SOME ASPECTS OF
VISUAL DISCRIMINATION IN THE
GOLDEN HAMSTER.

by

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ABSTRACT.

This research was concerned with visual discrimination in the golden hamster. Relevant literature on the rat suggests that discrimination of simple geometrical shapes is determined by the isolation of a distinctive figural element; this is normally the base line. Learning of solid shapes is transferred to outlines and size alterations, but not to rotated figures and figure-ground brightness reversals.

Some of these results may be experimental artifacts produced by the technique of investigation, in which the main flaws appear to be the use of large figures and a fixed choice distance. In the series of experiments reported here on form discrimination in the golden hamster, techniques were developed to meet these criticisms.

The major experiment of this series indicated that golden hamsters were able to learn a brightness discrimination rapidly. Form discrimination of a triangle from a circle was more difficult and learning slow. However, all animals achieved discrimination scores above the 0.01 level of significance.

Transfer tests showed that, as with rats, the response was to the positive figure and not to the negative.

Generalisation extended to rotated figures, to both the tops and bases of figures, and to all alterations in size except the smallest (0.25 cms.); a behavioural measure of visual acuity had evidently been reached at this point. The results indicated that the animals were responding to the figure as a whole rather than to its parts. A complete breakdown in discrimination occurred when the figure-ground brightness relationship was reversed. A subsidiary experiment showed that hamsters were capable of perceiving depth.

The results obtained on rotated figures and the parts of figures suggest either that form discrimination in the golden hamster is substantially different from that in the rat, or that they are due to the smaller figures used and the freedom of scrutiny allowed.

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CONTENTS

CONTENTS (Contd.)

APPENDICES

TABLES

FIGURES

FIGURES (Contd.)

Page no.

PLATES

Page no.

I INTRODUCTION

This research was designed to investigate visual discrimination in the golden hamster in terms of depth, brightness and form. The latter was considered particularly important, in view of the large amount of work with other species in this field.

The choice of the golden hamster as an experimental animal was not entirely arbitrary. Apart from the availability of the hamster in this laboratory, the genetic purity of the wild agouti type, in contrast to the mutant strains of rats used for most experiments, suggested that information on the animal's powers of visual discrimination would be valuable. This was considered particularly important in view of the fact that mutations can give rise to defects which introduce unknown, uncontrolled variables; where such anatomical and physiological defects are present, it is possible to confuse sensory impairment with conceptual limitations.

Some difficulty has arisen over the aspects of the figure which determine form discrimination. Results obtained with rats suggest that the figures are differentially discriminated in terms of their parts only, namely the base lines; there is little or no transfer to rotated figures; squares and circles are confused, except when the animals have been previously trained on horizontal and vertical striations. Lashley (1938) found that there was no transfer when the figure-ground brightness relationships were reversed, although Reetz (1957) obtained positive results with rats and mice. On the other hand, rats can learn to discriminate between different orientations of the same figure, and transfer to different sizes and from solid figures to outlines is good.

Work with other species indicates that chickens and fishes also discriminate figures in terms of their parts, but that discrimination is based on the parts that most clearly differentiate the figures, rather than upon the base lines. Higher mammals and octopuses, however, tend to respond to the whole figure, and are less disturbed by changes in rotation; the higher mammals are also able to transfer discrimination when the brightness relationships of the figure and background are reversed (Sutherland 1961).

Consideration of the results with rats suggested that errors may have arisen through the techniques used to obtain them. It was felt that the figures used in most experiments were too large (2 to 4 inches base), and that the methods were confusing discriminative distance with discriminative ability.

Because of these possibilities, smaller figures (2.0 cms.) were used in the form discrimination experiments described in this thesis. Modification of the technique was difficult; it was thought essential that the apparatus should be so designed that the animal was able to show its maximum discriminative ability. As little is known about the limitations imposed by the animal's optical system, it was necessary to eliminate the arbitrary conditions imposed by a fixed-distance choice. Since the golden hamster is unable to jump far, any form of apparatus that necessitated jumping was inapplicable; it was also desirable to reduce any tendency to position habits as far as possible. Thus, apparatus was required which both satisfied these criteria, and provided a statistically sensitive measure of discriminative ability.

In the sections that follow, relevant literature on visual discrimination is reviewed. Next, since the golden hamster is a species of animal which is rarely used in comparative psychology, a brief description of some of the relevant morphological and behavioural characteristics has been included, with some discussion of the problems arising from sources of motivation and from methods of handling.

The probable structure of the eye, in so far as it affects form discrimination, is then outlined.

The succeeding sections deal with the experiments. The measurement of visual acuity, and the presence or absence of depth perception are treated first. Then an account is given of preliminary attempts to investigate brightness and form discrimination in the hamster; this section is predominantly methodological in emphasis, since considerable difficulty was encountered in the early stages of the work in developing a suitable apparatus for use with a new species, while at the same time attempting to avoid some of the methodological shortcomings apparent in the techniques which have been used with rats.

The final part of the thesis reports the major experiment, carried out when an apparatus satisfying the necessary criteria had been devised. During this experiment, the animals were trained to discriminate a triangle from a circle; information on certain aspects of the discrimination and on the extent of the concept was obtained by giving transfer tests, in which the questions of size variation, part versus whole, figure-ground reversal, alternative figures and rotations were examined.

In so far as these investigations were successful, it was considered that this research would be of value in contributing to the knowledge of a different species, and perhaps in adding further evidence on some of the controversial points which have arisen in the study of visual discrimination in small mammals.

II REVIEW OF THE LITERATURE

The Gestalt psychologists can be said to have drawn attention to the problem of form perception in the 1920's. In their attempt to combat the theories of nineteenth century nativism and empiricism, they produced, besides a revolutionary theory, a large amount of experimental evidence on form discrimination and learning. Sutherland (1961) remarks that this era was noted for a multitude of experiments insufficiently guided by theory.

In early experiments the methods employed were often so specific to the animal being investigated as to admit of no useful general conclusions. Morgan (1939) points out that progress in the acquisition of knowledge concerning the psychological capacity of animals is largely dependent upon the development of satisfactory instruments of measurement; in psychology this is particularly true of the study of animal vision. One of the first to introduce a more general method of investigation was Yerkes (1907) who evolved a prototype of apparatus which was devised to induce the animal to give a differential response to two or more stimuli. Lashley (1930a), Fields (1928) and Munn (1931), among others, (for example, Gentry 1934, Morgan 1939) developed this line of attack, with a view to controlling the more obvious external variables, such as olfactory and tactile cues, automatic control of reward and punishment, and so forth.

Since then, the problem of visual discrimination has attracted greater attention; more species of animals are being investigated, and a great deal of work in the field of vision has been produced, of which that of Hebb, Deutsch, Dodwell, Sutherland, J.Z. Young and von Frisch are only a few of the examples. However, there are, oddly enough, few really comparative studies in which one species is compared systematically with another. There are two ways of tackling this problem: first, for two individual experimenters to use the same techniques on two different species, and secondly, for one experimenter to study several different species.

Bearing the comparative basis in mind, it was decided to see if there was any similarity between rats and golden hamsters in terms of visual discrimination. There is no apparently relevant work on hamsters, apart from a recent study in Germany by Rensch and Rahmann (1960), who studied the effect of the drug Pervitin on the golden hamster's ability to remember a learned discrimination between horizontal and vertical stripes; a modified form of Munn's two-door apparatus was used.

It was therefore necessary to turn to the literature on the rat, and the most immediately relevant background in terms of methodology appeared to be the work of Lashley, Fields and Munn, who, between them, have provided a quantity of data on the rat's ability to distinguish between various symbols.

Since a discussion of all the work in the field of visual discrimination is beyond the scope of this thesis, the following sections are concerned chiefly with these three experimenters, and are divided as follows: the first section describes the methods that were used; the second summarises the results and the general conclusions that may be drawn from them, while, in the third section, the validity of both method and results is examined, and their applicability to the golden hamster discussed.

A. Techniques and Apparatus Used In Visual Discrimination Experiments.

The prototype of the two-choice visual discrimination apparatus was devised by Yerkes in 1907, primarily to study vision in the dancing mouse. The animal, which was food-deprived, was trained to discriminate between two stimuli placed in the end-wall of the choice-box; the stimuli, which were covered with frosted glass and illuminated from behind, were separated from one another by a partition.

After a correct choice, the animal was able to go through a door in the side-wall, and down a passage to a compartment at the opposite end of the choice-box; here it was rewarded with food. It was then readmitted to the choice-box for the next trial. A wrong choice was punished with electric shock.

The importance of this apparatus lay in the method of inducing an animal to make a differential response to two or more stimuli, so that the nature of the sensory processes could be studied. However, although the apparatus was theoretically applicable to most species of animals, it never gave any very satisfactory results; although easy discrimination problems, such as differentiation between black and white, were adequately demonstrated, the substitution of form discrimination was still producing negative findings after as many as 2000 trials. Williams (1926) was unable to teach dogs to discriminate in this situation.

Fields (1928) criticised Yerkes' apparatus on three grounds: i) the situation was unnecessarily complex; ii) there was a marked lack of contiguity between the stimulus and the reward, and iii) the presence of a partition between the stimuli meant an arbitrary choice distance for the animal, which was not necessarily best suited to its powers of accommodation.

Fields (1928) modified the Yerkes apparatus by leaving out the partition, and by presenting the stimuli as different-shaped holes; the rat had to go through the correct hole, after which it obtained food on the other side. However, although he appeared to be able to train rats to discriminate on this apparatus, Fields (1929) later showed that the discrimination had been based on tactile and kinaesthetic cues rather than on visual ones; blinded rats were still able to achieve scores significantly above chance. He therefore placed the holes immediately below the stimuli, and succeeded in training rats to discriminate simple geometric forms in about 800 trials.

Meanwhile, Lashley (1930a) had devised a new type of apparatus which was considerably more successful than its predecessors; the rate of discrimination learning was faster, and satisfactory results were obtained in less than 100 trials. The criterion for learning was usually 150 trials (Lashley 1938). Lashley's method of scoring results is perhaps worth attention: all correct choices were called trials. Thus a rat making two wrong jumps first would be recorded as having made 1 trial and 2 errors. Therefore 150 trials are equivalent to 150 correct choices, although not necessarily correct <u>first</u> choices. Lashley used ~~the~~ an atypical correction method[1] of training and judged the

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[1] In the usual correction method, the animal corrects its own mistake. In Lashley's method, the animal was replaced on the jumping stand after an error.

animals in terms of errors. Fields, on the other hand, used the word "trial" in the more usual sense: that is, he used it to denote one run through the apparatus, thereby including both the correct choice and the errors.

The apparatus consisted of a platform, from which rats were trained to jump a distance of 25 cms. to one of two stimulus cards (measuring 15 x 15 cms.) exposed side by side; the correct card fell back when pushed, giving the rat access to food on the other side. The wrong card was fixed; thus, a wrong choice resulted in a bump, and a fall into the net, which acted as punishment. The preliminary training is lengthy: the rat is trained to jump to the two holes by gradually increasing the distance between the jumping platform and the apertures; when the required distance is reached, the apertures are closed with the stimuli and training on discrimination begins.

The importance of Lashley's technique centres on the following points: by the nature of the situation, all activity is focused on the stimuli themselves, which become signs for reward or punishment; this is unlike Yerkes' apparatus, where a great deal of preliminary running around in front of the stimuli may occur, and where the long alleys to the reward may never become associated with the stimuli themselves. In Lashley's apparatus, there is close temporal and spatial contiguity between the response and either reward or punishment. There is also an enforced pause before the choice, thus increasing the possibility that the animal will be effectively stimulated by the stimuli, rather than making an immediate undiscriminating response (Muenzinger & Fletcher, 1937). Neither of these situations occurs in Yerkes' apparatus.

The chief difficulties with this apparatus lie, firstly, in the length of preliminary training necessary, and secondly, in the fact that the apparatus is limited to small animals who can be trained to jump. Moreover, if a rat is faced with a difficult discrimination problem, it may refuse to jump at all; it is then necessary to force it to do so by resorting to electric shock, air blasts, pushes and so forth, all of which may make the rat jump indiscriminately, quite apart from the introduction of undesirable extraneous factors.

Some years later, Fields (1932b), having used Lashley's technique for some time, modified the jumping apparatus by introducing five possible stimulus card positions instead of two. The jumping platform was a long strip running in front of the stimuli. Grether and Wolfle (1936) altered the apparatus so that, instead of having to jump, the rat ran along an elevated pathway to the stimulus; in the case of a wrong response, the pathway collapsed. This method obviated the necessity of training the animals to jump beforehand.

Munn (1931) also developed a form of apparatus designed to overcome some of the difficulties inherent in Lashley's method. This apparatus, which combines several features of both Lashley's and Yerkes' techniques, requires the minimum amount of preliminary training, and is readily adaptable to different species of animals. The stimuli cards are, as in Lashley's apparatus, fixed to doors which give immediate access to food. However, the approach to the cards is continuous, so that the animals do not have to learn to jump the correct distance; an electric grid immediately precedes the stimuli cards, enabling a wrong response to be punished. Olfactory stimuli are controlled by placing the food equidistantly between the two doors. Since the door openings are the same shape, the rat cannot learn the discrimination on the basis of non-visual cues.

Munn claims that this apparatus has every advantage noted for Lashley's method, and that it also yields comparable results. A similar form of apparatus has been used by Grice (1948) and Gibson and Walk (1956).

Twenty years later, Fields (1953) modified the jumping apparatus still further by combining a series of five-choice jumping stands in such a way that a correct jump on one stand brought the animal onto the jumping platform of the next stand; it only obtained food after it had reached the fifth and last stand. This meant that there was only one unit of reward for five trials, which, when motivation depends on deprivation, prevents rapid satiation during a long experimental run, thereby maintaining a fairly consistent drive level. In the case of an error, the animal fell into a net; it was able to climb a ladder back onto the jumping platform. The jumping distance in this case was 21 cms.

Fields found this apparatus to be an improvement on Lashley's original technique, and he gives a valuable list of criteria for assessing the efficiency of a discrimination apparatus. These are as follows:

a) The number of trials given before the simplest problem learnt by a group of representative subjects.
b) the number of man-hours spent per animal in training it to meet the simplest criterion.
c) the permanence and stability of retention of previously learned responses.
d) the degree and kind of motivation required.
e) the adaptability of the apparatus and technique to a variety of problems.
f) the number of problems which can be investigated simultaneously.

g) the suitability of response to a number of animal species.

h) the extent to which the attention of S may be directed to the pertinent points of the problems.

i) the ease with which various elements of the total problem can be isolated for control.

j) the reproducibility of experimental findings in other laboratories.

k) freedom from the possibility of gross methodological and scoring errors on the part of the experimenter.

l) the statistical sensitivity, reliability and validity of the results obtained.

Fields found that if his apparatus was used as a series of two-choice units (i.e. only doors 2 and 4 in each panel were used) then the rat jumps to one, makes an error, and merely climbs the ladder and jumps to the other. Thus, "rats quickly learn this alternation, and do not pay as much attention to the crucial part of the problem." However, if <u>different</u> pairs are used in series, the animal's attention is directed more to the problem and is less dependent on kinaesthetic cues.

The SMVDA can also be used for an oddity test; for example, the first panel would have 20mm striations both positive and negative, the second panel would have 15mm striations, and so on.

Tuitional controls are possible; thus, panels 1 and 2 might have one positive symbol each, with 4 blanks; panel 3 would then have one positive symbol and four negative symbols, panel 4 would be a reinforcement of 1 and 2, and panel 5 would repeat panel 3. This, Fields maintains, is a most efficient method for establishing discrimination; it is apparently possible to establish simple multiple-choice problems on this serial apparatus in less than 20 trials, where one trial = 5 jumps.

