DEVELOPMENT OF "RIGHT-LEFT" CONCEPT IN CHILDREN BETWEEN Ages of FOUR AND TWELVE YEARS.

by

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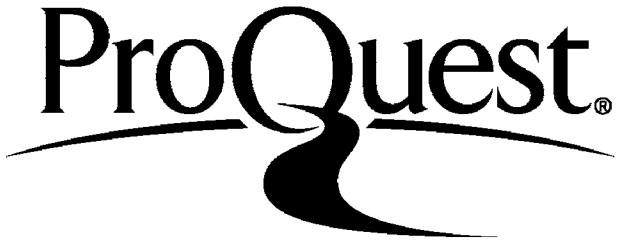

ABSTRACT

About fifteen years ago, the unreflecting acceptance of such concepts as right and left as simple polarities, virtually prevented most serious researchers from investigating closely how a child comes to differentiate and name both sides of his body and succeeds in doing so on other persons as well as on himself.

Work done by Spionek and Benton in particular has highlighted the various stages through which the development of the right-left concept progresses. Initially it is identified on oneself then on other people and on objects. The problem now is to isolate the variables which have a determining influence; this involves an evaluation of the extent of their influence and their interaction.

A sample of eighty boys and girls, four to twelve years old was selected and seven tests covering the variables thought to be relevant were administered to them, namely: body schema, vocabulary, abstract reasoning, space relations, handedness, and motor co-ordination; a measure of knowledge of right and left was also employed. The data obtained on those tests together with the age element were submitted to Principal Component Analysis.

This statistical analysis shows that maturation is the most important of all components extracted. A second component was one of directional orientation and a third, of gross visuo-motor coordination. A fourth factor also emerged involving handedness and right-left discrimination on others. This investigation of

handedness gave rather puzzling results; further examination suggested that the concept was over-simplified, it is an intricate multidimensional characteristic, rather than a unitary one.

It is concluded that verbal ability plays a part throughout the whole evolution of the right-left concept while age and body image are relevant only when the child is applying the concept to himself; space orientation is correlated with this application on other persons.

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I REVIEW OF THE LITERATURE

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SECTION I

REVIEW OF THE LITERATURE

One of the first skills a child learns in school, if he has not been taught at home already, is to distinguish his right hand from his left. The next step is to apply this new concept to objects in his environment and then to orient himself in space. To all appearances this learning process is relatively straightforward, yet for a good many children and a surprising number of adults the last step proves to be well-nigh impossible. When requested to give instructions on how to get somewhere or when having to follow such instructions, many soon start fumbling and eventually become thoroughly confused trying to understand how to go right after this building, left at this corner and then right again here, etc., etc., or even simply to indicate when to turn at a crossroad, they will say: "You turn right" while pointing in the other direction; most perplexing...

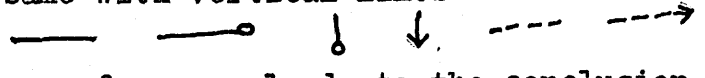
What then are the mechanisms underlying the emergence of directional orientation or rather which are the variables assisting its development? This will be the object of study of the present thesis. To start with, the literature pertinent to the point at hand is reviewed in Section I, Section II defines the problem specifically dealt with in this study while the detailed design of the experiment is treated in Section III. The results and the relevant statistical analysis are presented in Section IV and these are then fully discussed in Section V. The final section (VI) is a statement of the conclusions drawn from the study as a whole.

In order to place the present investigation in its appropriate context, the review of the literature which follows will be concerned with writings in the associated areas, beginning with those related to dyslexia, then cerebral dominance, laterality and after them the work done on the developmental aspect of the Right-Left concept will be reviewed.

A - DYSLEXIA

The ability to differentiate one side of the body from the other, right from left is thought to be of critical import in the case of dyslexics, i.e., children who experience more than normal difficulty in acquiring reading skills commensurate with their age, opportunity and ability. In fact the study of dyslexia has been and is still investigated in close connexion with sidedness, or laterality as it is often called, and cerebral dominance. A large amount of research has been done in this field and results are enmeshed with contradictions.

Reversals are a frequent form of reading difficulty, letters are inverted: b for d, q for p and words read starting from the end thus: "was" is seen as "saw", or "tab" as "bat", etc. Studying the phenomenon of rotation, Fabian (1945) went about testing 586 children of mixed nationality in public schools; amongst other tasks he requested them to draw simple horizontal lines, some with direction accentuated some without, and the same with vertical lines:



Their performance leads to the conclusion that normal nursery school children and school beginners exhibit vertical rotation of horizontal figures; this tendency disappears between seven and eight years. It would

seem that the verticalization phenomenon is greatly facilitated if the horizontality of the figures is emphasized. The direction from left to right, inherent in teaching how to read, emphasizes this horizontality and could explain what Fabian names the "multiplaned axial rotation" of letters and words which are not mirror-images.

A rather commonly expressed opinion of dyslexia, or congenital word blindness as it is most often called, is that it is a hereditary condition. The most complete review of the literature on this question is that of Drew (1956) who discusses over one hundred articles some of which go as far back as 1896. He gathered the impression from them that congenital word-blindness is an inherited characteristic having no neurological correlates. The striking fact about these articles is the extreme variability of their results when reporting the incidence of dyslexia in the population. The main reason for this discordance Drew attributes to the lack of unanimity in defining congenital word-blindness and consequently in giving a causal explanation for it as well as specifying diagnostic criteria. Some trace its origin to birth injury, others to prenatal accident, mixed dominance or emotional disturbance, and still others will have it that dyslexia is only the lower end of the reading continuum. Drew himself studied three cases of familial dyslexia: a father and two of his sons by different wives. Although his sample is restricted it was studied and tested exhaustively in the light of findings from the literature. Nominal aphasia - e.g. errors in writing from dictation, in copying, in matching written name read silently with the object, - was present together with confusion of yellow and

white and rotation of blocks in Block Design tasks, abnormal responses on the Face-Hand test and Right-Left disorientation, mixed eye-hand preference, reversals and auditory visual phonetic disintegration. He underlines the fact that while all the research he reviewed had not come across any neurological correlates, it is probably because these correlates were not looked at closely or tested adequately. Borel-Maisonny, Eustis and Launay are quoted as agreeing with him. Although he admits that in his three cases no constant neurological sign is evident, he adds that if these diverse symptoms are looked upon as various manifestations of Gestalt disturbances, "then the entire symptom complex becomes a coherent entity" and congenital word-blindness can be seen as the outcome of the delayed development of the parietal lobes, and would be a hereditary dysfunction with a dominant mode of transmission.

This is a purely physiological explanation for reading problems, some authors have gone to the other extreme and have supported a uniquely psychological one, or rather psychoanalytic one. Amongst these Wagenheim (1959) can be placed. After administering the California Test of Mental Maturity and Progressive Achievement and a questionnaire to parents about diseases their children had contracted in infancy, he found that early contraction of disease (measles, chicken pox, mumps, and german measles) was significantly related to reading achievement if it had occurred between ages of two and three in boys only, these boys IQs being generally in the normal range rather than in the low or high range. These results he explains by the fact that at this period aggressive fantasies are reinforced through language and

thought. If the parents are too restrictive they become the target of the child's destructive fantasies. Unable to compete with the overpowering father-figure, it becomes the subject of fear and guilt feelings. When the disease appears at this stage, it is seen as punishment coming from an unknown force, thus imposing a great deal of stress on the nervous system. Dyslexia in this instance would merely be a manifestation of emotional blocking.

One cannot scan the literature in this field without mentioning one of the most well known and controversial figures, that of Orton (1937). Since the publication of his book: "Reading, Writing and Speech Problems in Children" he has been strongly acclaimed and supported by certain people and vehemently criticized by others. At first sight his theory is quite attractive, explaining so much so simply. What was his view on the matter? De Merlis (1959) summarized it by writing that reading difficulties are ascribed to differences in functional organization of visual memory centers of the two cerebral hemispheres. There would be three levels of cortical elaboration: 1) the perceptive level, which is the controlled awareness of external stimuli, 2) the recognitive level, which is the recognition of objects, these levels, both involve the two hemispheres, 3) the associative level controlling communicative skills of speech, reading and writing. The oneness of impression in the brain is achieved by hemisphere dominance rather than by fusion of the two images. The physiological habit of dominance is mostly predetermined by heredity. In reading, both sides of the brain are activated, but only the engrams of the dominant side are operative. Interferences are caused by a failure

to establish complete dominance, so that there are interferences by the mirrored engrams of the supposedly non-dominant side. Developmental alexia, or strephosymbolia as Orton coined it, is difficulty in rebuilding in the right order of presentation sequences of letters and sound.

The main criticism of Orton's theory is the lack of solid and reliable experimental data to substantiate it. There has been some studies in its favour however. A recent experiment is that of Koos (1954); he gave to 109 white middle class children in grades one, two and three, a handedness test, a test of binocular and monocular vision, the California Test of Mental Maturity, the Otis Quick Scoring Test, the Gates Reading Test and the Stanford Achievement Test. A significant difference in reading achievement was observed when all the subjects in all three grades, under the group median IQ range of 125, were compared for eye dominance: those having mixed eye-hand preference scoring significantly lower on reading achievement than those with unilateral preference. No difference in reading rank was found between similar dominance groups in the above median range of IQ.

The great majority of studies, however, do not agree with either Orton or Koos, the one carried out by McFie (1952) amongst others. He observed the presence or absence of the phi-phenomenon in twelve cases of reading disabilities, assuming that by comparing the extent to which apparent movement is seen in the two halves of the field of vision, Jasper and Raney's test enables an estimate to be made of the dominant hemisphere. Generally the hemisphere indicated as dominant by the phi test coincided with the one indicated

by the subject's handedness. Almost all of his twelve cases of reading disability reported little or no apparent movement. Jasper's earlier experiment done with stutterers had given similar results. McFie deduces from his evidence that dyslexia is not due to a confusion in cerebral dominance with the failure to elide antitropic records in the minor hemisphere, as Orton would have it, but to the fact that neurophysiological organisation corresponding to dominance had not been established in either hemisphere.

B - CEREBRAL DOMINANCE

This question of hemisphere dominance or cerebral dominance as it is more often called, arises quite frequently when the literature on dyslexia is reviewed. Before we proceed any further it would be apropos to give an account of it, first of all looking at phylogenetic explanations, then at a biological one and then at the relationship between cerebral dominance and different sensory-motor functions of the brain.

1) Phylogenetic theories: cerebral dominance or the tendency for certain functions of the brain to be localized in only one of the cerebral hemispheres has puzzled many scientists and led them to speculate as to it's origin and it's evolutionnary development in animal life. Here are two leading but contradictory theories.

a) According to J.Z. Young (1962) the bilaterality of the nervous system was a necessity when analogical mapping techniques were the only means of organizing and using sensory information; but as the representation of the outer world became more symbolic, so the contribution of bilaterality tended to diminish.

He bases his assertion mostly on comparisons of the visual apparatus of animals at different levels of the phylogenetic scale. He feels that the optic chiasma straightening the inversion produced by the lens could have been at the origin of all the crossings in the brain. Comparing the brain to a computer, he suggests that since the brain is so much slower in predicting events from past information and from that presently incoming, it cannot be operating on a digital or an abstract system like computers do when all their data is coded before use and storage. In the case of lower animals particularly, the memory is more isomorphic to the environment, thus permitting the organism to utilize all incoming information that is congruent with the map, and to ignore the rest. For example, recordings taken with microelectrodes from the cats visual cortex reveals the presence of a point-to-point projection from the cortex to the retina and the two maps obtained are congruent. This, Young takes as a strong argument in favour of analogue mapping. In higher mammals however, primates and man, the information which comes in from the receptors seems to be recoded somewhere along its way to the cortex, possibly at the level of the thalamus or of the reticular formation. Especially in language man has a sophisticated instrument that he can use to describe a stimulus impinging on the senses in terms of spatial dimensions and free the brain from resembling a map-like analogue. Thus the process of evolution would have brought about in humans the utilization of an abstract or symbolic system and bilaterality would become useless as soon as this abstract system is perfected. The fact that man can do without the non-dominant hemisphere or even the corpus callosum is

taken as an added proof of this theory. Thinking along the same line is another neurologist, Mishkin (1962).

b) On the other hand, Scheibel and Scheibel (1962) relying on entirely different facts, believe the opposite; for them bilaterality is the product of evolution and is in the process of attaining its peak in man. On the basis of complex neuroanatomical findings about the changes in presynaptic bushy arbors of axons along the phylum, they agree with Bok (1959) and Dubois (1914) that there would be: "five crucial jumps in forebrain or isocortical development from rodent to man; each jump characterized by one more complete cell division; each jump characterizing another level of species development." (Scheibel and Scheibel 1962, p.29). It would appear that the last jump, the one completely separating man from the monkey explains a good proportion of typically human operations. In addition there emerges now a concomitant cerebral characteristic-Dominance- the demonstrable functional nonparity of the hemispheres. The increasing dominance of one hemisphere would as they quote, be supported also by Tshirgi (1958) and Mach (1959) who tend to think that if an animal has a bilaterally symmetrical brain it "cannot differentiate between stimuli arriving at homologous points, being limited to mirror-image responses upon homologous right and left stimulation," (Scheibel and Scheibel, 1962, p.29). The asymmetry in the perceptual mechanisms is essential for spatial orientation and is becoming more accentuated with evolution.

c) In regard these two extreme views, Kuypers (1962) is inclined to take an intermediary position where the cortex may be functioning at an abstract or "digital"

level while the sub-cortical area would be working on an analogue system.

d) From a completely different field, Delacato (1959) an educational psychologist interested in reading difficulties also advocates a phylogenetic approach to this question of dominance. Taking the stand that during sleep man operates with the old brain or mid-brain, a relic from the amphibian level of animal life, he advocates that the decrease in temperature and blood pressure, rate of heart beat and of breathing, happening normally in sleep are all operations typical of the amphibian stage. Since then the brain would have become progressively more complex but keeping the old structures as if adding to them, everyone of them interdependent, but the highest level being the dominant one. During sleep or when a lesion or other cerebral accident has occurred, the lower structure becomes dominant. Man's contribution has been cerebral dominance which makes possible the fully upright position, three-dimensional vision, thumb and forefinger opposition and speech.

After examining films of infants and children Delacato noticed patterns of neurological organisation, they would start with wriggling, then crawling then creeping then walking. He thought that if a child jumped one step in this organisation, e.g. not learning how to creep before walking, that child might later be hindered in reaching the higher levels of organisation. As a corollary to this, it was his belief that stimulation of nerves and muscles by practising specially devised exercises could possibly impose the desired patterns on the slow or damaged brain. These exercises aimed toward the consistent use of one side of the body for eye, hand and foot in view of

establishing cerebral dominance, are an essential part of the rehabilitation program called the Doman-Delacato Method in which brain-damaged, retarded children and poor readers are trained.

Like Orton's, Delacato's rationale is a fascinating but broad sweeping one. He claims that it is widely applicable although little systematic research has been done to support this. That is why it is such a controversial issue. The only published report of an experiment testing the validity of the Doman-Delacato Method has been that of Robbins (1966). Taking second grade children from three schools, he equated them for race, religion, socio-economic level, intelligence, creeping ability and laterality. The first group was the control group; the second one, the non-specific group, was submitted to an activity program unrelated to the Doman-Delacato Method, and finally an experimental group was subjected to a training program lasting three months following the Doman-Delacato Method including cross-patterning, creeping, walking and specified writing positions. Robbins hypothesized that creeping and laterality, the supposedly critical indicators of neurological organization, would be directly related to reading ability, as claimed by the authors, and therefore that the addition of the Doman-Delacato Method to the regular curriculum would enhance reading and laterality development. Nevertheless, no significant differences were found between the three groups after the experiment had been carried out.

Although the Doman-Delacato theory may have some validity, the claims its authors make seem to be unrealistic to say the least. In fact one of the

criticisms directed at them is that they tend to oversimplify the problems of mental retardation, brain-damage and reading difficulty, and to use the "Method" indiscriminantly.

2) Biological explanation: besides the phylogenetic approach to cerebral dominance there are also biological ones, Kaplan (1960) mentions on one hand the Pavlovian view held by Bushrova that the origin of dominance is due to reflex-conditioning, and on the other hand, a social Darwinist view, that of Frauchiger who believes that the struggle between the two lobes of the thalamus results in one half dominating the other, leading to a dominance on a hemispherical level. Kaplan himself however believes that genetic and ontogenetic predispositions determine dominance. The larger size of the left hemisphere in right-handed people suggests an ontogenetic proclivity to left hemisphere dominance. If a person's genetic makeup is heavily loaded in favour of right lateral somatic dominance in addition to ontogenetic predispositions, he will as a result manifest strong lateral dominance. At the same time, genetic predispositions to dominance of the left side of the body would cancel out or at least diminish ontogenetic predispositions, hence the greater facility in the use of either hands often encountered in sinistrals. The argument is a rather theoretical one however and the main fact to support it, i.e. the greater size of the left hemisphere in right-handers, is a very moot one since many neuroanatomists believe that the disparity in size although real, is nevertheless too slight to account for such surprising difference in function as language for instance.

3) Cerebral dominance and brain functions:

a) Language: the studies of anatomical asymmetries in the brain started between 1825 and 1862, when Dax, Bouillaud and Broca successively discovered the link between language and a certain area of the left hemisphere. Very soon exceptions to this rule were made known and explained as resulting from left-handedness. Broca (1865) as quoted by Hecaen and Ajuriaguerra (1964), held that left-handed individuals spoke with their right hemisphere: "just as there are left-handed individuals, in whom the natural pre-eminence of the motor forces of the right hemisphere gives a natural pre-eminence to the functions of the left hand, so one can conceive that there may be a certain number of individuals in whom natural pre-eminence of the convolutions of the right hemisphere reverses the order of the phenomenon." From then on, the view that the language centers were located in the hemisphere opposite to the preferred hand became generally accepted. However in 1906 Weber mentioned the case of a thirty-six-year-old left-handed man who, though he wrote with the right hand, became aphasic and paralysed on the right side, but could still write with the left hand. Weber explains this by saying that writing with the right hand had located the language centers in the left hemisphere. Moreover the fact that young children who have not yet learned to write recover very quickly from aphasia after typhoid fever, is taken as further evidence that the essential factor in speech localization is the hand used for writing, since it is a language activity completely asymmetrical in almost everyone.

In the case of right-handed persons there is little doubt in anyone's mind that the left hemisphere

is generally the dominant one, the controversy arises when it comes to left-handedness. At this moment the opinions are divided into two groups: some hold that in left-handedness the centres of speech are generally in the left hemisphere while the others contend that in left-handedness the cerebral hemispheres are equipotential and consequently language is less localized. A number of scientists believe that the language centres are usually in the left hemisphere, no matter what hand is used for manual tasks. Ettlinger, Jackson and Zangwill (1956) studied ten cases of dysphasia concomitant with unilateral lesions in left-handed patients, eight of which had lesions on the left side and two on the right side. In the latter, aphasia was transitory. Minimal dysphasia was present in four cases, three with left side lesion and one with right side lesion. One case with left side lesion had no speech disorder at all. Disorder of the praxis and body schema was evident in three patients with left side parietal lesion, consistent left dominance for all major functions was present at least in five patients and probably in two more, uncertain right hemisphere dominance in two cases and only one single patient showed signs of left hemisphere dominance for praxis and topognosis and right hemisphere dominance for language processes. They infer from this evidence that although some degree of cerebral ambilaterality may exist in a certain proportion of cases, unilateral representation of speech on the left is the most prevalent form of cerebral organization in sinistrals.

Goodglass and Quadfasel (1954) examining 110 cases of left brain lesions reported in the literature from 1866 to 1954, and thirteen more cases of their

own, argue that left cerebral dominance for language is more frequent than right-handedness and right cerebral dominance for language less frequent than left-handedness. On the basis of their calculations 80% of left-handers developed aphasia after a left side lesion, so: "cerebral laterality for language and handedness is not directly linked and one does not determine the other."

Penfield and Roberts (1959) share the same opinion. They investigated 522 cases of aphasia, with the exclusion of those where cerebral injury had occurred before two years of age, noting handedness and site of lesion. These patients had been referred for the relief of focal epilepsy. It came out that only three cases out of 276 with right side lesion suffered from aphasia, two of these being left-handed and one right-handed. Yet left hemisphere lesion was correlated with right-handedness in twenty-nine out of 179 cases and with left-handedness in nineteen out of 67, these differences reaching the .05 level of significance. Additional data collected during electrical mapping of the cortex led them to the conclusion that the left hemisphere is the dominant one for speech, handedness not withstanding. Barring cases with cerebral injury before the age of two, no difference was found between left- and right-handedness in the frequency of aphasia after operation on the left hemisphere; no difference appeared either in the frequency of aphasia after operation on the right hemisphere in sinistrals and dextrals. Penfield and Roberts also hold that the right hemisphere can sometimes be dominant for speech but it would not solely be due to handedness.

Many writers tend to believe the opposite, that in sinistrals language is not as precisely local-

ized as it is in dextrals, instead it is represented in more or less both hemispheres. Such an arrangement would be a flexible albeit fragile one and account surprisingly well for the higher incidence but transient nature of aphasia in left-handers. Evidence to support this comes firstly from Gloning and Quartember (1966). They examined the connections between disturbances of higher brain performance and lateralization of a lesion in one of the hemispheres, in fifty-eight left-handed or ambidextrous patients. Alexia was the only defect that could be significantly associated with lesions of the left hemisphere. Agraphia was correlated with a lesion of the hemisphere concerned with the hand used for writing. They concluded that lateralization of speech in left-handers is not strongly developed and that while it is easily disturbed by lesions in either hemisphere it is subject to prompter recovery.

This type of organization would be very similar to the one presumed to exist in children. Krinauw (1950) performed hemispherectomy (not removing the caudate nuclei and its tail) in eleven children aged from eight months to twenty-one years. Epilepsy was present in ten of them, temper tantrums, mental retardation and hemiplegia in most of them. Return of motor power with lessening of spasticity, improvement of personality, elimination of epilepsy were some of the post operative results. At no time did aphasia appear, in fact language even improved in some patients. This would seem to be in agreement with Weber's theory of language organization in children, as seen above. (Id. (p 22).

In 1949 Wada discovered a technique to detect

hemispheric dominance by giving an intracarotid injection of sodium amytal; depending upon whether it is made to the dominant or the non-dominant side, the procedure elicits different reactions. The patient is requested to count and to keep his fingers in constant movement while his knees are drawn up. A few seconds after the injection, the contralateral arm and leg become limp and fall on the bed, while the homolateral ones remain in their previous position. If the dominant side has been injected the patient stops counting until the hemiplegia subsides but can move as requested with the ipsilateral side, thus indicating that he is conscious. If the injection is given on the non-dominant side, the patient can resume counting after a few seconds of initial confusion. Wada and Rasmussen (1960) used this technique in 12 successive cases of left-handed patients; six of them manifested aphasia after injection on the right side and six after injection on the left side. The test, although it has fascinating possibilities is not fool-proof however, and in some cases the EEG revealed bilateral modifications; the injection in these instances would be of no practical use since the results are so ambiguous.

