaction times of introverts and extraverts. Journal of Research in Personality, 8, 263-276.
- BRENER, J. & COOPER, C. (1978) Stimulus- or response-induced excitation. A comparison of the behaviour of introverts and extraverts. Journal of Research in Personality, 12, 306-311.
- BRENER, J. & FLAVEL, R. (1978) The effect of catch trials on speed and accuracy among introverts and extraverts in a simple RT task. British Journal of Psychology, 69, 9-15.
- BROADBENT, D.E. (1953) Noise, paced performance and vigilance tasks. British Journal of Psychology, 44, 295-303.
- BROADBENT, D.E. (1958) Perception and Communication. London: Pergamon Press.
- BROADBENT, D.E. (1971) Decision and Stress. London: Academic Press.
- BROADBENT, D.E. (1976) Noise and the details of experiments; a reply to Poulton. Applied Ergonomics, 7.4, 231-235.
- BROADBENT, D.E. (1978) The current state of noise research: reply to Poulton. Psychological Bulletin, 85, 1052-1067.
- BROADBENT, D.E. & GREGORY, M. (1963) Vigilance considered as a statistical decision. British Journal of Psychology, 54, 309-323.
- BROADBENT, D.E. & GREGORY, M. (1965) Effects of noise and of signal rate upon vigilance analysed by means of decision theory. Human Factors, 7, 155-162.
- BUCK, L. (1966) Reaction time as a measure of perceptual vigilance. Psychological Bulletin, 65, 291-304.
- BUCKALEW, L.W. (1973) Relationship between a physiological and personality index of excitability. Physiological Psychology, 1, 158-160.

- BUCKNER, D.N. & McGRATH, J.J. (1963) A comparison of performance on single and dual sensory mode vigilance tasks. In, Vigilance: a Symposium. Buckner, D.N. & McGrath, J.J. (Eds.) New York, McGraw Hill, pp.53-71.
- BUCKNER, D.N., HARABEDIAN, A. & McGRATH, J.J. (1960) A study of individual differences in vigilance performance. Technical Report 206-2, Goleta, California: Human Factors Research, Inc.
- BUTCHER, H.J. (1968) Human Intelligence. Its Nature and Assessment. University Paperbacks.
- BYRNE, D.G. (1976) Vigilance and arousal in depressive states. British Journal of Social and Clinical Psychology, 15, 267-274.
- CALCOTE, L.G. (1977) The interaction of introversion, neuroticism and the presence of an evaluative audience on simple reaction time performance. Unpublished Ph.D. thesis, Southern Mississippi University, U.S.A.
- CARR, G. (1971) Introversion-extroversion and vigilance performance. Proceedings of the 79th Annual Convention of the American Psychological Association, 6, 379-380.
- CASEY, J. & McMANIS, D.L. (1971) Salivary response to lemon juice as a measure of introversion in children. Perceptual and Motor Skills, 33, 1059-1065.
- CASTANEDA, A. (1956) Reaction time and response amplitude as a function of anxiety and stimulus intensity. Journal of Abnormal and Social Psychology, 53, 225-228.
- CATTELL, R.B. (1972) The interpretation of Pavlov's typology, and the arousal concept, in replicated trait and state factors. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp.141-164, Academic Press, New York and London.
- CHENG, F.Y. (1968) Reaction time of introverts v. extroverts in schizophrenics and normals. Acta Psychologica, taiwanica, 10, 45-51.
- CLARIDGE, G.S. (1960) The excitation-inhibition balance in neurotics. In Eysenck, H.J. (Ed.) Experiments in Personality, Vol.2, pp.107-154, New York, Praeger.
- CLARIDGE, G.S. (1961) Arousal and inhibition as determinants of the performance of neurotics. British Journal of Psychology, 52, 53-63.
- CLARIDGE, G.S. (1967) Personality and Arousal. Pergamon
- CLARIDGE, G.S. (1972) The schizophrenics as nervous types. British Journal of Psychiatry, 121, 1-17.

- CLARIDGE, G.S. & BIRCHALL, P. (1978) Bishop, Eysenck, Block and psychoticism. *Journal of Abnormal Psychology*, 87, 664-668.
- CLARIDGE, G.S. & CHAPPA, H.J. (1973) Psychoticism: a study of its biological basis in normal subjects. *British Journal of Social and Clinical Psychology*, 12, 175-187.
- COCHRANE, R. & DUFFY, J. (1974) Psychology and scientific method. *Bulletin of the British Psychological Society*, 27, 117-121.
- COHEN, J. (1967) An alternative to Marascuilo's 'large sample multiple comparisons' for proportions. *Psychological Bulletin*, 67, 199-201.
- COLQUHOUN, W.P. (1960) Temperament, inspection efficiency and time of day. *Ergonomics*, 4, 41-52.
- COLQUHOUN, W.P. (1962a) Effects of hyoscine and meclozine on vigilance and short-term memory. *British Journal of Industrial Medicine*, 19, 287-296.
- COLQUHOUN, W.P. (1962b) Effects of a small dose of alcohol and certain other factors on the performance at a vigilance task. *Bull. C.E.R. P.*, 11, 27-44.
- COLQUHOUN, W.P. (1971) Circadian variations in mental efficiency. In Colquhoun, W.P. (Ed.), Biological Rhythms and Human Performance. London, Academic Press.
- COLQUHOUN, W.P. & BADDELEY, A.D. (1964) The role of pre-test expectancy in vigilance decrement. *Journal of Experimental Psychology*, 68, 156-160.
- COLQUHOUN, W.P. & CORCORAN, D.W.J. (1964) The effects of time of day and social isolation on the relationship between temperament and performance. *British Journal of Social and Clinical Psychology*, 3, 226-231.
- COLQUHOUN, W.P. & FOLKARD, S. (1978) Personality differences in body-temperature rhythm, and their relation to its adjustment to night work. *Ergonomics*, 21, 811-817.
- COPPEN, A. & METCALFE, M. (1965) Effect of a depressive illness on MPI scores. *British Journal of Psychiatry*, 111, 236-9.
- CORCORAN, D.W.J. (1964) The relationship between introversion and salivation. *American Journal of Psychology*, 77, 298-300.
- CORCORAN, D.W.J. (1965) Personality and the inverted-U relation. *British Journal of Psychology*, 56, 267-274.

- CORCORAN, D.W.J. (1972) Studies of individual differences at the applied psychology unit. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour pp.269-290. Academic Press, New York and London.
- CORCORAN, D.W.J., & HOUSTON, T.G. (1977) Is the lemon test an index of arousal level? *British Journal of Psychology*, 68, 361-364.
- CORCORAN, D.W.J., MULLIN, J., RAINEY, M.T., & KRITH, G. (1977) The effects of rased signal and noise amplitude during the course of vigilance tasks. In Mackie, R.R. (Ed.) Vigilance : Theory, Operational Performance and Physiological Correlates, pp.645-663, Plenum Press, New York and London.
- CORLIS, R., SPLAVER, G., WISECUP, P., & FISCHER, R. (1967) Myers-Briggs type personality scales and their relation to taste acuity. *Nature*, 216, 91-92.
- COSTELLO, C.G. (1957) The control of visual imagery in mental disorder. *Journal of Mental Science*, 103, 840-849.
- CRAIG, A. (1977) Broadbent and Gregory revisited: vigilance and statistical decision. *Human Factors*, 19, 25-36.
- * CRAIG, M.J., HUMPHREYS, M.S., ROCKLIN, T. & REVELLE, W. (1979) Impulsivity, neuroticism and caffeine: do they have additive effects on arousal? *Journal of Research in Personality*, 13, 404-419.
- CRESPI, L.P. (1947) Quantative variation of incentive and performance in the white rat. *American Journal of Psychology*, 55, 467-517.
- DAFTUAR, C.N. & SINHA, J.K. (1972) Sleep deprivation and human performance. *Psychologia: an international journal of psychology in the Orient*.
- DAVENPORT, H.W. (1977) Physiology of the Digestive Tract: an Introductory Text. Chicago.
- DAVIES, D.R. & HOCKEY, G.R.J. (1966) The effects of noise and doubling the signal frequency on individual differences in visual vigilance performance. *British Journal of Psychology*, 57, 381-389.
- DAVIES, D.R. & TUNE, G.S. (1970) Human Vigilance Performance. London, Staples Press.
- DAVIES, D.R., HOCKEY, G.R. & TAYLOR, A. (1969) Varied auditory stimulation, temperament differences and vigilance performance.
- DEESE, J. (1965) Some problems in the theory of vigilance. *Psychological Review*, 62, 359-368.
- * CRAIG, A. (1978) Is the vigilance decrement simply a response adjustment towards probability matching. *Human Factors*, 20, 441-446.

- DIAMOND, M., DIAMOND, A.L. & MAST, M. (1972) Visual sensitivity and sexual arousal levels during the menstrual cycle. *Journal of Nervous and Mental Disease*, 155, 170-176.
- DUFFY, G. (1972) Activation and Behaviourism. London, Wiley.
- EASTERBROOK, J.A. (1959) The effect of emotion on cue utilisation and the organisation of behaviour. *Psychological Review*, 66, 183-201.
- EDMAN, G., SCHALLING, D. & RÜSSLER, A. (1979) Interaction effects of extraversion and neuroticism on detection thresholds. *Biological Psychology*, 9, 41-47.
- EKMAN, G., HOSMAN, B., LINDMAN, R., LJUNBERG, L. & AKARSON, C. (1967) Inter-individual differences in scaling performance. Report of the Psychological Laboratory, University of Stockholm, No.241.
- ELIASZ, A. (1973) Temperament traits and reaction preferences depending on stimulation load. *Polish Psychological Bulletin*, 4, 103-114.
- ENGSTROM, D.R., LONDON, P. & HART, J.T. (1970) E.E.G. alpha feedback training and hypnotic susceptibility. *Proceedings of the 78th Annual Conference of the American Psychological Association*, 5, 837-8.
- EVANS, P. (1975) Motivation. Methuen, London.
- EYSENCK, H.J. (1955) Cortical inhibition, figural afterthought and theory of personality. *Journal of Abnormal and Social Psychology*, 51, 94-106.
- EYSENCK, H.J. (1957) The Dynamics of Anxiety and Hysteria. Praeger, New York.
- EYSENCK, H.J. (1960) The Structure of Human Personality. Methuen, London.
- EYSENCK, H.J. (1966) Conditioning, introversion-extraversion and the strength of the nervous system. In *Physiological bases of individual psychological differences*, Symposium 9, International Congress of Psychology,
- EYSENCK, H.J. (1967) The Biological Basis of Personality. Springfield, Illinois, U.S.A.
- EYSENCK, H.J. (1972) Human typology, higher nervous activity and factor analysis. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp. 165-181, Academic Press, New York and London.