The statistical sensitivity and reliability of this apparatus has been greatly increased by comparison with Lashley's jumping stand. Whereas, in a two-choice apparatus, 9/10 correct first choices are significant at the 0.01 level, in the five-choice apparatus, with one positive to four negative doors per panel, 9/20 are significant at the 0.007 level.

The speed and accuracy with which animals can be trained on this apparatus indicate that some of the difficulties posed by the Yerkes and Lashley techniques have been successfully overcome. Position habits are less likely, and Fields' results suggest that the greater number of stimuli direct the animal's attention to the problem.

Fields claims that the greater variation in the kinaesthetic and other cues forces the rat to attend more closely to the visual cues than it might otherwise have done; this is particularly interesting in view of Lashley's (1938) comment on the weakness of visual attention in the rat. However, the lengthy preliminary training to jumping is still necessary, and this type of apparatus, like Lashley's, can still only be used for small animals with the ability to jump.

B. Major Experimental Findings On Visual Discrimination In The Rat.

The results obtained on the apparatus described in the previous section are summarised briefly, so that it is possible to draw some broad conclusions on the mechanism of visual discrimination.

Lashley (1938) found that brightness discrimination was more easily learnt than any form discrimination; for example, rats quickly learnt to distinguish between black and white, and grey and black.

When investigating form discrimination in the jumping stand, Lashley found that it was more difficult for rats to learn to discriminate an upright triangle from a square than to discriminate an inverted triangle from a square; it was also relatively easy for them to learn to distinguish between an upright and an inverted triangle. These findings suggested firstly, that orientation is easily distinguished in the jumping stand, and secondly, that similarity of the figure base lines can cause confusion.

Further difficulty was encountered when a square and a circle were presented; 75% of the rats failed to reach the criterion in 180 trials, although they learnt it eventually. However, a diamond and circle were learnt easily, and this supports the hypothesis that the base lines need to be markedly different in order for learning to take place with any rapidity.

As would be expected, a cross caused little difficulty, whether presented with a circle, an upright triangle, or, in a rotated form, (X), with a rectangle; all three pairs were learnt within the criterion of 180 trials. However, there appeared to be no <u>transfer</u> of learning from a cross (+) and an upright triangle to a rotated cross (X) and an inverted triangle. On the other hand, although learning to discriminate between an H and a cross (+) was more difficult, Lashley found that there was good transfer to 干 and X. Reetz (1957) found that rats and mice trained on a square and a cross transferred well when both shapes were rotated through 45^{o}. These results seem rather contradictory.

Other evidence on transfer suggests that form, rather than the area of brightness, is important; for example, Lashley found that there was excellent transfer from a discrimination between a solid upright and a solid inverted triangle to the outlines of these forms; there was also transference from a cross and an upright triangle to their outlines. Reetz (1957) obtained similar results with a cross and a square.

Of nineteen pairs of shapes presented, horizontal and vertical stripes were the most easily learned; there was good transfer to single lines, and also to interrupted lines (- - - -), provided that the gaps were not too large; there was even transfer to zigzag lines, provided that the deviation from the midline did not exceed the width of the original striation. However, it was also found that the rats showed a marked initial preference for the horizontal striations when they had been trained in the jumping stand. This suggests either that there is an innate preference for horizontal striations, or that these horizontal lines resemble the surface on which the animal is going to land.

Investigation of transfer to parts of the figure indicated that rats trained on a square and a diamond would transfer their discrimination to the lower halves of these figures, or to the inner lateral halves; however, when the upper halves or the outer lateral halves were presented, discrimination broke down. This again supports the base line hypothesis, and in the light of the preference for the horizontal striations, takes it a step further. It seems likely the rat fixates the lower half of the symbol because, when it jumps, this is the part of the symbol nearest the landing platform. Similarly it fixates the inner lateral halves because it tends to jump to the middle of the apparatus, in order to cling to the dividing partition separating the two figures should it have made a wrong choice.

Further work showed that ⊏ and ⊐ were more difficult to learn than ⊔ and ⊓ , while there was no significant difference between learning the pair ▽ and △ , and the pair ◁ and ▷ . These results, which again indicate the importance of the base line, also suggest that it is no more difficult to discriminate between up-down and left-right inversions than between other figures of comparable complexity but with genuine form differences.

When the relative brightness of the figure-ground relationship was reversed, there was no transfer at all; when a white triangle on a black ground became a black triangle on a white ground, the rat failed to recognise it.

Lashley (1938) pointed out that the rat tends to isolate an element of the visual stimulus. He also said that "Systematic tests have shown that the majority of animals do not react to the entire figure presented in the stimulus patterns.... The most important factor in defining the part-figure is the relation of the stimulus card to the surrounding frame."

Fields' work on visual discrimination is important, both because it essentially supports Lashley's results, and because he contributes original information on certain aspects of the problem hitherto unexplored.

Fields' early work (1928, 1929) in which he used a two-choice apparatus based on the Yerkes' model, suggested that rats could distinguish between equilateral triangles differing in apex position, between circles and stars, and between different combinations of circles. These results were obtained after modification of the apparatus to control tactile and kinaesthetic cues.

Munn (1930) severely criticised this work, on the grounds of it being a poorly controlled experiment; accumulated body odour from preceding rats, tactile cues from visual forms and movement cues from the experimenter holding the door ropes, may all have contributed to the apparently successful visual discrimination. Munn also felt that, because the blinded rats were unable to achieve significant scores, it was not possible to say that the seeing rats were successful because they were depending on visual cues alone. It is interesting to note that Fields, having trained his rats to discriminate between a positive upright and a negative inverted triangle, found that there was poor transfer when a rectangle was substituted for the inverted triangle. This suggests that the animals were discriminating purely in terms of the base lines - a result which supports Lashley's work - and also that they responded equally to both positive and negative figures; this result is not borne out by Fields' later work, in which variations in the negative figure did not disturb discrimination. Since the later experiments were more closely controlled, this suggests that perhaps some of Munn's criticisms were justified.

Two years later, Fields (1932b), using a slightly modified form of Lashley's jumping stand instead of the Yerkes apparatus, found that rats could distinguish between a circle and a triangle, but that if this triangle was inverted, discrimination broke down. If the upright triangle was rotated through 10°, discrimination, although impaired, was not seriously affected; if the rotation was as much as 20°, the number of correct choices fell to below chance level. Thus, once again, the results suggest that discrimination is in terms of the base lines of the figures. Fields tried to train his rats to discriminate between a circle and triangles in any rotation, but the amount of transfer of learning was extremely small; for example, it took 580 trials to learn the original upright triangle, a further 500 to learn the left rotation, 240 to learn the right rotation, and 230 to learn the inverted triangle.

The evidence suggests, however, that transfer, albeit very small, does occur, particularly in the latter stages of the training; that this is not avoidance of the negative figure is demonstrated by the fact that substitution of a cross, square or rectangle for the circle does not impair discrimination. There is considerable transfer from an equilateral triangle to a right-angle triangle.

It appears, therefore, that the base line of the positive figure is an important factor in form discrimination learning; minor alterations, such as changing the size of the base line angles from 60° to 45°, do not impair discrimination, while major alterations, such as changing the angle of the base line to the horizontal, do. Thus, the figural elements essential for discrimination gradually emerge.

Further work indicates that the base line angles themselves are not necessary for discrimination; Fields found that there was good transfer from a solid triangle and circle to an outline triangle with the corners missing (), which was paired with vertical striations. The base line is preserved, and reaction is to the positive figure, so the animals were still able to discriminate in terms of previous learning.

When outline figures were substituted for the solid triangle and circle, Fields, like Lashley and Reetz, found that there was excellent transfer; this supports the theory that discrimination depends on form rather than brightness.

Investigations in size variation suggested that, when rats were trained on an inverted and an upright triangle, or on an upright triangle and a circle, transfer was better when larger figures rather than smaller were substituted; although transfer to smaller figures did occur, it was not so successful. Fields also trained raccoons on a triangle and circle, and these animals showed good transfer when the size of the figure was changed independently. Alterations in the size of the negative figure had little effect, but the results were noticeably poorer when the positive figure was reduced in size. Here again there is reaction to the positive figure only. Among the rats, those with the most over-learning were the most accurate in discriminating size.

Like Lashley, Fields found a complete lack of transfer when the figure-ground relationship was reversed. He trained the rats to relearn the reversal, and found that this required more trials than the original learning. However, an interesting result was obtained: two rats, who succeeded in relearning this reversal, then transferred to other orientations of the triangle, although they had failed to do so originally, and had received no differential training on rotations with the reversed figures, but only on the originals. Fields suggests that the mechanism for shape discrimination is different from that for brightness discrimination, an observation borne out by the ease with which brightness discrimination is learnt in comparison with form discrimination. He goes on to say that the original failure to transfer from white figures on black to black figures on white was due to the new figures being placed in different categories from the originals with the change in brightness. This does not explain the recognition of the rotated figures; however, Fields implies that a point in time arrives when suddenly the rat is aware of the shape per se, unrelated to the brightness aspect, and that when this occurs, the concept of triangularity has been formed; thus, any rotated triangle is recognised for what it is. It is perhaps worth noting that the formation of this concept took over 40,000 trials altogether, which suggests that it is difficult to achieve. Unfortunately, no other work either for or against this point of view seems to have been published yet. The problem has now become one of cognitive rather than perceptual discrimination, and requires further investigation along these lines. Of particular interest is Fields' observation that overtraining established a reaction to a position but that it was detrimental to establishing a reaction to triangularity as a concept; this is in direct contrast to the relationship between overlearning and size generalisation.

Reetz (1957) obtained results totally opposed to those of Lashley and Fields; with figure-ground reversal, he obtained good transfer with rats and slight positive transfer with mice. It would be interesting to know whether his animals were subjected to overlearning or not. The problem of figure-ground reversal still appears to require investigation.

Munn's evidence on visual discrimination in the rat is again relevant, chiefly because of its having been obtained from two different types of apparatus.

The preliminary work was done principally at Lashley's request; Munn's (1930) rat was trained primarily to discriminate an upright triangle from an inverted triangle. Like both Lashley and Fields, he used a jumping stand and found that there was excellent transfer from the solid forms to their outlines. However, when the angle outlines only were presented, and the sides omitted (∧⌞⌟ , ⌜⌝∨), there was no transfer; similarly, omission of the horizontal line in both triangles (∧ ∨) caused a breakdown in discrimination; thus, the emphasis is again laid on the base line of the positive figure. Munn also found that when he presented the bases of the triangles (— ∨) he obtained transfer, but there was no transfer to the tops (∧ ‾). This suggests that the position of the base line on the symbol card itself is important, since raising it (which is the effect of presenting the tops of the figures in this case) impairs discrimination.

Munn (1931) then used a different type of apparatus, and, like Lashley, found that his rats failed to distinguish between a square and a circle. This result is valuable, since, having been obtained from a different type of apparatus, it detracts from the objection that, until now, all the results were similar through the experimenters having used the same technique. Again, like Lashley, Munn obtained discrimination between horizontal and vertical striae, and between triangles in different orientations. However, he also found that if a rectangle of equal area, brightness and base line was substituted for the original positive triangle, the rats transferred without difficulty; when a diamond was substituted for the negative figure, response to the rectangle still occurred. Response to the base line only has apparently taken place.

Later, Dodwell (1957) discovered that rats could learn to discriminate between a square and a circle if they were first trained to discriminate between horizontal and vertical striations, with the horizontal positive; the square was then positive in the succeeding pair. This discrimination was transferred without difficulty to an upright triangle and circle, but not to an inverted triangle and circle. These results again support the base line hypothesis, and suggest that the failure of Munn's and Lashley's rats to distinguish between a square and a circle was caused by the similarity in the base line. It is also apparent that the reaction, as before, is to the positive figure and not to the negative.

Dodwell's work on size generalisation supports Fields' results, in that he found that rats transferred discrimination more easily to larger figures than to smaller ones. However, since all Dodwell's work was done on outline and not on solid figures, his results cannot be taken as being strictly comparable, although it is obvious that the trend is in the same direction.

The broad conclusions which emerge from these results are as follows: brightness discrimination is considerably easier than form discrimination. However, form discrimination is possible; it depends upon an approach reaction to the positive figure rather than upon an avoidance reaction to the negative figure. The base line of the figure is the most important feature, discrimination depending upon this and not upon the whole figure. Discrimination is in terms of form rather than of area brightness; it would appear that rats are only able to distinguish between gross base line differences.

C. Critical Discussion.

Lashley's contribution to the study of visual discrimination is important. He opened up a new field of investigation and in doing so did three things: he drew attention to the problem of visual discrimination; he produced a type of apparatus which was noted for its simplicity, and experimental advantages over prece~~e~~ding types; he also produced a large quantity of results which provided a pointer for future research workers, since they now had data upon which to build preliminary hypotheses. The importance of this work in its bearing upon the theories of learning and physiological psychology in general does not need to be emphasised. However, there are points at which Lashley's methods do not seem entirely satisfactory; because of the way in which his results may have been determined by his method, these need to be examined more closely.

The jumping stand is obviously limited in its application since it can only be used for small animals that are able to jump; it is therefore difficult to obtain strictly comparable results from different species, for example a rat and a guineapig. There is an added disadvantage in that the preliminary training period is, of necessity, long, since the animal has to learn when and where to jump. In its favour, however, extraneous cues are adequately controlled.

The fixed-distance for the observation of the symbols seems dubious; freedom of scrutiny in this apparatus is impossible, since the stand is both too small and too narrow to allow either movement or a sideview of the symbols; the rat is forced to remain at a set distance and to view the figures from a head-on position. This may have something to be said for it, in that the figures are always seen from the same position, and the movement variable is closely controlled. However, this control of the point of observation does not seem strictly necessary at this stage of the investigations; these types of apparatus with fixed distances are essential if discrimination distance is being measured, but, in many experiments, (for example Fields and Lashley) the aim was to determine the more basic factor of discriminative ability. It seems more sensible to establish the range of this ability first, and then to investigate its variables. Many of the visual discrimination experiments appear to be confusing the two, and, in doing so, the experimenters are possibly misinterpreting the results. It is surely more important to discover the initial range of this ability, and <u>then</u> to define the limits, as imposed by distance. This can only be done in an apparatus which allows complete freedom of scrutiny.

It might seem possible to justify Lashley's choice of discrimination distance from his work on the image-forming power of the rat's eye (Lashley 1932). Lashley worked with excised eyes: he apparently looked through the eye, and measured the distances at which he could obtain fairly distinct images, a technique which is perhaps rather rough and ready. Generalisation from the functioning of an excised organ to the functioning of the same organ in the intact animal may also introduce problems. However, allowing that the method does give some information, it appears that the far focal point of most of the eyes examined by Lashley, was about 8 cms. A fixed jumping distance of 25 cms. would not, under the circumstances, appear to be making the optimal use of the animal's visual capacity, especially if Duke-Elder (1958) is correct in his assertion that there is a lack of accommodation in the nocturnal eye. It is in fact difficult to see that the choice of scrutiny distance of 25 cms. was other than arbitrary.

Other problems are raised by the type of animals used in these experiments. These animals were: a) Wistar albinos, from hooded stock, b) McCollum hooded, interbred with albinos, c) Self-coloured agouti (F_3 & F_4) from an original cross of albino and wild pigmented. It is commonly agreed that laboratory stock is often myopic; this tendency cannot have been helped by the interbreeding with albinos; it is not known whether the gene for albinotic myopia is completely recessive. Eye defects in mutants, although often strongly linked with coat colour, have been shown to assort independently of the coat colour genes. Besides the possibility of myopia, Lashley reports that 30% of his rats were found to be suffering from eye defects. It is only fair to say that similar investigations of experimental animals used in other studies might have revealed a similar state of affairs. However, it does mean that his results must be viewed with certain reservations as to their general applicability.

It is perhaps worth noting that many of Lashley's rats were pretrained on horizontal and vertical stripes, and that this may have affected their response to later discrimination problems, particularly in view of the apparent base line reaction.