Zangwill (1960) looked thoroughly at several often conflicting works relating cerebral dominance to aphasia, amongst others those of Jackson, Conrad, Roberts and Brain. At first he investigated with Humphrey 492 cases of unilateral brain injury, recording handedness, site of lesion and defects in the field of speech. Although the number of sinistrals reached only ten in the total sample, it was the authors' opinion that these patients were using their left hemisphere for all activities related to language

and that the accepted rule localizing speech in the hemisphere contralateral to the preferred hand, did not always hold, especially in cases of sinistrality. Yet in the light of further evidence Zangwill submits that while organisation of speech in dextrals is obviously directed from the left hemisphere, in left-handed persons inter-individual variability is more the rule and speech is not so clearly restricted to a single hemisphere. This arrangement, which he calls "cerebral ambilaterality" would entail greater chance of recovery after damage to either hemisphere but "in some individuals at least it would seem to carry the risk of a real handicap in learning to read, spell or draw." Considering that the studies in this area are often at odds with one another, his conclusion seems quite an objective and logical one.

More recently, Hecaen and Ajuriaguerra (1964) in their book on left-handedness have reviewed the literature exhaustively, looking for relationships between handedness and different brain functions. After a lengthy section on aphasia, they infer that representation of language may be different in left-handed and right-handed persons, the former having a representation more equally distributed in both hemispheres. They are inclined to think that the expression of language is not as localized as it's understanding; in sinistrals language representation is bilateral and the organization of all verbal functions less focally organized than it is in dextrals.

b) Audition: even if the majority of investigations on cerebral dominance are concerned with its relation to speech and to kindred disorders, there are still a good number who attempt to link it

to other functions. Roode (1963) for example ascertained the auditory dominance of his subjects and had them reading a simple 127 syllables passage under different conditions of delayed auditory feedback. Both the left and the right dominant groups showed a significantly longer mean syllable duration with delayed feedback to the dominant ear than to the nondominant ear. Percentage of phonation time was significantly higher for the right sided group under a condition of delayed feedback to the dominant ear as compared to the same condition applied to the nondominant ear. These differences did not occur with left sided subjects. He infers that the existence of a right cerebral language laterality appears to be a more common phenomenon than is generally thought.

Bryden (1965) classified his subjects from their responses to a ten item questionnaire enquiring about activities performed with one hand only and chose twenty right-handed and twenty left-handed individuals, (four of the latter group having direct parental or sibbling incidence of left handedness) with an equal number of men and women in each group. He then administered a dichotic listening task and one of tachistoscopic recognition. No significant differences were found between the two groups on either tasks. But on dichotic listening left-handers did better for the left ear and right-handers for the right ear, admittedly with a high variance. On the whole, left-handers revealed greater variability in their performance on the dichotic listening task, the four subjects with familial incidence of sinistrality being the most left dominant.

c) <u>Vision:</u> a very recent experiment by

Dimond (1968) illustrates the conflicting questions raised by hemisphere dominance. In order to study the lag in brain function, a technique of responses competition is generally used with two stimuli presented to the subject at very short interval. This experiment however modified the traditional method, and presented instead the two visual stimuli simultaneously to study differences in skill learning between each half of the brain as manifested by hand reaction. The subjects were right-handed undergraduates; half of them were trained to answer the stimulus with the left hand, the other half with the right hand. The groups showed no significant differences in their reactions. Would this indicate that at any one time either hemisphere can assume the dominant role? To answer this question the subjects were then asked to respond with both hands. A discrepancy was now found: if the left hand had been the one trained, its performance was not impeded when a paired response was called for, whereas if the right hand had been trained, reaction time greatly increased. Should this later discrepancy point to one hemisphere constantly being the dominant one? This is a typical dilemma of scores of researchers in this area of neuropsychology.

The output of studies on cerebral dominance seems almost inexhaustible. To name just a few authors who are active in this subject, there are Russell and Espir, (1961), Semmes, Weinstein, Ghent and Teuber (1960), Hecaen and Ajuriaguerra (1964) and Zangwill, who was just mentioned, and most of the members of the symposium held at John Hopkins School of Medicine in 1961 (Mountcastle, 1962).

It would seem that in a field as complex as that of hemisphere dominance, a fruitful statistical

approach would be the factor analytical one. Ricklan and Levita (1964) followed this technique in their study of seventy-one parkinsonian patients with unilateral basal ganglia lesions, tested before and after hemosurgery; forty-three had operations on the right side and twenty-eight on the left side. Thurstone Centroid Factor Analysis was applied to the data consisting of thirty-five measurements obtained from the Rorschach, Weschler-Bellevue, Bender-Gestalt, Human Figure Drawings and others. The writers gathered the impression from their results that since they had failed to discover any association between definite psychological functions and specific subcortical areas in either hemisphere, it could be that several psychological functions are "subserved by neural processes inherent in either, and/or both brain hemispheres" (sic). Therefore relative rather than absolute changes should be made to the meaning of hemisphere dominance.

Other possible explanations for the discordant outcomes of so many investigations are given by Hebb (1949); since most data on localization of brain function is collected from observations of patients before and/or after the removal of brain lesions, post operative effects can be attributed to: 1) the surgical removal itself, 2) diffuse brain damage caused permanently by the lesion, through pressure exerted on the rest of the brain tissues, 3) reversible physiological changes due to the surgical procedure on the edges of the lesion removed. On these grounds, he stresses the necessity of making use of control groups no matter how difficult they are to find, as they are vital to the rigorous validation of hypotheses in this field.

Bingley (1958) also suggests a few sources of error stemming mainly from: 1) lack of unanimity on

the definition of handedness, most of the time it is not operationally defined, 2) the impossibility of verifying the unilaterality of the lesion, especially when its origin was traumatic, 3) over representation of patients with language disturbances, 4) the fact that when left-handed subjects are requested to establish evidence of other left-handedness in their family, they have the advantage of recalling it more easily than right-handers would, since they are oversensitive to sinistrality. In the final analysis, this area of cerebral dominance is a particularly thorny one as so many of the critical variables remain to be clarified and the precise mechanisms whereby they influence the innumerable functions of the brain still elude us.

C - LATERALITY

Handedness which so often crops up in studies of brain dominance is but one aspect of laterality that many authors try to relate in one way or another to dyslexia. Yet there is a common stumbling block: the lack of agreement on the meaning of laterality and consequently in the use of different instruments to measure it. Whether it is applied to foot, hand, eye or ear, laterality is sometimes defined as greater skill, sometimes as preference and even consistent usage of one side of the body over the other. It is not surprising then that resulting data are so puzzling and difficult to compare. Mixed and crossed laterality, then eye and hand laterality, will be dealt with in the following pages.

1) Mixed and crossed laterality: one aspect of dyslexia highlighted by Orton and still explored today is mixed laterality or sidedness or mixed dominance as it can be called. A person is said to be

mixed dominant if for instance he uses his left hand for only one or two manual activities and his right one for the others, or vice-versa. He is crossed dominant if he is left handed and right eyed for example. Galifret-Granjon and Ajuriaguerra (1951) applied Hildreth's index of differentiated sidedness: Right-Left/Right + Left to scores on a dozen laterality tests given to 108 normal children and ninety-seven dyslexics aged between seven and thirteen years. Their conclusion was that: 1) sidedness evolves with age, dextrality tends to increase constantly, even after 10 years, 2) most often dyslexics are not so much left sided as badly lateralized, and 3) although dyslexics and normal readers are statistically different as a group on the extent of lateralization attained, the significance is not great enough to be discriminant except for group comparison. In the absence of clear-cut results, the authors speculate that there must be some structural organizations created during development which compensate for difficulties inherent in certain types of disharmony in lateralization. They also pay credit to Ombredane's assumption that left-sidedness is a motor rather than a sensory characteristic, periodically inhibiting exploratory movement in reading, an assumption which at the same time explains the particular slowness observed in dyslexics.

Harris (1957) on the other hand emphasized that significant relationships between dyslexia and certain forms of sidedness had not been brought to light because the tests used up to then were not appropriate. He then proceeded to introduce his own test of laterality consisting of one item to assess knowledge of Right and Left, ten to ascertain hand preference, five items to measure handedness (skill and

speed), two for "eyedness" and two more for "footedness." He administered it to 316 dyslexics between seven to eleven years with IQ's over 80 and to 245 unselected children. Upon comparing both groups performance at the ages of seven and nine for eye, foot and cross dominance, the only aspect on which they differed significantly was on mixed handedness; although mixed handedness decreased with age in favour of right-handedness in both groups, the seven-year-old dyslexics showed a larger proportion of mixed ratings on two out of five manual tasks and nine-year-olds on three out of five of these tasks.

It must be said that the Harris Test of Lateral Dominance does not always yield even those partial results. Balow (1963) used it in conjunction with Gates Primary Reading Test, Lorge Thorndike Intelligence Test and Reading Readiness Test. No relationship was found between any of the dominance ratings and reading achievement in 302 children of primary grade. He concluded that the Harris Test would not be useful in screening children for possible reading difficulties.

Trieshman (1966) investigated the link between dyslexia and handedness in sixty boys aged eight, using the Stanford Achievement Test, a series of motor tasks scored for difference in speed for each hand and a perceptual task (matching standard forms with comparison forms under memory conditions.) The hypothesis was that problem readers had less differentiated handedness than normals and make more perceptual errors. No differences in the incidence of differentiated handedness were found, and contrary to anticipation, problem readers had a higher perceptual rate regardless of their hand differentiation.

Stephens et al (1967) compared eighty-nine first graders on tests of reading readiness and of eye-hand preference, assuming that crossed eye-hand preference was a sign of mild neurological dysfunction, and that it interferes with learning of reading. They discovered no association between reading readiness and cross preference and sex.

Recently Zeman (1967) summarized fourteen highly relevant articles from the literature up to 1964 dealing with laterality and reading skill. In most studies no relationships could be established between the two; in a few studies some links were found but they were quickly contradicted by the results of still other workers. Zeman concludes by asking if the area concerned has been "substantially" investigated and his answer is: "If so, perhaps the research time that is being devoted to this area could be used more advantageously in studying other relationships in respect to reading." (id p123). Not very optimistic.

Finally Coleman and Deutsch (1964) analyzed the performance of eighty-six dyslexics and thirty-five normal readers from nine to twelve years old, to whom were administered the Harris Test of Lateral Dominance, a section of Benton's Right-Left Discrimination Test, Gates Primary Reading Test, Roswell-Chall Word Test and the WISC. It came out with the now almost predictable "no significant difference" between retarded and normal readers on eye, hand and foot preference nor on any combination of these, nor on the Benton Test. They suggest very soundly:

> "If existing tests of hand, eye and foot preference are assumed to measure accurately some underlying pattern of cerebral dominance, then incomplete cere-

bral dominance does not appear to be causally related to reading disability. If such measures are assumed to be open to experiential influence which may obscure the nature of some underlying pattern of cerebral dominance, then the relationship between dominance and reading disability has been inadequately tested." (id p.50). They go on to add that should a correlation be discovered between dyslexia and some type of cerebral dominance, there would still remain the task of defining the nature of the relationship, e.g. does dyslexia stem from incomplete cerebral dominance or is a developmental disturbance responsible for both conditions.

2) Eye dominance: this area of eye dominance while not as heavily investigated as the handedness one is nevertheless quite complex. Only a few studies will be dealt with, firstly that of Baeger (1953) since he uses a rather original device called "magic mirror". Technically it is a prism reversing the right-left directional axis and which he contends reverses also eye dominance and renders the stimulus letters similar to the image in the brain. While working with twenty-four dyslexic children of normal I.Q, he found correction of reading and writing reversals taking place sometimes in two lessons only and apparently the "magic mirror" was very popular with his subjects, His explanation for their quick recovery is a neurological and phylogenetic one. He speculates that the correction could occur in the area adjacent to the marginal gyrus in the post parietal lobe, since it is an area implicated in the body and space orientation functions and lying in close proximity to the speech centers. The latest developments on the phylogenetic level are always the most unstable according to Baeger, hence

language and reading would be the last functions to make the biaxial conversion, connected as they are to cortical areas associated with spatial orientation. Attractive though this may be, it still remains a hypothesis seriously in need of validation.

Among the many tests of eye dominance are tasks measuring simple visual acuity, monocular and binocular preference and even retinal rivalry. Jasper and Raney (1937) underlined the diversity of those techniques and the fact that this diversity could be the reason for the inconsistency which mars the results. Given the intricate neural structures of the visual system, they suspect that ocular dominance may not be a unitary trait for motor and sensory processes alike, thus dominance on a motor task such as sighting may be unrelated to dominance in visual perception or peripheral vision since each eye has a representation in both hemispheres cerebral dominance occurring in perception is likely to involve one half of each eye, yet when it comes to directing ocular movements, dominance could well be related to only one eye. In the conclusion to their survey of research concerned with eye laterality in different activities, they propose that while unilateral dominance may be characteristic of certain nervous structures, it is not necessarily present in neural organization as a whole. Indeed considering the various ocular mechanisms, dominance could be possible at least: 1) in motor control of the eyes, 2) in receptor mechanism of the eye itself, and 3) in central projection of the eyes.

Written in 1937, this conclusion is still applicable today where tests of eye dominance, especially in schools and dyslexic centers, are of-

ten used in a rather indiscriminate fashion with little attention given to the type of visual function the tests really measure.

3) Hand dominance: it has been often thought that the prevalence of dextrality in man is mostly due to social pressures, since in animals paw preference varies within the species. It is not quite as simple as that. Eighty-four adolescent and mature rhesus monkeys were tested by Warren (1953) to see which "hand" they used to pick up food. The monkeys were placed in front of a table divided into six parts, a well with food in each part. Very little ambidexterity was observable, each animal having its own paw preference; consistent left=and right-handedness were the two most common patterns, in approximately equal proportion.

Ettlinger (1961) summarizing the literature on the subject of limb preference in animals and in man suggests that: "the importance of environmental determinants, relative to anatomical factors, increases with phyletic status within the mammalian series." He also studied the differential effects of practice and task complexity on strength of handedness in forty-eight monkeys. While on the first test 55% of them manifested consistent preference, on the fourth test the proportion had risen to 78%; 45% showed opposite preference on test 1 and test 2 and a minority flucuated constantly despite extended training. Different types of surgical ablation were then performed on twenty-three of these animals, all three which had the left optic tract severed became blind in the right halves of the two fields of vision and from strong right-handedness turned to strong left-handedness. The inference was that: "the preferred hand is oppo-

site to the cerebral hemisphere receiving the relevant sensory inflow" One of the important determinant of handedness would thus be the nature of the sensory control of manual manipulation.

In humans, once it has been established handedness appears to be a more stable feature. But when does it crystallize? Opinions are divided on this subject, partly because some authors state the age when handedness for all manual tasks is established and others when some more general type of handedness asserts itself. For Griffiths (1954), by thirteen months an infant's handedness is already evident. Gesell and Ames (1947), studied children from eight weeks to ten years with twelve to forty-five children at each stage, using cinema and stenography to record their responses to cubes, pencil and paper and free construction situations. They consider that children oscillate between unilaterality and bilaterality until approximately their seventh year; trends to unilaterality at twenty-eight and thirty-six weeks are observed and towards bilaterality at twenty-four and thirty-two weeks for instance. The establishment of unilaterality starts around four years and is completed at about ten years. The tonic neck reflex would be of relative importance and for some unknown reason most children seem to have a tendency to turn their head to the right.

On observing forty-four children between the ages of two and four engaged in everyday activities (eating with fork and spoon, drinking from a glass, picking up toys and playing with them, etc.) Hildreth (1948) found that the trend is towards an increase in dextrality up to three years and a slight drop between three and four years.

For his part Kohen-Raz (1966) studied sixty-six infants from five to ten months old by presenting them rings and cubes for a maximum of four minutes at a time and scoring their responses for activity and for use of one or both hands (e.g. touching an object, grasping an object by each of the two hands, transferring from one hand to the other, etc.). This test called the Ring-Cube Test was intended to measure bimanual interaction and revealed an increase of ambidexterity in six to ten month old infants, but no definite pattern of right- or left-handedness at six months. Quoting Flament (1963) he mentions that at these ages the process of lateralization is not homogenous, in fact different sensory activities show fluctuating trends of lateral or bilateral development sometimes in opposite direction. Once the ability of spontaneous grasping is acquired around six months, it would be well to observe such aspects of sidedness as frequency, precision and speed concurrently with genetic precocity. On the whole Kohen-Raz would also support the idea of a definite tendency towards stable hand preference developing with age.

Some authors have tried to relate patterns of handedness to certain characteristics of manual activities. For instance, Brown (1962) examined the behaviour of ten nursery school children, focusing his attention on hand usage during free play. He found that half of them used one hand significantly more for both skilled and ego syntonic activities and this was not due to the fact that the dominant hand was already occupied or that ego-syntonic activities required greater skill. He concludes that the hypothesis associating differential hand usage to ego-syntonicity of the

activity the hand is involved in, is corroborated. Yet it must not be forgotten that the number of children on which he based his observations is quite small and does not provide very strong confirmation.

In an extensive investigation Durost (1934) submitted 1300 children (nine to fifteen years old) to four paper and pencil tests, two of which, namely The Treasure and Escape Tests, were similar to the labyrinth tests, that is, tracing a path with a pencil without touching the wall of the path, the third called the Pin Test used a push pin to pierce holes in a paper and the last one, The Target Test, was like the Pin Test except that an attachment blocked the wrist movement, forcing the use of forearm and shoulder muscles. The proportion of left handers on these activities varied from 4.25 to 5%. No distribution curve of scores for any of the four tests was typical of all of them, but as the test required finer co-ordination: 1) the standard deviation of scores increased, 2) the negative skewness became more and more pronounced as the left hand end of the distribution takes on more of the characteristics of an independent distribution, and 3) the mean of separate distributions for left and right hand moved apart. Handedness change with chronological age seems only very slight on The Treasure Test, on The Escape Test the direction is toward a more consistent sidedness for older children, the Pin Test shows changes but inconclusive ones while on The Target Test ambidexterity seems to increase with age. From this, it would appear to Durost that laterality follows the more general laws of proximo-distal development. In the Target Test the longer forearm and shoulder muscles are called into play but as the child develops, the co-ordination of

the longer muscles become more alike in both arms. In the Treasure and the Escape Tests however greater specialization is the rule.

When he reviewed the literature on handedness up to 1964 Palmer (1964) considered it in the light of neuroanatomy, cerebral dominance, motor and psychological development, individual differences and influence of genetic, perinatal and environmental factors. The major and amply justified criticisms he voiced about the research works on this subject were that they overlooked the motor development and multidimensional features of handedness in favour of a more empirical right-left distinction, and they largely failed to investigate the comparative use of proficiency measures and of learning curves for the two hands separately. The deadlock now arrived at by research on handedness he explains accordingly.

There is one aspect of handedness which has caused such a great amount of ink to flow and sparked off so many arguments and conjectures, that a word of it must be said at this point, it is sinistrality. Manual tools of prehistoric man, habits of biblical warriors, ancient religions like the solar cult as well as contemporary anthropological findings, all have been scrutinized in an attempt to account for left-handedness. In a more clinical vein, Humphrey (1951) had noticed that sinistrals seemed to be more variable in their hand preference and he proceeded to compare them to dextrals. His sample consisted of seventy individuals who considered themselves left-handed, one half of which wrote with the left hand, the other half with the right hand, and thirty-five subjects who regarded themselves as right-handed. Both groups of right-and left-handed, comparable in

terms of age, sex and education, filled in a questionnaire enquiring which hand they used for a number of activities. It came out that a surprising proportion of left-handed displayed inconsistent hand preference to the extent that as many as 25% declared using their right hand for unimanual games such as throwing, tennis and squash.

Clark (1957) exhaustively reviewed the literature on handedness and laterality and estimated that: 1) not only in the general population but even within individuals does variability of hand preference exist- 2) the incidence of dextrality is greater for those activities most related to school writing, 3) highly skilled and more practical tasks tend to elicit stronger hand preference, 4) left hand writers are but a fraction of the total number of left-handed individuals, since many more sinistrals have been made to write with their right hand while they were in school. Bingley (1958) came to very much the same conclusions.

A genetic study carried out by Trankell (1955) found that if couples are classified according to whether one, both or neither of them are left-handed, it can be predicted with unexpected accuracy whether their children will be left-handed or not; it is done by the simple application of Mendel's law with right-handedness as the dominant trait and left-handedness as the recessive one. This study is one of the more rigorous out of so many trying to link handedness and heredity. In this context it will be remembered that in the investigation mentioned above (Bryden, 1965) the presence of sinistrality in the family of the subjects was also established and the four who manifested the greatest left dominance on the tests were those who had direct parental or sibling incidence of left-handedness.

Looking back at the topic of dyslexia and laterality it can be seen as a highly disputed one; the numerous contradictions encountered almost everywhere seem to arise from an absence of agreement in defining both dyslexia and laterality and hence in the disparity of tools to measure the two elements. Whether it is described as an inherited condition, a neurological disability, a symptom of emotional disturbance, an immaturity of visuo-motor co-ordination or simply as the lower end of the reading ability continuum, dyslexia means different things to different people. Thus Fabian relates it to the development of space orientation, Drew to the disturbance of Gestalt functions, Wagenheim to a dynamic condition and Orton to a failure to establish eye dominance in the brain. Laterality is now neurological organisation, now skill, now consistent preference of side in various activities. The subject of mixed or crossed dominance so often tested does not yield stable nor significant data even after Harris' claim that adequate measures (i.e. the Harris Test of Lateral Dominance) would bring about the long awaited correlations. Jasper and Raney have revealed how intricate the area of ocular dominance really is, yet current tests of eye dominance are relatively simplistic and incomplete. It is known from Ettlinger and Warren that handedness in animals is rather evenly balanced between left and right and increases with task difficulty. In humans as in other primates, handedness increases with the degree of fine co-ordination involved in the task, but child psychologists cannot agree upon the age handedness is established in children, their approximations varying from eight months to ten years old. The total situation of research on handedness in general has been

excellently summarized by Palmer who advocates a more comprehensive approach instead of the piecemeal and often unoriginal work done in the last five to ten years. On left-handedness in particular, studies by Humphrey, Clark and Trankell have disclosed that left-handedness varies within individuals as well as between them and is greatly determined by the type of task performed; there is also evidence that it could be transmitted as a recessive trait.