- EYSENCK, H.J. (1975) Who needs a random sample? *Bulletin of the British Psychological Society*, 28, 195-198.
- EYSENCK, H.J. (1977) Psychosis and psychoticism: a reply to Bishop. *Journal of Abnormal Psychology*, 86, 427-430.
- EYSENCK, H.J. & EYSENCK, S.B.G. (1967) On the unitary nature of extraversion. *Acta Psychologica*, 26, 383-390.
- EYSENCK, H.J. & EYSENCK, S.B.G. (1969) Personality, Structure and Measurement. Routledge and Kegan Paul, London.
- EYSENCK, H.J. & EYSENCK, S.B.G. (1975) Manual of the Eysenck Personality Questionnaire. Hodder and Stoughton.
- EYSENCK, H.J. & EYSENCK, S.B.G. (1976) Psychoticism as a Dimension of Personality. London
- EYSENCK, H.J. & LEVEY, A. (1972) Conditioning, introversion-extroversion and the strength of the nervous system. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp. 206-220. Academic Press, New York and London.
- EYSENCK, M.W. & FOLKARD, S. (1980) Personality, time of day, and caffeine: some theoretical and conceptual problems. In Revelle et al, *Journal of Experimental Psychology: general*, 109, 32-41.
- EYSENCK, S.B.G. & EYSENCK, H.J. (1967a) Salivary response to lemon juice as a measure of introversion. *Perceptual and Motor Skills*, 24, 1047-1053.
- EYSENCK, S.B.G. & EYSENCK, H.J. (1967b) Physiological reactivity to sensory stimulation as a measure of personality. *Psychological Reports*, 20, 45-46.
- EYSENCK, S.B.G. & ZUCKERMAN, M. (1978) The relationship between sensation-seeking and Eysenck's dimensions of personality. *British Journal of Psychology*, 69, 483-487.
- FAGERSTROM, K.O. & LISPER, H.O. (1977) Effects of listening to car radio, experience, and personality of the driver on subsidiary reaction time and heart rate in a long-term driving task. In Mackie, R.R. (Ed.) Vigilance: Theory Operational Performance and Physiological Correlates, pp.73-86, Plenum Press, New York and London.
- FARLEY, F. & FARLEY, S.V. (1967) Extraversion and stimulus-seeking motivation. *Journal of Consulting Psychology*, 31, 215-216.

- FARLEY, F.H. & KUMAR, K.V. (1969) Personality and audiometric response consistency. *Journal of Auditory Research*, 9, 108-111.
- FELLOWS, B. (1973) Hypnotic susceptibility and personality as measured by the EPI. (Unpublished study) Cited by Gibson, H.B. & Curran, J.E. (1974) Hypnotic susceptibility and personality: a replication study. *British Journal of Psychology*, 65, 283-291.
- FERGUSON, R.E. (1970) The effects of signal probabilities, food intake, sex, and smoking on the gustatory response to sucrose, as measured by the theory of signal detectability. *Dissertation Abstracts International*, 30 (8-B), 3885.
- FISCHER, R. (1967) Genetics and gustatory chemoreception in man and other primates. In Kane, M. (Ed.) The Chemical Senses and Nutrition, pp. 61-71, John Hopkins Press.
- FISCHER, R. (1971) Gustatory, behavioural and pharmacological manifestations of chemoreception in man. In Ohloff, G. & Thomas, A.F. (Eds.), Gustation and Olfaction. Academic Press, London and New York.
- FISCHER, R., GRIFFIN, F., ARCHER, R., ZINMEISTER, S. & JASTRAM, F. (1965) Weber ratio in gustatory chemoreception; an indication of systemic (drug) reactivity. *Nature*, 207, 1049-1053.
- FISCHER, R., GRIFFIN, F. & PASAMANICK, B. (1965) The perception of taste: some psychophysiological, pathophysiological, pharmacological and clinical aspects. In Hock, P. & Zubin, J. (Eds.) Psychopathology of Perception, pp. 129-163, Grune and Stratton, New York and London.
- FISCHER, R. GRIFFIN, F. & ROCKEY, M. (1966) Gustatory chemoreception in man: multidisciplinary aspects and perspectives. *Perspectives in Biological Medicine*, 9, 549-577.
- FISCHER, R., HILL, R. & WARSHAY, D. (1969) Effects of the psychodysceptic drug psilocybin on visual perception: changes in brightness preference. *Exper.*, 25, 166-169.
- FISCHER, R. & KAEHLING, R. (1967) Increase in taste acuity with sympathetic stimulation; the relation of a just-noticeable taste difference to systemic psychotropic drug dose. In Wortis, J. (Ed.) Recent Advances in Biological Psychiatry, 9, pp. 183-195. Plenum Press, London.
- FISCHER, R., RISTINE, L. & WISECUP, P. (1969) Increase in gustatory activity and hyperarousal in schizophrenia. *Biological Psychiatry*, 1, 209-218.

- FOWLES, D.C., ROBERTS, R. & NAGEL, K.E. (1977) The influence of introversion-extraversion on the skin conductance response to stress and stimulus intensity. *Journal of Research in Personality*, 11, 129-146.
- FRANKMAN, J.P. & ADAMS, J.A. (1962) Theories of vigilance. *Psychological Bulletin*, 59, 257-272.
- FRANKS, C.M. (1956) Conditioning and personality: a study of normal and neurotic subjects. *Journal of Abnormal and Social Psychology*, 52, 143-150.
- FRANKS, C.M. (1957) Personality and the rate of conditioning. *British Journal of Psychology*, 48, 119-126.
- FRANKS, C.M. (1963) Ocular movements and spontaneous blink rate as functions of personality. *Perceptual and Motor Skills*, 16, 178.
- FRAZIER, T.W., RUMMEL, J.A. & LIPSCOMB, H.S. (1968) Circadian variability and vigilance performance. *Aerospace Medicine*, 39, 383-395.
- FREEMAN, G.L. (1937) The optimal locus of 'anticipatory tension' in muscular work. *Journal of Experimental Psychology*, 21, 554-564.
- FRIGON, J.Y. (1976) Extraversion, neuroticism and strength. *British Journal of Psychology*, 67, 467-474.
- FRITH, C.D. (1967) The interaction of noise and personality with critical flicker fusion performance. *British Journal of Psychology*, 58, 127-131.
- FRITH, C.D. (1968) Personality, nicotine and the salivary response. *Life Sciences*, 7, 1151-6.
- FURNEAUX, W.D. (1961) Neuroticism, extraversion, drive and suggestibility. *International Journal of Clinical and Experimental Hypnosis*, 9, 195-214
- FURNEAUX, W.D. & GIBSON, H.B. (1961) The Maudsley Personality Inventory as a predictor of susceptibility to hypnosis. *International Journal of Clinical and Experimental Hypnosis*, 9, 167-176.
- GALE, A. (1969) 'Stimulus hunger': individual differences in operant strategy in a button-pressing task. *Behaviour Research and Therapy*, 7, 265-274.
- GALE, A. (1977) Some E.E.G. correlates of sustained attention. In Mackie, R.R. (Ed.) Vigilance: Theory, Operational Performance and Physiological Correlates, pp. 263-284, Plenum Press, New York and London.

- GALE, A., BULL, R., PENFOLD, V., COLES, M. & BARRACLOUGH, R. (1972) Extroversion, time of day, vigilance performance and physiological arousal: a failure to replicate traditional findings. *Psychonomic Science*, 29, 1-5.
- GALIFRET, Y. (1962) Evaluation of the efficiency of a stimulus by means of central unit responses. *Journal of Physiology, Paris*, 54, 343-344.
- GELLHORN, E. (1968) Tuning of the nervous system. *Journal of Nervous and Mental Disease*, 147, 148
- GELLHORN, E. (1970) The emotions and the ergotropic and trophotropic systems. *Psychologische Forschung*, 34, 48
- GERSHWIN, G.V., KOZHERNIKOV, V.A., MARUSEVA, A.M., AVAKYAN, R.V., RADINOVA, E.A., ALTMAN, J.A. & SOROKO, V.I. (1960) Modifications in electrical responses of the auditory system in different states of the higher nervous activity. *The Moscow Colloquium on Electroencephalography of Higher Nervous Activity*,
- GIBSON, H.B. (1979) The application of hypnotic techniques to therapy: some problems of theory and practice. *British Journal of Medical Psychology*, 52, 141-145.
- GIBSON, H.B. & CORCORAN, M.E. (1975) Personality and differential susceptibility to hypnosis: further replication and sex differences. *British Journal of Psychology*, 66, 513-520.
- GIBSON, H.B., CORCORAN, M.E. & CURRAN, J.D. (1977) Hypnotic susceptibility and personality: the consequences of diazepam and sex of the subjects. *British Journal of Psychology*, 68, 51-59.
- GIBSON, H.B. & CURRAN, J.D. (1974) Hypnotic susceptibility and personality: a replication study. *British Journal of Psychology*, 65, 283-291.
- GINSBURG, N. (1969) Extraversion and adaptation to intermittent light. *Perceptual and Motor Skills*, 28, 195-201.
- GOODMAN, L. & GILMAN, A. (1955) The Pharmacological Basis of Therapeutics. Macmillan, New York.
- GRACZ, J. (1977) The cutaneous-galvanic reaction as an indication of pre-start emotional intensity. *Psychologiczny*, 20, 117-129.
- GRAHAM, F.K. & CLIFTON, R.K. (1966) Heart rate change as a component of the orienting response. *Psychological Bulletin*, 65, 305-320.
- GRANGER, G.W. (1957) Night vision and psychiatric disorders. *Journal of Mental Science*, 103, 48-79.

- GRANGER, G.W. (1960) Abnormalities of sensory perception. In Eysenck, H.J. (Ed.) Handbook of Abnormal Psychology pp. 108-166. Pitman, London.
- GRAY, J.A. (1964) Pavlov's Typology. Pergamon Press.
- GRAY, J.A. (1967) Strength of the nervous system, introversion-extraversion, conditionability and arousal. Behaviour Research and Therapy, 5, 151-169.
- GRAY, J.A. (1970) The psychophysiological basis of introversion-extroversion. Behaviour Research and Therapy, 8, 249-266.
- GRAY, J.A. (1971) The Psychology of Fear and Stress. Weidenfeld and Nicolson, London; McGraw Hill, New York.
- GRAY, J.A. (1972) Learning theory, the conceptual nervous system and personality. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp.372-399, Academic Press, New York and London.
- GRAY, J.A. (1976) The behavioural inhibition system: a possible substrate for anxiety. In Feldman, M.A. & Broadhurst, A. Theoretical and Experimental Bases of The Behaviour Therapies. Wiley, London.
- GREEN, D.M. & SWETS, J.A. (1974) Signal Detection Theory and Psychophysics. Robert E. Kreiger.
- GREGG, L.W. & BROGDEN, W.J. (1952) The effect of simultaneous visual stimulation on absolute auditory sensitivity. Journal of Experimental Psychology, 13, 1-11.
- GREGORY, R.L. (1966) Eye and Brain. Weidenfeld and Nicolson, London.
- GRICE, G.R. (1968) Stimulus intensity and response evocation. Psychological Review, 75, 359-373.
- GRICE, G.R., HUNT, R.L., KUSHNER, B.A. & MORROW, C. (1974) Stimulus intensity, catch trial effects and the speed-accuracy tradeoff in reaction time; a variable criterion theory interpretation. Memory and Cognition, 12, 758-770.
- GRICE G.R., HUNT, R.R., KUSHNER, B.A. & NULLMEYER, R. (1976) Associative processes and strategies in disjunctive reaction time. Memory and Cognition, 4, 433-445.
- GRICE, G.R., NULLKEYER, R. & SCHNIZLEIN, J.M. (1979) Variable criterion analysis of brightness effects in simple reaction time. Journal of Experimental Psychology: Human Perception and Performance, 5, 303-314.
- GRIER, J.B. (1971) Nonparametric indices for sensitivity and bias: computing formulas. Psychological Bulletin, 75, 424-429.