Finally there is the question of symbol size. The symbols in Lashley's experiments usually had a base measuring about 9 cms., although this was varied for some studies from about 11 cms. to 3 cms. The rat was placed either 20 or 25 cms. away. The span of vision required to take in both symbols adequately would be, from side to side, not less than ten inches; vertically, about three inches would be necessary. It is a little difficult to reconcile Lashley's experimental techniques with his physiological observations; for example, he Lashley (1932) states that the clearest angle of vision is probably about 16°. However, in the jumping stand, and with the size of symbols that Lashley used, an angle of over 60° is required in order for the animal to see both of the largest symbols clearly and at once; to see one symbol clearly, it would need an angle of 30°. An angle of 16° would only include one of the smallest symbols. One must assume that either Lashley relied on the rat continuously shifting its gaze, or alternatively, he may have considered that his estimated value for the total range of the binocular field, namely 117°, (see p. 74) was adequate for this type of discrimination. If we accept his calculation that 101° of the 117° binocular field was hazy vision, it is hard to see why he chose symbols of this size. On the other hand, if Duke-Elder's (1958) estimation of the binocular fields in the rabbit and squirrel is nearer to that of the rat, it is likely that uniocular vision must have been used to a great extent; in this case, presumably some scanning motion of the head would be essential to cover the area given by the stimulus.[1]

What seems to emerge from this is that it is unlikely that the rat would be able to look at the whole figure easily, and parts of it might assume a rather artificial importance. The base lines were roughly on a level with

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[1] According to Lashley, (1938), the average minimal angle for resolution of two points at a distance of 20 cms. was 1°41', while the minimal visual angle for acuity was 26' in the pigmented rat and 52' in the albino rat (Lashley 1930b).

the animal's head, and, in most cases, they may have provided an adequate guide as to its choice. This would perhaps account for the confusion between the square and the circle reported in these experiments; the difference between the base line of the square and the curved base of the large circle would be slight if seen from a distance by a myopic subject. Once the square is rotated through 45°, the animal learns the discrimination rapidly; this is understandable, since an angle has now come within its immediate range of vision, and the difference between the two base lines is marked.

Lashley (1938) remarked on the apparent presence of a sensitive area in the upper inner quadrant of the retina, which might be responsible for better vision in that area; it determines the line of fixation of the rat's eye at 50° from the optical axis. This is quite possible, but it is difficult to arrive at a criterion for "sensitive". It is likely that central vision is better than peripheral vision, but how bad is the peripheral vision? Is the rat sensitive only to light changes peripherally and not to form? At present, there seem to be no satisfactory answers to these questions.

Results have shown that rats will, however, eventually learn to discriminate a square from a circle; it therefore appears that the animal is capable of responding to the form as a whole when it is necessary, or possibly of responding to the whole of the lower half rather than just to the base line. The lack of confusion between a triangle and a circle suggests that the pointed corner angles are possibly important. On the other hand, the animal may respond to some extent to the whole of the figure within its visual field; thus, the apical point of the triangle would be fairly distinct, and its width within the visual range; it is unlikely to be confused with the circle. There is a definite point of fixation (the apex) on the vertical axis, which, from Lashley's experimental results, would appear to be more important than the horizontal axis; there is no such point on the square. This is an alternative explanation for the ease with which a rotated square and a circle are learnt. Dodwell's (1957) results indicate that it is possible to direct the animal's attention to the properties of the square by preliminary training, thereby speeding learning; however, his results cannot be said to contribute much to the problem of discrimination between solid figures, since he only used outlines. Therefore, training on horizontal stripes enables transfer to the single horizontal line forming the base of the outline square; this merely confirms Lashley's findings on the ease of transfer from striations, particularly since, according to previous evidence, rats respond only to the base line.

Fields' original work on the modified Yerkes' apparatus is susceptible to criticism on the grounds suggested by Munn, namely, that apart from the lack of information in Fields' paper, there were many tactile, olfactory and auditory cues available. One major criticism was that the rats were unable to see the tops of the forms at all under certain conditions of illumination. However, Fields later adapted the Lashley technique, with slight modifications; the most important was the replacement of the circular jumping stand by a rectangular bridge in both the two- and five-choice jumping apparatuses. This allowed for greater movement and some exploratory drive; it was also equidistant from all the figures. Unfortunately, however, Fields found that a rat faced with a difficult discrimination problem sometimes refused to jump; he therefore tweaked its tail to encourage it. This probably had the effect of making the rat jump indiscriminately, and may have affected the results.

Nevertheless, the five-choice apparatus appears to be a more sensitive instrumant, particularly in the five-unit form in which it appeared in 1953. Fields claims that learning is quicker, retention better and accuracy higher; the statistical sensitivity is an important factor. He obtained discrimination of 1 mm. striae with albino rats, at a distance of 21 cms., supporting Lashley's assessment of their visual acuity. Nevertheless, Fields is still open to many of the major criticisms that apply to Lashley: his apparatus is restricted in its application; he uses large symbols (28 sq. cms.); he employs a fixed distance for scrutiny. Admittedly, Fields' five-unit five-choice apparatus is described as an instrument for measuring the effect of radiation, or some other controlled variable, on discrimination; this is quite acceptable, but it would seem advisable to have apparatus capable of being used to investigate visual discrimination per se, since this field of study still presents a great number of problems.

Munn's (1930) original work with the jumping stand is not very reliable, as he only used one rat; however, his results support those of Lashley and Fields.

Munn (1931) later used a two-choice apparatus with a continuous approach. This apparatus is adaptable to many species of animals, since it is not confined to the jumping varieties; tactile and olfactory cues appear to be adequately controlled. However, an electrical grid was used to provide shock as punishment for a wrong choice; although there is no apparent fixed choice distance, it is likely that the rat would try to choose before it stepped onto the grid; the possibility of a fixed distance effect might therefore occur, since there is no complete freedom of scrutiny. Apart from this, the effect of shock on discriminative behaviour is possibly adverse. (see pps. 66 - 68). The size of the symbols was similar to those used by Lashley and Fields.

Dodwell's (1957) results are of interest, but there is too little information in his paper for it to be of much assistance. Firstly, he used outline figures, which makes comparison with other peoples' results difficult. This was done for a theoretical reason, namely that Lashley's rats might have been responding to the distribution of brightness rather than to form. This is odd, since the excellent transfer from the solid forms to their outlines, demonstrated by all the experimenters, would seem to contradict this notion.

Secondly, he does not state what the widths of these outlines were, but merely that they were constant. Thirdly, he gives no measurement for the jumping distance, and one must assume that, like Lashley, it is either 20 or 25 cms. Fourthly, the figures were raised on the background, and the depth of the material is not given; the introduction of a third dimension seems to introduce extra variables, and to confuse the original problem. Finally, two out of twelve animals were discarded during the experiment: it would be interesting to know for what reason.

Here again, the results are difficult to interpret, due to lack of information, the use of a fixed choice distance and large, outline symbols.

D. Summary.

From the relevant literature on visual discrimination in the rat, it appears that brightness and form discrimination both take place, although the latter is more difficult to achieve. Simple geometrical forms can be discriminated from one another, whether they differ essentially in shape, or only in orientation. Results indicate that form discrimination is determined by the base of the figure rather than by the whole, and that generalisation to differences in size and from solid figures to their outlines is relatively easy; the response is one of approach to the positive figure rather than of avoidance of the negative figure. Breakdown in discrimination occurs when the positive figure is rotated, when only the tops of the figures are presented and when the brightness relationships of the figure and background are reversed.

Examination of the techniques used to obtain these results suggests two things: firstly, the response to the base of the figure may be an experimental artifact introduced by the large size of the symbols. Secondly, the animal's response apparently depends primarily on gross base line differences; this type of response may be affected by myopia, lack of lens accommodation and therefore by the arbitrarily fixed distance for scrutiny.

III THE GOLDEN HAMSTER

A. Introduction.

This section has been introduced partly to supply information about the hamster which may not be readily available elsewhere, and partly to discuss some variables which are relevant to the learning situation involved in the discrimination tasks to be described later. This second aspect has been developed at some length, since little attention seems to have been given to these variables, and it is felt that they may be more critical for the success or failure of the experiment than is usually allowed. Further, as previous workers in this field seem to have assumed that rats will only learn under conditions of maximal stress, the type of motivation used in this research represents so radical a departure from the standard procedures as to require some justification.

B. Physical Characteristics.

1. Species

The golden hamster (Mesocricetus auratus, Waterhouse 1839) belongs to the order Rodentia, family Muridae, sub-family Cricetinae (Ellermann 1940). The animal is a native of Syria, and the present population of animals in captivity is descended from a female and her litter found near Jerusalem in 1930; the genetic purity of the stock is therefore rather exceptional. This species of hamster is closely related to other hamster species in Asia and Europe, and differs chiefly in being smaller and less savage (Hindle 1947).

Mutations in both coat and eye colour have occurred during breeding in captivity, but the agouti wild type is genetically dominant; it was this type that was used in this research.

2. Appearance

The wild type golden hamster is a small animal measuring between 10 and 15 cms. from nose to tail, and weighing about 150 gms. when fully grown. The head is squarish in shape, the nose is less pointed than in a rat, while the eyes are large, black and prominent. There are two bilateral cheek pouches, used for carrying nesting material, food and other small objects. The short tail measures about 1 cm. in length; the small legs are held close to the body.

The fur is soft, short and thick; the top coat of the back and head varies from light to dark red-brown, while the fur on the belly and legs is light grey or white; the undercoat is a mid-grey. A crescent of black fur stretches from the sides of the neck under the chin.

C. Behavioural Characteristics Relevant to the Discrimination Experiments.

Hamsters are semi-nocturnal animals, and, as such, exhibit a typical activity cycle. Although they can be woken easily at any hour of the day, they tend to be most active in the morning or evening twilight, this activity lasting for two or three hours at a time. (Lawlor 1961).

The optimum temperature for golden hamsters is from 70° to 75°F.; extreme variations in temperature can cause behavioural deviations such as hibernation. However, under the laboratory conditions in which these animals were kept, a constant temperature of 72°F. was maintained throughout the experiments.

Golden hamsters can be fed satisfactorily on fresh green food or root vegetables, together with a continuous supply of a balanced dry commercial diet (MRC 41 B and SG 1). They drink little or no water, provided they have enough fresh greenstuff. The food is hoarded in large quantities and stored near the nest; only one or two ounces of food are actually eaten a day, in small quantities at intervals during the 24 hours; however, the amount hoarded may be as much as five times the hamster's own body weight (Waddell 1951).

Two other behavioural aspects directly relevant to the work to be reported are jumping and washing. Owing to the hamster's relatively short and delicate back legs, and the lack of large femoral muscles, the springing jump does not usually exceed a few inches. This type of jump is apparent in two situations: firstly, it may occur in moments of stress, such as unaccustomed restraint through handling, or a sudden unexpected noise or movement; it is then undirected, the hamster launching itself haphazardly into space. Secondly, a hamster, when perched on top of a suitable object, may try to jump from this onto the top of the surrounding apparatus wall or onto another object. When doing this, an animal can be seen assessing the distance before the attempt; the maximum distance it can cover is about four to five inches. A final type of jump could more justifiably be called a drop; this the hamster does frequently if given the chance. The animal allows itself to slide over the edge of the surface until it is holding on by its back legs; it searches for a further foothold, and, if none is available, lets go and drops. Due to an apparent lack of adequate righting reflexes and possibly to a delicate skeletal structure, this can result in broken limbs, concussion and even death. However, such drops usually only occur when the animal is familiar with the situation, and when it can see enough to form some idea of the depth involved; drops into the black unknown do occur, but are much less frequent. (See Section V).

Washing is important in that the two types observed give some idea of the hamster's state of agitation. The prolonged washing, for grooming purposes, only takes place in environments with which the animal is thoroughly familiar and at ease. This grooming is thorough, slow, relaxed and intent, and the animal is often impervious to environmental changes in the way of noise and movement. The grooming often lasts for 20 minutes or more, and is succeeded by a long, slow stretch.

The second type of washing can more accurately be called displacement activity. This occurs in situations where the animal is agitated or frustrated, and is a parody of the grooming procedure. The washing is usually restricted to the head, and is performed in short, sharp jerky movements. The whole procedure may only last a few seconds, and is often succeeded by violent activity, such as rushing about, or scrabbling at the walls of the apparatus.

Although more traditional measures of emotionality (Hall 1934) such as urination and defaecation, might have been thought more critical than displacement washing, in fact, displacement washing seems to give a better measure of emotionality in the hamster. In two unpublished studies performed in this laboratory, it was found that, in the open field, urination never occurred and defaecation was very rare; when it did occur, it did not appear to be a very good indication of emotionality since there was little correlation between its occurrence and refusals to take food. In a repetition of Hall's (1934) original validating experiment on the open field with 10 hamsters, defaecation occurred twice out of a 100 possible occurrences; on both occasions the animals concerned did not refuse to eat.

However, increasing the stress value of the open field by confining the animal in a small wire cage in the centre of it had no effect on defaecation and urination scores, but it increased the incidence of displacement washing significantly ($p < 0.01$). It seems, therefore, that displacement washing is a more accurate index of agitation.

D. Handling as a Variable in the Discrimination Experiments.

Several recent investigations (Levine 1960, Bernstein 1952, 1957, Bovard 1958, Weininger 1956) suggest that animals that are handled in infancy show greater resistance to stress in adult life than those which are not; these handled animals show less emotional reactivity, greater exploratory drive and fewer errors in maze-learning, supporting Bovard's hypothesis that early handling raises the threshold to later stress, through reduction of the pituitary, adrenal and sympathetico-adrenal medulla responses. It seems, therefore, that early handling of experimental animals is advisable, if the learning capacity is not to be blocked by excessive emotional reaction to the testing situation.

It was on this basis, therefore, that all the hamsters used on the experiments reported in this thesis were handled for about ten minutes a day for two weeks, prior to any training in experimental situations. However, the hamster resists being picked up more than the rat; although it is amenable to handling for a short time, prolonged handling in experimental situations results in wriggling, violent efforts to escape, and a marked increase in the level of agitation. This resistance is probably due to several factors: the skeletal structure of the hamster is considerably more flexible and delicate than that of the rat, and with its narrow shoulders, the hamster is able to wriggle out of any hole the size of its neck; it is therefore difficult to find any really firm structure by which a wriggling hamster can be grasped, and this results in overall pressure which probably hurts it. The thin skin, with its soft fur and almost complete lack of guard hairs, is probably sensitive to touch; intense human smell is possibly unpleasant. Whatever the reasons, however, the hamster dislikes excess handling, and this shows itself in apparently purposeless activity, such as scrabbling and displacement washing.

These observations indicate that, although the hamster is docile and easy to handle in relatively undisturbing situations, in experimental situations which are emotionally disturbing in themselves, it seems advisable to reduce the amount of handling as much as possible. Thus, the agitation level would not be increased still further, and more available energy would be directed towards the learning of the problem rather than being dissipated in purposeless activity.

The problem of excess handling was reduced in two of the preliminary experiments (see pps. 101 and 125) by introducing multi-unit apparatus. However, handling was not eliminated entirely until the final experiment (see pps. 136 ff.).

In this case, a simple procedure involving a plastic mug was adopted. This had been found to be very successful when used in experimental classes by students who were unaccustomed to hamsters; an untrained animal could be carried by an inexperienced person with the minimum detriment to either.

The procedure was therefore as follows for the final experiment: the animals were handled manually for about three weeks before the experiment. During the experiment itself, they were transported in the mug. All animals rapidly learnt to enter the mug, and to turn round inside so that they faced outwards. The experimenter's hand was placed loosely over the top as a precaution. However, wriggling and pushing was rare, and the hamsters travelled quietly. Thus, the environment in which they were carried was always constant and there was no tight restraint at any time.