Since no conclusive results seem to be achieved by relating dyslexia and laterality, perhaps the reason is that too little is yet known about each one of them and that separate and thorough studies would be more productive. Concerning laterality alone, not much is known regarding its development in normals, how it varies with different body organs and type of activities to be carried out for example. Indeed, why not attack the problem of laterality from a new angle and ask how children grow to recognize one side of the body from the other and how they acquire the concepts of right and left. We will probably be in a much better position then to tackle the question of laterality. Otherwise it can only mean additional investigations in an already overcrowded and barren ground. The advice given by Palmer and others should be heeded.

D - RIGHT-LEFT DISCRIMINATION.

This particular work is concerned with discrimination of right and left in normal children; presently the genetic development of the right-left concept and Benton's pertinent studies at the University of Iowa will be covered.

The earliest attempt at compiling norms can

be traced back to Binet and Simon in 1906. Their Intelligence Scale at the time included an item at the six year level whereby the child was asked to show his right hand and his left ear. In 1911 they revised the scale, kept the item but transferred it to the seven year level, where 75% of the children passed it. Although the question on right-left was retained in the 1916 revision, it vanished completely in 1937.

Next was Gordon's Hand and Eye Test (1923) whereby children were requested to imitate movement made by the examiner, e.g. touching their ear with their hand on the same side as his, whether he was facing them or standing with his back to them. Girls turned out to do better than boys up to eight years, after that boys were more successful and Gordon suspected intelligence to be in some way related to the performance. The only hitch to this last speculative assumption is that IQ measures have proved otherwise.

Piaget's theory of reasoning in the child extends also to the knowledge of right and left (Piaget, 1923). His short test requires first of all that the child identifies right and left on himself, then on others, then that he works out the positional interrelationship of three objects. On the basis of his results, the child would recognize right and left on himself at 6 or 7 years and only later can be distinguish it on others and later still on objects; this Piaget attributes to the egocentric orientation or intellectual narcissism typical of the younger child. For him right and left discrimination develops concomitantly with mental ability such as language and reasoning and with socialization of thinking, and is not due to any incidental experiential factor. However Piaget has

not pushed the investigation of this concept very far, only inasmuch as it is connected with spatial relations and more generally to conceptualization. Some later authors have replicated his studies; amongst others Elkind (1961) has tested 210 children from five to eleven years old, thirty at each age level, selected from a population of 800, with Piaget's original test slightly modified. His findings are closely similar to Piaget's but more detailed. He discovered that knowledge of right and left proceeds from an undifferentiated, global knowledge to concrete differentiation and to the formation of abstract concept; so the seven or the eight-year-old knows where right and left are on himself but not yet where they are on other persons facing him or on objects; then between the ages of eight and ten he gradually learns to recognize other people's right and left and finally between ten and eleven he has grasped the relativity of right and left and can indicate on which side of an object is another object (e.g. a pencil is on the left of a key).

Belmont and Birch (1963) also validated Piaget's work with 148 children with normal IQ from kindergarten to grade six. They included items for assessing hand, eye and foot laterality with consistency as the criterion for hand and eye activities and skill and consistency for foot dominance. Of the seven-year-olds 75% could discriminate right and left on their own body and on others but only the eleven-year-olds could situate objects in relation to one another. Accurate right and left discrimination showed no significant correspondence with sex, grade nor lateral preference but, contrary to what would have been expected, preceded the stabilization of hand preference by about two years.

The most systematic investigation on learning to name right and left parts of the body was done by Halina Spionek a polish psychologist (1961). In the beginning of her book she reviews almost 300 articles relating her topic to testing of right and left discrimination, pathology of spatial orientation and normal sensory-motor and mental development. She then goes on to describe her research which consists of observing children in their natural environment, compiling the answers to series of questionnaires presented to their parents and later experimenting on the effects of training and transfer on the ability to differentiate right and left. The observations coupled with data provided by the questionnaires led her to believe that the orientation of both sides of the body is a function of the environment and of incidental learning; parents and teachers do not notice nor remember specific situations of learning or of social import which are definitely related to the emergence of right and left differentiation ability in their children and therefore she concluded that interviewing them cannot be a reliable source of information on which to build hypotheses about environmental and educational influence on right and left development.

The utilization of questionnaires confirmed that the items degree of difficulty corresponded to 1) the choice of the first question, and 2) the order in which questions are asked concerning: a) the two sides of the body and b) the arms and legs and other organs. Moreover certain principles become evident: e.g. if you ask a child where is his left hand and then where is his left foot, he will show the one that is on the same side as the hand he had just indicated. This is the principle of conservation of the same side

of the body and would definitely put the left handed child at a disadvantage since the first question generally is about the right hand. A child that has just named a part of his body as Right has a tendency to name the opposite one as Left, this is the principle of opposition of paired organs. Children learn to show correctly their right or left limb or paired organs to a certain order, this is called the hierarchy of paired organs: thus hands are differentiated first, then feet and only after that ears and eyes. This is evident not only when the child is acquiring the ability to identify his right and left side but even before that when he starts naming parts of his body. Finally when a child is asked to show one hand he will show the one which is used more frequently, this is called the priority of the hand most often used.

Experiments in the laboratory with 100 children whose age ranged from two to seven, using the association technique of training, support the above idea. The children were placed in a machine recording foot and hand movements (pedals for the feet and rubber bulbs for the hands) and the exercise was presented as "You be the Driver" game. It was noticed that saying Right or Left while showing the child which side it referred to or associating it with passive movements was not adequate, but that the quickest and most reliable method was to relate the word Right or Left with active movements in response to a visual stimulus, i.e. a red light appearing and the word pronounced, would mean the left hand must squeeze the bulb in front of it. There were several series of these exercises varying in degree of complexity and adapted to the different ages. In the light of these experiments Spionek stated that children can be taught to

distinguish and name both sides of their body up to two years earlier than they would do so normally. However in very young children (three-and four-year-olds) the ability remains limited to the parts which were submitted to training and cannot be generalized.

Another study in a relevant if not similar field is that of Newson (1955). Handedness, she thinks, and IQ have only a slight association with the perceptual inability (common in five-year-olds), to distinguish between a line figure and its mirror image; experience in writing seems to be the sole relevant factor. This perceptual difficulty becomes more prominent when the letters are of the particular symmetric category where one half is the duplicate of the other half, e.g. S,N,Z. Other determinants of letters within the alphabet such as meaningfulness, closure, complexity and length/breadth ratio, would have no additional influence. Fifty-two nursery school children four-and-a-half-years old from working class families were trained by having their right and left hands marked with rubber bands of different colours and by being shown every day objects orientated in a certain direction (a policeman pointing right, a flag or shoe pointing left for instance); then formboards with insets and holes of the same colour were used, the two sides facing opposite points and only one of them movable; finally wire figures were matched with identical shapes drawn in black ink. A control group spent an equal amount of time at playing games. It was hypothesized that the child must first be conscious of the difference between various directions before he can realize that a figure and its mirror image are two distinct figures, even if the words right and left have yet no meaning for him. Therefore the notion of

directional difference was underlined and, when possible, related to kinesthetic cues so that the meaning of the words could be felt in the childs own body. The drawings presented were graded in order of abstraction or symbolism, initially using living and concrete objects and eventually ending with letters. It was discovered that four-and-a-half-year-olds were able to recognize figures and their mirror images if they had been trained to do so, whereas untrained five-year-olds still could not. Newson suggests that the incapacity to discriminate between a line figure and its mirror image in five-year-olds is caused entirely by lack of familiarity and practice with the concepts involved, and that there would be some evidence for postulating that the progress of reading and writing in the first year of schooling is not so much dependent on intelligence as on learning early enough how to distinguish a figure from its mirror image.

Benton and his colleagues at the University of Iowa have carried out extensive research on the development of the Right and Left concept in children, e.g. how it is established first of all on the self, then on others and which variables have an effect on it. A standard twenty-item question scale was generally employed although a slightly modified version or even one which included items related to mirror image behaviour were also utilized. The reported odd-even reliability fluctuated between .88 to .92 on samples of normal children (Swanson and Benton, 1955, Swanson 1954); test-retest reliability on equivalent forms when administered at a twenty minute interval was .72 and if the interval was extended to ten weeks it decreased to .67.

Five aspects of right and left discrimination are covered in the test: 1) with eyes open: a) showing single body parts, b) executing single and double commands, c) showing body parts of a person facing the subject, 2) with eyes closed: a) showing single and body parts on self, b) executing single and double commands. Two other scales of sixteen and thirty-two items respectively were occasionally used and Benton does not always specify which particular one he employed in a given experiment; he assures the reader however that they are all equivalent from the psychometric point of view (for the thirty-two item form cf. Appendix I.)

The normative study (Swanson, 1954) done on 158 six-to nine-year-olds of average IQ and socioeconomic background, revealed the scores to follow a negatively accelerated curve with respect to age. The six-year-olds scored slightly above the point that could be reached by sheer chance and the nine-year-olds did not perform as well as the average adult. He would suggest that the development of Right and Left starts around the five year level and postulates that it is completed at about ten years. At no age could he detect either significant sex differences (contrary to Gordon's finding) or differences in performance under conditions of use or deprivation of vision, the correlation between "eyes open" and "eyes closed" items being .51 (Benton, 1959, p.29).

In order to verify whether physical or psychological development was the critical determinant underlying the increase of right-left discriminative ability with age, Benton (1959, p.35) reported that comparison between performance of children with normal and superior intelligence revealed the brighter ones as being precocious and scoring higher at all age

levels. In fact, six, seven, and nine-year-olds in the superior group performed at a level commensurate with their mental age. Normal children were also compared to mental defectives. Benton (1955) carried out an investigation on familial, brain-injured (including cases of trauma, infection and neoplasm) and undifferentiated (unknown etiology) mentally retarded children whose age varied from nine to twenty-two years, IQ's from 40 to 75 and mental age from six to nine years. It was found that: 1) different types of mentally deficients did not obtain significantly different scores, 2) at the seven, eight and nine year level, their scores were significantly lower than those of the matched groups of normals. It is worth noting that the only cases mentioned in the literature where mental deficiency does not decrease the right-left discrimination ability are those of hemiplegic patients; there it would appear that the hemiplegia enhances a sense of differentiation between both sides of the body and accelerates right-left orientation not only on the self but on other persons also (Benton 1959, p.50).

Partly associated with mental deficiency or at least with slow intelligence is the case of children in institutions. The lack of intellectual stimulation and of individual attention has often been recognized to be linked with dull IQ. This effect was investigated on a small scale and appeared to be irrelevant to the emergence of the right-left ability, institutionalized children performed either slightly above or below normal children living at home (Benton, 1959, p.34).

Attention was also given to the influence of

handedness, (Benton, 1959, p.36), sixty-six subjects were given the Benton Test and a questionnaire ascertaining the hand used for thirty-five activities (e.g. writing, erasing, cutting, folding etc.) The correlation was significant but quite low at .24. It is interesting to mark that a more recent study (Crookes and Greene,1963) although employing different and shorter measures of handedness and right-left differentiation also found a slight link between these two variables, overshadowed unfortunately by the much higher correlation between intelligence and right-left discrimination.

Types of response to "self" and "others" and to crossed command items were subsequently analysed to see if any pattern could be detected (Benton 1959, p.30). On the one hand, scores for items concerning "own body" and other persons hinted that while mastery of the right-left concept on one's own body is a prerequisite condition, it is by no means the sole basis of its correct application on other persons. Children who score high on "other person" score high on "own body", but the relationship is not a reversible one. On the other hand mistakes in reacting to crossed commands fall into two categories: ipsilateral and systematic reversals. The former is when a child places his right hand on his right shoulder when requested to put his right hand on his left shoulder for instance; this seeming incapacity to cross the midline of the body, present in young children and in some brain-damaged patients alike, is a perplexing phenomenon, specially since it is not directly linked with age (Gordon found it in roughly similar proportion amongst seven- to fourteen-year-olds and the University of Iowa six-year-old group had a high ratio of

ipsilateral responses even when they succeeded perfectly a list of ten single commands). Following Quadfasel, Benton (1959 p.32), expresses the opinion that it might be the manifestation of a primitive reaction tendency which in brain-damage would come out overtly as a sort of release phenomenon. The other but less frequent reaction is when a child consistently uses the Right label for Left and vice-versa, he can distinguish one side of the body from the other but has the tags mixed up. Benton (1958) further compared the performance of groups of average IQ children whose ages ranged from six to ten on tasks of arithmetic, reading, language skills, handedness and right-left discrimination. On this last test, were selected only the ones scoring either 14 or 16 (on a total possible score of 16) or -14 to -16, i.e. high discrimination but inverting the Right-Left labels, on the Benton test. Those exhibiting systematic reversals had a mean reading score lower than the control group; they were also slower in other language skills such as spelling, grammar, and punctuation and significantly inferior on differentiating Right and Left on other persons. This led Benton to conclude that verbal and abstract abilities are essential to the understanding of the right-left concept's relative character.

Benton (1959, p.43) in a brief study and a cursory review of the literature with respect to the performance of adults on such measures, revealed that though adults achieve perfect or near perfect scores on his test, remarkable individual differences emerge when the tasks are more difficult as Benton reports that they are on the Thurstone and the Kao and Li scales.

In his book "Right-Left Discrimination and Finger Localization" (1959,p.141), Benton postulates the necessity of yet another determinant which he calls: "the Right-Left gradient". Long before the child can grasp the abstract meaning of the words Right and Left, he must be able to distinguish physically one side of his body from the other. It seems that at this stage the symbolic concepts of Right and Left are not required and the vital role accrues to the Right-Left gradient. This gradient would crystallize through information received from sensory receptors, mostly visual and somesthetic ones. The child comes to differentiate gradually single lateral parts of his body as he uses them in motor activities and as various stimuli impinge on his senses. From these various stimulations he gets a feeling of "differentness" although he cannot put it into words. These sensori-motor processes provide the basis on which is built the simpler structure of side differentiation. Handedness at this point would be a motor expression of the Right-Left gradient. When this basis is firmly established, symbolic processes begin to take over and eventually the child extends his knowledge from himself to others and to surrounding objects. Finally the Right-Left concept has been stripped of its concreteness and has attained the level of generalization.

In summary of the literature of right-left discrimination it would appear that there are certain steps in learning to differentiate both sides of the body on oneself. Preschoolers can be trained to learn up to two years earlier than they would normally if left to themselves, but then this learning can only be applied to the limbs or organs that were submitted to training, it is not transferable. Right and Left

are presumed to be verbal concepts; a sensori-motor factor, or Right-Left gradient makes consistent discrimination of lateral body parts on oneself possible by five or six years of age. But to be able to apply this directional orientation on others the Right-Left concept must have reached a more abstract level. Children who consistently but in a reverse order distinguish both sides of their body, usually are retarded in their verbal development. Mental defectives and normals of the same mental age show no difference in lateral orientation while children with superior IQ perform at about the same level as normal children of similar MA. On the whole, of the following variables: sex, institutionalization, handedness, MA, body schema, language ability and age, only the last four are relevant to the formation of the Right-Left concept.

II PRESENTATION OF THE PROBLEM.

SECTION 11.

PRESENTATION OF THE PROBLEM.

The nature of dyslexia and laterality and their interdependence have been the subject of innumerable investigations going as far back as 1896. What is more these investigations employed different tools, concepts, and definitions making comparison of results difficult if not altogether impossible, and their explanations a challenge to the most fertile imagination. Hence after the formulation and testing of so many hypotheses, few conclusive statements are warranted as to the nature of dyslexia and laterality and no clear-cut relationship between them can be inferred with any certainty. The more lucid and far-seeing authors unanimously recommend that future research should be oriented in a different direction.

Studies carried out by Spionek, Newson and Benton, disclose a wide new field which could be the source of discoveries essential in the end to disentangle the laterality and dyslexia deadlock. They have already established that children can name and identify both sides of their body at first, after which they can transfer these labels to other persons. Sensorimotor then verbal processes, it would seem, consecutively facilitate this task. Mastery of lateral orientation is established approximately by twelve years of age and would be determined by chronological and mental age as well as by verbal ability and body image.

Instead of examining the disorders of directional orientation as some authors such as Head,

Quadfasel and others have done, Benton, Spionek and Newson's approach seems to be the best suited to the problem confronting everyone at the moment. Only after clarifying the ontogenesis of Right and Left, and the factors that are pertinent to it can one attempt to elucidate the mechanisms underlying the pathology of lateral orientation in dyslexics, ill-lateralized children, and brain-damaged adults.

The present study therefore proposes to investigate, with normal children, the relationship and interdependence between the growth curves of the right-left concept and that of seven relevant variables, namely: age, language ability body schema, spatial relations, abstract reasoning, motor maturation and handedness. In the light of the literature reviewed, specially the findings of Newson, Spionek and Benton and his colleagues at the University of Iowa, learning to differentiate which is Right and which is Left would by no means be a simple task. In fact it seems warranted to suppose that it develops in close parallel with a number of other intellectual and motor abilities, not forgetting the maturation element which often plays such a prominent role in studies involving this age group. Indeed the main conclusion to be derived from the contributions to this field is that the emergence of the Right-Left concept is undoubtedly multidetermined.

The essential task now is to assess the comparative value of each of these eight variables mentioned above which are known as or suspected of influencing the discrimination of Right and Left. Which variable has the strongest effect? How much do they weigh, relatively to one another, in the process of

acquiring the concept? Are there any particular combination or interaction of elements which have a critical bearing on the point at hand? This type of query definitely calls for an all-embracing approach as the most fruitful and expedient one to bring forth conclusive answers.

Accordingly, this investigation endeavours to establish the presence or absence of one or several factors connected with the development of the concept in question. A factorial method was therefore selected as the most promising and appropriate one to fulfil this specific aim. The statistical procedures chosen for this undertaking will be detailed in the next section after full descriptions of the sample and of the psychometric instruments utilized in the experiment have been presented.

III EXPERIMENTAL DESIGN

A. Sample.

1. Criteria of selection.
2. Description of the sample.
3. Conditions of testing.

B. Test Battery.

1. Motor development.
2. Body schema.
3. Benton Right-Left Discrimination Test.
4. Language ability.
5. Abstract ability.
6. Space Relations.
7. Handedness.

C. Statistical Treatment.

SECTION 111.

EXPERIMENTAL DESIGN.

In order to test the hypothesis that one or several factors may be linked with the development of the right-left concept in normal children, a battery of seven tests was administered to primary school pupils. The criteria of selection and description of the sample, description of the tests employed, testing conditions and finally the statistical methods applied to the data will be the subject matter of this section.

A - SAMPLE

1) Criteria of selection: the principal aim pursued in collecting the sample was to select a group as heterogeneous as possible with a high proportion of IQ's in the median range. Also the subjects should vary in age from four to twelve years, which Benton suggests as a range covering the emergence and complete acquisition of the concept. Therefore children from an infant school and a junior school located in an area housing working class and lower middle class families were chosen as most likely to fulfil these IQ and age requirements. The infant school numbered 118 boys and girls from four years to seven years six months and the junior school totalled ninety-three girls and 118 boys from seven and a half to twelve years old.

The names of five boys and five girls were picked at random from each age group. The only children not included in the population were the cases where reading was so poor as to warrant attendance at special

reading classes; there were fifteen such children, nine of them boys. Most of them had language difficulties due to the recent immigration of their families to Britain from Greece, Italy and the West Indies. They were excluded on the grounds that their verbal handicap would lower their scores on the test battery in general, introduce an uncontrolled variable in the experiment, and not do justice to the subjects themselves. Although there were children from immigrant families in the rest of the population and hence in the sample, their verbal skills were comparable to those of the English children and their functioning in class was adequate. It was not deemed necessary therefore to eliminate them from the population. It should be mentioned that the proportion of immigrants in the area was not greater than 15%.

2) Description of the sample: as will be seen from Tables 1 and 2, the ages and age ranges of the boys and girls were relatively equivalent in each of the eight age groups, the widest mean difference being 2.6 months in the five-year-old group. Means for the total number of boys and total number of girls were identical; boys and girls could thus be combined together to make a single group at each age.

3) Conditions of testing: the children were fetched in turn from their class and taken to a quiet room by the Examiner. There the tasks were introduced very briefly thus: "I have some games here for you and I would like you to show me how well you can do them." Immediately the first test was presented. All seven tests were administered in the order in which they are detailed below and according to standard instructions; each session lasted on average forty-five

Table 1.

Mean age for each age group of the Boys, Girls, and Boys and Girls groups combined.

Age Group	Boys and Girls	Boys	Girls
4yr.	4yr. 6 mo.	4yr. 5.8mo.	4yr. 6.2mo.
5yr.	5yr. 5.9mo.	5yr. 3.6mo.	5yr. 6.2mo.
6yr.	6yr. 3.6mo.	6yr. 3.6mo.	6yr. 3.6mo.
7yr.	7yr. 5.2mo.	7yr. 5.2mo.	7yr. 5.2mo.
8yr.	8yr. 6.1mo.	8yr. 3.6mo.	8yr. 6.6mo.
9yr.	9yr. 5.9mo.	9yr. 5.0mo.	9yr. 6.8mo.
10yr.	10yr. 5.6mo.	10yr. 6.8mo.	10yr. 4.4mo.
11yr.	11yr. 5.0mo.	11yr. 3.6mo.	11yr. 4.4mo.
Total	9yr. 6.0mo.	9yr. 6.0mo.	9yr. 6.0mo.

Table 2.

Age range of the separate age groups of boys and girls.

Age Group	Boys	Girls
4yr.	4yr. 0mo.-4yr. 10mo.	4yr. 0mo.-4yr. 10mo.
5yr.	5yr. 1mo.-5yr. 9mo.	5yr. 3mo.-5yr. 8mo.
6yr.	6yr. 3mo.-6yr. 9mo.	6yr. 1mo.-6yr. 11mo.
7yr.	7yr. 2mo.-7yr. 10mo.	7yr. 1mo.-7yr. 9mo.
8yr.	8yr. 0mo.-8yr. 11mo.	8yr. 2mo.-8yr. 10mo.
9yr.	9yr. 2mo.-9yr. 9mo.	9yr. 3mo.-9yr. 11mo.
10yr.	10yr. 3mo.-10yr. 11mo.	10yr. 1mo.-10yr. 8mo.
11yr.	11yr. 2mo.-11yr. 7mo.	11yr. 1mo.-11yr. 6mo.

minutes. The testing was carried out during the normal school hours, and extended all through Lent term 1967.

B - TEST BATTERY.