- GUILFORD, J.P. (1954) Systems in the relationship of affective value to frequency and intensity of auditory stimuli. *American Journal of Psychology*, 67, 691-698.
- GULIAN, E. (1970) Effects of noise on arousal level in auditory vigilance. *Acta Psychologica*, 33, 381-393.
- GULIAN, E. (1971) Psychophysiological correlates of auditory vigilance under noise conditions in introverts and extroverts. *Revue Roumaine Sciences Sociales-Série de Psychologie*, 15, 125-136.
- GULIAN, E. (1972) Focussing of attention and arousal level under interaction of stressors in introverts and extroverts. *Revue Roumaine Sciences Sociales-Série de Psychologie*, 16, 153-168.
- GULIAN, E. (1974) Noise as a stressing agent. *Studia Psychologica*, XVI, 160-168.
- GUSKI, R. (1975) An experiment on the relationship between noise intensity, awareness of the situation, and performance, *Zeitschrift für Experimentelle und Angewandte Psychologie*, 22, 584-599.
- HAKE, H.W. & RODWAN, A.S. (1966) Perception and recognition. In Sidowski, J.B. (Ed.) *Experimental Methods and Instrumentation in Psychology*, pp.332-381, McGraw Hill, New York.
- HALMTCOVA, O. (1965) Manifestations of psychic characteristics in a vigilance task. *Studia Psychologica*, 7, 258-270.
- HARE, R.D. (1970) Psychopathy: Theory and Research. John Wiley & Sons, New York.
- HARKINS, S. & GEEN, R.G. (1975) Discriminability and criterion differences between extraverts and introverts during vigilance. *Journal of Research in Personality*, 9, 335-340.
- HASLAM, D.R. (1972) Experimental pain. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp. 242-253, Academic Press, New York and London.
- HASTRUP, J.L. (1979) Effects of electrodermal lability and introversion on vigilance decrement. *Psychophysiology*, 16, 302-310.
- HATFIELD, J.L. & SODERQUIST, D.R. (1969) Practice effects and signal detection indices in an auditory vigilance task. *Journal of the Acoustical Society of America*, 46, 1458-1463.
- HEBB, D.O. (1955) Drives and the c.n.s. (conceptual nervous system). *Psychological Review*, 62, 243-254.

- HEILIZER, F. (1975) The law of initial values (LIV) and personality. *The Journal of General Psychology*, 92, 273-290.
- HILGARD, E.R. & BENTLER, P.M. (1963) Predicting hypnotizability from the Maudsley Personality Inventory. *British Journal of Psychology*, 54, 63-69.
- HILL, A.B. (1975) Extraversion and variety-seeking in a monotonous task. *British Journal of Psychology*, 66, 9-13.
- HINK, R.F., FENTON, W.H., jr., TINKLENBERG, J.R., PFEFFERBAUM, A. & KOPELL, B.S. (1978) Vigilance and human attention under conditions of methylphenidate and secorbarbital intoxication: an assessment of using brain potentials. *Psychophysiology*, 15, 116-125.
- HOGAN, M.J. (1966) Influence of motivation on reactive inhibition in extraversion-introversion. *Perceptual and Motor Skills*, 22, 187-192.
- HOLLAND, J.G. (1958) Human vigilance, *Science*, 128, 61-67.
- HOOD, J.D. (1968) Loudness discomfort level and auditory fatigue. *Journal of the Acoustical Society of America*, 44, 959-964.
- HORNE, J.A. & OSTBERG, O. (1975) Time of day effects on extraversion and salivation. *Biological Psychology*, 2-3, 301-307.
- HORNE, J.A. & OSTBERG, O. (1977) Individual differences in human circadian rhythms. *Biological Psychology*, 5, 179-190.
- HOROWITZ, S. (1970) Strategies within hypnosis for reducing phobic behaviour. *Journal of Abnormal Psychology*, 75, 104-112.
- HOWARTH, E. & SKINNER, N.F. (1969) Salivation as a physiological indicator of introversion-extraversion. *Journal of Psychology*, 73, 223-238.
- HUMMEL, H. & LESTER, D. (1978) Extraversion and simple reaction time. *Perceptual and Motor Skills*, 45, 1236.
- HUMPHREYS, M.S., REVELLE, W., SIMON, L. & GILLILARD, K. (1980) Individual differences in diurnal rhythms and multiple activation states: a reply to M.W. Eysenck and Folkard. *Journal of Experimental Psychology: General*, 109, 42-48.
- HUNTERMARK, J. & WITTE, K.L. (1978) Vigilance performance as related to task instructions, coaction, and knowledge of results. *Bulletin of the Psychonomic Society*, 12, 325-328.
- INGHAM, J.G. (1966) Changes in MPI scores in neurotic patients: a three year follow up. *British Journal of Psychiatry*, 112, 931-9.

- IPPOLITOV, F.V. (1972) Interanalyser differences in the sensitivity-strength parameter for vision, hearing and cutaneous modalities. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp. 43-61, Academic Press, New York and London.
- IRVINE, D.R., WEBSTER, W.R. & SACK, KH. (1970) Effects of repetitive stimulation and state of arousal on cochlear potentials. Experimental Neurology, 29, 16-30.
- ISAAC, W. (1960) Arousal and reaction times in cats. Journal of Comparative and Physiological Psychology, 53, 234-236.
- JENKINS, H.M. (1958) The effect of signal rate on performance in visual monitoring. American Journal of Psychology, 71, 647-661.
- JERISON, H.J. (1967) Signal detection theory in the analysis of human vigilance. Human Factors, 9, 285-288.
- JERISON, H.J. & PICKETT, R.M. (1964) Vigilance; the importance of the elicited observing rate. Science, 143, 970-971.
- JOHN, I.D. (1967a) A statistical decision theory of simple reaction time. Australian Journal of Psychology, 19, 27-34.
- JOHN, I.D. (1967b) Sequential effects of stimulus characteristics in a serial reaction time task. Australian Journal of Psychology, 19, 35-40.
- JOHNSTON, W.A., HOWELL, W.C. & GOLDSTEIN, I.L. (1966) Human vigilance as a function of signal frequency and stimulus density. Journal of Experimental Psychology, 72, 736-743.
- JONES, F.N. & MARCUS, M.J. (1961) Subject effect in judgements of subjective magnitude. Journal of Experimental Psychology, 61, 40-44.
- JONES, H.G. (1960) Learning and abnormal behaviour. In Eysenck, H.J. (Ed.) Handbook of Abnormal Psychology, Basic Books, New York.
- KAKIGI, S. & IMASHIOYA, H. (1972) Foreperiod interval, alpha blocking, heart rate and simple reaction time. Acta Psychologica, 36, 459-470.
- KALLMAN, W.M. & ISAAC, W. (1977) Altering arousal in humans by varying ambient sensory conditions. Perceptual and Motor Skills, 44, 19-22.
- JEFFREY, D.W. (1969) Age differences in serial reaction time as a function of stimulus complexity under conditions of noise and muscular tension. Dissertation Abstracts International, 30 (11-B), p.5258.

- KEISTER, M.E. & McLAUGHLIN, R.J. (1972) Vigilance performance related to extraversion-introversion and caffeine. *Journal of Experimental Research in Personality*, 6, 5-11.
- KELVIN, R.P., LUCAS, C.J. & OJHA, A.B. (1965) The relation between personality, mental health and academic performance in university students. *British Journal of Social and Clinical Psychology*, 4, 244-253.
- KENNEDY, R.S. (1972) Individual differences in auditory vigilance performance on the bard-pass ability (B-Ps) test: some theoretical considerations. *Human Factors Society National Symposium*. pp.1-21.
- KERR, A.C. (1961) The Physiological Regulation of Salivary Secretion in Man.
- KEUSS, P.J.G. (1972) Reaction time to the second of two shortly spaced auditory signals both varying in intensity. *Acta Psychologica*, 36, 226-238.
- KEUSS, P.J.G. & ORLEBEKE, J.F. (1977) Transmarginal inhibition in a reaction time task as a function of extraversion and neuroticism. *Acta Psychologica*, 41, 139-150.
- KIBLER, A.W. (1965) The relevance of vigilance research to aerospace monitoring tasks. *Human Factors*, 7, 93-99.
- KIHLSTROM, J.F. (1979) Hypnosis and psychopathology: retrospect and prospect. *Journal of Abnormal Psychology*, 88, 459-473.
- KILLEEN, P.R., HANSON, S.J., & OSBORNE, S.R. (1978) Arousal; its genesis and manifestation as response rate. *Psychological Review*, 85, 571-581.
- KISHIMOTO, Y. (1979) Effects of signal rate, stimulus rate, signal probability on visual vigilance performance. *Japanese Journal of Psychology*, 49, 341-348.
- KJELLBERG, A. (1977) Sleep deprivation, arousal and performance. In Mackie, R.R. (Ed.) Vigilance: Theory, Operational Performance and Physiological Correlates. pp.529-536. Plenum Press, New York and London.
- KLINE, M.V. & LINDER, M. (1967) Psychodynamic factors in the experimental investigation of hypnotically induced emotions with particular reference to blood glucose measurements. *Acta Medica Psychosomatics*. Proceedings of the 7th European Conference of Psychosomatic Research, Rome.
- KNOWLES, J.B. (1960) The temporal stability of MPI scores in normal and psychiatric populations. *Journal of Consulting Psychology*, 24, 278.
- KOCHER, E.C. & FISHER, L. (1969) Subjective intensity and taste preference, *Perceptual and Motor Skills*, 28, 735-740.
- KOELGA, H.S. (1970) Extraversion, sex, arousal and olfactory sensitivity. *Acta Psychologica*, 34, 51-66.
- KOHLFELD, D.L. (1969) Effects of ready-signal intensity and intensity of the preceding response on simple reaction time. *Journal of Experimental Psychology*, 82, 104-110.

- KISHIMOTO, Y. (1977). Visual vigilance performance of extraverts and introverts under two conditions of signal frequency. *Japanese Journal of Psychology*, 48, 53-57.
- KOHLFELD, O.L. & GOEDECKE, D.W. (1978) Intensity and predictability of background noise as a determinant of simple reaction time. *Bulletin of the Psychonomic Society*, 12, 129
- KOK, A. (1975) Individual differences in heart rate and skin resistance during information processing. *Nederlands Tijdschrift voor de Psychologie*, 30, 255-275.
- KOVAC, D. & HALMIOVA O, (1973) Is there a direct relation between emotional stability and strength of nervous processes. *Studia Psychologica*, XV, 314-320.
- KOZLOWSKI, C. (1977) Demand for stimulation and probability preferences in gambling decisions. *Polish Psychological Bulletin*, 8, 67-73.
- KUECHLER, H.A. & DODWELL, P.C. (1968) Auditory signal detectability as a function of pre-experimental shock. *Quarterly Journal of Experimental Psychology*, 20, 305-308.
- KULYUTKIN, Y.N., ZYRYANOVA, N.G. & SUKHOBRSKAYA, G.S. (1972) Influence of neurodynamic factors on individual characteristics of problem solving. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour pp. 334-341. Academic Press, New York and London.
- LACEY, J.I. (1959) Psychophysiological approaches to the evaluation of psychotherapeutic process and outcome. In Rubenstein, E.A. & Parloff, M.A. (Eds.) Research in Psychotherapy, pp. 160-208, American Psychological Association, Washington, D.C.
- LACEY, B. & LACEY, J.I. (1964) Cardiac deceleration and simple visual reaction time in a fixed foreperiod experiment. Paper presented at the Society for Psychophysiological Research, Washington, D.C., October 1964.
- LACEY, J.I. & LACEY, B.C. (1958) The relationship of resting autonomic activity to motor impulsivity. Research publication of the Association for Research in Nervous and Mental Disease, 36, 144-209.
- LEON, B.N. (1974) Pain perception and extraversion-introversion. *Perceptual and Motor Skills*, 38, 510.
- LESTER, D. (1974) A Physiological Basis for Personality Traits: a New Theory of Personality. Springfield, Illinois.
- LE VERE, T.E., MORLOCK, G.W., THOMAS, L.P. & HART, F.D. (1974) Arousal from sleep: the differential effect of frequencies equated for loudness. *Physiology and Behaviour*, 12, 573-582.