The success of this type of handling was apparent when the behaviour of Groups I and II on the Serial Multiple Visual Discrimination Apparatus (SMVDA) (see pps. 124 ff.) was compared, Group I being transferred by hand and Group II by mug. The amount of scrabbling, displacement washing and the general level of agitation was considerably reduced in Group II, and, unlike Group I, there was never any 'freezing' or motionless withdrawal in the experimental situation. With Group I, the experimental session sometimes had to be terminated before it was complete, since the animals were too agitated to make it worth continuing; this never occurred with Group II.

It would appear, therefore, that early handling is important for raising the stress response threshold in adult animals, and for training them to become accustomed to the experimenter and consequently relatively docile. However, excess handling in a situation which is already disturbing (such as the learning of a discrimination problem) apparently acts as a further threat, and learning is retarded by agitation (Tolman 1954). Elimination of handling in the actual experimental situation produces a marked decrease in this agitation, and therefore, presumably in the cortico-adrenal output. This seems advisable, in view of the physiological damage to internal organs which prolonged stress can cause. (Selye 1950).

E. Motivation in Experiments Which Involve Complex Learning.

1. The use of exploratory drive as a source of Motivation.

Previous experience in this laboratory had established that hamsters could be adequately motivated for simple learning tasks, by rewarding their curiosity. Confinement in a 'dull' environment with the possibility of reaching a more 'interesting' area produced efficient escape learning. (Lawlor 1959). It was felt that it was worthwhile attempting to use this sort of motivation for the complex learning task involved in this research rather than resorting to the stronger, more classical forms of motivation such as shock, food deprivation and so forth.

The reasons for this were twofold: firstly, there is certain theoretical interest in establishing the limits of the efficacy of mild motivation of this kind in complex learning with a Rodent species. Secondly, a hamster, in comparison with a rat, is easily over-excited, and under conditions of strong motivation, the agitation level is likely to rise so steeply as to make the animal impossible to work with in experimental situations. Tolman's (1954) suggestion that agitation, or excessive emotional arousal, disrupts the learning process is supported by general observation of hamsters. There seems to be a point beyond which a golden hamster cannot become accustomed to an unpleasant situation, however much training and preliminary handling are administered to raise the stress threshold.

On this basis, exploratory drive was used as a means of motivation. The golden hamster in captivity is notable for its curiosity; it will spend most of its waking time exploring its environment and attempting to escape from its cage. In a new environment, every aspect is subjected to a thorough and persevering examination, by means of smell, taste, touch and sight. Even when an animal is familiar with an environment, each day means a fresh investigation. Hamsters are alert and interested in all that is going on around them, and will climb any available object which will give them a view of the laboratory, even though this climbing demands a great deal of persistence.

This strong exploratory drive provides a consistent source of mild motivation. Although it appears to decrease when external stimulation is slight or absent throughout life, it is not entirely extinguished (Lawlor 1959). Among animals who are handled from an early age, it is marked and was found to be quite adequate in a complex experimental situation, where the only punishment is in the form of locked doors. In the later stages of SMVDA II (see pps. 136ff.) additional positive food reinforcement was offered, in the form of a very small piece of peanut; however, this did not appear to affect behaviour in any way, and in fact was sometimes totally disregarded by the hamster, the reward offered by the goal box being more important.

The goal box was designed to stimulate and sustain exploratory behaviour. Thus it was considerably larger than either the choice box or the living cage, and contained complex, novel stimuli. These stimuli were moveable, so that the novelty of the situation was maintained.[1]

In a short motivation study performed in the laboratory, the relationship of delay-of-escape times and reward times was investigated, the hypothesis being that variation in the length of these times would affect the strength of the exploratory drive. Only three significant results were obtained: firstly, that the animal's emergence into the goal box on the first trial of a block of trials was considerably slower than on succeeding trials in the same block, due to the choice box being explored; observations of behaviour in the visual discrimination experiments supported this finding. Secondly, with the minimal amount of delay time (the animal being released from restraint as soon as it was placed in the choice box), there was a positive linear relationship between the reward times and the emergence times; thus, the shorter the reward time, the quicker the succeeding emergence time. This relationship was lost when longer delay times were introduced. Thirdly, there were significant differences between the animals.

The important finding in relation to the visual discrimination work was the second one: the relationship

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[1] Work by Berlyne and Slater (1957) supports the hypothesis that exploratory behaviour is aroused by spacious, novel and complex stimuli.

between emergence and reward times. The graph (Appendix A) indicated that very short reward times would produce a quick dash through the apparatus. This was to be avoided if possible, on the grounds that the hamster would be unlikely to examine the symbols and would press doors indiscriminately; the agitation level would probably also rise. At the other end of the distribution, too long a reward time (three minutes or more) produced long emergence times, suggesting that the animal's exploratory drive was more than partially satisfied. In the face of a complex learning problem, therefore, it seemed likely that the hamster would remain in the choice box. On this evidence, a range of 1½ to 2½ minutes reward time apparently fulfilled the requirements of maintaining the hamster's exploratory drive at the most satisfactory level for problem learning.

2. Other types of Motivation.

It is possible to use other stronger forms of motivation, but this seems inadvisable in view of the agitation which such stress would produce.

Electric shock provides strong negative motivation which can be closely controlled; however, little work has been done on the effects of prolonged cutaneous shock. It has been shown that electroshock convulsion can disturb retention of complex tasks and impair maze learning (Duncan

1945; Porter and Stone 1947; Braun, Russell and Patton 1949). In view of such marked behavioural disturbances under these conditions, it seems unwise to assume that mild cutaneous shock has no effect on the electrical activity of the nervous system, (Brazier 1960) and the possible long-term effects seem questionable.

Other forms of negative motivation, such as air-puffs, buzzers, and falls, have been used; air puffs and high frequency sounds are liable to induce audiogenic seizures (Hall and Martin 1940; Humphrey and Marcuse 1939) while low frequency buzzers have little effect upon a hamster's behaviour (see pp. 101 ff.). The falls into a net, used by both Lashley (1930a, 1938) and Fields (1932a, 1953) are likely to produce physiological shock.

Strong negative motivation requires strong positive motivation to force the animal to make a response; water-, food-, and sex-deprivation are all possible sources of positive motivation. However, since the hamster drinks very little, water-deprivation is inapplicable. Food-deprivation, while starving the animal, also frustrates the strong hoarding-drive of the hamster, and this would cause marked distress; since the feeding requirements of the hamster are complex in comparison to the rat (Poiley 1950) it is very likely that food-deprivation would result in vitamin deficiency, which seems particularly ill-advised when investigating vision (Morgan 1942).

Observation suggests that use of the sex-drive as motivation would be difficult; animals are likely to become over-excited. Alternatively, among hamsters in laboratory conditions, the sexes are usually kept separate. Prolonged segregation can result in a marked decrease of the sex drive (Jenkins 1928) and under these conditions it is unlikely that motivation would be either adequate or consistent from one animal to another.

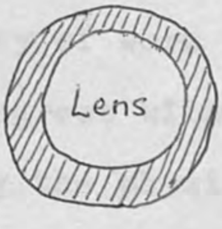
The argument against all these stronger types of motivation lies in the amount of stress they produce. Selye (1950) has shown that severe stress causes physiological shock in terms of adreno-cortical output; if prolonged, this can result in extensive physiological damage. Since the hamster's threshold to stress appears low in comparison with the rat, it was considered both wiser and kinder not to use these types of motivation if possible.

IV THE STRUCTURE OF THE EYE

There appear to have been no physiological investigations of the eye of the golden hamster, and in order to obtain some idea of the probable optical structure, it is useful to look at the available information on the Rodent order in general, and on the rat in particular. The rat is a closely allied member of the same family (Muridae) and provides a particularly useful comparison in that it is a semi-nocturnal animal.

The eye of a nocturnal vertebrate is characterised by several important features; these features affect the amount of light received, and the way in which this light is received.

The lens is normally large in proportion to the rest of the eyeball:



Dissection of a hamster eye has shown that the proportion of lens:eyeball is similar to that of a rat, and that the lens is almost spherical.

This enormous lens is essential in order that as much light can be gathered as possible from the dim surroundings; however, this in turn means that alteration in lens shape is difficult, particularly since the anterior and posterior chambers of the eye are, of necessity, small. Therefore, accommodation to both near and far distances is either lacking or feeble in nocturnal mammals; in fact, in most rodents, except for the squirrel, the ciliary muscles are vestigial, if not absent, while the suspensory ligament is well developed. This is supported by Lashley's (1932) observations.

It becomes apparent that the emphasis is on sensitivity to light rather than on sensitivity to form. Munn (1932) found that discrimination of brightness in the rat was excellent; in contrast Sgnonina (1936) mentions that, with guinea pigs, which are diurnal, the intensity of two greys had to differ by as much as one third before discrimination occurred. The majority of work on brightness discrimination in nocturnal animals agrees with Munn's findings, and further support is provided by the physiologists. Thus, the retina of the rat and mouse, both of which are semi-nocturnal, is rod-rich; it has a high proportion of rods to cones, probably in the region of 100:1. It is interesting to note that these cones have been found (O'Day, 1947), although they are few in number; this contradicts the earlier theories, which maintained that nocturnal mammals had pure rod retinas and, indeed, it seems easier, with the presence of cones, to account for the apparent occurrence of form perception.

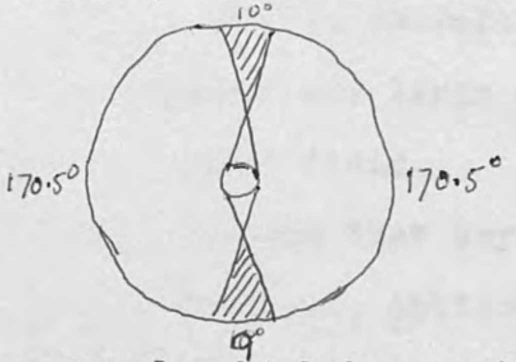
One would expect, on the foregoing evidence, that visual acuity would be poor by comparison with Primates. Physiological evidence on refraction suggests that, in natural surroundings, small wild mammals, such as rodents, tend to hypermetropia of as much as +7 to +10 dioptres; this particularly applies to the nocturnal types, who tend to rely on an appreciation of differences in illumination and in movement, rather than on imperfect pattern vision. Myopia in wild animals in natural conditions appears to be rare and sporadic, but among domestic animals, kept in hutches, such as guineapigs and rabbits a marked degree of myopia often develops. However, a brief investigation of a hamster's eye revealed no distinctive abnormalities in the way of myopia or lens deformation (see pp~~s~~. 79.).

Since emmetropic static refraction is necessary for achieving a high degree of visual acuity, the results obtained by Munn (1930, 1931), Karli (1954), Lashley (1930a, 1938) and others, are not surprising. In a series of training experiments, form discrimination in rats was found to be relatively poor; the minimum visual angle for a pigmented rat was 26' and for an albino rat 52' (Lashley 1930b), while the minimal visual angle for the resolution of two points was 1°41' (Lashley 1932). However, in view of the difference between the wild and domestic - and therefore, presumably, the laboratory - stock, these results are probably not very reliable, and Lashley remarks on the myopia of the eyes he investigated. However, the divergence of the findings as a whole from those on Primates (for example, the minimum visual angle in Man is 0.5') is so large that it seems reasonably safe to assume, on both physiological and behavioural grounds, that visual acuity in nocturnal rodents is poor.

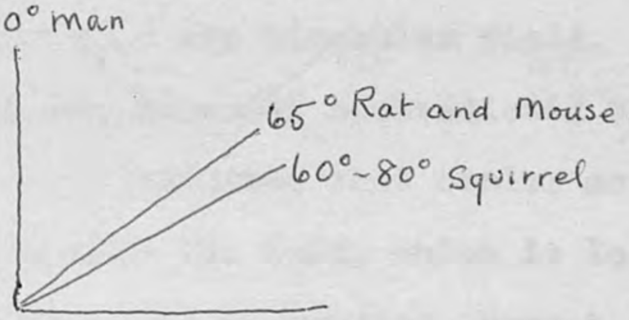
Further physiological work on the actual retinal structure indicates that an area centralis in the form of an ill-defined horizontal band exists in both the rabbit and the squirrel, which are diurnal. This area is assumed to assist visual acuity, since the receptor elements are more closely packed there than anywhere else in the retina. It is possible, however, that, in some nocturnal animals, this area may increase sensitivity rather than acuity, since, in a rod-rich retina, it is rods rather than cones which will be multiplied. There is apparently no fovea.

The poor degree of visual acuity in the lower nocturnal mammals is apparently supported by the lack of distance judgement shown by rats in an experiment by Greenhut and Young (1953). In this experiment, it was found that rats had little or no perception of distance when assessing the accuracy of jumps. Gibson and Walk (1960), on the other hand, used the visual cliff technique and found that hooded rats were able to perceive depth (confirming an earlier finding by Takatsuki (1937) with albino rats.) It is difficult to know whether the two experiments are measuring the same factor, since, in Greenhut and Young's experiment, the perceived distance has to be translated in terms of muscular activity; thus the distance judgement may be masked by poor co-ordination. Alternatively, distance judgement may be a refinement of depth perception, or possibly a separate ability altogether, although the latter seems less likely. A repetition of the Gibson and Walk experiment with hamsters (see pps. 83 to 95) indicated that depth perception was well-developed in these animals.

A major consideration in any investigation of vision is the ratio of the uniocular to the binocular field. The extent of the binocular field is determined largely by the position of the eyes in the head; thus, animals with laterally placed eyes have a smaller field of binocular vision than those with eyes frontally placed. The binocular field of the rabbit, according to Duke-Elder (1958) is approximately 10° in the front and 9° behind:



whereas in the squirrel, which has protruding eyes, the binocular field is 25° to 30°.[1] It seems likely that the hamster, whose eyes also protrude to a considerable extent, has a binocular field more closely approaching that of the squirrel than that of the rabbit. This is even more likely if the angle between the optical axis and the body midline is similar to that of the rat:



The uniocular field in vertebrates appears to be relatively constant, averaging in angular size about 170°.

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[1] Lashley (1932) maintains that, in the living rat, the binocular field may extend to as much as 117°. This seems a little hard to reconcile with Duke-Elder's measurements for other Rodents.

Lashley (1932) states that it is as much as 207° in the dark-adapted pigmented rat eye, but that this is considerably reduced as illumination increases, and the size of the pupil decreases. It is likely, therefore, that the uniocular fields in the hamster are large enough for an overlap to occur to form a binocular field.

It is a mammalian feature that any ocular movement, whether it is lateral, vertical, oblique or convergent, is always conjugated. However, this movement is restricted in the lower classes, such as Rodents, and Duke-Elder (1958) suggests that the eyes of the mouse and rat are motionless, possibly because vision is poor everywhere; even the squirrel, with a cone-rich retina and good acuity, has very little ocular movement. This lack of movement is compensated by head movement to some extent, so that the object of attention is brought into the binocular field. This suggestion is, however, directly contradicted by Lashley's (1934) evidence, which indicates that ocular movement in the rat is good, and that the bulb, which is loosely suspended in the orbit, can be rotated through at least 90° without strain. According to his observations, the extrinsic muscles, of which there are four rectus and two oblique, are large, suggesting good control of movement. Ocular movement in the hamster has been frequently observed, and can be great enough for a crescent-shaped band of grey conjunctiva to be seen in either the nasal or temporal orbital regions.

Lashley draws attention to the rat's power of protruding its eyes, so that as much as two-thirds of the bulb may project beyond the orbital edges. When the lids are tightly closed, the eye is retracted into the orbit until the corneal surface is almost flush with the superorbital ridge; the pressure of the lids appears to be the chief factor in retraction. The golden hamster also has the power of protruding its eyes when necessary; thus, a sleepy hamster's eyes are almost flat, while the eyes of a fully alert animal protrude very noticeably; it is possible to watch the eyes become more prominent as the animal wakes up. Both uniocular and binocular fields are presumably increased as this occurs; the eye is also capable of receiving a greater amount of illumination.