1) Motor development: the problem here was to find a short task which could yield information as to which stage of motor maturation a child had reached. The Lincoln Oseretsky Motor Development Scale and the Rutgers Drawing Test were at first considered but later rejected because they were too time-consuming. Finally "Draw a Diamond", one of the items of the VII year level of the Stanford-Binet 1960 L-M Revision (Terman, Merril, 1960) was decided upon since most 7 and 8 year olds can perform adequately on it and they are at the mid-point of the age distribution. Moreover it is a brief task and even four-year-olds will attempt it without reluctance. The test itself has been well constructed, standardized and revised through scores of years. The subject is presented with a diamond figure printed on a page and is instructed to "Draw one just like this. Make it just here." The instructions are repeated twice and the child must draw three diamonds similar to the one on the page. The point is credited if one of the three drawings satisfies all of the following criteria: 1) well defined angles, 2) the shape of the figure more diamond-like than square or kite-shaped, 3) the pairs of angles must be approximately opposite.

2) Body schema: the Goodenough "Draw a Man" test was selected to assess a child's image of

his own body and scored according to the Goodenough Intelligence Scale. The subject was merely told: "On this paper I want you to draw the picture of a man just as well as you can." Points were ascribed for essential details first, then for secondary ones, e.g., hat, cane, etc. Copy of the scorable items contained in Appendix 11 illustrates the type of details judged to be pertinent and normalized on a standard school population by Goodenough. Directions for deciding when to credit each item are not included herein but can be found in Goodenough (1925, p.90-111).

3) Benton Right-Left Discrimination Test: the test itself and the reliability coefficients have already been discussed above in Section 1. (Page 50). The thirty-two item scale (Appendix 1) was preferred since the greater number of items reduced the influence of chance, specially when the test would be later broken down into subsections for further analysis. Since the correlation was so high between eyes open and eyes closed items, all responses to single commands with or without the aid of vision were counted together and those to double commands handled the same way.

As mentioned earlier, Benton considered it important to distinguish the child who completely confused Right and Left from the one who identified consistently one side of his body from the other but reversed the labels, thus obtaining negative scores. So as not to penalize the latter and differentiate it from the former, the University of Iowa studies established a convention whereby if a score of -14 to -16 on a possible total of 16 or -16, or -22 to -24 on a possible total of 24 or -24 was obtained, it was counted as correct. This project also takes this element into account but

it seemed less arbitrary to count as correct not only those performances where the perfect score is almost reached but all those falling below Benton's cutting point e.g. crediting the highest score whether it be positive or negative, for instance if a child reverses 15 out of 24 items and responds correctly to the other 9, the score used in this study would be the -15 one and it would be treated as +15 although notice would be taken of its particular character. The point in this case is to ascertain first and foremost if a child can distinguish both sides of his body.

4) Language ability: the Vocabulary subtest of the British adaptation of the Weschler Intelligence Scale for Children was used to measure verbal skills; it is a well constructed scale with a solid reputation of long standing. The Stanford-Binet (L-M form) Picture Vocabulary was administered in addition to the four-year-olds but the ceiling of the test was found to be too low for them; their scores ranging from 10 to 18 had a too narrow distribution to allow for sufficient interindividual discrimination. These results were therefore not utilized. Taking into consideration the statistical analysis and the fact that the WISC did not provide norms for the four-year-olds, it was decided to use raw scores instead of scaled scores for the computations.

5) Abstract ability: the Raven Progressive Matrices served as a measure of the capacity to abstract. There are two versions, the first one containing sets A, Ab, and B, (1947), the second one covering sets A, B, C, D, and E (1958). The first version is intended for children up to eleven years of age while the other one can be administered to eleven-

year-olds up to and including adults. Because of the correlation techniques involved later on, it was decided to give the first version to everyone and in addition sets C, D and E to the eleven-year-olds. It should be said that items in sets A and B in both versions are identical except that for the under eleven age group they are in colour while they are in black and white for children above that age. The test being so well-known in England and elsewhere, will not need to be described any further here.

6) Space relations: the Space subtest of Thurstone's Primary Mental Abilities was chosen to assess spatial orientation. The complete test itself was devised after a careful factor analysis of over 100 tests. On the basis of these results the Thurstones constructed an intelligence test composed of five primary factors as the authors call them, and adapted them to three age groups: 5 to 7 years old (Primary), 7 to 11 years-old (Elementary) and 11 to 17 years-old (Intermediate). The factors in question are: Verbal Meaning, Space Relations, Reasoning, and for the eleven-year-olds a Number and a Word Fluency factor. The Primary group have the first two factors plus a Perceptual Speed, a Quantitative, and a Motor factor, while the Elementary group have the first three factors plus a Perception and a Number factor.

This SRA Primary Mental Abilities Space subtest was the only measure of space orientation that could be found which was adapted to such a wide age range and so well standardized on over 50,000 school children from five- to seventeen-year-olds. There are three sets, one for each age group. A raw score is obtained and can be converted into a Mental Age for the Primary and Elementary group, while the Intermediate's

raw score is converted into a quotient score similar to an IQ score in the sense that 100 is the mean score. The most satisfactory way to place the scores for all three age groups on a comparable basis is to convert them to Mental Ages; thus the quotient scores are converted by reversing the traditional formula:

$$IQ = \frac{MA(100)}{CA} \qquad \text{to:} \qquad MA = \frac{IQ(CA)}{100}$$

It seemed justifiable to administer the five to seven years version to the four-year-olds since the test provides conversions of raw scores to as low a Mental Age as three years.

The test items are included in Appendix 111a, b, c, with the appropriate instructions accompanying them. Reliability coefficients are given as .866, .788 and .96 for the five-to-seven, seven-to-eleven and eleven-to-seventeen groups, and they appear to have been attained through the split-half method (Thurstone and Thurstone, 1953, 1954 and 1958).

7) Handedness: the choice of instrument was more difficult here since a good proportion of the articles published on this topic used their own personal tests and there are many to choose from. Of the better known, Crookes and Greene(1963), Roudinesco and Thyss (1948) and Harris (1956), the latter was selected mainly because the number of items was larger, standardization had been carried out and the items covered hand preference as well as skill. One section asks the child to mime how he executes ten activities: throwing a ball, winding a watch, hammering a nail, brushing his teeth, combing his hair, turning a door

knob, holding an eraser, using scissors, cutting with a knife, and writing. According to the percentage of activities executed with one hand, the Subject is classified as being strongly left-or right-handed, moderately left-or right-handed, or mixed. The same categories apply to describe the comparative speed of both hands when performing four activities: dealing cards, tapping, i.e. making dots in printed rows of small squares, signing one's name and writing simultaneously with both hands numbers from one to twelve (in this case skill is only considered). In the present experiments only children from seven years upwards were administered the last two tasks since the younger ones had not yet learned to write.

It should be mentioned that for all tests except the SRA Space Relations subtest, raw scores were used throughout instead of the given norms, centiles and quotient scores usually provided as points of reference for clinical psychologists. Here the aim was intragroup comparison and not the relative position of a subject in a particular group. The direct scores also offered a greater range and so a more sensitive scale for comparison. What is more, in some cases the norms did not cover the whole age range and would not have allowed all the scores to be on the same basis, e.g., the WISC Vocabulary Scale from five years up only.

C - STATISTICAL TREATMENT

The study was designed for Principal Component Analysis and all the computations were done at the London University Institute of Computer Science using the EXCHLF statistical library programs. The first correlation matrix included the results from the seven above mentioned tests and the age variable. Four

components were extracted, then rotated according to the Varimax rotation technique.

In order to explore the data in greater detail than the first treatment permitted, it was necessary to introduce some modifications of the material, notably the breakdown of the total scores on the Benton and on the Harris tests. However the scores for the five other tests from the original battery of seven, were retained in their initial form. A second Principal Component Analysis was carried out on the data after it had been differentiated in this way and yielded more interesting and more informative results.

The Benton test was subdivided into responses to: 1) single commands on self, 2) double commands on self, 3) single commands on others, 4) double commands on others, 5) systematic reversals, 6) ipsilateral responses, 7) total commands on self, i.e. single and double commands together and 8) total commands on others.

The results of each of the three tasks in the Harris: Handwriting, Tapping and Dealing Cards were subdivided into: 1) time difference between the performance of both hands, 2) total time taken by both hands, and 3) Durost's ratio of hand speed differentiation:

$$D = \frac{R-L}{R+L}$$

where one considers the difference of time taken by both hands in proportion to the total time taken by the right and left hand. (Durost, 1934, p.247). The activity involving the simultaneous use of both hands

to write down numbers from 1 to 12 was not included here as it had proven impossible for too many children, the results were ambiguous and it did not seem to contribute much to the point at issue. Finally it appeared that performance on Handwriting was closely related to how well the child could write, i.e. the younger ones capable of writing only their christian name to the eleven-year-olds signing their christian, middle and family name. To evaluate more precisely the effect of this behaviour, the number of letters written down in the handwriting task was included as a variable.

The second correlation matrix and Principal Component Analysis therefore took into account twenty-six variables in all, from which eight components were extracted. These variables are listed in Table 3. A partial correlation was also computed in order to see the effect of age, the closest approximation of the maturation factor often critical in developmental studies of this kind.

Table 3.

List of 26 variables used in the second Principal Component Analysis.

1. Age.
2. Goodenough Test.
3. WISC Vocabulary.
4. Raven Progressive Matrices.
5. SRA Space test.
6. Binet "Draw a Diamond" test.
7. Harris Test of Lateral Dominance.
8. Benton (Total score for 32 items) (Right-Left Discrimination Test.
9. Benton, single items on self.
10. Benton, double items on self.
11. Benton, single items on others.
12. Benton, double items on others.
13. Benton, ipsilateral responses.
14. Benton, Systematic Reversals.
15. Harris Handwriting task, total time taken by each hand.
16. Harris Handwriting task, difference between times taken by each hand.
17. Harris, Tapping, total time taken by each hand.
18. Harris, Tapping, difference between times taken by each hand.
19. Harris, Dealing Cards, total time taken by each hand.
20. Harris, Dealing Cards, difference between times taken by each hand.
21. Number of letters in name written in Handwriting.
22. Benton, Total score of items on self (single and double.)
23. Benton, Total score of items on others.
24. Harris Handwriting, D/T ratio.
25. Harris, Tapping, D/T ratio.
26. Harris, Dealing Cards, D/T ratio.

IV PRESENTATION OF RESULTS.

A. Right-Left Concept.

1. Right-left on self.
2. Right-left on others.
3. Benton Total Scores.
4. Ipsilateral Responses.
5. Systematic reversals.
6. Principal Component Analysis.

B. Harris Test of Lateral Dominance.

1. Harris Test and main variables.
2. Total Scores and Time Subscores on the Harris Test.
3. Time Subscores on the Harris Test.

C. Age Effect.

SECTION IV

PRESENTATION OF RESULTS

The aim of this section is to give the final data on which the discussion (section V) and conclusions (section VI) have been based. The raw data has not been included although means and standard deviations are available in Table 8 and in Appendix VI. The data here presented are those derived from the statistical analysis of the original material; they are given in three subsections pertaining to the following three major areas: A) the right-left concept as it is established on the self, then on others, together with the components relevant to its development, B) handedness as assessed by the Harris Test of Lateral Dominance, and C) the effect of age.

A - RIGHT-LEFT CONCEPT.

1) Right-Left on Self: Table 4 (P. 77) shows that total scores for Right-Left items on self are correlated .782 with age, .711 with Goodenough, .753 with Vocabulary, .649 with Raven, .716 with Space Relations, .600 with Draw a Diamond, -.019 with the Harris and .911 with the Benton Total Score. However if you split these Benton Total Scores into their two sub-scores you find in the same table that correlations of Single and Double Commands respectively are with age: .610, .760 with Goodenough, .623 and .666, with Vocabulary, .572 and .737, with Raven, .459 and .648, with Space Relations, .558 and .695, with Draw a Diamond, .424 and .599, with Harris, -.079 and .005, and with Benton, .686 and .893.

Table 4.

Correlations between responses to Single, Double Commands, Total Scores of Right-Left on self and the 8 main variables, with and without the influence of age.

Scores	Age	Goode-nough.	Vocab-ulary.	Raven	Space Relat.	Diamond	Harris	Benton (Tot.Sc.
S.Comm. age.	.610	.623	.572	.459	.558	.424	-.079	.686
S.Comm. no age.		.263	.145	-.102	.076	-.033	-.153	.415
D.Comm. age.	.760	.666	.737	.648	.695	.599	.005	.893
D.Comm. no age.		.098	.287	.053	.115	.108	.072	.731
Tot.Sc. age.	.782	.711	.753	.649	.716	.600	-.019	.911
Tot.Sc. no age.		.179	.292	.006	.124	.077	-.117	.762

2) Right-Left on Others: It can be seen from Table 5 (P. 79) that when it comes to recognizing Right and Left on another person, the Total Scores are correlated .325 with age, .369 with Goodenough, .456 with Vocabulary, .389 with Raven, .461 with Space Relations, .329 with Draw a Diamond, .188 with Harris and .538 with the Benton Total Score. Furthermore correlations between these 8 main variables and the Single and Double Command items which make up the Total Scores are respectively with age .271 and .304, with Goodenough .266 and .392, with Vocabulary .389 and .417, with Raven, .313 and .376, with Space Relations .401 and .412, with Draw a Diamond .287 and .293, with Harris .138 and .197, and with Benton Total Score .386 and .574.

3) Benton Total Score: the correlations with the eight main variables except the Harris are all substantial. As can be seen from Table 6 (P. 80) the Benton Total Scores have a correlation of .801 with age, .759 with Goodenough, .820 with Vocabulary, .722 with the Raven, .793 with Space Relations, .632 with Draw a Diamond and .068 with the Harris Test.

4) Ipsilateral responses: as expected ipsilateral responses are negatively correlated with age and with most tests of the original battery. Table 6 (P. 80) show that these responses have a correlation of -.621 with age, -.509 with Goodenough, -.627 with Vocabulary, -.512 with the Raven, -.559 with Space Relations, -.480 with Draw a Diamond, .086 with the Harris and -.705 with Benton Total Score.

5) Systematic Reversals: these are also negative but they are generally lower than those

Table 5.

Correlations between responses to Single, Double Commands, Total Scores of Right-Left on others and the 8 main variables, with and without the influence of age.

Scores	Age	Goode-nough	Vocab-ulary	Raven	Space Relat.	Diamond	Harris	Benton (Tot.Sc).
S.Comm. age.	.271	.266	.389	.313	.401	.287	.138	.386
S.Comm. no age.		.076	.306	.164	.346	.136	.124	.293
D.Comm. age.	.304	.392	.417	.376	.412	.293	.197	.574
D.Comm. no age.		.263	.310	.231	.310	.110	.185	.579
Tot.Sc. age.	.325	.369	.456	.389	.461	.329	.188	.538
Tot.Sc. no age.		.188	.354	.225	.378	.143	.176	.491

Table 6.

Correlations between Ipsilateral responses, Systematic Reversals, Benton Total Scores and the 8 main variables with and without the influence of age.

Scores	Age	Goode-nough.	Vocab-ulary.	Raven	Space Relat.	Diamond	Harris	Benton (Tot.Sc.
Ipsi. age.	-621	-509	-627	-512	-559	-480	086	-705
Ipsi. no age.		-014	-252	-004	-055	-056	163	-443
Syst.Re. age.	-360	-348	-273	-276	-324	-183	164	-400
Syst.Re. no age.		-096	054	041	-027	120	202	-199
Bent. Tot.age	801	759	820	722	793	632	068	
Bent.Tot. no age.		283	459	176	332	126	022	

obtained in the case of ipsilateral responses. Systematic reversals (Table 6 P.80) are correlated -.360 with age, -.348 with Goodenough, -.273 with Vocabulary, -.276 with the Raven, -.324 with Space Relations, -.183 with Draw a Diamond, 0.164 with the Harris and -.400 with Benton Total Score.

6) Principal Component Analysis: the latent roots of the correlation matrix and the percentage of the variance they account for were computed and tested for significance according to the procedures outlined in Lawley and Maxwell (1963). The results of the first Principal Component Analysis carried out, including the correlation matrix and the latent roots are contained in Appendix IV and V and the four components extracted, before and after rotation are listed in Tables 7a and 7b (P. 82). The components were scaled so that the sum of elements in each vector was equal to the corresponding latent root, the largest element in each vector being taken as positive. As it can be ascertained, the rotation procedure in this case does not appear to render the components more meaningful, quite the opposite in fact. All the variables have either distinctly high or low loadings on the unrotated Components 1 and 2; Component 3 has all low loadings except for 2 variables with -.3 and +.5 loadings which Component 4 is correlated only at 0.3 and 0.2 with 3 variables, both these latter Components accounting for 5.6% and 3.6% of the variance each. Loadings on the 4 rotated Components are not so easily polarized.

The contribution of the Harris Test to the four Components was a rather puzzling one since it was correlated very highly with Component 2 and not at all with any of the others. The heterogeneity of its

Table 7a.

First Principal Component Analysis. Loadings of each of the 8 variables on the four Components extracted, percentage of variance accounted for by each Component.

Variable	Comp. 1	Comp. 2	Comp. 3	Comp. 4
Age	0.942	-0.092	-0.044	-0.127
Goodenough	0.889	-0.063	-0.059	0.037
Vocabulary	0.919	-0.023	0.039	0.211
Raven	0.862	0.073	-0.343	-0.301
Space Rel.	0.944	-0.041	-0.009	-0.037
Diamond	0.799	0.084	0.562	-0.147
Harris	0.165	0.982	-0.039	0.063
Benton (Tot.)	0.884	-0.102	-0.090	0.333
Percentage of the variance accounted for.	70%	12%	5.6%	3.6%

Table 7b.

First Principal Component Analysis. Loadings of each of the 8 main variables on the four Components extracted, after rotation by the Varimax method.

Variable	Comp. 1	Comp. 2	Comp. 3	Comp 4
Age	0.581	-0.022	0.415	-0.635
Goodenough	0.657	0.020	0.332	-0.506
Vocabulary	0.782	0.075	0.380	-0.360
Raven	0.417	0.134	0.185	-0.855
Space Rel.	0.635	0.036	0.422	-0.559
Diamond	0.373	0.102	0.877	-0.252
Harris	0.025	0.995	0.064	-0.063
Benton (Tot.)	0.870	0.015	0.216	-0.329

items covering tasks as diverse in the skill required for it as handwriting, tapping and card dealing in addition to the dimensions of perceptual-motor speed, proficiency and hand preference, ruled out the hypothesis that the Harris Test measured a very pure factor related only to Component 2. At this point it was decided to break down the items and repeat the Principal Component Analysis. It also appeared that more information could be gained from the Benton treated in a similar manner; the second Principal Component Analysis was then carried out on the 26 variables mentioned in Table 3(74).

Means and standard deviations of scores for every variable are contained in Table 8 (P. 85). Means and standard deviations had been computed separately for Boys and Girls, but since they were so similar (as can be ascertained from Appendix V1), they were combined for the Principal Component Analysis. The statistical procedures followed in the second Principal Component Analysis are identical to those utilized in the first one. Correlation matrix and latent roots can be found in Appendices V11 and V111 and the loadings of each variable on the 8 new components together with the amount of variance accounted for by the components are found in Table 9 (P. 86). Thus Component 1 is highly correlated with age and all tests except with the Harris Test and its subdivisions. More or less the reverse happens on Component 2 where the Harris subscores and total scores weigh heavily and the others very little. These two components are the most important ones since they account for 39% and 12% of the variance respectively. The other 6 components account for 8% to 3% of the variance and contain an increasingly

Table 8.

Means and standard deviations on the 26 variables.

Variable	Mean	Standard deviation.
1	95.65	27.73
2	20.42	8.94
3	22.45	10.74
4	22.05	11.29
5	94.50	36.73
6	0.62	0.48
7	2.45	0.79
8	22.45	6.75
9	6.65	1.68
10	11.96	4.59
11	2.22	1.60
12	1.53	1.43
13	1.60	2.48
14	0.26	0.44
15	65.22	29.68
16	18.83	15.39
17	72.40	29.41
18	9.40	5.99
19	54.11	19.70
20	9.67	7.54
21	12.10	4.88
22	18.61	5.77
23	3.76	2.67
24	0.28	0.13
25	0.13	0.08
26	0.18	0.15

Table 9

Second Principal Component Analysis. Loadings of each of the 26 variables on the 12 components extracted and percentage of variance accounted for by each component.

Variable	Comp.I.	Comp.II	Comp.III	Comp.IV	Comp.V.	Comp.VI	Comp.VII	Comp.VIII
1	0.919	-0.048	-0.086	-0.090	-0.109	0.117	-0.055	0.133
2	0.863	0.075	-0.059	-0.120	0.050	0.038	0.056	0.200
3	0.908	0.099	-0.037	-0.010	0.009	0.076	-0.083	-0.058
4	0.820	0.137	-0.051	-0.063	-0.172	0.117	-0.020	0.041
5	0.913	0.093	-0.014	0.031	0.011	0.123	-0.097	0.099
6	0.768	0.141	-0.001	-0.100	0.057	0.271	-0.059	0.117
7	0.102	0.423	0.285	0.078	-0.205	0.540	0.283	-0.264
8	0.942	0.004	-0.032	0.057	-0.004	-0.173	0.117	-0.174
9	0.684	-0.322	0.156	-0.184	-0.029	-0.205	0.198	0.115
10	0.854	-0.243	-0.035	-0.191	0.005	-0.045	0.091	-0.307
11	0.361	0.582	-0.183	0.539	0.006	-0.180	-0.133	0.111
12	0.475	0.412	-0.038	0.536	0.040	-0.237	0.317	-0.140
13	-0.697	0.306	0.169	0.214	-0.064	0.102	-0.100	0.359
14	-0.413	0.242	-0.173	0.059	0.088	0.448	0.222	-0.218
15	-0.279	0.525	-0.038	-0.529	0.214	-0.396	0.154	0.032
16	0.014	0.780	-0.110	-0.513	0.207	-0.150	-0.128	-0.094
17	0.814	-0.261	-0.019	0.122	0.005	0.234	0.007	0.332
18	0.437	0.188	0.582	-0.074	-0.565	-0.052	-0.029	0.093
19	-0.417	0.332	0.267	-0.162	0.211	0.174	0.519	0.258
20	0.271	-0.019	0.740	0.073	0.594	0.053	-0.024	0.021
21	0.591	0.383	-0.359	-0.361	0.156	0.039	0.105	0.264
22	0.880	-0.288	0.017	-0.205	-0.005	-0.093	0.130	-0.208
23	0.471	0.568	-0.128	0.611	0.024	-0.234	0.087	-0.007
24	0.157	0.699	-0.037	-0.171	0.046	0.296	-0.419	-0.198
25	-0.079	0.409	0.633	-0.201	-0.539	-0.288	-0.032	-0.024
26	0.402	-0.088	0.619	0.172	0.555	-0.046	-0.208	-0.087
% of variance	39.73	12.99	8.15	7.62	5.90	4.86	3.50	3.29

greater proportion of 0.2 and 0.1 loadings until Component VIII has only 3 loadings of 0.3 and ~~seven~~ thirteen others in the 0.2 and 0.1 categories while the rest of the 10 left are less than 0.1.