- LEVINE, J.M., ROMASHKO, T. & FLEISHMAN, E.A. (1973) Evaluation of an abilities classification system for integrating and generating human performance research findings. An application to vigilance tasks. *Journal of Applied Psychology*, 58, 149-157.
- LISPER, H.O., KJELLBERG, A. & MELIN, L. (1972) Effects of signal intensity on increase of reaction time on an auditory monitoring task. *Perceptual and Motor Skills*, 34, 439-444.
- LOEB, M. & ALLUISI, E.A. (1977) An update of findings regarding vigilance and a reconsideration of underlying mechanisms. In Mackie, R.R. (Ed.) Vigilance: Theory, Operational Performance and Physiological Correlates, pp. 719-750, Plenum Press, New York and London.
- LOEB, M. & BINFORD, J.R. (1968) Variation in performance on auditory and visual monitoring tasks as a function of signal and stimulus frequencies. *Perception and Psychophysics*, 4, 361-367.
- LOLAS, F. & ANDRACA, I. (1977) Neuroticism, extraversion and slow brain potentials. *Neuropsychobiology*, 3, 12-22.
- LONDON, P., HART, J., & LEIBOVITZ, M. (1968) E.E.G. alpha rhythms and hypnotic susceptibility. *Nature*, 219, 71-72.
- LOO, R. (1979) Neo-Pavlovian properties of higher nervous activity and Eysenck's personality dimensions. *International Journal of Psychology*, 14, 265-274.
- LUBIN, A. (1967) Performance under sleep loss and fatigue. In Kety, S., Evarts, E. & Williams, H. (Eds.) Sleep and Altered States of Consciousness, pp 506-513, Williams and Wilkins, Baltimore.
- LUNGI, M. & RYLE, A. (1969) The stability of scores on the Eysenck Personality Inventory in a university population. *British Journal of Psychiatry*, 115, 1201-1202.
- MACKAY, C., COX, T., BURROWS, G. & LAZZERINI, T. (1978) An inventory for the measurement of self reported stress and arousal. *British Journal of Social and Clinical Psychology*, 17, 283-284.
- MACKIE, R.R. (Ed.) (1977) Vigilance: Theory, Operational Performance and Physiological Correlates. Plenum Press, New York and London.
- MACKWORTH, J.F. (1969) Vigilance and Habituation. Penguin.
- MACKWORTH, J.F. (1970) Vigilance and Attention: a Signal Detection Approach. Penguin.

- MACKWORTH, J.F. & TAYLOR, M.M. (1963) The d' measure of signal detectability in vigilance-like situations. *Canadian Journal of Psychology*, 17, 302-325.
- MACKWORTH, N.H. (1948) The breakdown of vigilance during prolonged visual search. *Quarterly Journal of Experimental Psychology*, 1, 6-21.
- MACKWORTH, N.H. (1950) Researches in the measurement of human performance. Medical Research Council Special Report 268, H.M.S.O., reprinted in Sinaiko, H.A. (Ed.) (1961) Selected Papers on Human Factors Design and Use of Control Systems, pp. 174-331, Dover Publications.
- MALMO, R.B. (1959) Activation: a neuropsychological dimension. *Psychological Review*, 66, 367-386.
- MALMO, R.B. (1966) Studies of anxiety: some clinical origins of the activation concept. In Spielberger, C.D. (Ed.), Anxiety and Behaviour, Academic Press, New York.
- MALMO, R.B. & BELANGER, D. (1967) Related physiological and behavioural changes: what are their determinants? *Research Publications of the Association for Research in Nervous and Mental Disease*, 45, 283-318.
- MANDELBAUM, J. (1941) Dark adaptation; some physiological and clinical considerations. *Archives of Ophthalmology*, 26, 203-239.
- MANGAN, G.L. (1967) Studies of the relationship between neo-Pavlovian properties of higher nervous activity and Western personality dimensions: IV. A factor analytic study of extraversion and flexibility, and the sensitivity and mobility of the nervous system. *Journal of Experimental Research in Personality*, 2, 124-127.
- MANGAN, G.L. (1978a) Inhibitory ease - a personality type? *Pavlovian Journal of Biological Science*, 13, 177-181.
- MANGAN, G.L. (1978b) The relationship of mobility of inhibition to rate of inhibitory growth and measures of flexibility, extraversion and neuroticism. *The Journal of General Psychology*, 99, 271-279.
- MANGAN, G.L. & FARMER, R.G. (1967) Studies of the relationship between Neo-Pavlovian properties of higher nervous activity and Western personality dimensions, I. The relationship of nervous strength and sensitivity to extraversion. *Journal of Experimental Research in Personality*, 2, 101-106.
- MARKS, I.M., BOULOUGOURIS, J.C. & MARSET, P. (1971) Flooding versus desensitisation in the treatment of phobic patients: a crossover study. *British Journal of Psychiatry*, 119, 353-375.
- MARTON, M. & URBAN, Ya (1966) An electroencephalographic investigation of individual differences in the processes of conditioning. Proceedings of the Eighteenth International Congress of Experimental Psychology, Moscow, Ninth Symposium, pp. 106-109

- MEDDIS, R. (1973) Elementary Analysis of Variance for the Behavioural Sciences. McGraw-Hill.
- MEDEIROS, E.E & McMANIS, D.L. (1974) Assessment of introversion-extraversion in children: brief report. Perceptual and Motor Skills, 38, 429-430.
- McGILL, W.J. (1963) Stochastic latency mechanisms. In Luce, R.D., Bush, R.R. & Galanter, E. (Eds.). Handbook of Mathematical Psychology (Vol. 1). Wiley, New York.
- McGOWN, C. (1976) The effect of motor and sensory set on reaction time and muscle electrical activity. Research Quarterly, 47, 708-715.
- McGRATH, J.J. & HARAEEDIAN, A. (1963) Signal detection as a function of intersignal-interval duration. In Buckner, D.H. & McGrath, J.J. (Eds.) Vigilance: a Symposium, pp. 102-9 McGraw-Hill.
- McGUINNESS, D. (1974) Equating individual differences for auditory input. Psychophysiology, 11, 113-120.
- McGUINNESS, D. (1976). Away from a unisex psychology: individual differences in visual sensory and perceptual processes. Perception, 5, 279-294.
- McMARRIS, D.L., MCCARTHY, M. & KOVAL, R. (1978) Effects of a stimulant drug on extraversion level in hyperactive children. Perceptual and Motor Skills, 46, 88-90.
- McNICOL, D. (1973) A Primer of Signal Detection Theory. George Allen & Unwin Ltd.
- MICHAELIS, W. & EYSENCK, H.J. (1971) The determination of personality inventory factor patterns and intercorrelations by changes in real-life motivation. Journal of Genetic Psychology, 118, 223-34.
- MIELZUSKI, C. (1974) Effect of white noise on the reaction time of mentally retarded subjects. American Journal of Mental Deficiency, 79, 39-43.
- MILLER, N.E. (1959) Liberalisation of basic S-R concepts: extensions to conflict behaviour, motivation and social learning. In Koch, S. (Ed.) Psychology: A Study of a Science. Study I: Conceptual and Systematic. Vol.2. Pp. 196-292.
- MILNER, A.D., BEECH, H.R. & WALKER, V.J. (1971) Decision processes and obsessional behaviour. British Journal of Social and Clinical Psychology, 10, 88-89.
- MISCHEL, W. (1968) Personality and Assessment. Wiley, New York.

- MOHAN, J., MURIZAL, N. & BABRA, H. (1974) Fluctuation of attention as a function of personality and intermittent distraction. *Behaviorometric*, 4, 8-14.
- MORUZZI, G. (1960) Synchronizing influences at the brain stem and the inhibitory mechanisms underlying the production of sleep by sensory stimulation. In Jasper, H.H. & Smirnov, G.D. (Eds.) *Moscow Colloquium on Electroencephalography of higher nervous activity. Electroencephalography and Clinical Neurophysiology*, 13.
- MOWRER, D. H. (1940) Preparatory set: some methods of measurement. *Psychological Monographs* No. 52
- MULLER, R. & MAUERMAN, W. (1975) Experience in category rating and the exponent in Stevens's power law. *Studia Psychologica*, 17, 178-187.
- NARAYANAN, S. & NATARAJAN, P. (1975) A measure of preparatory set (expectancy) in terms of motion perception and its relation to extraversion-introversion and neuroticism. *Journal of Psychological Researches*, 19, 41-45.
- NEBYLITSYN, V.D. (1956) The relationship between sensitivity and strength of the nervous system. In Teplov, B.M. (Ed.) Typological Features of Higher Nervous Activity in Man, Vol.1. Moscow: Akad. Pedagog. Nauk RSFSR.
- NEBYLITSYN, V.D. (1957) Individual differences in the strength and sensitivity of both visual and auditory analysers. *Voprosy Psikhologii*, 4, 153-169. English translation contained in O'Connor, N. (Ed.) Recent Soviet Psychology, Pergamon Press, Oxford (1961)
- NEBYLITSYN, V.D. (1959) An investigation of the connection between sensitivity and strength of the nervous system. In Teplov, B.M. (Ed.) Typological Features of Higher Nervous Activity in Man, Vol.2. Moscow: Akad. Pedagog. Nauk. RSFSR.
- NEBYLITSYN, V.D. (1960) Reaction time and strength of the nervous system. First communication: Typological differences in the way in which the 'law of strength' takes effect when stimulus intensity is varied. *Dokl. Akad. Pedagog. Nauk. RSFSR. No.4.*, 93-100.
- NEBYLITSYN, V.D. (1963a) On the structure of the basic properties of the nervous system. *Voprosy Psikhologii*, No.4.
- NEBYLITSYN, V.D. (1963b) An electroencephalographic investigation of the properties of strength of the nervous system and equilibrium of the nervous processes in man using factor analysis. In Teplov, B.M. (Ed.) Typological Features of Higher Nervous Activity in Man, Vol.3, pp. 47-80, Akad. Pedagog. Nauk RSFSR, Moscow.