It would appear, then, that the nocturnal eye is attuned to a high development of light sense, rather than to visual acuity. The optimal environment for a nocturnal animal is in either the morning or evening twilight, and it depends essentially on senses other than vision. Form vision need only be crude, since only hazy outlines are visible; colour vision would not be particularly useful. Brightness discrimination and perception of movement are of considerably greater importance, and it is to these ends that the nocturnal eye seems peculiarly adapted.

General observation suggests that these physiological features, characteristic of the Rodents, apply to the golden hamster. Behaviourally, the olfactory and auditory senses are more important than the visual, in that the hamster appears to discriminate between sounds and scents to a very high degree; unfamiliar, slight sounds attract immediate attention, while the scent of other hamsters can be picked up easily after a long interval; any unfamiliar object is thoroughly investigated by both smell and touch. Observation indicates that vision is subsidiary to these senses, and that the hamster is mildly photophobic; however, any sudden unusual movement on the part of the experimenter, from a few inches to several yards away, is immediately noticed, and it appears, from results to be reported later in the text (see p.83ff), that vision is also important in assessing depth. No experimental work on the relative importance of the olfactory, auditory, tactile and visual senses has been done, and these comments are based on general observation.

V PRELIMINARY INVESTIGATIONS

A. Introduction.

Before investigating visual form discrimination in an animal about which relatively little is known, it is necessary to enquire into the basic aspects of this animal's vision. As the hamster is a semi-nocturnal animal, it seems likely that its visual capacity, being of secondary importance, is more limited than that of its other senses (see p.76). It therefore seemed advisable to try and ascertain some of the limits of this capacity, before trying to teach the animal a problem which might possibly be beyond its capabilities.

There appeared to be two important basic aspects of vision to be investigated: first, it should be possible to determine whether there are any marked eye abnormalities common to, or occurring frequently within, the species; this seemed particularly necessary in view of reports of this having been observed in previous studies on rats (Lashley 1938). Secondly, some knowledge of the limits of visual acuity was required, in order that the visual discrimination problems to be presented could be kept within the bounds of the animal's capabilities. Finally, a further aspect of vision which could be easily investigated was perception of depth; it seemed advisable to do this as well so that as much general information as possible could be obtained.

B. Eye Examination.

Three golden hamsters, which were being used in a current experiment (for details, see appendix B), were taken to the Department of Pathology at the Institute of Psychiatry.

Under the direction of Dr. W. Brierley, each animal was anaesthetised; one eye was then relaxed with atropine, and examined with an opthalmoscope.

No eye abnormalities were observed during this investigation; it also appeared that hamsters were not markedly myopic. It was interesting to note, however, that considerably more atropine was required to relax a hamster's eye than the eye of an albino rat.

C. Visual Acuity.

No method of investigation other than that proposed by Smith (1937) appeared to be available. Briefly, the animal is held in a firm stationary harness, which is placed in the centre of a rotating cylinder of black and white striae; the animal has a pointer attached to the end of its nose to record head movements. Theoretically, the animals show reflex movements of the head and eyes to perceived movement, and so it should be possible to establish the limits of their acuity. An experiment was therefore attempted along these lines.

In connection with investigating acuity, it seemed possible that a hamster, being a nocturnal animal, would probably see better in a weak light than in a strong; the effect on visual acuity of alterations in illumination had therefore to be investigated as well. Thus, although it was not known whether the strength of illumination was really important, it seemed wiser to investigate the possibilities of an optimum light value in order that the discriminative ability could be determined as accurately as possible, and so that the results of the main experiment would not be partially invalidated through using the wrong illumination.

The precise aim of this experiment, which is reported in Appendix C , was to determine whether a golden hamster has sufficient visual acuity to discriminate 2° stripes at a distance of 28.6 cms., and if so, the optimal value of illumination necessary for this discrimination.

The apparatus (see plate I.) consisted of a cylinder lined with black and white stripes; this cylinder, which

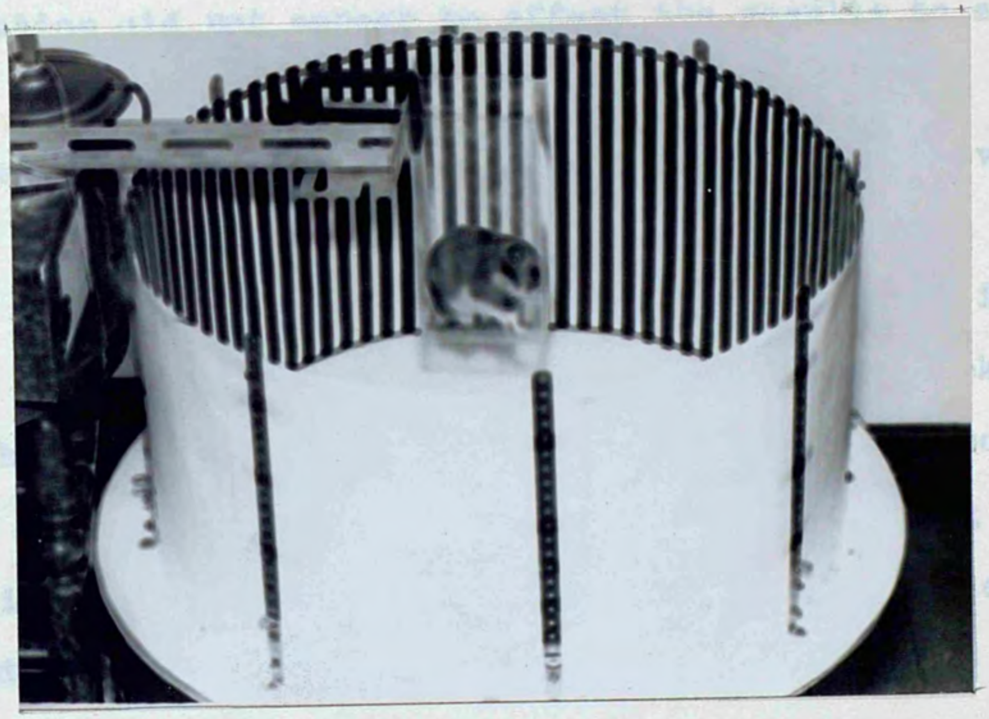


Plate 1. Hamster in visual acuity testing apparatus (after Smith 1937)

was evenly illuminated, rotated independently of a central perspex box. The animal under investigation was placed in the perspex box, and its reactions to the rotating drum, in terms of reflex head and eye movements, were observed.

General observation of three animals suggested that they were able to see the stripes; the intensity of illumination did not appear to affect the results to any extent.

These results must be treated with reserve, however, for two reasons: since it is impossible to harness a hamster satisfactorily, the animal moved continually in the perspex container; it was therefore difficult to pick out reflex head movements from gross body movements. Also, the iris of the eye is large and dark, apparently merging with the pupil, and so making it difficult to observe reflex eye movements. Both of Smith's criteria were therefore inapplicable.

The only criterion, apart from a few subjective judgements as to reflex movement, was the phenomenon mentioned by Smith, in which the animals appear to become comatose after a few minutes in the apparatus. All three hamsters used in this experiment became lethargic; assuming that this was caused by the regular movement of the stripes, this phenomenon can possibly be taken as some sort of a criterion - in which case, with an illumination provided by 100 to 220 volts, through a 60 watt 240 volt bulb at a distance of three feet from the animal, hamsters appeared to be able to see 2-degree stripes. The whole basis of this criterion is so shaky, however, that the experiment was not pursued much further.

However, this experiment does serve to pinpoint some of the problems that arise when visual acuity is being investigated. An objective method is required, which, like Smith's, is quick, does not require pre-training, and which gives a behavioural measure of acuity, but which is also applicable to all animals, and not just to those which can be easily handled and controlled.

D. Perception of Depth.

This was a further possibility for a preliminary investigation of basic processes, and one that could be studied relatively easily. It was felt that, although hamsters are nocturnal and therefore are more inclined to rely upon tactile and olfactory cues than upon visual cues, it was possible that they were similar to rats in that they could rely solely on visual cues when necessary. Gibson and Walk's (1960) visual cliff technique was therefore employed to investigate depth perception in the hamster.

Forty-two hamsters were used in this experiment;

details are given in Appendix B . They included animals of both sexes and of different ages.

1. Apparatus.

The apparatus, (see Plate 2) was a smaller version of Gibson's, consisting of one fixed horizontal surface placed 3 feet from the ground, and one moveable surface whose distance could be varied to any one of four positions. Both surfaces were covered with contrasting squared material, and were joined by a "cliff face" of the same stuff. The whole of the top of the apparatus was covered with one continuous sheet of plate glass, and the surfaces were divided by a platform (2" deep, 3" wide) placed on top of the glass, this platform being also covered with the squared material. The glass was bounded by an 8" deep surround of hardboard, to prevent the animals from falling onto the floor; the entire apparatus was built on a dexion framework, and was moveable. Further details of this apparatus and a diagram are given in Appendix D .

The illumination was kept as even as possible by using one overhead lamp, and six wall anglepoise lamps, so placed that both surfaces received approximately the same amount of light; the photometer reading for incident light received by these surfaces was 17 fc.

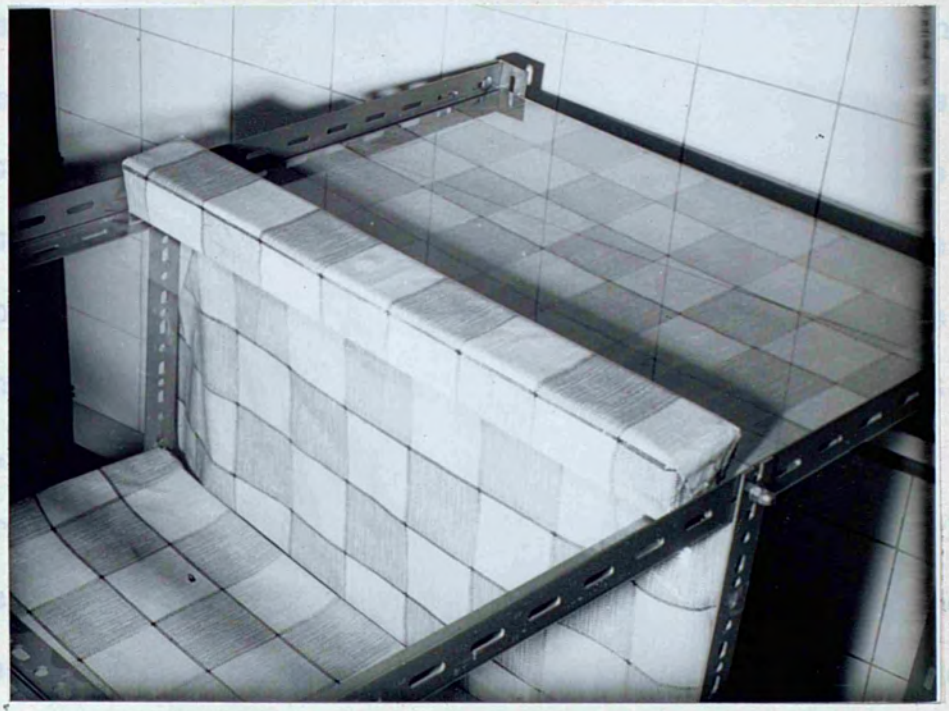


Plate 2. Visual cliff apparatus (after Gibson 1960)

2. Design of Experiment.

The following variables which might have affected the animals were controlled: the illumination was kept constant throughout the experiment; the animal was always placed in the centre of the platform facing away from the experimenter; the animals were transported from cage to apparatus and vice versa in a plastic mug, thus making the conditions as nearly identical for each animal as possible; the sheet of glass was wiped after each block of five animals to reduce olfactory stimuli; and finally the design of the apparatus ensured that the platform was deep enough to prevent the hamster from feeling the glass with its whiskers.

There was some doubt about the efficiency with which the olfactory clues had been controlled, but test experiments with a few animals in which the whole surface was made to look solid suggested that they did not follow the scent of other animals; however, there is still a slight possibility that smell may have been more important than it appeared. One other uncontrolled factor in this experiment should perhaps be mentioned: a few of the hamsters appeared to lose their balance on the platform (which was narrow and slightly slippery); in this case they often slipped backwards onto a surface they were not looking at. In fact this did not happen very often, and when it did, it was recorded as a response to that side.

In the design of the experiment, the order of presentation of the various depths of cliff, the position of the experimenter and the possibility of learning were all taken into account. The design was as follows: the forty-two animals were divided into 9 groups; eight groups had five animals in them, while the remaining group had only two.

Using a Latin square of ABCD, where each letter denotes a specific cliff depth, each group of animals was put through a different sequence of depths. The presentation was therefore as follows:

Key to letters	Latin square	Order of groups of animals
A: 24" cliff depth	A B C D	1, 5, 9.
B: 12" cliff depth	B C D A	2, 6.
C: 6" cliff depth	C D A B	3, 7.
D: 18" cliff depth	D A B C	4, 8.
E's position - by apparatus	Left Right	

E's position relevant to the apparatus was thus distributed equally over the cliff conditions; she stood on a different side for each half of each block.

Each block of animals was tested as follows: with the cliff depth adjusted to the requisite height, the animal was released in the centre of the platform separating the two surfaces. After it had made a response by climbing from the platform onto one or other of the surfaces, it was returned to its cage. If, however, the animal remained on the platform for more than 3 minutes, it was removed and a non-response was recorded.

When the five animals had been tested on the one depth, the cliff depth was altered, and the procedure repeated until all four depths had been tested. All 42 animals were tested during the same day, and no animal was given the same depth twice.

3. Results.

The results were recorded as follows:

S - animal chooses solid side
C - animal chooses cliff side
R - animal remains on platform
R_1 - animal walks on edge of cliff side

R_1 was introduced when it was found that a few of the animals descended onto the cliff side, but were careful to walk on the ledge supporting the glass; in the final analysis, R_1 was therefore counted as an "S" response.

The results obtained during this experiment, which are summarised in Tables 1 and 2 and Figure 1, were:

i) that there were no significant effects attributable to the order of presentation, to the experimenter's position, to the age or sex of the animals, or to

TABLE 1.