Considering the results of the first Principal Component Analysis it was not judged necessary nor useful to apply rotational methods here.

B - HARRIS TEST

Measures of handedness as assessed by the Harris Test of Lateral Dominance will now be presented in relation to the other seven main variables and to the Time Subscores of the same test; intercorrelations of these subscores between themselves are included here as well.

1) Harris and main variables: Table 10 (P. 88) contains the correlations between the Total Scores on the Harris Test of Lateral Dominance and the other seven variables. It can be seen that with age it is .068, with Goodenough, .099, with Vocabulary, .135, with Raven .201, with Space Relations .114, with Draw a Diamond .180, and with Benton .068.

2) Total Scores and Time Subscores on the Harris: Correlations between these scores are listed in Table 11 (P. 89). Total Scores on the Harris and total time taken by both hands are correlated -.056 on Handwriting, -.057 on Tapping and .200 on Dealing Cards; correlations between the same Total Scores on the Harris and the difference in time taken by the right and the left hand on the Handwriting task is .081, on Tapping .257, and on Dealing Cards .128, while D/T (i.e. times difference/total) on Handwriting, Tap-

Table 10.

Correlations between Total Scores on the Harris Test of Lateral Dominance and the seven other main variables.

Other variables.	Harris Total Scores.
Age	0.068
Goodenough	0.099
Vocabulary	0.135
Raven	0.201
Space Relations	0.114
Diamond	0.180
Benton	0.068

Table 11.

Correlations between Total Scores and Time Subscores on the Harris Test of Lateral Dominance.

Time Subscores.	Harris Total Scores.
Handwriting T.	-0.056
Tapping T.	-0.057
Dealing Cards T.	0.200
Handwriting D.	0.081
Tapping D.	0.257
Dealing Cards D.	0.128
Handwriting D/T.	0.332
Tapping D/T.	0.282
Dealing Cards, D/T.	0.047

ping and Dealing Cards in that order are .332, .282 and .047 with Total Scores on the Harris.

3) Time Subscores on the Harris: intercorrelations between various Time Subscores on the Harris test are to be found in Table 12 (P. 91). The most complete ones, the Difference/Total indices are as follows: -.250 between Handwriting D/T and Tapping D/T, .011 between Handwriting D/T and Dealing Cards D/T and .016 between Tapping D/T and Dealing Cards D/T.

C - AGE EFFECT.

The wide age range of the sample made it very likely that a maturation factor could be operating especially in Component 1. In order to ascertain its effect it was decided to partial out the age variable from the correlation matrix. Of the 138 original correlations significant at .01 only 34 remained significant at that same level when the age effect had been partialled out, as can be seen from Table 13, and also in Tables 4, 5, and 6. Although most of them have been substantially lowered and a good proportion are correlations between a test and its subdivisions or subdivisions between themselves, there are a few that still arise interest amongst others. 1) Goodenough's correlations of .364 with Space Relations, and .349 with Number of Letters in Name, 2) Vocabulary's .459 and .547 with Benton Total Score and Space Relations respectively, 3) Space Relations correlation of .378 with Benton on Others, and 4) Handwriting's D/T -.314 with Tapping Total.

Table 13 (P. 93) also reveals that a number of correlations became significant only after the age variable had been kept constant, thus 1) Harris with

Table 12

Correlations between the Time Subscores of three items of the Harris Test of Lateral Dominance: Handwriting, Tapping and Dealing Cards.

Time	Handwriting			Tapping			Dealing Cards
Subscores	T	D	D/T	T	D	D/T	T
Hdw.T;							
Hdw.D;	715						
Hdw.D/T;	129	699					
Tap.T;	-477	-335	-084				
Tap.D;	-067	003	122	370			
Tap.D/T;	295	287	182	-250	736		
D.Cd.T;	310	270	011	-341	-081	183	
D.Cd.D;	-046	-021	034	243	205	094	206
D.Cd.D/T;	-115	-077	011	344	210	016	-164

Note: decimals have been omitted.
D: difference between times taken by each hand.
T: total time taken by both hands.
D/T: ratio of difference of times to total time.
D.Cd.: Dealing Cards.

Table 13. Correlations significant after age is partialled out.

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	10	21	22	23
1	Age																						
2	Goodenough																						
3	Vocabulary	253*																					
4	Raven																						
5	Space Relations	364*	547*	315*																			
6	Draw a Diamond		264*		295*																		
7	Harris			258																			
8	Benton (Total)	282*	459*		332*																		
9	Benton Self Single	263*						415*															
10	Benton Self Double		287*					731*	278*														
11	Benton Others Single		306		346			293	-289														
12	Benton Others Double	263	310		311			579*			512*												
13	Ipsilateral Responses		-252*					-443*		-678*													
14	Systematic Reversals								-292														
15	Handwriting Totals														744*								
16	Handwriting Difference														-414	-522							
17	Tapping Total					290*																	
18	Tapping Difference																						
19	Deal. Cards Total																						
20	Deal. Cards Difference				288														286				
21	# of Letters in Name	349*													631	622							
22	Benton Self Total		292*					762*	602*	934*			-626*										
23	Benton Others Total		354*		378*			490*			887*	851*											
24	Handwriting Diff./Total				277				-327		284					708*	-314				310*		
25	Tapping Diff./Total						326*											840*					
26	Deal. Cards Diff/Total						289																

* Significant at the .01 level before and after age is partialled out.

Note: Decimals have been omitted.

Raven at .258 is the only significant correlation of the Harris test with any other variable, 2) Space Relations with the two Harris subtests, .288 with Dealing Card Difference and .277 with Handwriting Difference/Total, 3) Benton on Self Single Commands -.327 with Handwriting Difference/Total, 4) Handwriting Total of -.414 with Tapping Total and 5) Number of Letters in Name .631, .622 and .310 with Handwriting Total, Difference and Difference/Total respectively.

The partial correlations procedure actually increased some of the correlations i.e. Handwriting Difference/Total and Benton on Self Single Commands went from -.174 to -.367, Number of Letters in Name and Handwriting Difference from .491 to .622 and Handwriting Difference/Total and Tapping Total from -.084 to -.414.

Finally, the correlations significant originally that did not meet the 0.01 level of significance after the influence of age had been neutralized can be found in Table 14, (P. 94) they vary from .287 to .734 and cluster mainly around variables 1, 4, 5, 6, 17, 19, 21, 22 and 23 whose correlations with age had been rather high ranging from +.592 to +.789.

Now that the results of the Benton, the Harris and the age effect have been presented, they can be discussed in the next section.

It should be said at this point that a cluster analysis was carried out in addition and five factors were extracted. However only the Principal Component Analyses will be discussed in this thesis. The remainder is included in Appendix IX for reference purposes, but since they are of little assistance in

Table 14. Correlations significant only before age is partialled out.

		.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12	.13	.14	.15	.16	.17	.18	.19	.20	.21	.22
1	Age																						
2	Goodenough																						
3	Vocabulary																						
4	Raven		718	723																			
5	Space Relations																						
6	Draw a Diamond		650		569																		
7	Harris																						
8	Benton (Total)				722		632																
9	Benton Self Single			572	459	558	424																
10	Benton Self Double		666		648	695	599																
11	Benton Others Single				313		287																
12	Benton Others Double				376		293																
13	Ipsilateral Responses		-509		-512	-559	-480			-484													
14	Systematic Reversals		-348	-273		-324			-400		-362			303									
15	Handwriting Total																						
16	Handwriting Difference																						
17	Tapping Total		697	722	642	734			701	567	653			-489									
18	Tapping Difference		317	393	431	381	370		384	325													
19	Deal. Cards Total			-384	-313	-322			-400		-406			392				370					
20	Deal. Cards Difference																	-341					
21	# of Letters in Name			529	548	543	553		507		417			367	-415								
22	Benton Self Total		711		649	716	600											485					
23	Benton Others Total		369		389		329											688	337	-403		421	
24	Handwriting Diff./Total																					319	
25	Tapping Diff./Total																				900		336
26	Deal. Cards Diff/Total			339		347												344					

Note: Decimals have been omitted.

Note: Decimals have been omitted.

understanding the results, they will not be considered directly, although they have been included for the sake of completion.

V DISCUSSION OF RESULTS.

A. Benton Test.

1. Right-left on self.
2. Right-left on others.
3. Crossed commands.
4. Benton Total Scores.

B. Handedness.

1. The Harris Test and other variables.
2. The Harris Test and its own items.
3. Items of the Harris Test and other variables.
4. Items of the Harris Test within themselves.
5. Difficulties in the assessment of handedness.
   a) Definition of handedness.
   b) Multidimensional aspect of manual activities.

C. Components of Right-Left Concept.

1. Component 1.
2. Component 2.
3. Component 3.
4. Component 4.

SECTION V

DISCUSSION OF RESULTS

As seen earlier, dyslexia and laterality are both so complex and ill-defined that a direct approach has precluded fruitful results. This investigation then will not attempt to solve the problem of their nature or their interrelationship but will concentrate rather on one specific feature of laterality which is the development of the right-left concept. First of all the data from the Benton Test will be discussed, followed by handedness as measured by the Harris Test of Lateral Dominance and finally the factors pertinent to the development of right-left discrimination. Only correlations significant at the .01 level or beyond will be considered in the discussion.

A - BENTON TEST

The children's behaviour will be analysed in the way they apply right-left labels to themselves and to others and respond to crossed commands.

1) Right-left on self: if the total scores for correct response to items of right-left on oneself are considered, correlations are found to be high with all variables except with Harris; the highest .782 with age, .753 with Vocabulary, .716 with Space Relations, .711 with Goodenough, .649 with Raven and .600 with Draw a Diamond (Table 4, P.77). Once age is partialled out however, the only significant correlation left is with Vocabulary and it is quite low at .292. Age then and to a lesser extent Vocabulary would be the relevant variables here.

Yet if the responses to right-left items on oneself are divided into single and double commands, there occurs a split in the results. Both are highly related to age but double commands even more so at .760 against .610. On the one hand single commands correlate with Goodenough .623, with age .610, with Vocabulary .572, with Space Relations .558, with Raven .459, and with Draw a Diamond .424. On the other hand double commands are correlated with the same variables but in a different order: age .760, Vocabulary .737, Space Relations .695, Goodenough .666, Raven .648, and Draw a Diamond .599. When age is neutralized (cf. Table 4, P. 77) single commands still retain a correlation (although low) with the Goodenough .263 and double commands with Vocabulary .287. This last correlation might reflect an ability to follow instructions, ability which would be more essential for double commands than for single commands. On the whole age has an overriding effect on the knowledge of right and left on oneself; while Vocabulary, especially when it concerns double items, and the Goodenough with single items, have a slight but definite influence on the child's performance.

2) Right and Left on others: in this case all correlations are low even before the low correlation for age is partialled out. In fact, when they are broken down into single and double items, the only significant correlations are those emerging after the age effect has been eliminated. Then the total number of correct responses to right and left on others (cf. Table 5, P. 79) has a correlation of .461 with Space Relations and .456 with Vocabulary, decreasing to .378 and .354 respectively. Its own correlation of

.325 with age is not significant. When the age effect is accounted for, single and double items correlate respectively at .306 and .310 with Vocabulary and .346 and .311 with Space Relations.

It is interesting to note that age seems to affect the development of the right-left concept only on oneself and has very little influence on its application to others, while Vocabulary is correlated with both "on self" and "on others". Moreover the body image appears to be a determinant solely in the case of right-left applied to oneself, possibly by being a sort of prerequisite structure, along the line of the right-left gradient postulated by Benton (1959, p.144). The proprioceptor and motor processes which he assumed to be part of the right-left gradient could to some extent underlie the body image concept as well, i.e. these processes from which a child learns to differentiate parts and sides of his body contributing to the development of the body schema; this in turn facilitating if not controlling the ability to draw a man. Spatial orientation becomes important at a later stage when the labels right and left are applied to others; at that moment the completely relative nature of right and left has to be grasped in order to reverse right and left if necessary according to the other person's position in relation to oneself.

3) Crossed commands: the two erroneous responses possible to a crossed command are either not to cross at all, e.g. (1) placing the right hand on the right eye instead of placing it on the left eye, that is an ipsilateral response, or (2) to execute the complete opposite of the command, e.g. placing the

left hand on the right knee instead of the right hand on the left knee, that is systematic reversals. As for the ipsilateral responses, Gordon and Benton had found that it was only slightly connected with age. However in this study, while the correlation is also negative i.e. -.621, it is considerably larger. Looking at the graph in Figure 1 (P.101), one can observe how the frequency of these responses diminishes irregularly and that they finally disappear at nine years. So indeed age does bear an overriding relationship to ipsilateral responses but this is not a smooth decline with age; rather the relationship seems almost to follow an all-or-nothing principle, its distribution being somewhat arbitrary below the age at which it ceases to occur. Correlations between ipsilateral responses and other variables are all negative (Table 6. P. 80) as expected: -.627 with Vocabulary, -.559 with Space Relations, -.512 with the Raven, -.509 with the Goodenough, and -.480 with Draw a Diamond. However, once the effect of age is accounted for only the correlation with Vocabulary remains significant albeit as low as -.252. So Benton and Quadfasel's (Benton, 1959, p.32) speculation that the inability to cross the midline of the body is the manifestation of a primitive reaction tendency cannot be supported with the present finding where a negative correlation is still left between ipsilateral responses and Vocabulary when the age effect has been removed. The observation that the scores of adults on many subtests of general intelligence scales deteriorate to a certain extent after brain damage, although Vocabulary subtests scores remain generally unaffected, may have relevance here.

Benton's hypothesis that systematic reversals

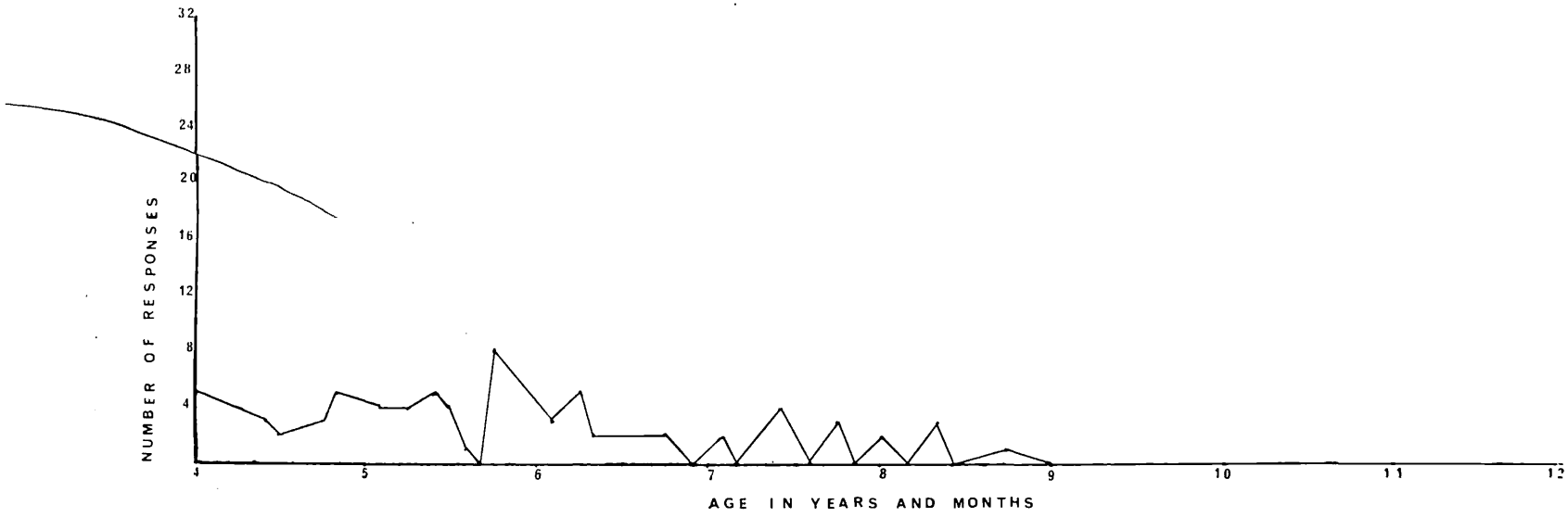


Fig. 1. Number of ipsilateral responses as a function of age on the Benton Test of Right-Left Discrimination.

are probably related to slowness in the development of verbal skill is not supported here either. Systematic reversals (Table 6, P. 80) were found to be correlated negatively with age -.360, Goodenough -.348, Space Relations -.324, Raven -.276, and finally Vocabulary -.273. The uneven effect of age can be observed from the graph in Figure 2 (P.103). The one with the Raven is not significant and further more they all become negligible after the partial correlations to remove the age effect. Could the discrepancy between Benton's data (1958) and this one be due entirely to the difference in method of selection? He had taken extreme groups, one with children making little or no systematic reversals, the other with the highest number of systematic reversals possible on his test. He then compared their performance on a variety of verbal tasks. His results were given in terms of percentage with no mention of the level of significance. His other study compared a group of children with reading disability with a group of normal children free from this disability on their success on the Benton Test of Right-Left Discrimination. There the trend in the results made him conclude that verbal abilities, conceptualization and symbolization had more to do with the differentiation of right or left on others and with systematic reversals than body schema did even when his highly selected samples (which should normally magnify possible differences) did not yield significant differences. On all this evidence it would seem that the main causes of systematic reversals have yet to be discovered.

4) Benton Total Score: Benton's view on the overall development of right-left discrimination is that the four following variables are relevant:

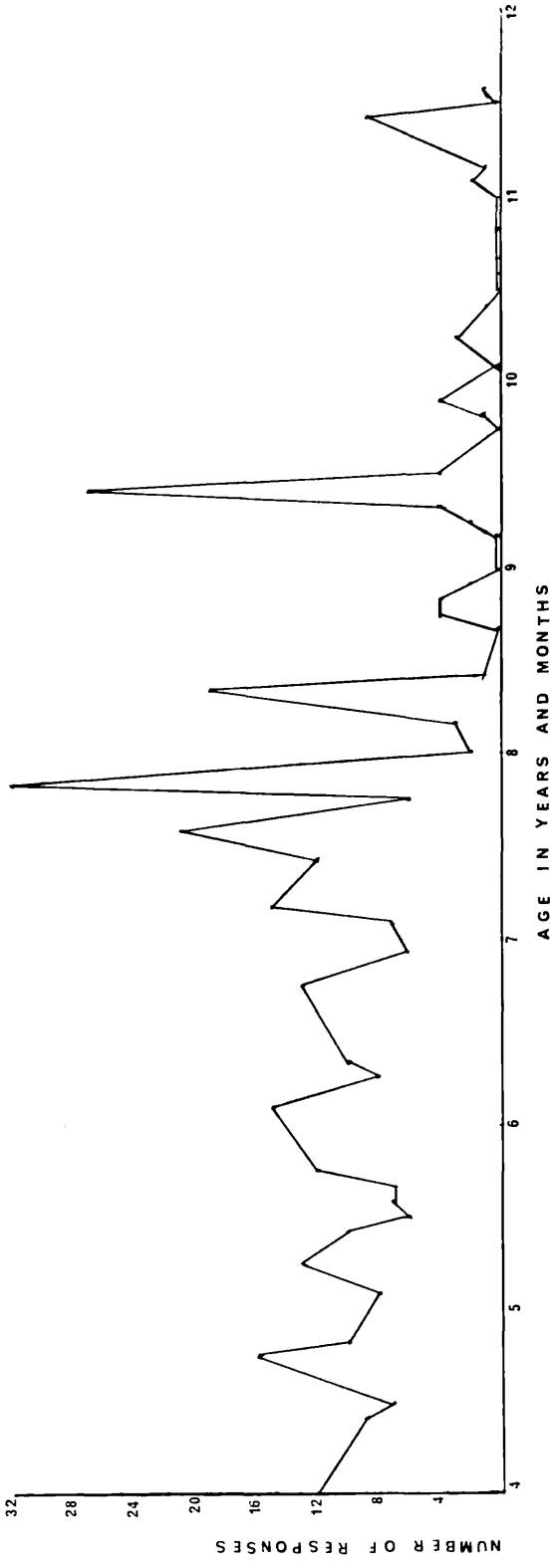


Fig. 2. Number of systematic reversals as a function of age on the Benton Test of Right-Left Discrimination.

chronological age, mental age, language ability and body schema. This was generally corroborated in the present investigation; the highest correlation to Benton Total Score being .820 with Vocabulary, then .801 with age, .793 with Space Relations, .759 with Goodenough, .722 with Raven, and .632 with Draw a Diamond (cf. Table 6, P. 80). How important age is in this matter is revealed when it is partialled out: three out of the former correlations decrease to the point of not being significant any more and the ones left, e.g. Vocabulary (.459), Space Relations (.332), and Goodenough (.282) are drastically diminished. The graph in Figure 3 shows how the Total Scores increase with age. The contributions of Space Relations was not predicted as such, by Benton. Space Relations also have a high correlation of .820 and .364 with Goodenough before and after age is partialled out; this would suggest that orientation in space is as much as component of the ability to draw a man as it is of discrimination of right and left.

Discussing the necessity of a right-left gradient to explain the early establishment of right-left orientation, Benton (1959, P.144) mentions handedness as one motor expression of this gradient. To support his assumptions he quotes a study where a significant but low correlation of +.24 between his test and hand preference appeared. Crookes and Greene(1963) had also found a slight link between these two variables. Here however Benton's test (Appendix VII) correlates .701 and .507 with Tapping Total and Number of Letters in Name respectively. But since these correlations go down to .188 and .068 when age is cancelled out, (Appendix X) it can be inferred that maturation is the main variable responsible for these figures. Another

Fig. 3. Total Scores on the Benton Test of Right-Left Discrimination as a function of age.

element accounted for by this same factor is the motor development as measured on Draw a Diamond, it sinks to .126, much below the significance level of .01 after the partial correlation. The only finding to throw light on the handedness/gradient problem is that of Belmont and Birch (1963) who reported that hand preference precedes right-left differentiation by about two years and therefore assumed the two abilities to be independent of each other. In fact this discrepancy of two years between the growth curves of handedness and right-left differentiation would make it virtually impossible in this case to arrive at a high and significant correlation.