- NEBYLITSYN, V.D. (1972) Fundamental Properties of the Nervous System, translation edited by Mangan, G.L., Plenum Press, New York-London.
- NEBYLITSYN, V.D., GOLNBERG, E.A., RAVICH-SHCERBO, I.V., & YERMOLAYEVA-TOMINA, L.B. (1965) A comparative study of brief methods of determining the basic properties of the nervous system in man. In Teplov, B.M. (Ed.) Typological Features of Higher Nervous Activity in Man, Vol. 4, Prosveshcheniye, Moscow.
- NEBYLITSYN, V.D. & GRAY, J.A. (Eds.) (1972) Biological Bases of Individual Behaviour, Academic Press, New York and London.
- NETTLEBECK, T. (1973) Individual differences in noise and associated perceptual indices of performance. Perception, 2 11-21.
- NOSAL, C. (1971) Effect of noise on performance and activation level. Polish Psychological Bulletin, 2, 23-29.
- NOWLIS, V. (1966) Research with the Mood Adjective Check List. In Tomkins, S.S. & Izard, C.E. (Eds.) Affect, Cognition and Personality, Tavistock, London.
- O'CONNOR, N. (Ed.) (1961) Recent Soviet Psychology, Pergamon Press, Oxford.
- O'CONNOR, N. (Ed.) (1966) Present-day Russian Psychology; a Symposium by Seven Authors. Pergamon, Oxford.
- O'GORMAN, J.G. (1977) Individual differences in habituation of human physiological responses; a review of theory, method, and findings in the study of personality correlates in non-clinical populations. Biological Psychology, 5, 257-318.
- O'HANLON, J.F., & KELLEY, G.R. (1977) Comparison of performance and physiological changes between drivers who perform well and poorly during prolonged vehicular operation. In Mackie, R.R. (Ed.) Vigilance: Theory, Operational Performance and Physiological Correlates pp.87-110, Plenum Press, New York and London.
- OLSHANNIKOVA, A.Y. & ALEKSANDROVA, N.I. (1969) On the reliability of the motor reaction indices. In Nebylitsyn, V.D. (Ed.) Problems of Differential Psychophysiology, Vol. VI, 'Prosveshcheniye' Publishers, Moscow.
- ORLEBEKE, J.F. (1973) Electrodermal, vasomotor and heart rate correlates of extraversion and neuroticism. Psychophysiology, 10, 211-212.
- OSWALD, I. (1962) Sleeping and Waking: Physiology and Psychology. Elsevier, Amsterdam.

- OZBAYDAY, S. (1961) The effect of darkness and light on auditory sensitivity. *British Journal of Psychology*, 52, 285-291.
- PANGBORN, R.M., CHRISP, R.B., BERTOLERO, L.L. (1970) Gustatory, salivary and oral thermal responses to solutions of sodium chloride at four temperatures. *Perception and Psychophysics*, 8, 69-75.
- PARASURAMAN, R. & DAVIES, D.R. (1977) A taxonomic analysis of vigilance performance. In Mackie, R.R. (Ed.) Vigilance: Theory, Operational Performance and Physiological Correlates, pp.559-574, Plenum Press, New York and London.
- PARDES, M. (1965) Eysenck's introversion-extraversion, boredom and time estimation. *Dissertation Abstracts International*, 26 (6B), 3488.
- PASSINGHAM, R.E. (1970) The neurological basis of introversion-extraversion: Gray's theory. *Behaviour Research and Therapy*, 8, 353-366.
- PAYNE, R.B. & HARTY, G.T. (1954) The effect of experimentally induced attitudes upon task proficiency. *Journal of Experimental Psychology*, 47, 267-273.
- PECK, R.E. (1959) The SHP test: an aid in the detection and measurement of depression. *American Medical Association Archives of General Psychiatry*, 1, 35-40.
- PFAFFMAN, C. (1971). Taste psychophysics. In Lowenstein, W.R. (ed.), Handbook of Sensory Physiology, Vol. I. Springer-Verlag, Berlin.
- PHILIPP, R.L. & WILDE, G.J.S. (1970) Stimulation seeking behaviour and extraversion. *Acta Psychologica*, 32, 269-280.
- PLOTNIKOFF, N., BIRCIS, L., MITOMA, C., OTIS, L., WEISS, B. & LATIES, V. (1960) Drug Enhancement of Performance. Report for Physiological Psychology Branch, Psychological Science Division, Office of Naval Research, Department of the Navy, Washington, D.C.
- POPPER, K.R. (1968) The Logic of Scientific Discovery. Hutchinson, London.
- POULTON, E.C. (1977) Arousing stresses increase vigilance. In Mackie, R.R. (Ed.) Vigilance: Theory, Operational Performance and Physiological Correlates, pp.423-460, Plenum Press, New York and London.
- POULTON, E.C. & EDWARDS, R.S. (1979) Asymmetric transfer in within-subjects experiments on stress interaction. *Ergonomics*, 22, 945-961.

- POWER, R.P. & THOMPSON, W.T. (1970) Simulation of introversion and extraversion on the lemon test. *British Journal of Psychology*, 61, 91-93.
- PUSHKIN, V.N. (1972) Vigilance as a function of strength of the nervous system. In Nebylitsyn, V.D. & Gray, J. A. (Eds.) *Biological Bases of Individual Behaviour*, pp.310-324, Academic Press, New York and London.
- RABAVILAS, A.D., BOULOUGOURIS, J.C. & STEFANIS, C. (1976) Duration of flooding sessions in the treatment of obsessive-compulsive patients. *Behaviour Research and Therapy*, 14, 349-355.
- RAMSAY, R.W. (1969) Salivary response and introversion-extraversion. *Acta Psychologica*, 29, 181-187.
- RAVICH-SCHERBO, I.V. (1969) Evaluation of the strength of the nervous system by the dependence of the reaction time on the intensity of the stimulus. In Nebylitsyn, V.D. (Ed.) *Problems of Differential Psychophysiology, Vol.VI.*, 'Prosveshcheniye' Publishers, Moscow.
- REASON, J.T. (1967) Relationships between motion after-effects, motion sickness susceptibility and 'receptivity'. Ph.D. thesis, University of Leicester.
- REASON, J.T. (1969) Individual differences in auditory reaction time and loudness estimation. *Perceptual and Motor Skills*, 26, 1089-1090.
- RECHTSCHAFFEN, A. & BOOKBINDER, L.J. (1960) Introversion-extraversion and kinaesthetic after effects. *Journal of Abnormal and Social Psychology*, 61, 495-496.
- REED, G.F. & FRANCIS, T.R. (1962) Drive, personality and audiometric response consistency. *Perceptual and Motor Skills*, 15, 681-682.
- REVELLE, W.R. (1973) Introversion-extraversion, skin conductance and performance under stress. *Dessertation Abstracts International*, 35(1-B), 487-8.
- REVELLE, W., AMARAL, P. & TURRIFF, S. (1976) Introversion-extroversion, time stress and caffeine: effect on verbal performance. *Science*, 192, 149-150.
- REVELLE, W., HUMPHREYS, M.S., SIMON, L. & GILLILARD, K. (1980) The interactive effect of personality, time of day, and caffeine: a test of the arousal model. *Journal of Experimental Psychology: General*, 109, 1-30.
- RIZLEY, R. & REPUCCI, N.D. (1972) Pavlovian conditioned inhibitory processes in behaviour therapy. In progress in Maher, B.A. (Ed.) *Experimental Personality Research, Vol.7.* pp.209-264. Academic Press.

- RODRIGUEZ, J. & MIKUSINSKI, E. (1977) Salivation as a physiological measure of the dimension of introversion-extraversion. *Revista Latino Americano de Psicologia*, 9, 201-211.
- ROUTTENBERG, A. (1968) The two-arousal hypothesis: reticular formation and limbic system. *Psychological Review*, 75, 51-80.
- ROZHDESTVENSKAYA, V.I. (1973) The effects of the strength of the nervous system and activation level on performance in a monotonous task. *Voprosy Pshikologie*, 19, 49-57.
- ROZHDESTVENSKAYA, V.I. & LEVOCHKINA, M.A. (1972) Functional state when performing monotonous work and strength of the nervous system. In Nebylitsyn, V.D. (Ed.) Problems of Differential Psychophysiology, VII. Moscow *Pedagogica*.
- ROZHDESTVENSKAYA, V.I. & YERMOLAYERA-TOMINA, L.B. (1966) A study of mental capacity for work in relation to typological characteristics of the nervous system. *Proceedings of the Eighteenth International Congress of Experimental Psychology, Moscow, Ninth Symposium*, pp.51-59.
- ROZHDESTVENSKAYA, V.I., GOLUBEVA, E.A. & YERMOLAYERA-TOMINA, L.B. (1972) Alterations in functional state as affected by difference kinds of activity and strength of the nervous system. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp.291-309, Academic Press, New York and London.
- ROZHDESTVENSKAYA, C.I., NEBYLITSYN, V.D., BORISOVA, M.N. & YERMOLAYERA-TOMINA, L.B. (1960) A comparative study of various indices of strength of the nervous system in man. *Voprosy Psikhologii*, 5, 41-56.
- RUBIN, L.S. (1962) Autonomic dysfunction as a concomitant of neurotic behaviour. *Journal of Nervous and Mental Disease*, 138, 558-574.
- REED, G.F. (1961). Audiometric response consistency, auditory fatigue and personality. *Perceptual and motor skills*, 12, 126.
- RULE, S.J. (1966) Subject differences in exponents of psychophysical power functions. *Perceptual and Motor Skills*, 23, 1125-1126.
- SACHS, D.A. & DIESENHAUS, H. (1969) The effects of stress and order of administration on measures of state and trait anxiety. Unpublished manuscript, New Mexico State University, Las Cruces, New Mexico.

- SALES, M., GUYDOSH, R.M. & IACONO, W. (1974) Relationship between 'strength of the nervous system' and the need for stimulation. *Journal of Personality and Social Psychology*, 29, 16-22.
- SALES, S.M. & THROOP, W.F. (1972) Relationships between kinaesthetic after effects and 'strength of the nervous system'. *Psychophysiology*, 9, 492-497.
- SANFORD, A. (1974) Criterion effects in simple reaction time: results with stimulus intensity and duration manipulations. *Journal of Experimental Psychology*, 95, 370-374.
- SATINDER, K.P. (1967). New experimental approach to Pavlovian typology in rat. *Proceedings 75th Annual Convention of the American Psychological Association*, Vol. II, pp. 67-8.
- SAVAGE, R.D. (1964) Electro-cerebral activity, extraversion and neuroticism. *British Journal of Psychiatry*, 110, 98-100.
- SEIF, T.F. & HOWARD, J.H. jr. (1975) Stimulus compatibility effects of an accessory visual stimulus on auditory sensitivity. *Perception and Psychophysics*, 17, 504-510.
- SEMENOVSKAYA, Ye.N. (1947) The role of attention in changes in sensitivity in the visual system. *Probl. Fiziol, Optik.* 4, 148-168.
- SHANNON, I.L. & FELLER, R.P. (1970) Simplified procedure for measuring the effect of gustatory perception on parotid gland flow rate. *Journal of Dental Research*, 49, 532-6.
- SHIGEHISA, P.M., SHIGEHISA, T. & SYMONS, J.R. (1973) Effects of intensity of auditory stimulation on photopic visual sensitivity in relation to personality. *Japanese Psychological Research*, 15, 164-172.
- SHIGEHISA, T., SHIGEHISA, P.M.J. & SYMONS, J.R. (1973) Effect of interval between auditory and preceding visual stimuli on auditory sensitivity. *British Journal of Psychology*, 64, 367-373.
- SHIGEHISA, T. & SYMONS, J.R. (1973s) Effect of intensity of visual stimulation on auditory sensitivity in relation to personality. *British Journal of Psychology*, 64, 205-213.
- SHIGEHISA, T. & SYMONS, J.R. (1973b) Reliability of auditory responses under increasing intensity of visual stimulation in relation to personality. *British Journal of Psychology*, 64, 375-381.