The responses of forty-two hamsters to the visual cliff at four different depths

Depth of cliff	A 24"	D 18"	B 12"	C 6"	Total no. of responses.
S response	37	32	26	22	117
R1 response	1	2	2	4	9
C response	4	8	13	15	40
R response	-	-	1	1	2
Total:	42	42	42	42	168
X^2 test (1 d.f.)	13.76	8.05	2.74	1.48	22.26
P value for S response	$P<0.001$	$P<0.005$	NS	NS	$P<0.001$

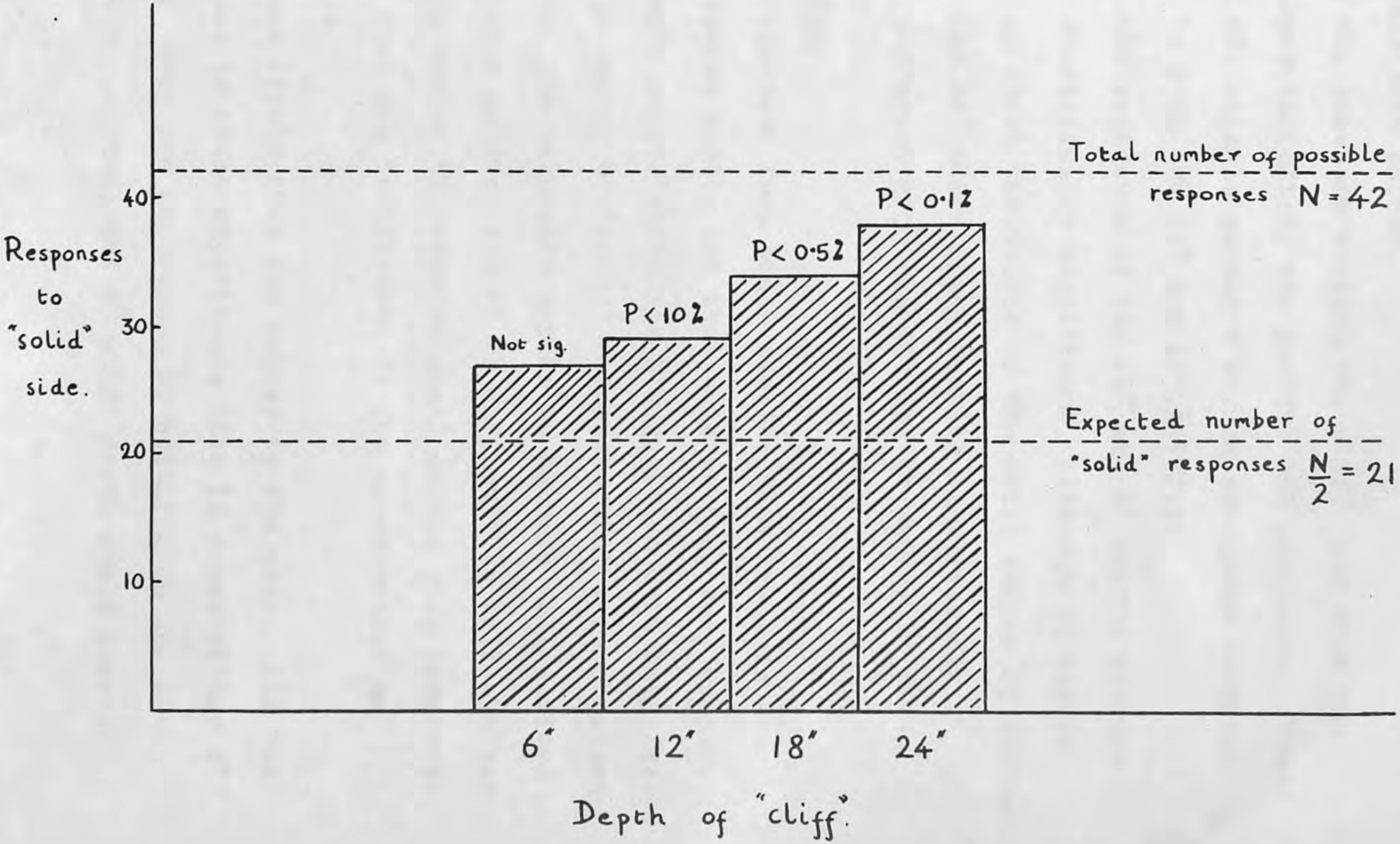
TABLE 2.

Comparison of responses to four different cliff depths.
P values for X^2 tests.

Depth of cliff.	A 24"	D 18"	B 12"	C 6"
A 24"	-	NS	0.025	0.005
D 18"	-	-	NS	NS
B 12"	-	-	-	NS
C 6"	-	-	-	-

FIGURE. 1. **DEPTH PERCEPTION : VISUAL CLIFF**

Levels of significance of the responses made by 42 animals to the "solid" side when the "cliff" depth is varied.



their coat colour.

ii) that the hamsters avoided the cliff, and that the deeper the cliff, the greater the avoidance. Thus:

  a) the animals showed a strong avoidance response to both the 24" and 18" cliffs,

  b) the avoidance of the 12" and 6" cliffs was not statistically significant, although it occurs in about two-thirds of the total number of choices,

  c) the 24" cliff gives results significantly different from the 12" and 6" depths.

4. Conclusion.

It is apparent from these results that hamsters are able to perceive depth, and that neither age, sex, colour, order of depth presentation nor E's position were responsible for the high number of "solid" responses that were obtained.

However, the responses appear to be more well-defined for the greater depths, and it is difficult to tell whether hamsters are unable to perceive small depths with accuracy, or whether they are indifferent to the consequences of lesser falls.

It seems likely that the latter is the case. All the hamsters used in these experiments live in cages either 6" or 8" deep; they are accustomed to swinging on the mesh of the cage top. Thus, the 6" cliff depth would present no dangers.

Takatsuki (1937) found that albino rats could discriminate between depths, but that the threshold for depth discrimination became lower as the distance increased; the threshold is about 3 cms. in distances less than 20 cms., increasing to about 9 cms. in those between 40 and 50 cms. This suggests that not only is depth perception good in rodents, but that smaller distances are perceived with greater accuracy. The trend of the results obtained in the main experiment therefore suggests that all the depths are perceived, but that the response is determined by the amount of danger attached to any one of them.

It would be interesting to pursue this particular problem by investigating the first appearance of depth perception in the young hamster, and by testing the possibility of depth perception being determined by motion parallax or binocular parallax, or both. However, none of these last three aspects were considered relevant to the main study, and they were therefore not pursued for the time being. However, three further experiments were carried out to eliminate the possibility of experimental artifacts arising through differences in illumination.

5. Control Experiments.

Since a query was raised as to whether differences in the illumination of the two sides of the visual cliff had affected the results, the following control series were run:

(i) Pre-existing preference for either the light or the dark side:

The surface illuminations of the cliff and solid side were altered so that, in the two testing conditions, they were as follows:

a) cliff side = 1 fc., and solid side = 14 fc.
b) cliff side = 20 fc., and solid side = 2 fc.

Thus, one side was dark and the other light.

The cliff was set at 24". Using the same procedure as before, except that illumination and not cliff depth was altered, six animals were tested under both conditions.

All six animals chose the solid side both times. It was therefore concluded that there was no pre-existing preference for either the light or the dark side.

(ii) Equalisation of the amount of reflected light received at the platform, rather than equalisation of the incident light received by the solid and cliff surfaces:

The photometer reading for reflected light on both sides of the platform was 11 fc. The main experimental procedure was followed, including the use of the Latin square and the four different depths. The photometer reading was kept constant by adjusting the source of the illumination with a Variac. Eleven animals were used.

The results were similar to those obtained in the main experiment:

Cliff depth:	24"	18"	12"	6"	Total
Total S responses	11	9	9	8	37
Total C responses	-	2	2	3	7

The preference for the solid side was significant at the 0.005 level. The trend of these results follows the same pattern as those of the main experiment. It therefore appears that differences in illumination are not responsible for the preference for the solid side.

(iii) Control of depth perception in the visual cliff by the squared material only:

As Gibson and Walk (1960) had found that hooded rats showed no depth perception when the entire apparatus was covered with a homogeneous grey material, this experiment was repeated with the hamsters.

The apparatus was shrouded with grey material, so that none of the dexion framework showed, and shadows were reduced as much as possible. All the sides of the cliff side were covered, so that any distance cues that might have been provided by the floor were removed. The photometer reading for incident light on both solid and cliff surfaces was 25 fc.

The cliff depth was set at 24". Following the previous procedure, ten animals were given one trial each. All chose the solid side, only one animal showing any hesitation.

In this case, the perception of depth was independent of the squares on the original material. However, the inadequate control of shadows may have given additional cues. Also, the apparatus was small in comparison with Gibson and Walk's; thus, the corners of the cliff well might come within the hamster's field of vision and provide parallax cues.

VI METHODS AND APPARATUS

A. Pilot Study.

1. Introduction

The results of the experiments quoted in Section V, and other more general observations of the hamster's use of vision in day-to-day activities, formed the basis of a short pilot study in visual discrimination learning.

2. Summary of Method and Results

In this study, a two-choice box was designed with a continuous approach, and doors which opened in response to a push if the choice was correct. The source of motivation was exploratory drive, and the reward was in terms of release into an open area. Plates 3-6 shows this apparatus, and a detailed description of the technique and results is given in Appendix E .

Six animals were trained to respond positively to a 2.0 cms. equilateral triangle and negatively to a 2.0 cms. diameter circle. However, only one animal achieved a significant discrimination score in 200 trials; this animal was given transfer tests to investigate the extent of generalisation to size, to rotated figures, to reversal in figure-ground brightness relationships, to alternative

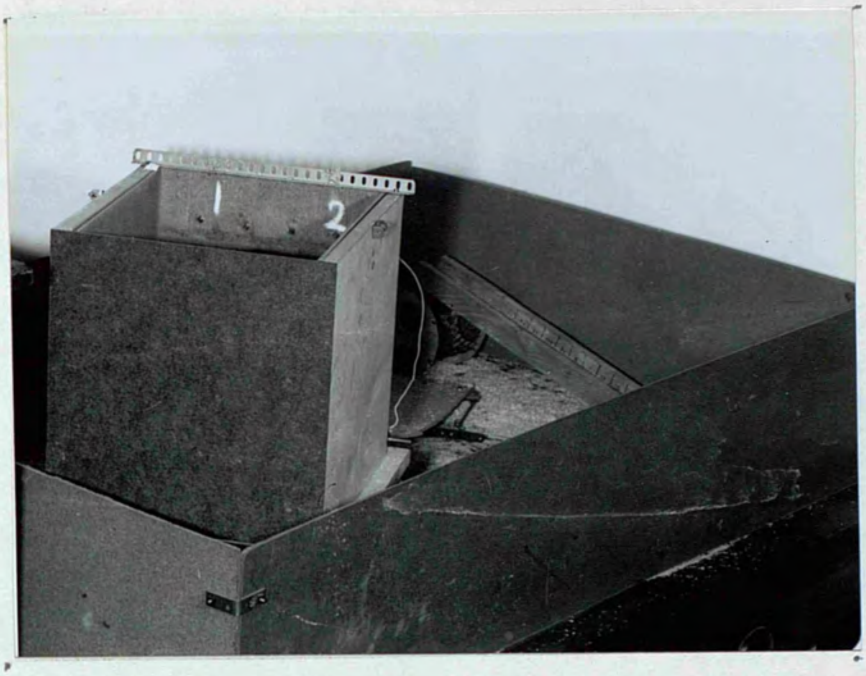


Plate 3. General view of the two choice apparatus

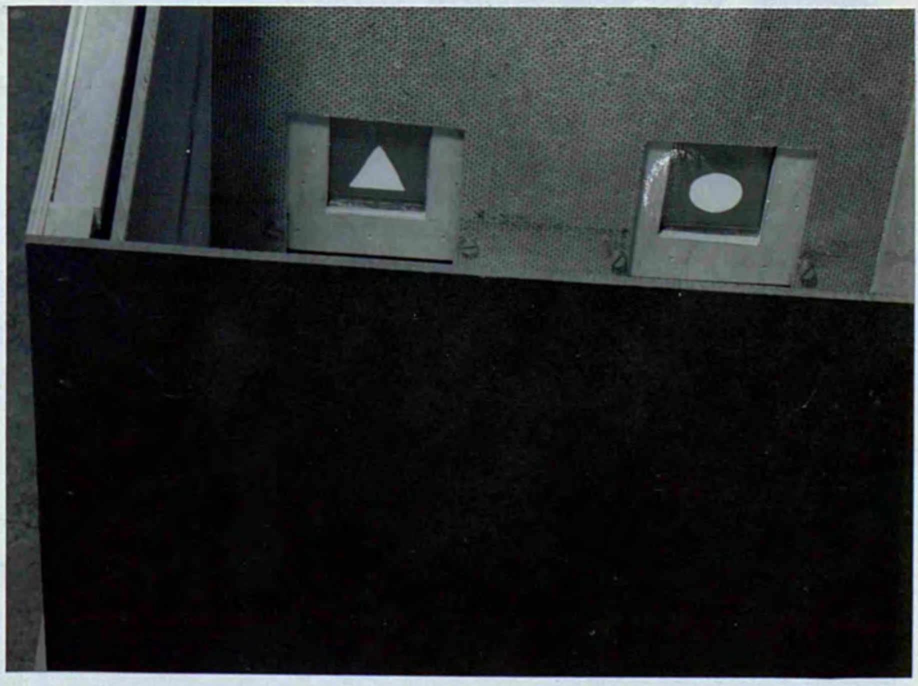


Plate 4. View of the doors with stimuli in place
(two choice apparatus)

Plate 5. The front of two choice apparatus, showing no. 2 door locked.

Plate 6 Hamster emerging from choice box.

negative figures and to parts of the figure.

The results were not conclusive, but they indicated that the response was one of approach to the positive figure rather than of avoidance of the negative figure; generalisation to smaller figures was possible. A 2.0 cms. triangle rotated through 45° and a 0.5 cms. triangle rotated through 90° were recognised, while a 2.0 cms. triangle rotated through 90° was not.

There was no transfer when the figure-ground brightness relationship was reversed. When alternative figures were substituted for the circle, discrimination was not impaired, except in the case of the cross; then there appeared to be some confusion. The final tests, on the parts of the figure, showed that there was transfer to the tops but apparently not to the bases; the whole figure seemed to be preferred to the parts.

3. <u>Discussion</u>.

The results of this experiment raised a query as to the efficiency of the method employed; only one animal out of six reached an acceptable learning criterion in nearly 200 trials. Yet observation indicated that the remaining five knew the problem, although the results were so inconsistent. The chief fault seemed to lie in the high number of correct choices required to reach an acceptable significance level (for example, 9 out of 10 - $P < 0.01$), which gives very little leeway for adverse circumstances; the noise of builders, or of people interrupting the experiment, walking down corridors, slamming doors and so on could be very disturbing. Hamsters are extremely easily distracted, and this apparatus gave too small a margin of error under the circumstances.

A further drawback was the amount of handling required for each series (see Section III); this can act as another disturbing factor, and may well have partially accounted for the wide variation in the results. In future experiments, therefore, it seemed advisable to eliminate handling as far as possible.

Two points did emerge from this study, however, which were of interest. First, the continuous approach to the stimuli, and the resulting lack of a fixed distance for stimuli observation appeared to be quite feasible, besides allowing for the unknown acuity range. Secondly, the small size of the symbols, as compared with those used by Lashley, have been shown to be adequate, and are possibly more satisfactory, for reasons which have been discussed elsewhere (see Section II).

The results of this pilot study, albeit from only one animal, suggested that golden hamsters are capable of learning form discrimination, and of making a generalisation to size; the remaining results, concerning background reversal, alternative negative symbols, Gestalt figures and rotated figures, are interesting, and possibly indicative, particularly in view of the apparent contradiction of some of the results obtained with rats. In fact the real problem at this stage was to find a method which would make it possible to test these possibilities with accuracy. The method had to be one which could be used with all hamsters rather than with the occasional genius.

Initially it seemed that the method must be modified to cope with the following main problems, any of which might have been interfering with the efficiency of the testing procedure. a) The amount of handling needed to be reduced; the animals were overexcited and nervous in spite of pretraining. b) Some modification of the learning task seemed essential; observation suggested that the hamsters had learnt the discrimination, but the technique made it difficult to show this in any acceptable form. The hamsters were easily distracted and the statistical criteria very stringent in a two-choice situation. c) It also seemed possible that motivation was too weak, and the adequacy of the exploratory drive by itself had to be questioned.

There seemed to be four possible lines of approach to these problems:

(a) To devise an apparatus which would reduce handling.

(b) To increase the negative motivation.

(c) To use the same apparatus as in the pilot study, but with carefully controlled delay and reward times, in the hope that this would utilise the motivational drive to the maximum, without introducing other sources of motivation.

(d) To invent an entirely different type of apparatus from those hitherto used in the study of visual discrimination.

These four possibilities were tackled in that order.