On the whole Benton's hypotheses are upheld; it does indeed seem that age is the principal contributing factor in right-left discrimination, followed in order of importance, by Vocabulary, Space Relations and body schema. Although there are no measures of mental age as such in this study, scores on Vocabulary or on Goodenough's Draw a Man Test (which are frequently used in clinical practice as an approximation of mental age) are both significantly correlated to the concept in question. Age, on the one hand, is apparently important only in so far as right-left differentiation on oneself is concerned and explains very little of this differentiation on others, the same applies to body schema. On the other hand, verbal ability is relevant to both aspects of the right-left concept on oneself and on others, while Space Relations steps in the picture only when the child is beginning to grasp the relative quality of the right-left concept. Chronologically therefore the development of the right and left is linked throughout with verbal skills; in addition age and an adequate corporal image are essential in the

initial learning stage; later on good orientation in space is needed to perfect the acquisition of the right-left concept in its abstract form. This is compatible with the fact that hemiplegic children have a good grasp of right-left on themselves and on others, whatever their mental age. Because of their motor handicap the awareness of a difference between both sides of their body is heightened and appears earlier than in normal children. Body schema becomes the critical and overwhelming element surpassing all others in importance. The correlation, with age and without age, between Total Scores on the Benton Test and subscores on the different parts into which the Benton was divided, are worth a glance. They are generally quite high except for right and left on others (single and double commands) where both subscores containing only four items each are very vulnerable to disruptive chance effects. Moreover Total Scores on the Benton have in most instances a higher correlation with each variable than any of its subtests have. By current test standards the Benton Test could be judged to be very well constructed; it evidently has a high content validity, particularly when it is compared with the Harris Test of Lateral Dominance which is considered in the next section.

B - HANDEDNESS

The Harris Test will be discussed first in relation to the other variables and then in terms of its own items; the interconnections of these items with other variables is analysed and lastly, explanations of the puzzling results with the Harris will be sought. Only the differentiation indices i.e. D/T*, have been

* D/T: ratio of $\frac{\text{difference of times taken by each hand}}{\text{total time taken by both hands}}$

examined in the discussion since they are the most meaningful of the handedness measures: they take into account not only the difference in speed of both hands, but also this difference in relation to the total speed, e.g. a difference of five seconds for a subject whose right hand takes ten seconds and his left hand five seconds is not directly comparable to another subject who takes forty-one seconds with the right hand and forty-six with the other hand.

1) The Harris Test and other variables: what is most striking about the Harris is its lack of correlation with age, especially in the present context where the maturation factor seems all pervasive. The only correlation significant at .01 level is one which appears after age has been partialled out (.258 with Raven Progressive Matrices) and even this is quite small (Table 10, P. 88). Moreover the contention advanced by Harris that there was a link between handedness and age was not upheld, the correlation being .068; this will be discussed at greater length in the next section.

2) The Harris Test and its own items: it had been thought that examining the subtest of the Harris Test of Lateral Dominance might elucidate its eccentric isolation from the other seven main variables. The original test scores were based on gross differences in performance of both hands, so these differences were refined and correlated with the Total Score on the Harris Test. The correlations thus obtained were low and two of them decreased marginally when the age effect was cancelled (cf. Table 11,P. 89). Handwriting D/T went from .332 to .326 and Dealing Cards D/T from .047 to .031 (neither significant) while Tapping D/T remained stationary. The items, especially

when compared with the close intercorrelation of the Benton scale items have so little connection with their Total Score that one wonders in the end what exactly this test is supposed to be measuring. Its validity can be seriously questioned: the analysis of the items' relationships to one another, as studied later, only serves to confirm this disquiet. This is all the more surprising since the Harris Test of Lateral Dominance is so frequently and confidently relied upon in clinical practice, particularly with children presenting reading and writing problems. Obviously its face validity is greater than its content validity.

3) Items of the Harris Test and other variables: just like the Harris Total Score, the three items: Handwriting, Tapping and Dealing Cards have low and non-significant correlations with age. There are only three significant correlations in all after age is partialled out; all three involve Handwriting D/T (see Table 13, P.92) which correlates .277 with Space Relations, 0.284 with Benton "on others" (single items) and -.327 with Benton "on self", (single items). The correlation with Space Relations probably reflects the spatial factor involved in handwriting, but it is too small to warrant much speculation. The same applies to Handwriting D/T and Benton "on others" although here the two are loaded highly on Component 2 as will be discussed later. The correlation between Handwriting D/T and Benton "on self" is not very high either but its negative sign is the chief reason for giving it more attention. A possible explanation could be provided from an article by Chateau (1962) where after investigating which hand was used for handwriting,

cutting with a knife and throwing a ball, by children from four- to seventeen-years old, he came to the conclusion that for activities under heavy social pressures like handwriting, lateralization was quite marked; however for other ones, particularly for play activities the percentage of lateralization while strong at nursery school age, diminished in favour of increasing ambidexterity until the age of ten. This phenomenon he attributed to the fact that in early childhood the child is taught many activities by adults who consistently use one particular hand and often encourage the child to use his right one for all social behaviour e.g. eating, drinking, accepting objects from someone, etc. When the child is about four, he becomes aware of a certain autonomy notably in play activities: he can do things by himself, the way he wants to, without the interference of grown-ups. As games become more and more important, he discovers that he can use both hands indifferently and now he even takes pride in his newly acquired ambidexterity. Handwriting is one of the few tasks where adult pressure is still making itself felt. Thus paradoxically, the child's awareness of both sides of his body increases at the same time as handwriting is learned from four to five years on till approximately ten; this covers almost the total age range of the sample utilized in this research. Hence the concommittant development of handwriting and ambidexterity could be the underlying factor responsible for the small negative correlation between Handwriting D/T and Benton on Self (single items).

4) Items of the Harris Test within themselves: the situation here is very simple: not only

are the correlations between the items non-significant, but they are also very low, virtually null in fact, and unaffected by the presence or absence of the age factor (Table 12, P. 91). Yet they are claimed to be adequate and representative measures of handedness. Considering in addition that each one of them has a very low correlation with the Total Score for hand dominance, as seen previously, one cannot but again wonder about the construction of this test and hence about its validity. It follows that if the items of a test have no relation to each other, nor to the total score, it is highly unlikely that this total score measures any specific ability, or anything at all for that matter; the test would be a collection of items bearing no relation to the question under discussion and the total score would be meaningless. It must be granted nevertheless that all tests supposedly quantifying the degree of hand dominance in other investigations are built on the same rationale as the Harris, and more often than not, are even less systematic in their approach. This issue will now be considered in more detail.

5) Difficulties in the assessment of handedness: the two principal stumbling blocks in the construction of handedness tests are: a) agreement on the definition of handedness and b) the multidimensional nature of manual activities.

a) Definition of handedness: information about a person's handedness are currently obtained in a variety of ways: i) asking the person directly if he is right- or left-handed, ii) giving him a questionnaire about hand preference for various activities, or iii) measuring and comparing the efficiency (by speed and/or skill) of the two hands on a number of manual tasks. It is

widely believed that all three methods yield the same answer. However a study by Humphrey (1951) revealed the question to be more complex; this study was reviewed in Section I (P.41). As will be remembered the main finding was that left-handers were much less consistent in their manual preference than right-handers, i.e. more than 25% of the left hand writers answered that they preferred the right hand for unimanual skills such as tennis or squash.

Pursuing the matter, Benton, Meyers and Polder (1962) compared the handedness of 106 subjects, forty of which reported that they were strongly or moderately left-handed and sixty-six that they were strongly or moderately right-handed. A questionnaire similar to Humphrey's was presented and comparison of the right and of the left hand on two tasks were made: cutting with scissors (scored for speed and accuracy) and a fine manual dexterity task involving the use of tweezers and small pins, and requiring control of arm movement as well as fine finger coordination. It was found that as far as groups were concerned, both right- and left-handers could be distinguished relatively well, but the variability inside the group was quite large and so was the overlap in scores. While the self-classified right-handers rarely exhibited greater skill with the non-preferred hand, 63% of the self-classified moderately left-handed had a right hand superiority. Yet on the tweezer task two dextrals manifested left hand superiority while four sinistrals showed right hand superiority. Some ambidexterity was found in both left- and right-handed groups, mostly amongst those who classified themselves as being moderately right- or left-handed. The greater variability was found amongst the left-handed subjects. The

authors alleged that the left-handed group showed less variability on the scissor cutting task because scissors were generally made to facilitate the use of the right hand while the greater unfamiliarity of the tweezer task brought out more clearly the wider range of handedness in sinistrals. Their findings in response to the questionnaire, confirmed those of Humphrey: all the self-classified strongly right-handed persons reported consistent preference of the right hand on all activities compared to 75% of the self-classified moderately right-handed subjects; 33% of the strongly left-handed and 75% of the moderately left-handed persons expressed inconsistent hand preference.

A more thought-provoking finding is that of Hull (1936) as quoted by Clark (1957) where he gave his sample a forty item questionnaire about hand preference for different activities, followed by a test of their performance of these same activities. He discovered that only fourteen items of the questionnaire were reliable over time and only fourteen of the activities were actually performed with the same hand they were reported to be, the items involving bimanual activities being the less reliable of all. As Hull concluded a small questionnaire can be more useful than a long but unreliable one, everything hinges on the selection of the items; thus the idea that the longer the test the better the chances of assessing handedness more accurately needs revision.

Another source of variance in ascertaining handedness is the nature of the task used to assess hand dominance, whether this assessment be of hand efficiency or preference. Roudinesco and Thyss (1948) maintained that the ratio of left-handedness found in various studies increased with the number of tests used

and with their lack of relation to learned movement. A study by Seren (1965) investigated the difference between right and left hand performance on the following variables: strength of grip, unilateral and bilateral tapping, two point discrimination, speed of index finger, pressure sensitivity and point localization. Dextrals and sinistrals both performed significantly better with their preferred hand only on the first four of the seven tasks and on two point discrimination. Another study by Simon (1964) found no relationship between consistent hand usage and the relative superiority of the preferred hand on a steadiness test. He presented twenty-four subjects self-classified as strongly right-handed and twenty-four self-classified as strongly left-handed with a questionnaire ascertaining which hand was used for five tasks: writing, turning a screwdriver, throwing a ball, holding a tooth brush and swinging a tennis racket. His right-handed subjects reported using their right hand for all five activities but nine out of the twenty-four left-handers reported that they used their right hand for one or more of the activities. He then compared their performance with each hand on the Standard Steadiness Test using a proboscope and several small holes in a steel surface. On this task there were only limited data to support the theory that the superiority of the preferred hand is greater in right-handed persons than in left-handed ones and no correspondence could be established between consistency of hand used and the superiority of the preferred hand. These results are not incompatible with those of Benton et al. and of Seren. There is a need to clarify which activities elicit ambidexterity and which elicit superior

performance of one hand over the other. The type of movement required (arm, hand, wrist or finger) and the amount of practice with the task are probably relevant variables, but it remains to be proved.

The absence of agreement on a definition of handedness stems, it seems, from the multiplicity of methods used for assessing it. Humphrey and Benton et al. established the wider variance in hand dominance of subjects who classify themselves as sinistrals, including i) strong left-handedness associated with an inconsistent left hand preference, ii) the extreme cases of self-classified left-handers exhibiting actual superiority of the right hand, and not forgetting the problems of iii) ambidexterity and inconsistency of hand laterality. The choice of items of a questionnaire, if one is used, is critical for the results obtained, as Hull clearly demonstrated. The lack of correlation discovered in the present research between three handedness measures together with the study carried out by Seren seriously suggest that hand dominance, even when assessed by actual comparison of right and left hand performance, varies markedly with the activity selected for this purpose; Simon's results also point in that direction.

b) multidimensional aspects of manual activities: Webster (1966) speculates that there might very well be two factors in neuro-motor coordination as assessed by the Lincoln-Oseretsky Motor Development Scale. Working with dysphasic children (four to twelve years old), he found that their lack of laterality was prominent in fine neuro-muscular coordination tests although all of them scored much lower than their age norm on the test as a whole. He thinks that gross

neuro-muscular coordination may be acquired first and fine neuro-muscular coordination later. This would be compatible with the results of this research and might partly explain the lack of correlation between the three handedness tasks. The neuro-muscular coordination called for in Handwriting is much finer indeed than the one required by the other two tasks and this could be one of the reasons for their independence from one another. It could also possibly explain some of the disagreement in the results of studies dealing with handedness and even "eyedness" and "footedness".

It seems that a rewarding approach to this problem would be one of the factor analytic type whereby the essential element underlying handedness might be identified. One such study was carried out by Fleishman (1958) who analysed the responses of 204 trainee airmen on thirty-one tasks involving arm and leg movement, by Thurstone's Centroid Method. Seven factors were extracted; the first one called Response Orientation was an ability to respond correctly to a task requiring quick directional discrimination and orientation of movement pattern. The second one: Fine Control Sensitivity covered arm, leg, wrist and finger extension movement. The third, fourth, fifth and sixth factors were respectively: Reaction Time, Speed of Arm Movement, Arm Steadiness and Simultaneous Manipulation of Multiple Limbs. Factor I involved an element of directional orientation in space and Factor IV entailed gross motor coordination. It is interesting to note that although Fleishman included tasks concerning all four limbs, Factors IV and V have to do only with hand activities. As Palmer (1964) has suggested, what is needed is to study manual activities in their relation to hand differentiation and from this to try and discover the

relevant determinants. A really complete analysis along these lines has yet to be carried out.

Other variables besides the nature of the tasks themselves must affect hand performance. While it is true that dextrals exhibit higher hand differentiation on skilled tasks, they tend to be more ambidextrous when it comes to untrained ones. However sinistrals, no matter how strongly left-handed they are, because of the social pressures exerted towards the use of the right hand, have had many more opportunities to use their right hand than right-handed persons have had to use their left hand, specially on skilled tasks, since most of their teaching must have been given by dextrals. There is no doubt that training does affect the development of hand differentiation and hand efficiency but it is not known to what extent this is so. That training can be transferred from one activity to another has been given lip service, but only one experiment attempted to appraise its influence. Clark (1957) while studying hand, eye and foot dominance in children gave them a handwriting task, which is most intensely subjected to training, as well as an unlearned task using neuromuscular coordination very akin to that used in handwriting. She found a correlation of .46 for boys and .35 for girls between the two tests, which does indicate a certain degree of relationship. After careful examination of the field of handedness, giving particular attention to sinistrality, she concluded that fluctuations in degree of hand dominance is evident not only in the population in general but also in the same person, depending on the activity performed, with incidence of strong handedness higher for the more skilled tasks. This could apply to the data of Durost (1934) who

found that strong handedness was apparent on a fine finger control task while those requiring mostly arm and forearm movement were executed in comparable ways with the two hands.

Finally amongst the variables that probably exert some influence on strength of hand consistency, social pressure should be included. As seen earlier Chateau (1962) is one of those who have called attention to this point and provided facts to substantiate his assertion. He claims that most of the social behaviours are carried out with the right hand in a larger proportion of the population than many other activities because it is the socially accepted way of doing so. Children are taught these behaviours by right-handed persons or by left-handed persons using their right hand, who insist that the right hand should be used.

In brief, handedness cannot be considered any more as a simple attribute easily assessed by either asking a person if he is right- or left-handed, or what hand he uses for a few particular activities, nor even by testing his performance on a couple of tasks; none of these methods are satisfactory or reliable. Little wonder that results of handedness studies are contradictory when such simplified approaches have been adopted. In fact a totally new definition of handedness is called for taking into account the following findings: 1) left-handed persons are less consistent than right-handed ones when it comes to hand preference (Humphrey), 2) often the percentage of ambidextrous persons rises with the degree of unfamiliarity of the task (Benton et al.), 3) results of handedness tests or questionnaires depend critically on the items selec-

ted (Hull), 4) the more numerous the items are and the less they are concerned with learned movements the higher the ratio of left-handedness (Roudinesco and Thyss) and 5) the superiority of one hand over the other varies with the task presented (Seren), for example there is no hand superiority on a hand steadiness test (Simon).

The reason why an accurate and comprehensive definition of handedness is so difficult to arrive at is mainly due to the fact that it is not a unitary attribute as it is generally thought to be, but a multidimensional one. First of all there are strong suspicions that neuro-muscular coordination itself is not a single factor, Webster believed that gross and fine neuro-muscular coordi-nation are two separate elements maturing at different time. When he factor-analysed thirty-one movement tasks, Fleishman discovered up to seven different factors including aspects as diverse as directional orientation, reaction time, speed, etc. In addition, performance on handedness tests is to a certain extent influenced by previously learned skills (Clark) and by pressures exerted on a child especially when he is taught social behaviours.

C - COMPONENTS OF RIGHT-LEFT CONCEPT.

The principal aim of this project was to investigate which variables were relevant to the acquisition of the right-left concept, how they were interconnected and the possible presence of one or more components related to right or left discrimination. From the Principal Component Analysis eight components were extracted and the most meaningful ones will now be considered.

1) Component 1: accounts for 39% of the variance and is definitely the simplest component to

interpret as it is obviously one of general maturation. Most tests and subtests have a loading on this component equivalent to their correlation with age, though somewhat higher, as comparison of Table 9, (P. 86) and Table 12 (P. 91) will clearly highlight. This is not surprising in view of the fact that the age range of the sample extended over eight years, precisely at the critical period when progress in the development of both physical and psychological functions are the most dramatic. One would expect therefore the main variable to be one of maturation, alone responsible for a large proportion of the variation. Unforeseen however is the very minimal loading (.102) on this component of the Harris Test of Lateral Dominance and its parts, after Harris' assertion that there are "marked changes in handedness with increasing age" (1957, P.293). The Test of Lateral Dominance was also unrelated with age in the original correlation matrix. This casts serious doubts on Harris' contention and in fact is in complete contradiction to it. Although maturation and lateral dominance, as measured by the Harris Test, seem uncorrelated, all other main variables have their highest loading on Component 1, ranging from loadings of .760 to .942.

2) Component 2: accounting for 12.9% of the variance is almost the opposite of Component 1 in the sense that the order of the variables loadings on it is the reverse of that of their loadings on the previous component. The only high loading is on the Handwriting measures, the loading for Tapping is low and that for Dealing Cards lower still, this suggests that the tasks ascertaining handedness included in the Harris Test have little connections with Component 2.

In fact in the original correlation matrix it did come out that the indices of hand differentiation (Table 12, P.91) were barely correlated to each other, thus Handwriting D/T and Tapping D/T: .182, Handwriting D/T and Dealing Cards D/T: .011 and Tapping D/T and Dealing Cards D/T: .016. The other high loadings on Component 2 are Benton's right-left "on others" items. Although it would be tempting to call this component Hand Differentiation in Speed and Fine Motor Coordination, one has to consider not only the handwriting aspect but also the one concerning right-left discrimination as well. Previous research by Newson (1955), mentioned in Section I, (P. 49), established that the only skill positively correlated with the ability to distinguish a figure from its mirror-image was experience in writing. The link may also be present in Component 2: the strong training element inherent in writing and not in Tapping or Dealing Cards most likely increases directional awareness since it calls attention to the fact that the graphic movement must go from left to right. Moreover, by practicing always with the same hand the child eventually becomes conscious that one hand, the one which has received training, performs much better than the other, at least on a writing task. The effect of transfer of this asymmetry to other manual activities is unfortunately not yet established, and is a field wide open for investigation. One can well suspect though that there is at least a small amount of transfer. The directional awareness encouraged by writing exercises facilitates the insight that what is right and left on oneself becomes left and right on a person opposite to oneself; even if the labels Right and Left as such are

not used, the child realises that one side of himself is not in a mirror position on a person facing him but across. Component 2 could therefore be called: Directional Awareness, resulting probably from the training which children undergo when leaning to write. Other motor tasks likewise have a loading on Component 2 since at the age a child is faced with handwriting, he has already mastered a certain motor coordination necessary for Tapping and Dealing Cards. The Harris Test's loading on Component 2 would be due to the presence of Handwriting as one of its subtests. It should be noticed that Component 2 bears a resemblance to Fleishman's Factor I (mentioned in subsection B,5,b) in that both involve an element of directional orientation.

3) Component 3: is also concerned with hand activities; Tapping and Dealing Cards however differ from Handwriting in the fact that the visuo-motor coordination they require is less fine. Handwriting uses precise finger and wrist action while Tapping in young children is done with the whole arm and in older children with the forearm; Dealing Cards uses both hands and fingers but mostly forearm movement. In addition Tapping and Dealing Cards can be done just by following directions or imitating the Examiner, and thus requires little or no training, they are rather indications of general, untrained oculo-motor coordination. Of all measures of Tapping and Dealing Cards, the differentiation indices D/T are the ones with the highest loadings on Component 3. The component could then be named: Lateralization of Gross Visuo-Motor Coordination. A mere 8.1% of the variance is accounted for by this component and seven only of the twenty-six variables have

a higher loading than .2 on it. (Table 9, P. 86). It would correspond to Fleishman's Factor IV mentioned earlier, in that both entail gross motor-coordination.

4) Component 4: accounts for only 7.6% of the variance. While Component 2 is the motor or at least the non-verbal feature of right-left differentiation on others, Component 4 seems related to the semantic, abstract aspect of the right-left concept. Indeed Component 2 could be the prerequisite of Component 4 or the Stage I and Component 4 the Stage II in the acquisition of directional knowledge. Yet it still is difficult to identify with any precision the psychological nature of this component in view of the disparity of loadings on it, in particular the negative loadings of Handwriting Total Time taken by both hands (-.529) and Handwriting Difference in times taken by each hand (-.513). Until more is known about Component 4 it is best left unnamed.

In summary, age appears to be the main determinant involved in the recognition of right and left. It is correlated with all subtests of the Benton Test especially with items of left and right on others. Moreover it seems that three other variables have an effect on the development of the concept in question, their influence being visible at different periods in the development, i.e. body schema would be essential to learning to recognize right and left on oneself, while spatial orientation underlies the discrimination of it on others and verbal ability is related to the acquisition of the right-left concept through both its stages.

The handedness issue has proved to be a very complex one; it does not appear to be related to any

of the other variables in this study. In fact the validity of the Harris Test of Lateral Dominance is called into question, so are the definition of handedness and the various measures currently used to appraise it.

There emerged from the analysis of the data four main components. The first one is simply an age or rather a maturation factor; it is the largest and most important of all components; Component 2 is one of directional awareness. Component 3 represents lateralization of visuo-motor coordination while Component 4 is involved amongst other things with the verbal aspect of the right-left concept.

VI SUMMARY OF CONCLUSIONS.

A. Handedness.

B. Right-Left Concept.

SECTION VI.

SUMMARY OF THE CONCLUSIONS.

The original interest in dyslexia and laterality had to be narrowed down considerably since each of these concepts were very broad and confusing. It was decided therefore to limit the research to one aspect of laterality, i.e. handedness.