- SHIOMI, K. (1977) Threshold and reaction time to noxious stimulation; their relations with scores on Manifest Anxiety Scale and Maudsley Personality Inventory. *Perceptual and Motor Skills*, 44, 429-430.
- SHOR, R.E. & COBB, J.C. (1968) An exploratory study of hypnotic training using the concept of plateau responsiveness as a referent. *American Journal of Clinical Hypnosis*, 10, 178-197.
- SIDDLE, D. A. & MANGAN, G. (1971) Arousability and individual differences in resistance to distraction. *Journal of Research in Personality*, 5, 295-303.
- SIDDLE, D.A., MORRIS, R.B., WHITE, K.D. & MANGAN, G.L. (1969) Relation of visual sensitivity to extraversion. *Journal of Experimental Research in Personality*, 3, 264-287.
- SIMONSON, E. & BROZEK, J. (1952) Flicker fusion frequency: background and application. *Physiological Review*, 32, 349-378.
- SINGH, I.L., DIRIVEDI, C.B. & SINHA, M.M. (1979) Effects of anxiety on vigilance. *Perceptual and Motor Skills*, 49, 142.
- SIPP^RELLE, R.C., ASCOUGH, J.C., DETRIO, D.M. & HORST, P.A. (1977) Neuroticism, extroversion and response to stress. *Behaviour Research and Therapy*, 15, 411-418.
- SMALL, C.S. (1973) Extraversion and introversion: an arousal and habituation comparison. *Dissertation Abstracts International*, 34(8-B), 4059.
- SMITH, D.V. (1971) Taste intensity as a function of area and concentration - differentiation between compounds. *Journal of Experimental Psychology*, 87, 163-171.
- SMITH, R.P., WARM, J.S. & ALLUISI, E.A. (1966) Effects of temporal uncertainty on watchkeeping performance. *Perception and Psychophysics*, 1, 293-299.
- SMITH, S.L. (1968) Extraversion and sensory threshold; *Psychophysics*, 5, 293-299.
- SOKOLOV, Ye.N. (1963) Perception and the Conditioned Reflex. Pergamon Press, Oxford.
- SPEISS, J. (1973) Effects of pre-knowledge and stimulus intensity upon simple reaction time. *Journal of Experimental Psychology*, 101, 109-115.
- SPENCE, J.T. & SPENCE, K.W. (1966) The motivational components of manifest anxiety: drive and drive stimuli. In Spielberger, C.D. (Ed.) Anxiety and Behaviour, pp.291-326, Academic Press, New York.

- SPEILBERGER, C.D., GORSUCH, R.C. & LUSHENE, R.E. (1970) Manual for the State-Trait Anxiety Inventory. Palo Alto, California; Consulting Psychologists Press.
- STANDISH, R.R. & CHAMPION, R.A. (1960) Task difficulty and drive in verbal learning. Journal of Experimental Psychology, 59, 361-365.
- STEIN, J.R. (1976) Effects of feedback on performance of introverted and extraverted delinquents and non-delinquents. Criminal Justice and Behaviour, 3, 371-378.
- STEINER, K. (1967) Differentiation of extraverts and introverts on the basis of perceptual tasks. Dissertation Abstracts International, 28(4-B), p.1715.
- STEKLOVA, R.P. (1958) The relation between change in the visual sensitivity of the eye and alpha-depression during the action of auditory stimuli. In Voronin, L.G. et al (Eds.) The Orienting Reflex and Exploratory Behaviour. Moscow; Akad. Pedagog. Nauk RSFSR.
- STEKLOVA, R.P. (1959) Change in the visual sensitivity of the eye during the action of auditory stimuli of varying intensity. In Sikolov, Ye.N. (Ed.) The Orienting Reflex and Problems of Higher Nervous Activity, Moscow; Akad. Pedagog. Nauk RSFSR.
- STELMACK, R.M. & CAMPBELL, K.B. (1974) Extraversion and auditory sensitivity to high and low frequency. Perceptual and Motor Skills, 38, 875-879.
- STELMACK, R.M., BOURGEOIS, R.P., CHIAN, Y.C. & PICKFORD, C.W. (1979) Extraversion and the orienting reaction habituation rate to visual stimuli. Journal of Research in Personality, 13, 49-58.
- STEPHENS, S.D.G. (1969) Auditory threshold variance, signal detection theory and personality. International Audiology, 8, 131-137.
- STEPHENS, S.D.G. (1970) Personality and the slope of loudness function. Quarterly Journal of Experimental Psychology, 22, 9-13.
- STEPHENS, S.D.G. (1971) The value of personality tests in relation to diagnostic problems of sensori-neural hearing loss. Sound, 5, 73-77.
- STEPHENS, S.D.G. (1972) Hearing and personality: a review. Journal of Sound and Vibration, 20, 287-298.
- STEPHENS, S.D.G. & ANDERSON, C.M.V. (1971) Experimental studies on the uncomfortable loudness level. Journal of Speech and Hearing Research, 14, 262-270.

- STERNBACH, R.A. (1966) Principles of Psychophysiology. Academic Press, New York and London.
- STEVENS, S.S. (1956) The direct estimation of sensory magnitudes-loudness. American Journal of Psychology, 79, 1-25.
- STEVENS, S.S. (1969) Sensory scales of taste intensity. Perception and Psychophysics, 6, 302-308.
- STEVENS, S.S. & POULTON, E.C. (1956) The estimation of loudness by unpracticed observers. Journal of Experimental Psychology, 51, 71-8.
- STRELAU, J. (1970) Nervous system type and extraversion-introversion. A comparison of Eysenck's theory with Pavlov's typology. Polish Psychological Bulletin, 1, 17-24.
- STRELAU, J. (1972a) The general and partial nervous system types - data and theory. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp.62-73. Academic Press, New York and London.
- STRELAU, J. (1972b) A diagnosis of temperament by non-experimental techniques. Polish Psychological Bulletin, 3, 97-105.
- STRELAU, J. (1974) Temperament as an expression of energy level and temporal features of behaviour. Polish Psychological Bulletin, 5, 119-127.
- STRELAU, J. (1979) The role of temperament in mental development. Polish Psychological Bulletin, 10, 235-237.
- STROH, C.M. (1971) Vigilance: The Problem of Sustained Attention, Pergamon Press.
- TARRIERE, C. & HARTEMANN, F. (1964) Investigation into the effects of tobacco smoke on a visual vigilance task. Proceedings of the 2nd International Congress on Ergonomics, pp.525-530.
- TAYLOR, F. (1971). Relationships between introversion-extraversion and lean body mass and reaction time. Unpublished Ph.D. thesis, University of Alabama, U.S.A.
- TAYLOR, M.M. (1967) Detectability theory and the interpretation of vigilance data. In Sanders, A.F. (Ed.) Attention and Performance. Amsterdam, North Holland.
- TEICHER, W.H. (1954). Recent studies of simple reaction time. Psychological Bulletin, 51, 128-149.

- TEICHNER, W.H. (1974) The detection of a simple visual signal as a function of time of watch. *Human Factors*, 1b, 339-353.
- TEICHNER, W.H., AREES, E. & REILLY, R. (1963) Noise and human performance, a psychophysiological approach. *Ergonomics*, 6, 83-97.
- TEPLOV, B.M. (1972) The problem of types of human higher nervous activity and methods of determining them. In Nebylitsyn, V.D. & Gray, J.A. (Eds.) Biological Bases of Individual Behaviour, pp.1-10. Academic Press, New York and London.
- THACKRAY, R.I., JONES, K.N. & TOUCHSTONE, R.M. (1973) Self-estimates of distractibility as related to performance decrement on a task requiring sustained attention. *Ergonomics*, 16, 141-152.
- THAYER, R.E. (1967) Measurement of activation through self-report. *Psychological Reports*, 20, 663-678.
- THAYER, R.E. (1970) Activation states as assessed by verbal reports and four psychophysiological variables. *Psychophysiology*, 7, 86-94.
- THAYER, R.E. (1978) Toward a psychological theory of multi-dimensional activation (arousal). *Motivation and Emotion*, 2, 1-34.
- THEOLOGUS, G.C., WHEATON, G.R. & FLEISHMAN, E.A. (1974) Effects of intermittent, moderate intensity noise stress on human performance. *Journal of Applied Psychology*, 59, 539-547.
- THOMPSON, R.F., VOSS, V.F. & BROGDEN, W.J. (1958) Effects of brightness of simultaneous visual stimulation on absolute auditory sensitivity. *Journal of Experimental Psychology*, 55, 45-50.
- THRANE, V.C. (1960) Sensory and preparatory factors in response latency. I. The visual intensity function. *Scandinavian Journal of Psychology*, 1, 82-96.
- TONG, J.E., ELIGH, G., CAMPBELL, J. & SMITH, D. (1977) Tobacco smoking, personality and sex factors in auditory vigilance performance. *British Journal of Psychology*, 68, 365-370.
- TUROVSKAYA, Z.G. (1963) Correlation between some indices of human nervous system strength and mobility. In Teplov, B.M. (Ed.) Typological Features of Higher Nervous Activity in Man. Vo.3. RSFSR Academy of Pedagogical Studies, Moscow.

- VASILEV, A.N. (1960) The relation between reaction times to the onset and termination of a signal as an index of strength of the nervous system. *Voprosy Psikhologii*, 6, 113-122.
- VAUGHAN, H.G., COSTA, L.D. & GILDEN, I. (1966) The functional relation of visual evoked response and reaction time to stimulus intensity. *Vision Research*, 6, 645-656.
- VENABLES, P.H. & CHRISTIE, M.J. (1974) Research in Psychophysiology. Wiley, London.
- VENABLES, P.H. & TIZARD, J. (1956) The effect of light intensity on the reaction time of schizophrenics. *British Journal of Psychology*, 47, 144-8.
- VERILLO, R.T., FRAIOLI, A.J. & SMITH, R.L. (1969) Sensation magnitude of vibrotactile stimuli. *Perception and Psychophysics*, 6, 366-372.
- VICKERS, D., LEARY, J. & BARNES, P. (1977) Adaptation to decreasing signal probability. In Mackie, R.R. (Ed.) *Vigilance: Theory, Operational Performance and Physiological Correlates*, pp.679-704, Plenum Press, New York and London.
- VICKERS, D., NETTLEBECK, T., WILLSON, R.J. (1977) Perceptual indices of performance: the measurement of inspection time and 'noise' in the visual system. *Perception*, 1, 263-295.
- WARDELL, D. (1974) Stimulus intensity and introversion-extraversion. *British Journal of Social and Clinical Psychology*, 13, 425-426.
- WARE, J.R., SOPOWICZ, R.R. & BAKER, R.A. (1961) Auditory vigilance in repeated sessions. *Perceptual and Motor Skills*, 13, 127-129.
- WATKINS, W.H. (1966) Photic facilitation of tonal signal detection in a forced choice situation. *Psychonomic Science*, 6, 477-478.
- WATKINS, W.H. & FEEHRER, C.E. (1965) Acoustic facilitation of visual detection. *Journal of Experimental Psychology*, 70, 332-333.
- WATSON, J.P. & MARKS, I.M. (1971) Relevant and irrelevant fear in flooding. Cited by Lader, M. & Marks, I., Clinical Anxiety. (1971), Heinemann.
- WEIDENFELLER, E.W., BAKER, R.A. & WARE, J.R. (1962) Effects of knowledge of results (true and false) on vigilance performance. *Perceptual and Motor Skills*, 14, 211-215.