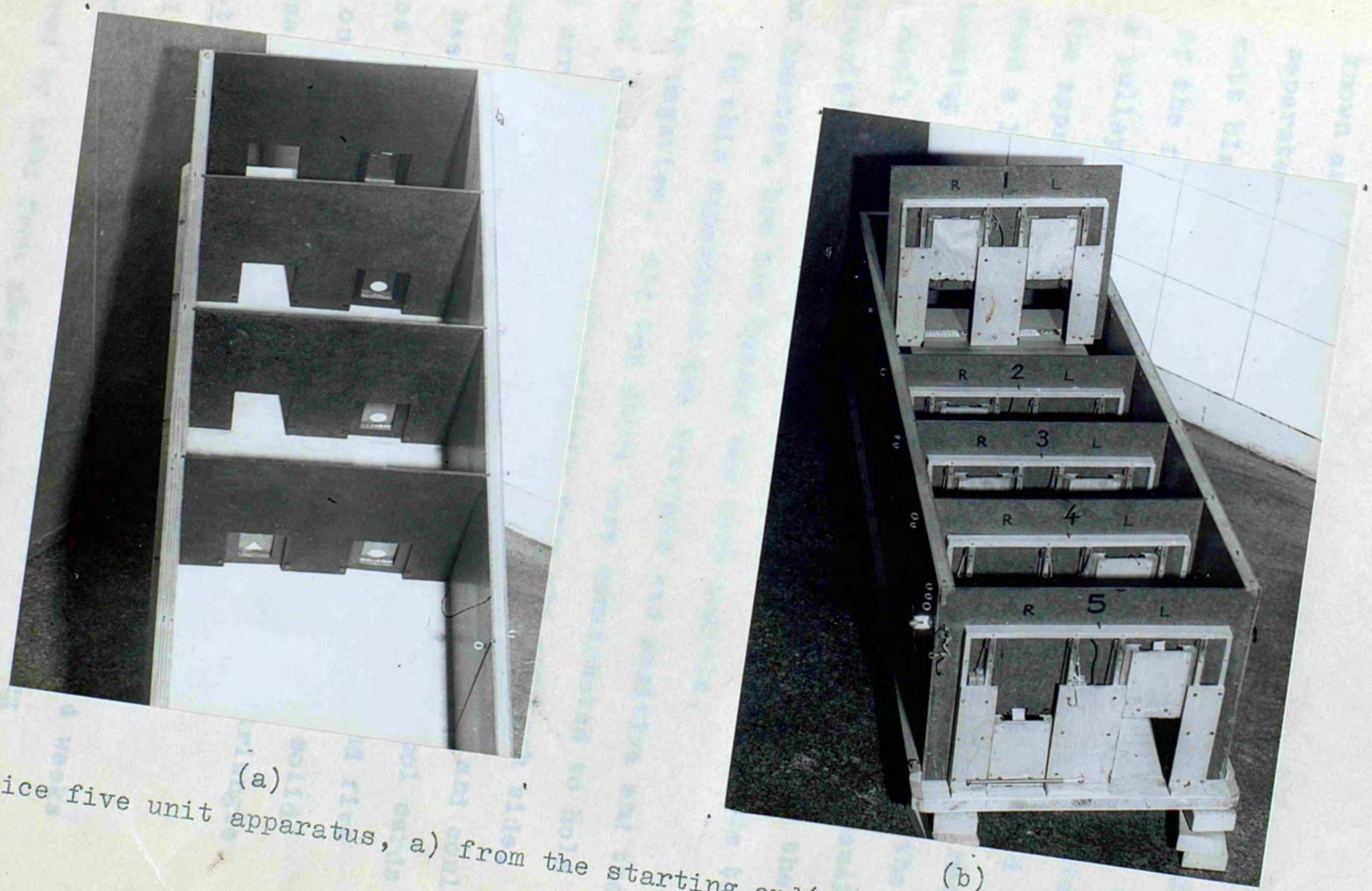
B. Reduction of Handling and Increase of Negative Motivation. (Five-unit two-choice Apparatus).

The answer to this problem seemed to lie in increasing the number of choice units per unit of reward; thus, the original pilot study apparatus was modified to give 5 panels in series, each panel with two choices. Each trial would then produce five separate choices instead of one per trial, and the handling would be reduced by 4/5, since two trials would give 10 choices. Apart from reduction in handling, the administration of the trials would also be considerably quicker. The addition of buzzers which could be wired to the negative doors, to add to negative motivation, was a feature of this new apparatus. These were used for part of the experiment to be described.

Six male golden hamsters, aged nine weeks, were used in this experiment (for details see Appendix B).

1. Apparatus: The apparatus (see Plate 7 ~~and Appendix~~) consisted of a choice box opening into a reward box, which was considerably larger than the choice box, contained sawdust, and several "toys", such as an activity wheel, two small iron grids, a wire cage and so on. The choice box was illuminated by two tungsten bar lights (150 watt 240 volt architectural Mazda strip lights, 48" long, straight, opal), which were placed 18" above the box, and whose intensity was controlled by a Variac. Tungsten lighting was chosen since it approximated most closely to daylight, being slightly reddish rather than blue, orange (sodium), yellow and so forth.

The choice box, made of brown hardboard, was divided into five sections; the first section was slightly larger than the others, which were all the same size, and was



(a)

(b)

Two choice five unit apparatus, a) from the starting end(first panel removed) b) from the front.

Plate 7.

known as the "starting box". All five compartments were separated from one another by panels, which were painted matt black on the approach (or starting box) side; each of the five panels contained two doors, which operated on a pulley-weight system, and slid upwards when pushed from the approach side. Each door could be locked when required; when a locked door was pushed hard enough to touch the locking bar, an electrical circuit was completed, causing a small light to flash and (if it was switched into the circuit) a buzzer to ring; the light was not visible to the hamster, but the buzzer was very audible.

In this experiment the triangle was positive and the circle negative. All ten doors were constructed to hold symbol cards, which were visible from the approach side. Each card was placed between two pieces of glass, and could be removed from the door when necessary. Ten symbol cards were used, five 2.0 cms. equilateral triangles, and five circles 2.0 cms. in diameter; these symbols were solid white on a black background. One circle and one triangle were used for each panel.

2. <u>Pre-training</u>:

All six animals were handled from the age of 4 weeks to 7 weeks, so that they became accustomed to being transferred by hand from their cages to the apparatus.

At the age of 8 weeks, the animals were put into the apparatus with the doors open, and were allowed to explore it thoroughly. After two days, the doors were closed, and a further three days were allowed for the subjects to learn to open them. Each animal spent approximately ten minutes in the apparatus per day.

When it was felt that the animals were sufficiently used to the apparatus and to being handled, training started on the 2.0 cms. standard triangle and circle.

3. Design of the experiment:

Choice of the triangle was scored as a correct response, and choice of the circle as an error; since the number of correct choices was fixed and the errors were not, the score is given in terms of correct choices.

During the experiment, each series consisted of four trials, where one trial is equivalent to one run through the apparatus, i.e. five choices; thus, 20 choices were made in a series. There were 19 series in all in this experiment, involving 380 choices for each animal.

The order in which stimuli are presented is an important variable in an experiment of this kind. The position of the correct stimulus was therefore randomised according to Gellermann's (1933~~a~~) system. Of the 1024 possible combinations of rights and lefts in a series of

10, Gellermann chose only those which met the following criteria:

i) each series must contain 5 rights and 5 lefts.

ii) no series could have more than 3 rights or 3 lefts in succession.

iii) at least 2 rights and 2 lefts must appear in both the first and the last halves of each series.

iv) each series must contain only 5 reversals from right to left or from left to right.

v) the series must offer a chance score of 50% correct from either simple or double alternation response.

Criteria i), ii) and iv) were intended to give a well-balanced series in which the formation of position habits would not be greatly encouraged. The third criterion was used because of the possibility of differential cues in the change of stimuli from side to side in some trials and not in others. The 5th criterion was chosen to minimise the subject's opportunity of making more than 50% correct responses through habits of alternation. The 19 series of 20 trials met these criteria.

The main extraneous variable which it proved impossible to control was noise. The intermittent sound of people and machinery continued to startle the hamsters from time to time, but there was nothing that could be done about this.

4. Procedure:

The animal was put in the reward box for a few minutes at the start of the experiment; it was then transferred to the first choice box and put midway between the doors at the back of the box. The choices were recorded as the animal made them, and S was allowed about one minute in the reward box after its last choice. Any necessary adjustment to the apparatus was made during this time. S was then returned to the choice box for the second trial.

For the first five series, each animal had the four trials consecutively. For series VI to XII, each series was broken up into 4 blocks, so that all the animals did the first trial, then they all did the second trial, and so forth. The experimental procedure was modified in this way since there appeared to be a tendency for each S to do better in the first trial than in the remaining three when they were administered in a block. As the experiment progressed, however, the hypothesis appeared to be unjustified; series XIII to XV were therefore given in two blocks of 2 trials each, and the remaining series (XVI to XIX) were administered as one block of four trials, as before.

Three types of lighting were used, to see whether the alteration of this controlled variable would affect the results to any extent. For the first eleven series, two tungsten bar lights were used; for the next four series, one bar light was used, and for the remaining four series, illumination was provided by the central room light.

For the last four series of the experiment, buzzers were added to the electrical system of the apparatus; since pressure on a locked door produced a loud noise from the adjacent side of the choice box, it was hoped that this additional negative motivation might increase the speed of discrimination learning.

Thus, during the experiment, lighting and the order of the series were varied, while negative motivation was increased.

Subject N had to be omitted after series XII, because of illness.

5. <u>Results</u>:

These are given in Table 3. They may be summarised by saying that:-

1) The animals showed little evidence, by objective criteria, of having learnt anything.
2) Neither light conditions nor the addition of negative reinforcement appeared to have any appreciable effect on the results.

TABLE 3.

Total number of correct choices for each of six animals during nineteen series of twenty choices each.

Conditions.	Series.	Animals						Mean
		O	M	RS	N	LS	T	Score.
Two bar Lights	1	10	9	10	8	10	9	9.3
	2	10	8	10	12	13	6	9.8
	3	9	11	9	8	12	8	9.5
	4	10	11	12	11	11	10	10.7
	5	9	11	10	8	8	10	9.3
	6	10	11	13	12	11	5	10.3
	7	7	9	7	9	8	6	7.7
	8	9	9	9	9	6	13	9.1
	9	12	14	17	11	13	10	12.7
	10	10	14	11	9	12	12	11.3
	11	11	9	9	11	8	11	9.8
One bar Light	12	13	11	4	11	6	8	8.8
	13	13	10	10	-	8	13	10.8
	14	9	5	8	-	11	7	8
	15	14	9	9	-	10	10	10.4
One room Light Buzzers	16	13	11	9	-	11	10	10.4
	17	12	12	11	-	12	17	12.8
	18	8	7	10	-	11	9	9
	19	8	14	11	-	14	10	11.6

6. Discussion.

It can be seen from the results that there is no marked improvement throughout the experiment. The results remain on or about the chance level all the time, and there is no sign of a learning curve occurring for the group as a whole or for any one individual animal, despite the fact that five animals made 380 choices each.

Thus, reduction in handling, variation in illumination and an increase in negative motivation do not appear to be the answer. Yet, observation indicated that the animals were aware of the difference between the two symbols, and, on two occasions, the score of 17 out of 20 correct choices (significant at the .05 level) was achieved. The chief problem still remained: what was the best method for obtaining a more consistent measure of behaviour? Or was there some unknown external variable responsible for behavioural variations, and if so, what was it? It seemed likely that a further modification in either apparatus or technique was the answer, and the investigation was accordingly pursued along those lines.

It should be noted here that the use of small lights as a means of recording errors was not found to be very satisfactory; the electrical circuits were not very sensitive, and a gentle push on the part of the animal was not enough to make a hard contact between the door and the locking bar for the completion of the circuit. Yet a gentle push was enough to tell the hamster that the door was locked. In future, therefore, straight observation by the experimenter seemed to be more reliable.

C. Controlled Delay and Reward Times. (One unit two-choice apparatus)

Since the amount of handling and of negative motivation were not responsible for the poor results, it seemed possible that the positive motivation, in the form of exploratory drive, was not being utilised to its fullest extent. A fixed reward time was therefore employed; also, a fixed delay time was incorporated, in the hope that this would increase the motivation to leave the apparatus. In order to try and obtain some sort of informative result, a plain black/white discrimination problem was used, since it was hoped that this, at any rate, would be within the hamster's capacity, even if the triangle versus circle problem was not. Assuming that the animal could learn this simpler task, there would be some sort of base line for comparison with succeeding results on more difficult problems. It had also been suggested that the animals were being given too many trials per day, and that this was contributing to the agitation level; it was therefore decided to reduce the number of trials administered per day, and see whether this had any effect.

A reduction of handling was included, since it was easy to incorporate this without altering the experiment in any way; if this did, in fact, decrease the level of agitation, if only in a small degree, it seemed worth including it.

1. Design of Experiment.

One male golden hamster, aged six months, was used in this experiment (for details, see Appendix B). The apparatus was like that used in the pilot study, in other words, a two-choice single unit opening into a reward box, but with two alterations:

i) A small aperture (3" deep, 2" wide) was cut in the back of the choice box; this opened into a moveable delay box (6" long, 4" deep, 4" wide), whose open front could be closed by a hardboard or perspex sheet sliding in vertical grooves; perspex was used for the last 24 series of the main experiment.

ii) A choice board, 4" deep, was inserted between the two doors.

An anglepoise light (60 watt 240 volt bulb) was suspended centrally above the choice box, 18" from the choice box floor.

The stimuli consisted of one plain white and one plain black slide; the white slide was positive. Both stimuli were mounted between glass; however, for the last four series, the glass was removed, and they were presented as matt surfaces; it was thought that reflection from the glass might have accounted for the hitherto poor results.

The animal was only handled directly at the beginning and end of each series; at other times, it was coaxed into the delay box at the end of each reward period. The delay time before a choice was fixed at 30 seconds, the animal being kept in the delay box for that time. Reward time after a choice was fixed at $2\frac{1}{2}$ minutes, while the time taken by S to make a choice was measured from the time it left the delay box. Each series in this experiment consisted of five trials and one series was given per day.

2. Procedure.

The animal was given considerable pretraining in addition to the usual training to open the doors of the apparatus. A guiding procedure was used, to see whether this would increase the speed of discrimination learning. During preliminary training, correct choices only were allowed; the alley to the negative door was blocked off by a sheet of hardboard for the first 2 series. This hardboard was replaced by perspex for a further 4 series; the negative symbol could therefore be seen but not approached.

During these 4 series, the perspex sheet was gradually moved nearer the negative door until it was just in front of it; it was then removed altogether.

The 28 series of the experiment proper were conducted with both doors accessible but with the negative door locked.

3. Results.

The results of the individual series are given in the graph (page 115), but may be summarised by saying that the animal gave no evidence of having learnt the discrimination.

4. Discussion.

Examination of the results shows a slight improvement after the first ten series, but the graph still remains at the chance level, except for the exceptional 5/5 result in Series 23. Later results did not support this fluke, however, and so the experiment was terminated. The length of time spent in training the animal was becoming out of proportion to the information received.