Studies in this field, particularly those of Benton, appeared quite promising especially those related to the verbal aspect of handedness: the concepts of right and left and the research reported in this thesis relates more closely to these studies than to any others. However other aspects of the topic, in particular handedness and lateral orientation, were also discussed in the preceeding section and conclusions concerning these areas are therefore summarized in the following paragraphs.

A - HANDEDNESS

A widely used test of handedness, the Harris Test of Lateral Dominance was claimed by its author to be an effective measure of laterality and to be decidedly related to age. On analysis however these underlying assumptions proved to be inexact and the validity of the test one of face validity only. The correlation with age was almost null and that with other variables equally low. More disturbing though was the fact that the tests items have low correlations not only between each other but with the total obtainable score as well. Although this project was initially concerned with handedness only in as much as it was one of the variables connected with the

integration of the right-left concept, the erratic results obtained on the Harris Test of Lateral Dominance could be explained solely by delving deeper into this specific area. The upshot of this was to realize that the Harris Test merely reflects the general consensus of opinions and assumptions about handedness, i.e. it is a unitary construct that can be assessed quickly, accurately, reliably and with little difficulty. Yet the weight of evidence pointing in the opposite direction is massive. It would appear that the issue is a very thorny one and that the assessment of handedness is impeded by the problems of arriving at a comprehensive definition and by the number of variables which seem to influence hand laterality. Hand skill and preference together with the type of task presented must be taken into consideration. Moreover social pressures and heredity are factors that definitely cannot be overlooked when endeavouring to appraise a person's handedness.

Thus the confusion arising from the data in the field of dyslexia, as was seen in Section I, could partly be ascribed to the preconceived and oversimplified notion that laterality is a straight-forward unitary attribute. Further exploration of the laterality question in this perspective seems warranted, namely finding the various dimensions of handedness and which of them are related to dyslexia and are likely to yield more workable results; until this has been done, work on laterality cannot be considered to throw any real light on the problem of dyslexia in spite of the general assumption that the problems are related.

B - RIGHT-LEFT CONCEPT

It had been already established that at first

the child learns how to differentiate right and left on himself at about six years of age and that later he can apply the labels on other persons around ten or eleven years. The aim of this project was not to pinpoint with greater accuracy the age stages where right and left discrimination takes place but instead to determine the factors relevant to the concept.

It would seem that many variables have a bearing on the emergence of the right-left concept, and this study clarified at which point in the concepts development each one is operant. There are four principal determinants in all; verbal ability for one appears to be necessary at the two main stages of right-left discrimination: correct application of the labels firstly to oneself and secondly to others.

In addition, three other variables have a role to play, with different degrees of importance admittedly, in the acquisition of directional knowledge. At first when a child is just beginning to learn the new concept, the age element is of prime importance; it is closely associated with learning to apply right and left on oneself. Normal attainment of this stage would also presuppose to a lesser extent a good perception of the body image. Once this step has been taken, age becomes irrelevant as it were and instead orientation in space is the crucial determinant in learning to distinguish right and left on other persons.

On the whole, Benton's findings that age, body image and language are important in the acquisition of the right-left concept were supported here. Benton had suggested moreover that systematic reversals and ipsilateral responses were attributable to insufficient verbal skills and a primitive reaction tendency respec-

tively. This data offers no evidence to confirm either of these suppositions.

It was also Benton's contention that one of the motor expressions of the construct he called the right-left gradient was handedness. There is no grounds to support this in the present study. In fact handedness itself appeared to be a very complex and multidimensional characteristic.

The Principal Component Analysis of the data revealed that maturation was the main factor accounting for much of the variance of all the test results; considering the wide age range of the sample, this is not completely unexpected. The second factor was one of directional orientation present in handwriting task and in the learning of right-left discrimination on other persons. The third factor was labelled Gross Visuo-Motor Coordination and the fourth one involved discrimination of right and left on others and some features of handedness, but the loadings of the variables on it could not be considered as arising from an easily identifiable unitary factor although the statistical evidence points to the existence of such a factor.

The two aspects of the right-left concept, i.e. as differentiated on oneself and on others, show quite a discrepancy in their loadings on most of the components; this supports the view that various sources contribute to the establishment of the right-left concept and their contribution to one stage does not often correspond to the one they give to the other stage.

APPENDIX I.

BENTON RIGHT-LEFT DISCRIMINATION TEST.

1. Show me your left hand.
2. " " " right eye.
3. " " " left ear.
4. " " " right hand.

5. Touch your left ear with your left hand.
6. " " right eye " " left hand.
7. " " right knee " " right hand.
8. " " left eye " " left hand.
9. " " right ear " " left hand.
10. " " left knee " " right hand.
11. " " right ear " " right hand.
12. " " left eye " " right hand.

13. Point to the man's right eye.
14. " " " " left leg.
15. " " " " left ear.
16. " " " " right hand.

17. Put your right hand on the man's left ear.
18. " " left hand " " " left eye.
19. " " left hand " " " right shoulder.
20. " " right hand " " " right eye.

With eyes closed:

21. Show me your right hand.
22. " " " left leg.
23. " " " right eye.
24. " " " left ear.

25. Touch your right ear with your right hand.
26. " " left knee " " right hand.
27. " " right eye " " left hand.
28. " " left ear " " left hand.
29. " " left eye " " right hand.
30. " " left knee " " left hand.
31. " " right shoulder " left hand.
32. " " right eye " " right hand.

APPENDIX II.

GOODENOUGH DRAW A MAN TEST SCORING LIST.

1. Head present.
2. Legs present.
3. Arms present.

4a. Trunk present.
4b. Trunk proportion.
4c. Shoulders present.

5a. Attachment of limbs. (A).
5b. Attachment of limbs. (B).

6a. Neck present.
6b. Neck outline.

7a. Eyes present.
7b. Nose present.
7c. Mouth present.
7d. Features in two dimensions.
7e. Nostrils shown.

8a. Hair present.
8b. Hair detail.

9a. Clothing present.
9b. Two articles non-transparent.
9c. Entirely non-transparent.
9d. Four articles shown.
9e. Complete costume.

10a. Fingers present.
10b. Number correct.
10c. Detail correct.
10d. Thumb shown.
10e. Hand shown.

11a. Arm joints.
11b. Leg joints.

12a. Proportion. Head.
12b. Proportion. Arms.
12c. Proportion. Legs.
12d. Proportion. Feet.
12e. Two dimensions.

13. Heel.
14a. Coordination. Lines A
14b. Coordination. Lines B
14c. Coordination. Head.
14d. Coordination. Trunk.
14e. Coordination. Arms & Legs.
14f. Coordination. Features.

15a. Ear present.
15b. Ear detail.

16a. Eye detail. Brow.
16b. Eye detail. Pupil.
16c. Eye detail. Shape.
16d. Eye detail. Glance.

17a. Chin and forehead shown.
17b. Chin and forehead; detail.

18a. Profile A.
18b. Profile B.

APPENDIX IIIa.

SRA PRIMARY MENTAL ABILITIES SPACE SUBTEST.
INSTRUCTIONS.

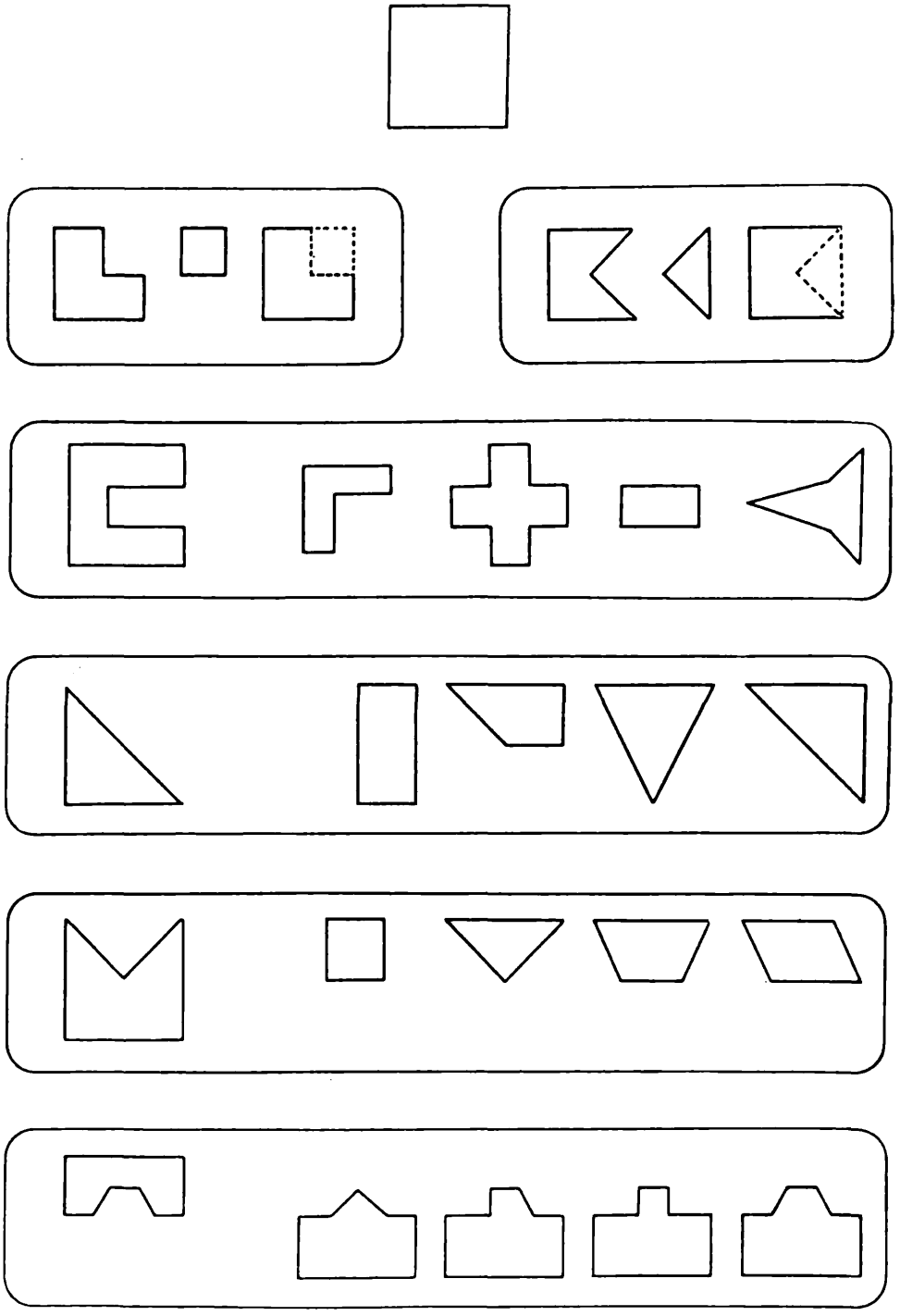
5 - 7 age group.
The test is divided into 2 parts, a marking and a completing one.

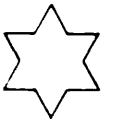
Marking part:

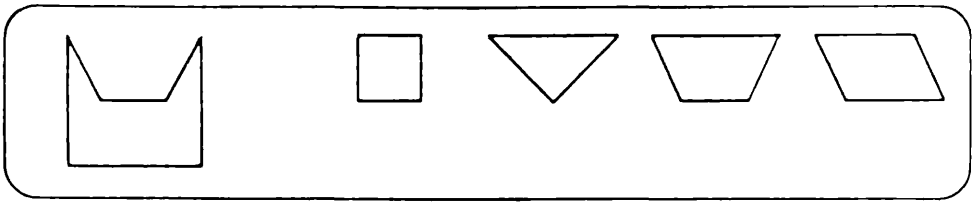
"Underneath the boy in the bathtub is a picture that looks like a square. Underneath the square are 2 boxes of pictures. Look at this picture (pointing to the L-shaped figure. It is not a square. It is a PART of a square. This (pointing to the small square) is the REST of the square. If we slide them together they make a whole square-like this (pointing to the third figure). Now look at this picture (pointing to the first picture in the second box. It is PART of a square. This is the REST of the square (pointing to the second figure in the box). If we slide them together they make a whole square-like this (pointing to the third figure).

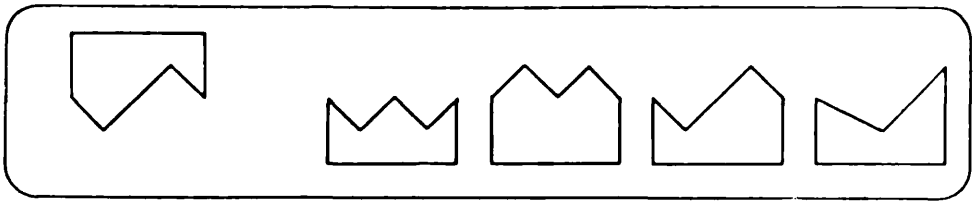
Completion part:

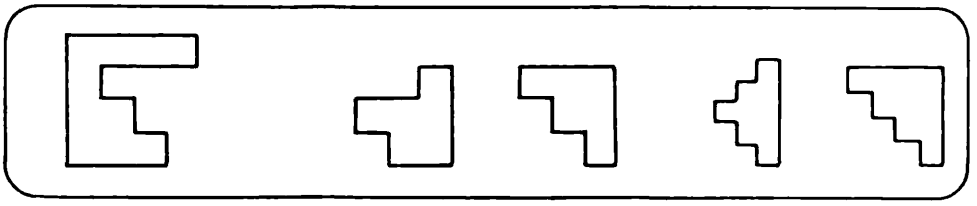
"There are pictures of a teacher and of children in school. Underneath the teacher is the picture she drew. Underneath the children is the picture they drew. The children tried to make their picture look just like the teacher's picture but they did not quite finish it. You finish it for them. Make the children's picture look just like the teacher's."

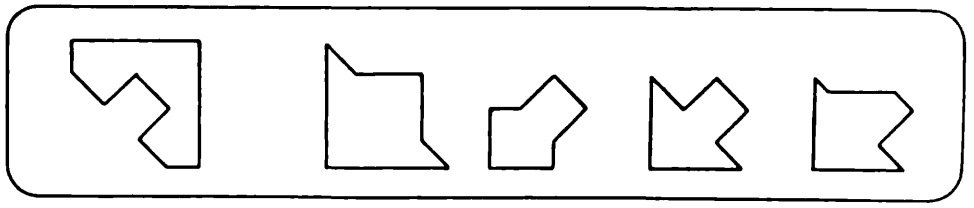




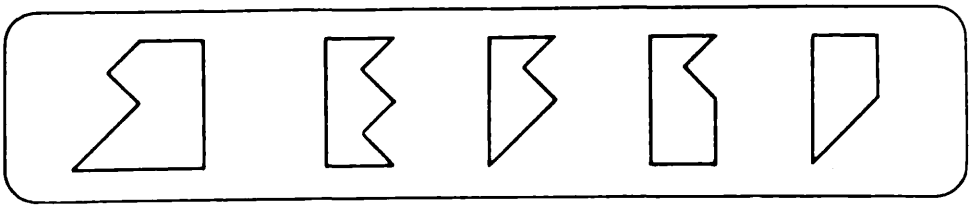


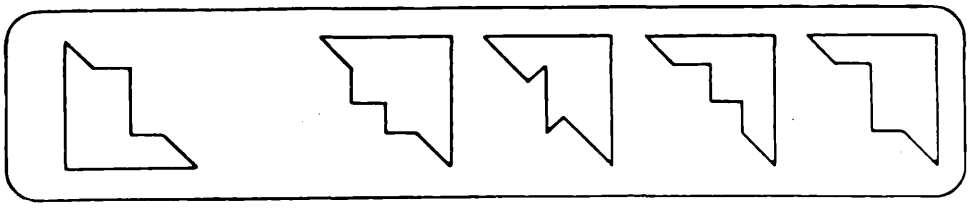


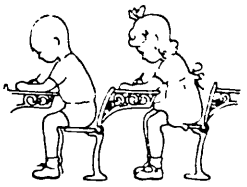


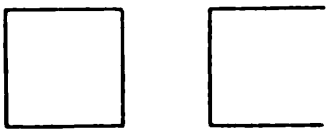


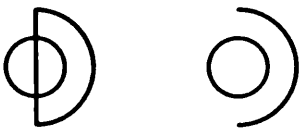

TOOTH
PASTE

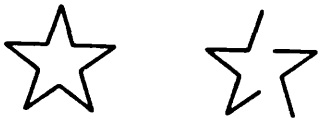


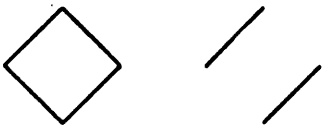


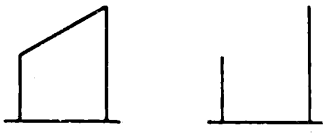


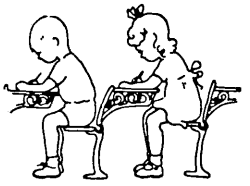


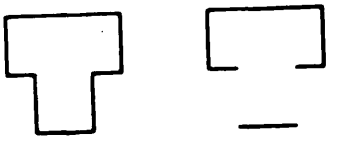


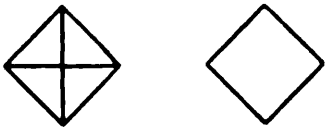


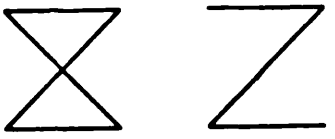


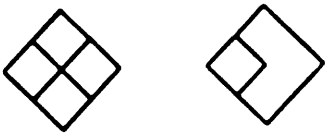


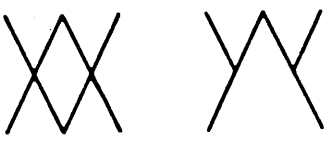


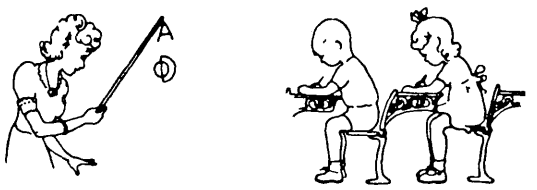


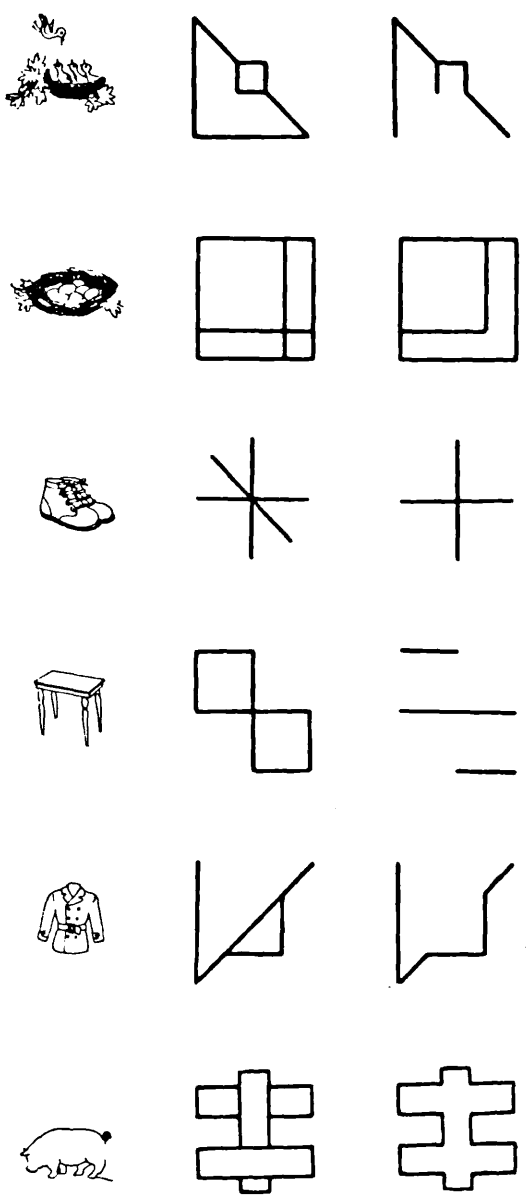












Appendix 111 b.

SRA Primary Mental Abilities Space Subtest.
Instructions.

7 - 11 age group.

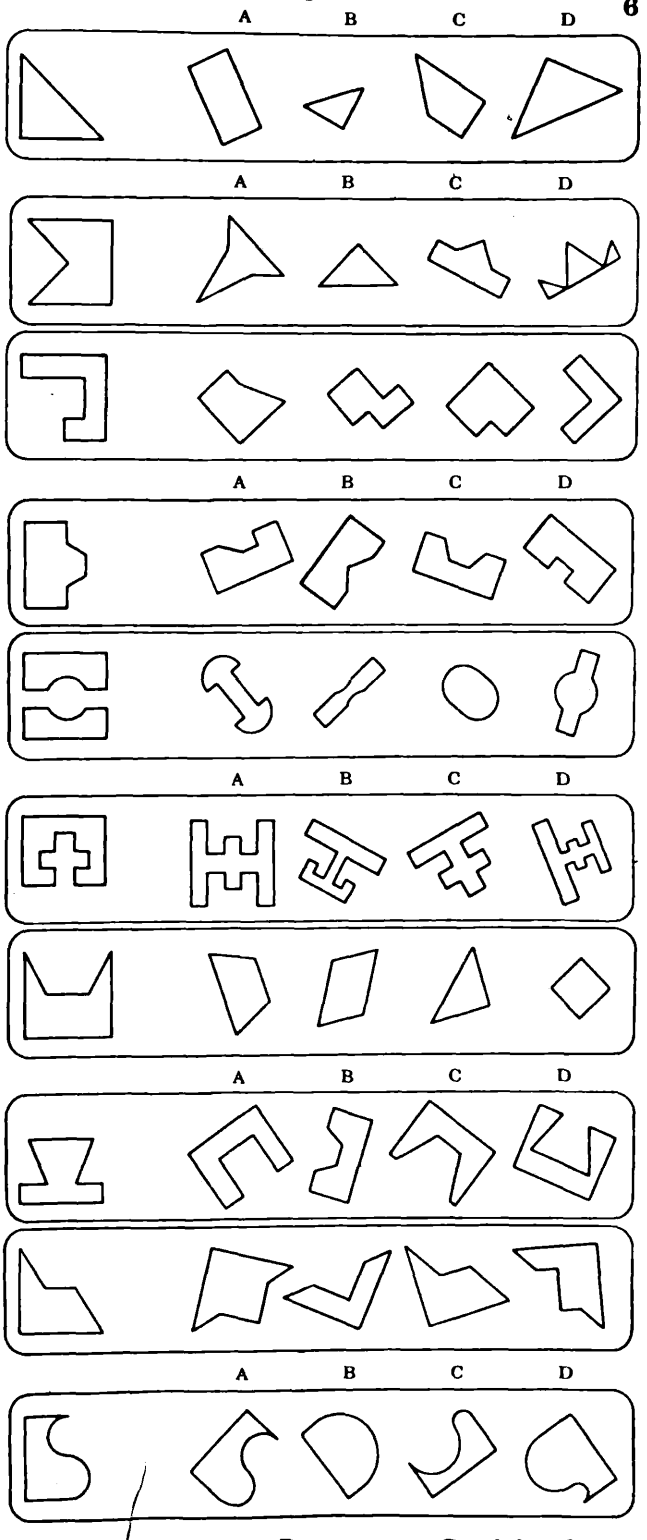
"Look at the first drawing in the row." (pointing to the triangle). It is part of a square. We are going to look at the other drawings in the row to find the other part of the square. Which one of the drawings "A" (pointing), "B" (pointing), "C" (pointing) or "D" (pointing), is the rest of the square?... That is right; it is D. If we slide the "D" around to the right position it will finish the square. Notice that the "D" is the answer in the first row of drawings.