- WEISEN, A. (1965) Differential reinforcing effects of onset and offset of stimulation on the operant behaviour of normals, neurotics and psychopaths. University of Florida. Unpublished Ph.D. thesis.
- WEISS, B. & LATIES, V.G. (1962) Enhancement of human performance by caffeine and the amphetamines. *Pharmacological Review*, 14, 1-36.
- WELFORD, A.T. (1972) Skilled Performance: Perceptual and Motor Skills. Scott, Foresman and Company.
- WENAR, C. (1954) Reaction time as a function of manifest anxiety and stimulus intensity. *Journal of Abnormal and Social Psychology*, 49, 335-340.
- WENGER, M.A. & CULLEN, T.D. (1972) Studies of autonomic balance in children and adults. In Greenfield, N.S. & Sternbach, R.A. Handbook of Psychophysiology, pp.535-570. Holt, Rinehart and Winston, Inc.
- WERRE, F.F., FAVERY, H.A. & JANSEN, R.H.C. (1975) Relations between CNV and personality. *Electroencephalography and Clinical Neurophysiology*, 30, 277-299.
- WHALEN, P. (1966). Cited by Steiner, K. (1967). Differentiation of extraverts and introverts on the basis of perceptual tasks. *Dissertation Abstracts International*, 28(4-B), p. 2715.
- WHITE, K.D. (1977) Salivation: a review and experimental investigation of major techniques. *Psychophysiology*, 14, 203-212.
- WHITE, K.D. & MANGAN, G.L. (1972) Strength of the nervous system as a function of personality type and level of arousal. *Behaviour Research and Therapy*, 10, 139-146.
- WHITE, K.D., MANGAN, G.L., MORRISH, R.B. & SIDDLE, D.A.T. (1971) The relation of visual after-image to extraversion and neuroticism. *Journal of Experimental Research in Personality*, 3, 268-274.
- WIENER, E.L. (1967) Transfer of training from one monitoring task to another. *Ergonomics*, 10, 649-658.
- WILDING, J.M. & MEDDIS, R. (1972) A note on personality correlates of motion sickness. *British Journal of Psychology*, 63, 619-620.

- WILKINSON, R.T. (1958) The effects of lack of sleep on perception and skill. Ph.D. thesis, University of Cambridge.
- WILKINSON, R.T. (1963) Interaction of noise with knowledge of results and sleep deprivation. *Journal of Experimental Psychology*, 66, 332-337.
- WILKINSON, R.T. (1964) Artificial 'signals' as an aid to inspection task. *Ergonomics*, 7, 63-72.
- WILLIAMS, H.L., LUBIN, A. & GOODNOW, J.J. (1959) Impaired performance with acute sleep loss. *Psychological Monographs*, 73, whole No. 484.
- WILSON, G.D., TUNSTALL, O.A. & EYSENCK, H.J. (1971) Individual differences in tapping performance as a function of time on task. *Perceptual and Motor Skills*, 33, 375-8.
- WINTER, K., BROADHURST, A. & GLASS, A. (1972) Neuroticism, extraversion and E.E.G. amplitude. *Journal of Experimental Research in Personality*, 6, 44-51.
- WOLPE, J. (1969) The Practice of Behaviour Therapy. Pergamon, New York.
- WOODHEAD, M.M. (1969) Performing a visual task in the vicinity of reproduced sonic bangs. *Journal of Sound and Vibration*, 9, 121-125.
- WRIGHT, S. (1971). Applied Physiology. Revised by Keele, C.A. and Neil, E. Oxford University Press.
- YELLOTT, J.I. (1967) Correction for guessing in choice reaction time. *Psychonomic Science*, 8, 321-322.
- YERKES, R.M. & DODSON, J.D. (1908) The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative and Neurological Psychology*, 18, 459-582.
- ZENHAUSERN, R., POMPO, C. & CIAIOLA, M. (1974) Simple and complex reaction time as a function of subliminal and supraliminal accessory stimulation. *Perceptual and Motor Skills*, 38, 417-418.
- ZHOROV, P.A., & YERMOLAYERA-TOMINA, L.B. (1972) Concerning the relation between extraversion and the strength of the nervous system. In Nebylitsyn, V.D. & Gray, J.A. (eds.) Biological Bases of Individual Behaviour pp. 262-268. Academic Press, New York and London.
- ZUCKERMAN, M. & LINK, K. (1968) Construct validity for the sensation-seeking scale. *Journal of Consulting and Clinical Psychology*, 32, 420-426.
- ZWOSTA, M.F. & ZENHAUSERN, R. (1969) Application of signal detection theory to subliminal and supraliminal accessory stimulation. *Perceptual and Motor Skills*, 28, 699-704.

AFI ENDICES

APPENDIX A.

Details of material used to collect saliva.

No. 2 'Cotton wool rolls' (Wright's dental suppliers,
50, New Cavendish St. ,London)

5 cms.* 5 cms. dental swabs (Wright's dental suppliers,
as above).

Details of gauze:

B.F.C. absorbent cotton viscose gauze.

Details of pulse meter:

Manufactured by San-el company, Japan.

Details of white noise:

20Hz-20kHz. broad band.

Details of the chloride ion concentrations of the
lemon juice have been temporarily lost, so the author
is unable to present them at this moment in time.

APPENDIX A (cont.)

Details of homogenisation of lemon juice:

The juice from the lemons was extracted and placed in a small light opaque bottle which was regularly emptied into a larger, light opaque bottle which was kept in the experimenter's fridge during the extraction process. Once all the juice had been extracted the large bottle was inverted several times and then some of its contents were decanted into the sterile containers. This process was repeated until all of the juice had been transferred to these containers. The level of the juice was chosen to ensure that on expansion following freezing, there was no air space left at the top of the container. The containers were kept in the ice compartment of the experimenter's fridge.

Details of preparation of the stimulus solutions:

The lemon juice containers were defrosted and the contents poured together into jar 1 ('pure'). The contents were thoroughly mixed and 25 ml. were then pipetted off into jar 2 ('pure * 1/2'). Twenty five ml. of distilled water were then passed into jar 2 from a burette and the contents mixed thoroughly. Twenty five ml. of this mixture were then pipetted into jar 3 ('pure * 1/4') etc.

APPENDIX A (cont.)

Details of the preparation of the intermediate concentration:

Let us say that we wished to prepare a solution which was intermediate in concentration between solution A and solution B, where A was twice as concentrated as B. Nine mls. of A were pipetted into a clean jar and three mls. of distilled water were then passed into the jar from the burette. The contents were thoroughly mixed and this mixture was used as the intermediate concentration.

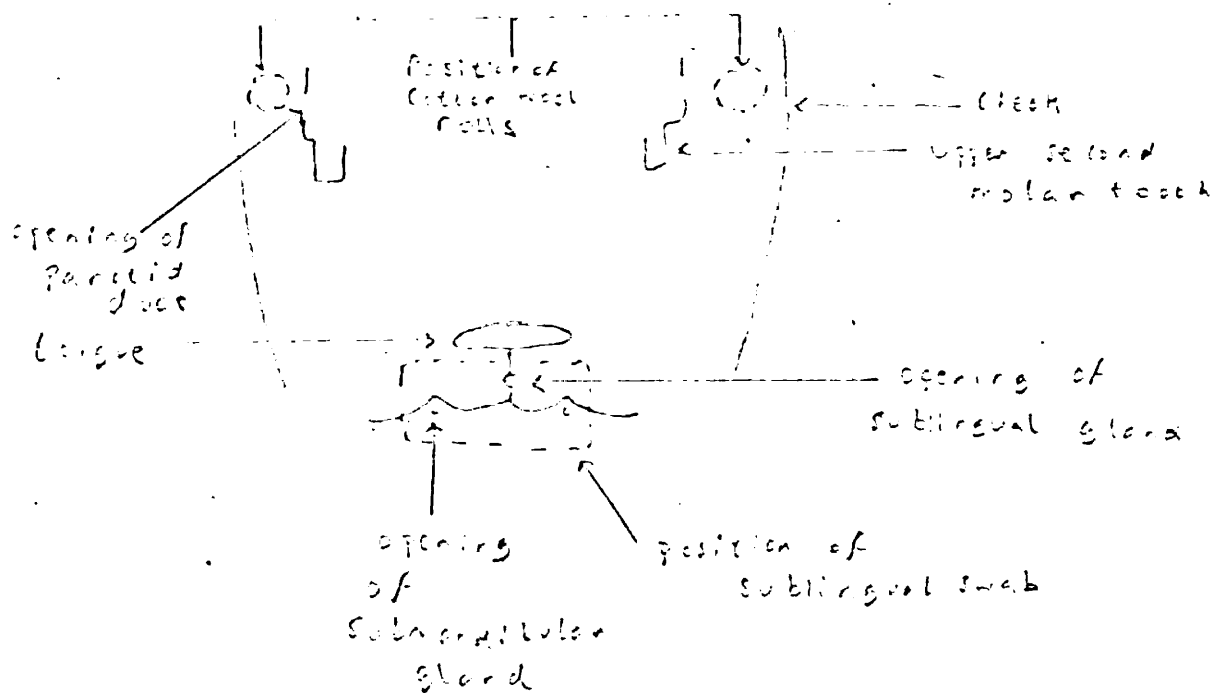
Detailed time sequence for taste experiment: procedure within each cycle.

Session 1.

Time 0.0	Rinse
30 secs(0.30)	Rinse
0.50	Turn on noise if necessary
1 minute(1.0)	Put in swabs
1.45	dip gauze in solution
1.50	Remove gauze from solution
1.55	Take gauze over to subject
2.0	Place gauze on subject's tongue and note heart rate.
2.15	Note heart rate
2.30	Note heart rate and remove gauze.
	Remove swabs. Turn off noise if necessary.
4.00	Start of next cycle

Time sequence for session 2.

- 0 min. Rinse
 - 0.25 Turn on noise if necessary
 - 0.45 Dip gauze in stimulus solution
 - 0.50 Take gauze out of stimulus solution
 - 0.55 Take gauze over to subject
 - 1.00 Put gauze on subject's tongue and note heart rate
 - 1.15 Note heart rate
 - 1.30 Note heart rate.
- Remove gauze.
- Turn off noise if necessary
 - Rinse
 - 2.00 Start of next cycle.



Cross section of subject's mouth showing positions of duct openings and of the cotton wool rolls and swab.

D
APPENIX A (cont.).
A

Hedonic tone scale :

a As unpleasant as it is possible to be

b

c

d Extremely unpleasant

e

f

g Moderately unpleasant

h

i

j Slightly unpleasant

k

l

m Neither pleasant nor unpleasant

n

o

p Slightly pleasant

q

r

s Moderately unpleasant

t

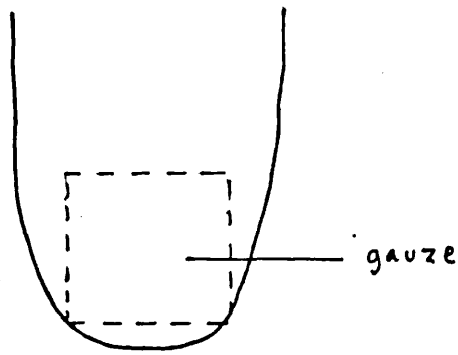
u

v Extremely unpleasant

w

x

y As pleasant as it is possible to be



Plan view of tongue showing position of gauze

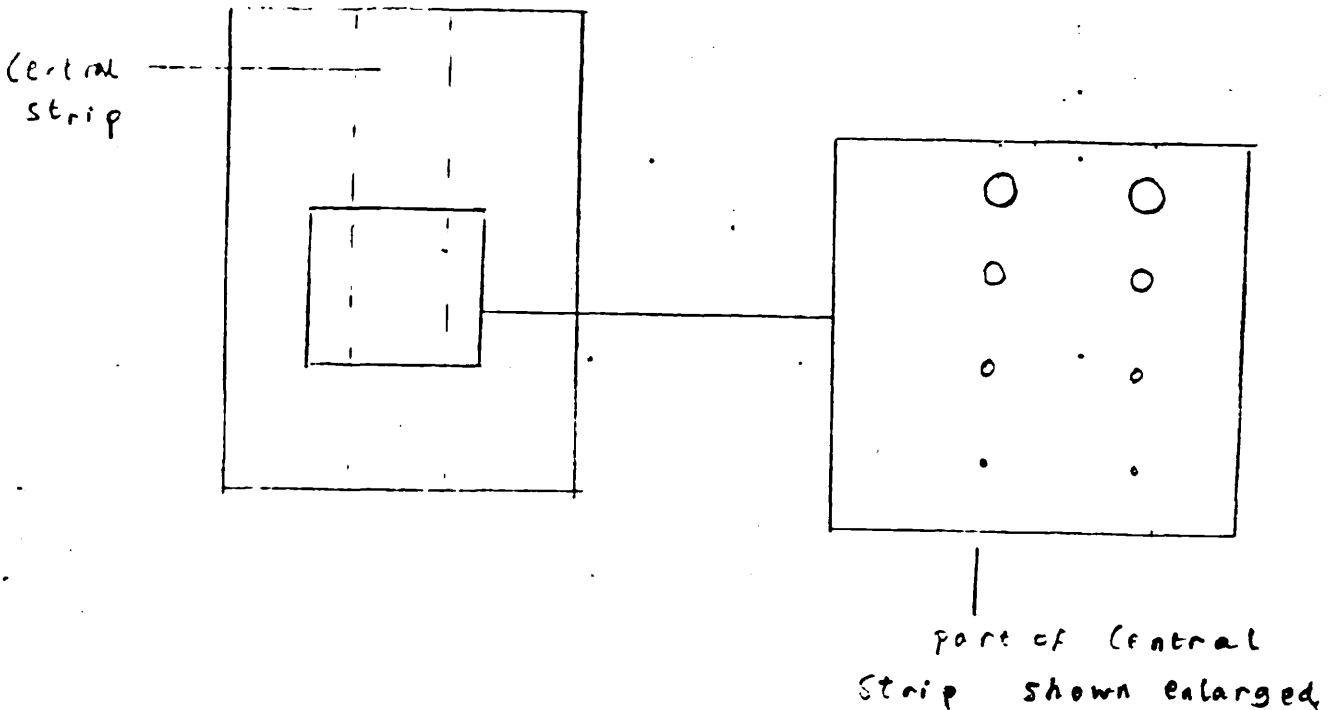


Diagram of pupil diameter card

The use of the pupil diameter card:

The subject was asked to face the wall and to focus on a spot on the wall with one eye covered. He was then asked to hold the pupil card vertically so that the line of holes was opposite the pupil, and to tell the experimenter in which set of holes the two holes seemed to be just touching. The pairs of holes were calibrated in millimetres of pupil diameter.

APPENDIX A (cont.)

The measurement of blood pressure:

The subject sat at the table with his left arm resting on the latter and with the left sleeve rolled up. The blood pressure cuff was placed on his left upper arm whilst a stethoscope was placed over the brachial artery in the left median cubital fossa. The cuff was pumped up beyond systolic pressure, and the pressure then gradually released until the arterial beats first appeared (systolic) and then became muffled (diastolic).

Details of the 36 subjects who took part in the main groups of experiments, at initial recruitment:

Mean systolic pressure (F.F.I.)

	Introverts			Extraverts		
	Mean	Variance	S.D.	Mean	Variance	S.D.
<u>Range</u>						
High N	8.77	5.69	2.39	16.33	7.5	2.74
Low N	9.66	9.25	3.04	17.00	13.5	3.67

Mean pulse

High N	14.33	16.5	4.06	13.44	16.52	4.06
Low N	5.00	6.25	2.50	7.00	2.00	1.41

Mean ages

	Introverts		Extraverts	
High N	19.9		19.9	
Low N	20.9		20.6	

APPENDIX B

Simple auditory reaction time task

Questionnaire scores(E.P.I)

	Introverts			Extraverts		
	Mean	Variance	S.D.	Mean	Variance	S.D.
<u>E score</u>						
High N	8.75	8.21	2.86	16.88	8.36	2.98
Low N	8.44	11.77	3.43	16.00	4.36	2.09
<u>M score</u>						
High N	15.75	8.75	2.96	14.22	3.19	1.79
Low N	8.00	6.75	2.60	6.00	2.00	1.41
<u>Mean IQ</u>						
High N	21.5			21.0		
Low N	22.1			21.9		

The formula for the parametric discrimination index(McNicol,1973):

If PH = probability of a hit

and PF = probability of a false alarm

then $z(H)$ = standardised normal 'z' score corresponding to PH

and $z(F)$ = standardised normal 'z' score corresponding to PF

$$\text{Parametric discrimination index} = z(H) - z(F)$$

Correlations between scales derived from the initial E.P.I. questionnaires and the E.P. Q. questionnaires given at the time of the joint signal detection/simple visual reaction time task:

E.P.I. scale	E.P.Q. scale	correlatic
E	E	0.448
N	N	0.818
L	L	-0.037
Sociability	E	0.391
Impulsivity	E	0.403

Psychometric scores for subjects whose results were analyzed as part of the joint signal detection/ simple visual reaction time task:

	Low P	High P
Mean	3.00	7.38
Variance	2.27	6.38
S.D.	1.51	2.53

Correlations between scales derived from initial E.P.I.s and E.P.Q. given at the time of the vigilance experiment.

E.P.I. scale	E.P.Q. scale	Correlation
E	E	0.727
N	N	0.747
L	L	0.599
Sociability	E	0.675
Impulsivity	E	0.523

Psychoticism scores for subjects whose results were analysed as part of the vigilance task :

	Low P	High P
Mean	3.83	5.19
Variance	2.12	5.90
S.D.	1.46	2.34

APPENDIX C

Pattern of signals in vigilance task :

Each session consisted of four ten minute blocks ,and each one was preceded by a ten minute buzzer period. Below are given the times within each ten minute period at which a signal was presented.

	Buzzer period	Block I	Block2	Block 3	Block 4
Low signal	0.58(0 min-	0.58	0.34	1.22	0.58
frequency	utes, 58 sec				
,session I	onds)				
	1.32	1.04	2.06	1.28	2.06
	3.04	1.38	4.30	2.26	4.30
	4.12	3.10	5.38	3.00	4.36
	5.34	4.32	6.36	4.08	6.32
	5.40	5.40	7.58	6.32	8.04
	7.36	7.36	8.04	8.28	8.38
Low signal					
frequency,	0.58	0.58	0.34	0.58	1.22
session 2	1.04	1.32	2.06	2.06	1.28
	1.38	3.04	4.30	4.30	2.26
	3.10	4.12	5.38	4.36	3.00
	4.32	5.34	6.36	6.32	4.08
	5.40	5.40	7.58	8.04	6.32
	7.36	7.36	8.04	8.38	8.28

APPENDIX C (cont.)

	Buzzer period	Block 1	Block 2	Block 3	Block 4
High signal	0.26	0.26	0.14	0.21	0.67
frequency	0.32	0.53	0.22	0.26	0.20
,session I	0.44	1.25	0.59	1.00	0.48
	0.47	1.36	1.34	1.13	0.56
	0.56	2.07	2.10	1.40	1.30
	1.04	2.43	2.42	1.57	2.02
	1.37	3.12	3.11	2.30	2.06
	2.09	3.40	3.28	2.49	2.25
	2.38	4.01	3.46	3.11	3.02
	3.05	4.10	3.50	3.14	3.29
	3.16	4.15	4.13	3.21	3.50
	3.23	4.23	4.47	3.27	4.01
	3.30	4.26	5.06	3.56	4.18
	3.47	4.59	5.09	4.28	4.24
	4.18	5.17	5.21	5.04	4.40
	4.32	5.52	5.48	5.39	4.45
	5.00	6.29	6.14	5.57	5.07
	5.24	6.57	6.35	6.01	5.40
	5.47	7.15	6.41	6.24	5.43
	6.22	7.22	6.50	7.01	6.12
	6.41	7.28	6.57	7.13	6.35
	7.17	7.51	7.25	7.39	7.01
	7.33	8.25	7.41	7.47	7.13
	7.55	8.37	7.46	8.15	7.44
	7.59	8.51	8.08	8.26	7.58
	8.33	9.08	8.41	8.42	8.22
	8.51	9.27	8.54	8.56	8.57
	9.28	9.40	9.25	9.05	9.15
	9.49	9.56	9.36	9.36	9.24

APPENDIX C (cont.)

	Buzzer period	Block 1	Block 2	Block 3	Block 4
High signal	0.26	0.26	0.07	0.14	0.21
frequency	0.53	0.32	0.20	0.22	0.26
session 2	1.25	0.44	0.48	0.59	1.00
	1.36	0.47	0.56	1.34	1.13
	2.07	0.56	1.30	2.16	1.40
	2.43	1.04	2.02	2.42	1.57
	3.12	1.37	2.06	3.11	2.30
	3.40	2.09	2.25	3.28	2.49
	4.01	2.38	3.02	3.46	3.11
	4.16	3.05	3.29	3.50	3.14
	4.15	3.16	3.50	4.13	3.21
	4.23	3.23	4.01	4.47	3.27
	4.26	3.30	4.18	5.06	3.56
	4.59	3.47	4.24	5.09	4.28
	5.17	4.18	4.40	5.21	5.04
	5.52	4.32	4.45	5.48	5.39
	6.29	5.08	5.07	6.14	5.57
	6.53	5.24	5.40	6.35	6.01
	7.15	5.47	5.43	6.41	6.24
	7.22	6.22	6.12	6.50	7.01
	7.28	6.41	6.35	6.57	7.13
	7.51	7.17	7.01	7.25	7.39
	8.25	7.33	7.13	7.41	7.47
	8.37	7.55	7.44	7.46	8.15
	8.51	7.59	7.58	8.08	8.26
	9.08	8.33	8.22	8.41	8.42
	9.27	8.51	8.57	8.54	8.56
	9.40	9.28	9.15	9.25	9.05
	9.56	9.49	9.24	9.36	9.36

APPENDIX C(cont.)

Correlation matrix for state measures derived from vigilance task

1=Tstress
2=TARCUSAL

3=ANX

'No noise, before'

1	1.00		
2	-0.23	1.00	
3	0.733	-0.34	1.00
	1	2	3

'No noise, after'

1	1.00		
2	-0.04	1.00	
3	0.66	-0.19	1.00

'noise, after'

1	1.00		
2	-0.15	1.00	
3	0.61	-0.22	1.00

'noise, before'

1	1.00		
2	-0.33	1.00	
3	0.66	-0.35	1.00