Look at the first drawing in the next row. It is part of a square. Can you find the rest of the square in the row? Find the letter which goes with it... That is right. It is the "B" drawing for if we slide the "B" drawing around, it will fit into the first drawing and finish the square.

Do the same thing for the next row of drawings. Look at the first one. It is part of a square. Find the drawing which is needed to complete the square. Tell me which letter goes with it. For each row you show me which one of the other drawings is part of the square.

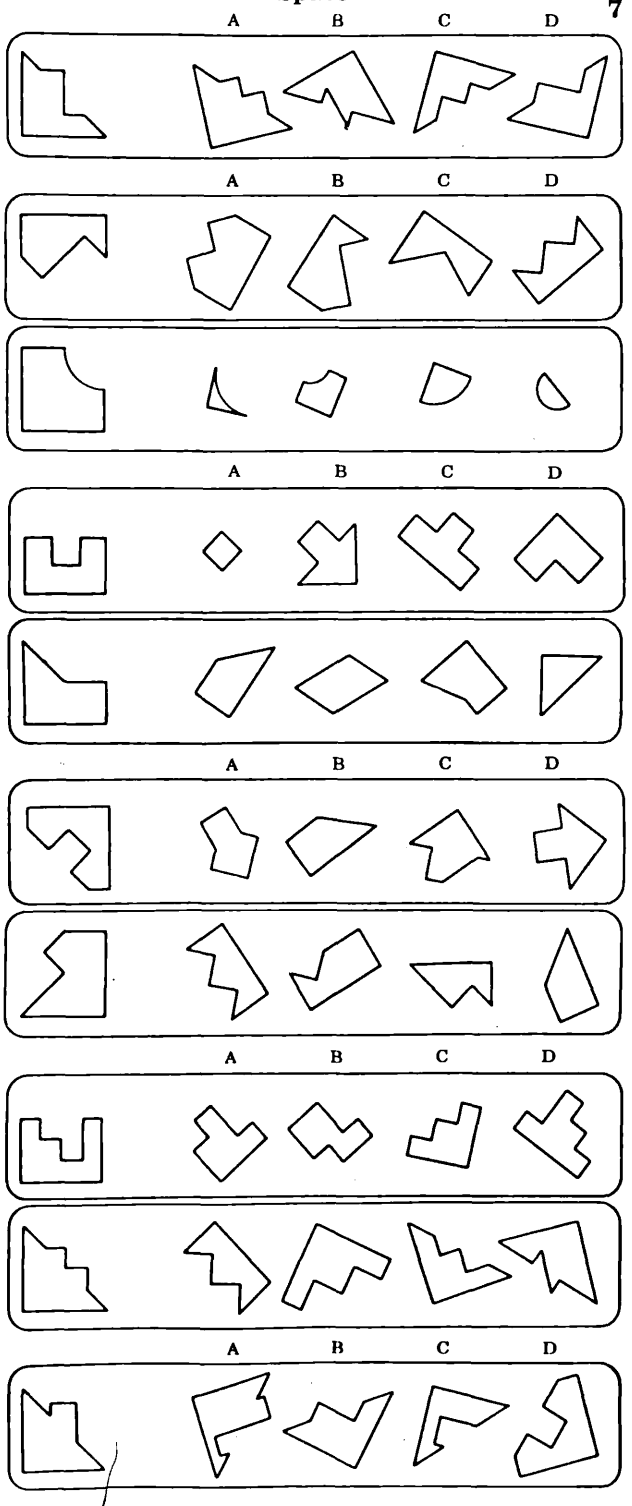
Space

6



Do not stop. Go right ahead.

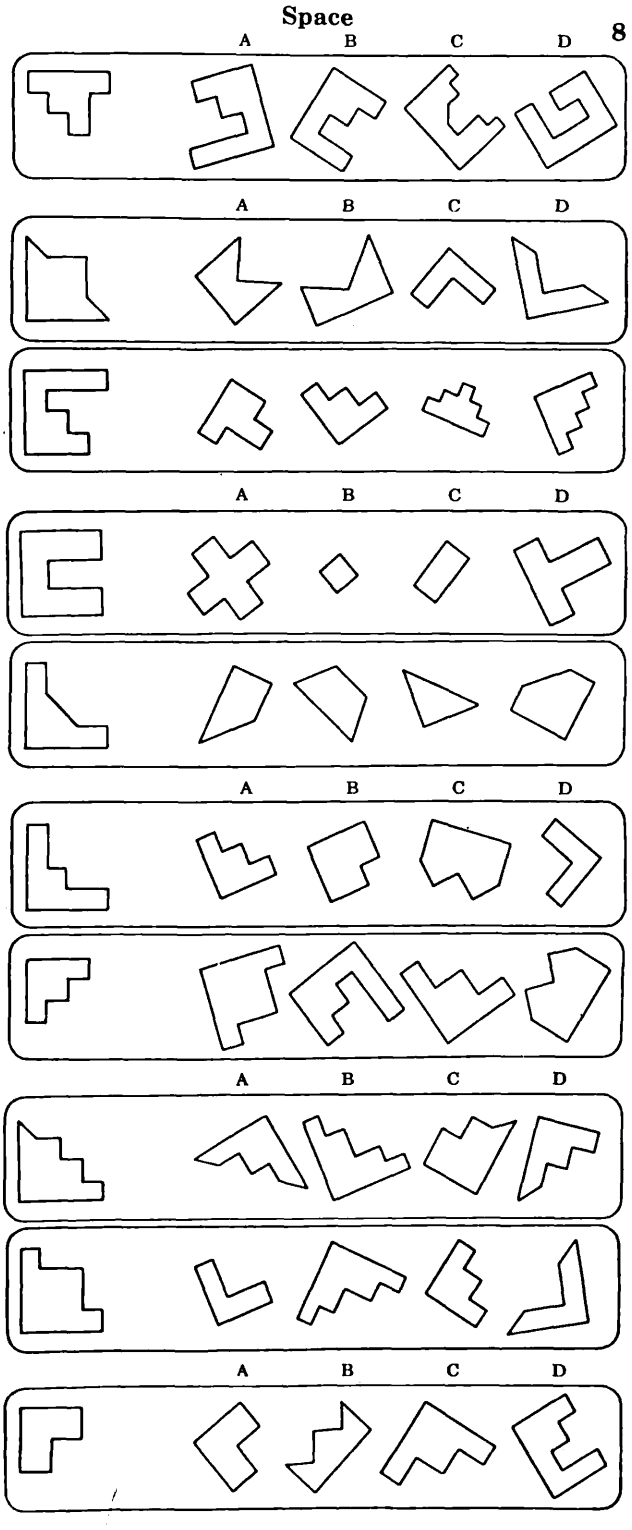
Space 7



Do not stop. Go right ahead.

Space

8



Stop.

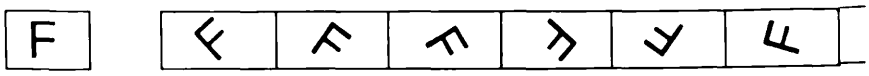
Appendix IIIc.

SRA Primary Mental Abilities Space Subtest.
Instructions.

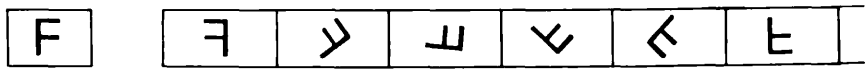
SPACE

PRACTICE EXERCISES

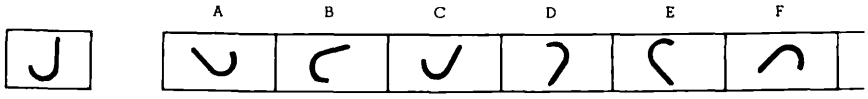
Look at the row of figures below. The first figure is like the letter F. All the other figures are like the first one, but they have been turned in different directions.



Now look at the next row of figures. The first figure is like the letter F. But none of the other figures looks like an F, even if they were turned right side up. They are all made backward.

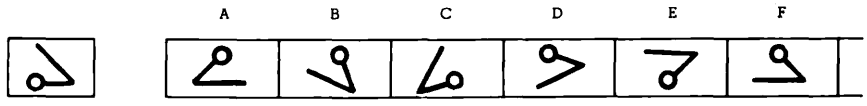


Some of the figures in the next row are like the first figure. Some are made backward.



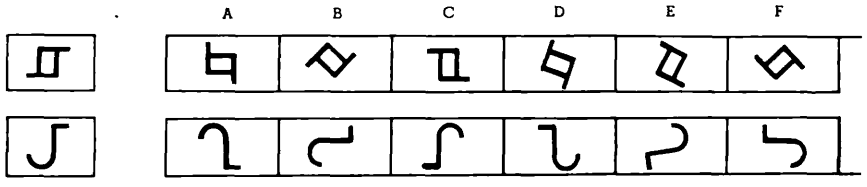
Figures C, E, and F are LIKE the first figure. X's have been marked in [C], [E], and [F] on the Answer Pad. Notice that ALL the figures which are LIKE the first figure have been marked.

In the row of figures below, mark an X in the box of EVERY figure which is LIKE the first figure. Do NOT mark the figures which are made backward.



You should have marked an X in [A] and in [E].

In the two rows below, mark an X in the box of EVERY figure which is LIKE the first figure in that row. If you wish to change an answer, draw a circle around this box like ⊗. Then mark the new answer in the usual way.



In the first row, you should have marked [A], [D], and [F]. In the second row, you should have marked [C] and [F].

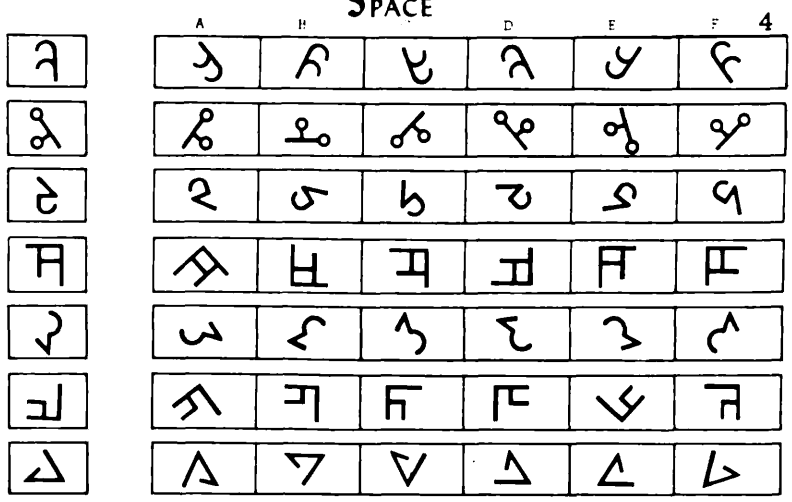
Remember that in each row, there may be any number of figures LIKE the first one.

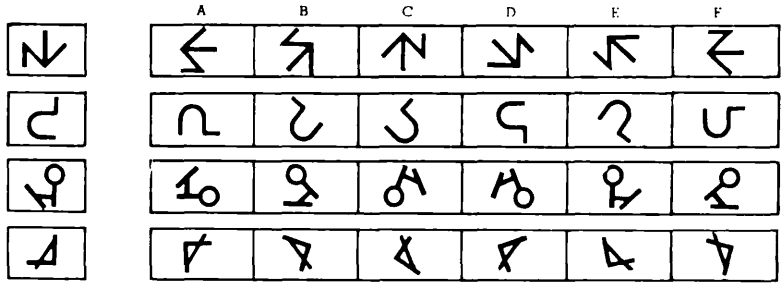
Be sure you understand how to work this kind of problem. When the examiner gives the signal, you are to work more problems like those above.

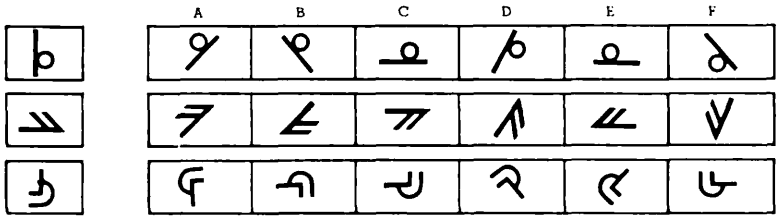
Work quickly, but try not to make mistakes. You will have 5 minutes for the test. You are not expected to finish in the time allowed.

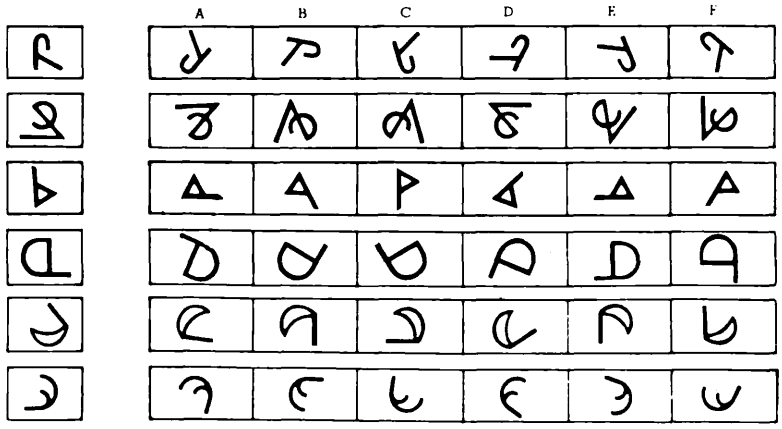
STOP HERE—DO NOT TURN THE PAGE UNTIL THE EXAMINER TELLS YOU

SPACE









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APPENDIX IV.

Lower triangle of 8 variables correlation matrix.

Variable	1	2	3	4	5	6	7	8
1 Age	1							
2 Goodenough	.830	1						
3 Vocabulary	.834	.770	1					
4 Raven	.827	.718	.723	1				
5 SRA Space	.866	.820	.873	.805	1			
6 Diamond	.725	.650	.705	.569	.729	1		
7 Harris	.068	.099	.135	.201	.114	.180	1	
8 Benton	.801	.759	.820	.722	.793	.632	.068	1

APPENDIX V

Latent roots of the first Principal Component Analysis and the percentage of variance each one accounts for.

Variable	Latent roots	percentage of variance it accounts for.
1	5.602	70.019
2	1.003	12.533
3	0.450	5.626
4	0.291	3.633
5	0.251	3.141
6	0.194	2.421
7	0.123	1.504
8	0.090	1.122

APPENDIX VI.

Means and standard deviations on 8 variables calculated separately for girls and boys.

Variable	Means		Standard deviations	
	G	B	G	B
1	95.68	95.58	27.56	28.26
2	21.55	19.30	8.85	9.00
3	20.72	24.18	9.11	12.03
4	21.10	23.00	10.60	12.01
5	92.00	97.00	31.82	41.32
6	0.65	0.60	0.48	0.50
7	2.65	2.25	0.70	0.84
8	21.85	23.05	6.42	7.11

Appendix VII. Correlation matrix for the second Principal Component Analysis.

1	Age																									
2	Goodenough	830																								
3	Vocabulary	834	770																							
4	Raven	827	718	723																						
5	Space Relations	866	820	873	805																					
6	Draw a Diamond	725	650	705	569	729																				
7	Harris	068	099	135	201	114	180																			
8	Benton (Total)	801	759	820	722	793	632	068																		
9	Benton Self Single	610	623	572	459	558	424	-079	686																	
10	Benton Self Double	760	666	737	648	695	599	005	893	607																
11	Benton Others Single	271	266	389	313	401	287	138	383	-055	049															
12	Benton Others Double	304	392	417	376	412	293	197	574	189	273	552														
13	Ipsilateral Responses	-621	-509	-627	-512	-559	-480	086	-705	-484	-817	-022	-152													
14	Systematic Reversals	-360	-348	-273	-276	-324	-183	164	-400	-435	-362	-048	-086	303												
15	Handwriting Total	-297	-141	-227	-175	-286	-162	-056	-232	-182	-253	028	-104	172	219											
16	Handwriting Difference	-018	124	128	097	060	154	081	026	151	-050	216	094	072	123	715										
17	Tapping Total	789	697	722	642	734	695	057	701	567	653	220	232	-489	-235	-477	-335									
18	Tapping Difference	398	317	393	431	381	370	257	384	325	302	158	182	-143	-223	-067	003	370								
19	Deal. Cards Total	-400	-278	-384	-313	-322	-216	200	-400	-271	-406	-140	-073	392	246	310	270	-341	-081							
20	Deal. Cards Difference	135	219	227	102	259	233	128	214	231	191	-002	125	-102	-185	-046	-021	243	205	206						
21	# of Letters in Name	592	648	529	548	543	553	150	507	281	417	304	259	-367	-185	310	491	485	086	-078	-044					
22	Benton Self Total	782	711	753	649	716	600	-019	911	775	973	023	272	-792	-415	-259	-085	688	337	-403	220	421				
23	Benton Others Total	325	369	456	389	461	329	188	538	068	175	895	866	-094	-075	-039	179	262	196	-127	066	319	159			
24	Handwriting Diff./Total	135	172	257	237	254	275	332	116	-174	017	308	155	107	103	129	699	-084	122	071	034	328	-038	267		
25	Tapping Diff./Total	-081	-086	-069	020	-070	-064	282	-069	-024	-133	026	027	237	-084	295	287	-250	736	183	094	-155	-114	031	182	
26	Deal. Cards Diff/Total	249	278	339	206	347	285	047	356	307	308	104	195	-204	-219	-115	-077	344	210	-164	900	008	336	170	011	016
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Note: Decimals have been omitted.

APPENDIX VIII

Latent roots of the second Principal Component Analysis and the percentage of variance each one accounts for.

1	10.332	39.739
2	3.380	12.997
3	2.119	8.150
4	1.983	7.629
5	1.535	5.906
6	1.265	4.865
7	0.911	3.505
8	0.857	3.927
9	0.750	2.884
10	0.562	2.158
11	0.504	1.937
12	0.415	1.597
13	0.334	1.284
14	0.265	1.020
15	0.213	0.821
16	0.175	0.675
17	0.138	0.532
18	0.100	0.384
19	0.093	0.358
20	0.057	0.221
21	0.035	0.133
22	0.010	0.030
23	0.004	0.016
24	0.000	0.000
25	-0.000	-0.000
26	-0.000	-0.142

APPENDIX IX

Cluster Analysis and variances of each factor.

Variable	Factor A	Factor B	Factor C	Factor D	Factor E
1	823	304	-055	192	163
2	771	347	062	249	118
3	794	426	064	283	167
4	726	364	060	154	231
5	796	430	016	304	160
6	684	307	099	259	157
7	061	176	115	087	269
8	819	507	-203	286	162
9	625	068	-166	270	153
10	796	168	-090	250	087
11	233	887	190	051	092
12	338	875	055	160	104
13	-649	-090	111	-154	048
14	-326	-070	145	-202	-154
15	-232	-038	736	-081	116
16	008	166	901	-049	146
17	730	241	-307	294	063
18	348	181	017	207	932
19	-344	-115	226	022	051
20	195	064	-012	975	150
21	528	298	394	-018	-035
22	815	153	-122	279	115
23	321	961	143	119	114
24	108	247	729	023	152
25	-098	028	260	055	932
26	294	159	-063	975	113
Positive variance:	7.234	3.922	2.287	2.741	2.185
Negative variance:	0.710	0.028	0.153	0.074	0.025
Total variance:	7.944	3.950	2.440	2.814	2.210

Note: Decimals have been omitted for the factor loadings.

Appendix X. Correlations after age is partialled out.

1	Age																								
2	Goodenough																								
3	Vocabulary	253																							
4	Raven	103	105																						
5	Space Relations	364	547	315																					
6	Draw a Diamond	127	264	-078	295																				
7	Harris	077	142	258	110	190																			
8	Benton (Total)	282	459	176	332	126	022																		
9	Benton Self Single	263	145	-102	076	-033	-153	415																	
10	Benton Self Double	098	287	053	115	108	-072	731	278																
11	Benton Others Single	076	306	164	346	136	124	293	-289	-250															
12	Benton Others Double	263	310	231	311	110	185	579	005	067	512														
13	Ipsilateral Responses	014	-252	004	-055	-056	164	-443	-169	-678	194	049													
14	Systematic Reversals	-096	054	041	-027	120	202	-199	-292	-147	055	027	109												
15	Handwriting Total	197	039	131	-062	081	-037	010	-001	-045	118	-015	-016	126											
16	Handwriting Difference	249	260	199	152	242	083	067	-176	-056	230	104	077	125	744										
17	Tapping Total	122	188	-032	164	290	-182	188	176	134	010	-014	002	085	-414	-522									
18	Tapping Difference	-025	121	197	079	128	251	118	114	-000	057	069	145	-093	059	011	098								
19	Deal. Cards Total	105	-100	035	052	118	249	-146	-037	-171	-036	056	200	120	219	286	-045	093							
20	Deal. Cards Difference	194	209	-017	288	198	120	180	190	138	-041	089	-024	-147	-007	-018	225	166	286						
21	# of Letters in Name	349	079	130	075	223	136	068	-126	-063	185	102	001	037	631	622	036	-202	215	-156					
22	Benton Self Total	179	292	006	124	077	-117	762	602	934	-315	057	-627	-230	-045	-114	184	045	-158	186	-084				
23	Benton Others Total	188	354	225	378	142	176	490	-174	-117	887	851	145	048	064	196	008	077	004	024	166	-162			
24	Handwriting Diff./Total	108	265	225	277	259	326	014	-327	-133	284	121	245	164	179	708	-314	075	138	016	310	-234	238		
25	Tapping Diff./Total	-033	-002	157	001	-007	289	-007	032	-110	051	054	239	-122	284	287	-303	840	164	107	-132	-080	061	195	
26	Deal.Cards Diff/Total	132	245	-000	272	156	031	269	203	189	039	129	-066	-143	-045	-075	249	124	-072	903	-179	235	098	-023	038

Note: Decimals have been omitted.

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