Once again, the fixed reward time, the enforced delay time, together with the reduction in both handling and the number of trials per day have not provided the answer; the animal sometimes gave the impression of recognising the symbols and at other times did not. The so-called "delay" time was often used for scrabbling in the delay box, or for displacement washing; at times, the animal merely froze

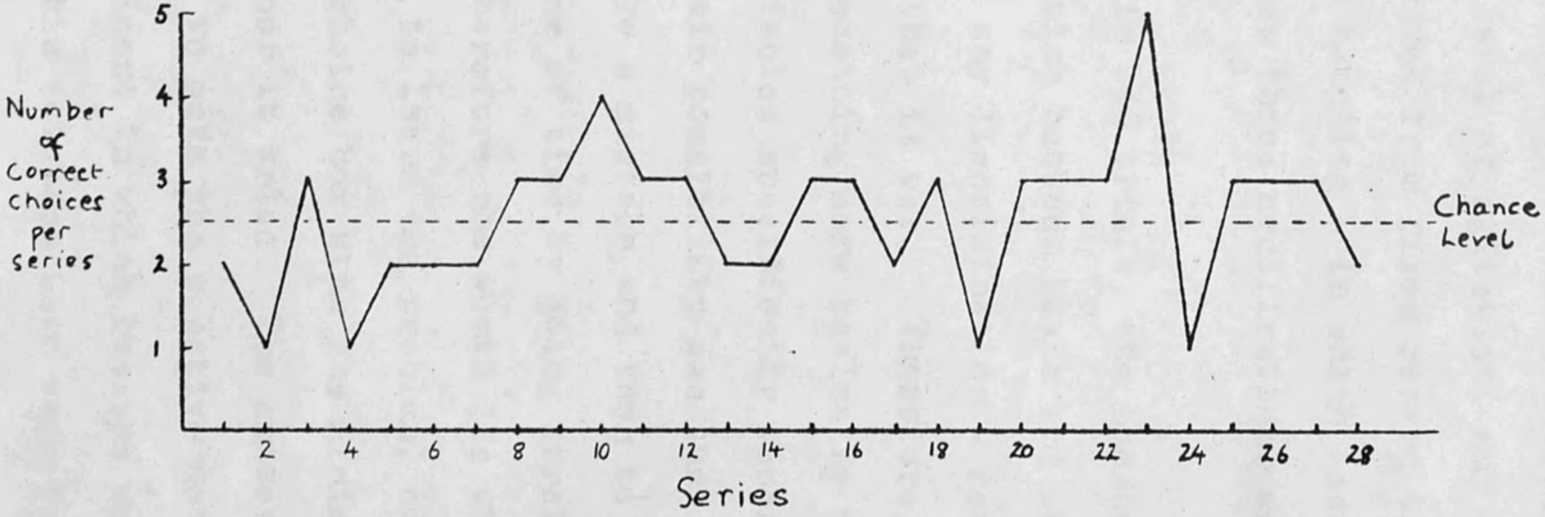


FIGURE 2.

One-unit two-choice apparatus: correct choices made by one animal during brightness discrimination training.

in the corner, and took no notice of the aperture, even when the slide was removed. It seemed therefore that this forced delay was more destructive than constructive, in that it heightened the level of agitation, and thus possibly offset any benefit received from fixed reward time, and reduction in trials and handling - in which case, the benefit gained from these three modifications was probably slight.

It was felt that, in 140 trials, the hamster should have learned to distinguish between black and white, if it was capable of learning any discrimination - former observations indicated that it was. Therefore, it seemed likely that there was something more basically wrong with the method than the variables specifically controlled in this experiment. The main possibility was that the animal found it too easy to make a mistake and then to correct it within a very short space of time by going straight to the correct door; it was therefore not worth its while, to put it anthropomorphically, to learn the problem, since it was able to get out of the choice box with the minimum of difficulty, whichever door it tried. The answer to this might have seemed to be to make the negative door more unpleasant, but the experiment in which buzzers were used (see page 101ff) did not make this solution seem very promising.

It appeared that an impasse had been reached. Conclusive evidence was still needed to show that the animals were capable of learning a discrimination task with any degree of accuracy.

D. New Type of Apparatus.[1]
(Circular)

Having attempted several modifications of both apparatus and method, it was decided to break away from the traditional type of apparatus altogether. The experiment described below incorporated a simple learning device, which is chiefly important for the fact that nearly all the visual area presented to the animal within the apparatus is part of the discrimination problem; there are therefore no irrelevant distracting features.

1. Apparatus.

The design of the apparatus is shown in plate 8 and appendix L. The whole of the apparatus could be rotated on a central pivot attached to a large base board. Thus, the direction of the cylinders in relation to the experimenter could be easily changed for each trial.

Cylinders A and B acted as "discrimination areas"; A was lined with one stimulus, and B with the other, for example, black and white. The perspex cylinder in the central choice

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[1] This experiment was designed and performed by Dr. Monica Lawlor.

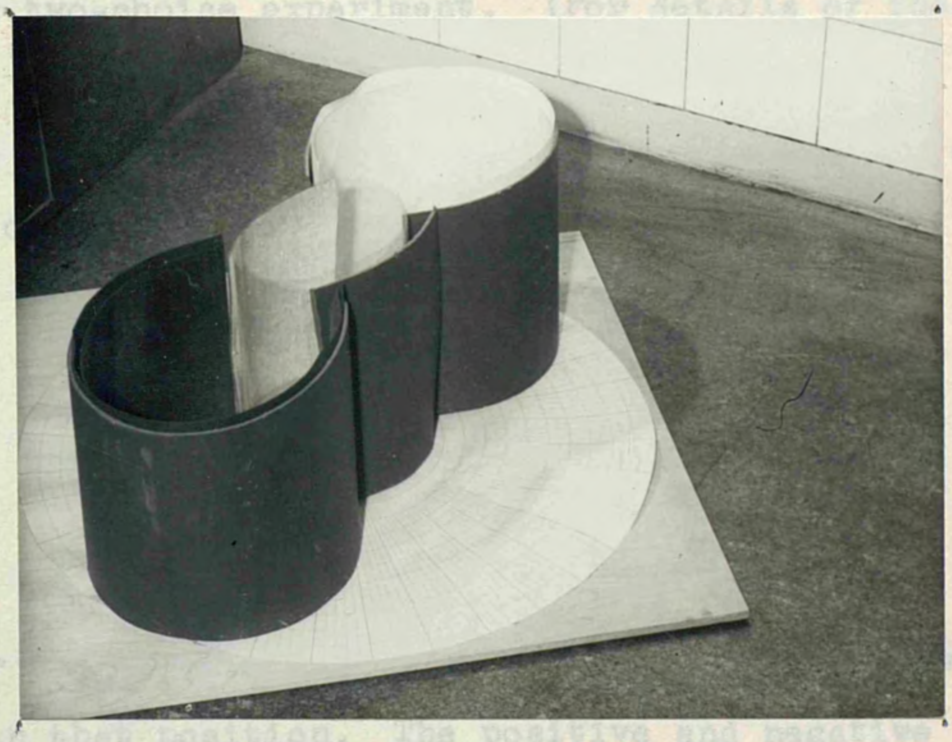


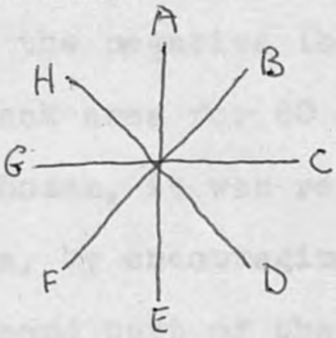
Plate 8. Circular choice apparatus

chamber was moveable; when removed, it gave access to both A and B.

2. Design of Experiment.

Two male golden hamsters, OA and BA, aged eight months, were used for this experiment; BA had been used in the previous two-choice experiment. (For details of these animals, see Appendix B).

The positions of the apparatus were randomised over the following positions:



Thus for any given letter, the positive stimulus would be placed in that position. The positive and negative stimuli were changed between cylinders about every fourth trial, that is, once in each series.

The stimuli used were white (positive) and black (negative). The animal was always placed in the centre of the choice cylinder at the beginning of each trial. Olfactory and tactile cues were eliminated by the perspex cylinder, as its position could be altered, and it could be wiped.

Each series consisted of five trials, one series being given per day.

3. Procedure.

Since two different procedures were used, these will be described separately.

a) Animal OA:

The experiment was divided into two parts: in series I to V (25 trials) the animal was allowed ten seconds in the central perspex area; it was then released into whichever side it chose. If the negative (black) side was chosen, it was left in the black area for 60 seconds; if the positive (white) side was chosen, it was released from this area into an open reward area, by encouraging it to climb up E's sleeve.

During the second part of the experiment, namely series VI to XIII (32 trials), the animal was released from the perspex cylinder only when it touched the side nearest the positive area. A correct choice was recorded only if it touched the positive side first. Thus it could not get into the negative area, and was rewarded for each correct response.

b) Animal BA:

The technique used for OA during the second part of the experiment was also applied to this animal, but was used for 9 series (42 trials).

4. Results.

The figures 3+4 (see pps. 121 and 122) show that OA achieved a discrimination score of 80% after 35 trials. The marked drop on series XI occurred after a lengthy break in training.

BA learnt the discrimination rapidly, and obtained a score of 100% correct after 27 trials; it made 16 correct choices during the last 17 trials.

5. Discussion.

The results of this experiment were valuable in that they established that a golden hamster is capable of learning a simple discrimination very rapidly. This is particularly important in view of the fact that, in the preceding experiment, Animal BA had exhibited no evidence of learning of the same black/white discrimination even after 150 trials. However, this same animal showed satisfactory brightness discrimination so rapidly in the circular apparatus that it seems likely that some learning had taken place in the previous experiment.

The following points arise out of this: firstly, although learning may take place in the two-door apparatus, this apparatus is not designed to show the full extent of this learning. Secondly, the circular apparatus appears to focus the animal's attention on the essential problem;

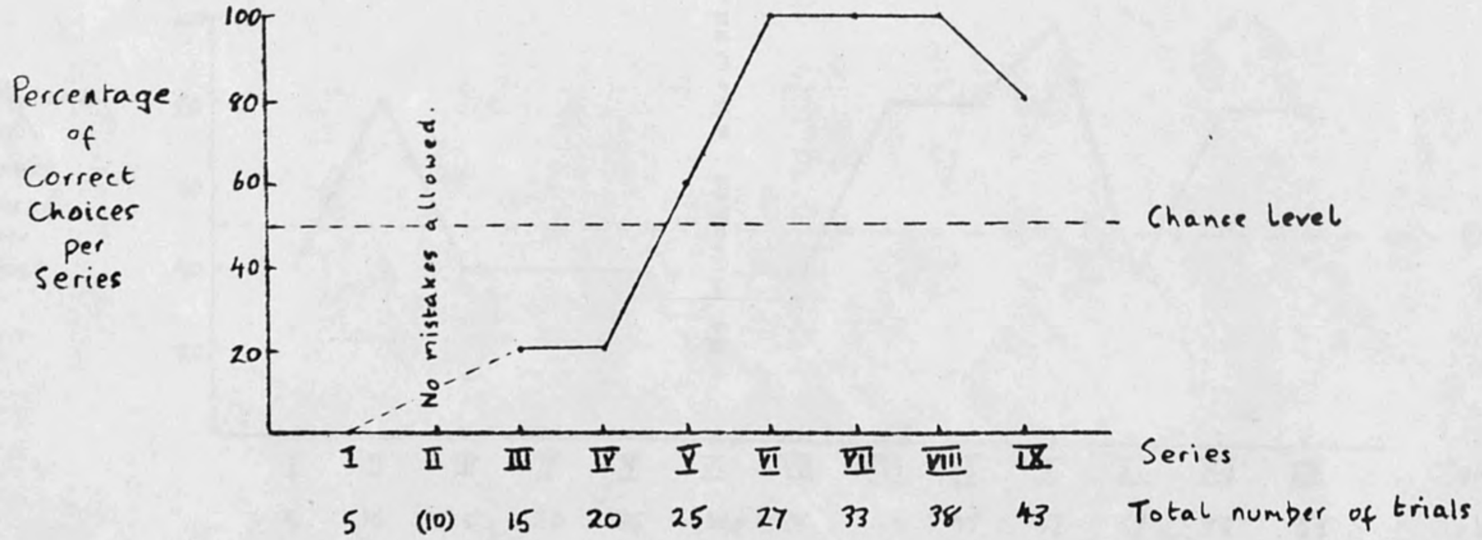


FIGURE 3. Circular Apparatus: Correct Choices made by animal MB5♂OA on brightness discrimination.

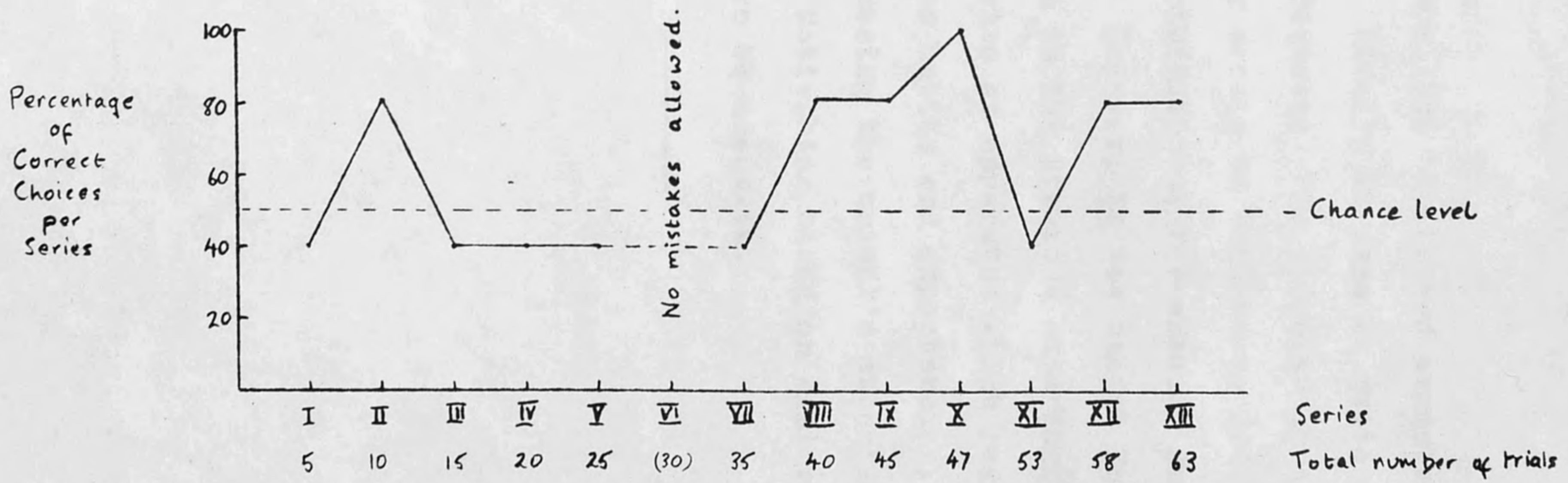


FIGURE 4. Circular Apparatus: Correct choices made by animal MB5♂BA on brightness discrimination.

and the formation of position habits and expectations is almost impossible. Finally it made it quite clear that the reward was adequate. The circular apparatus is restricted by its very nature to brightness discrimination and certain form discriminations, for example horizontal and vertical stripes. However, it was useful in elucidating the points of weakness in the previous experimental designs. It now remained to devise an apparatus which reduced the possibility of position habits and expectancies, and was more effective in focussing the animal's attention on the discrimination task. Motivation based on exploratory drive could be taken to be adequate.

VII FORM DISCRIMINATION AND GENERALISATION (SERIAL MULTIPLE VISUAL DISCRIMINATION APPARATUS)

A. Introduction.

The results of the last experiment quoted in Section VI established that a simple discrimination can be learnt. However, for the more complex type of discrimination, this apparatus is obviously not suitable. The other experiments did not produce results that were statistically acceptable, either with simple black/white discrimination, or with more complex triangle/circle discrimination. Various aspects of technique or method were modified during the experiments, but none of these relatively minor modifications proved to be useful. The apparatuses hitherto used were evidently not designed to show the full extent of learning which had taken place.

The answer to these problems seemed to lie in focusing the animal's attention more closely on the discrimination task. It was then found that Fields (1953) had adapted Lashley's technique to give a multi-door, multi-panel jumping apparatus for rats, which, he claimed, gave better results with a shorter training time. In place of the single two- or three- choice unit, he used a five-choice, five-unit apparatus, maintaining that it was more reliable, and that it was considerably quicker to use. (See Section II).

The following experiments were therefore based on Fields' technique which, when adapted to hamsters rather than to rats, seemed a logical answer to the problems that had arisen during this study, namely: a direction of the animal's attention to the problem, and the greatly increased statistical sensitivity and reliability.

Since this experiment was performed twice, with two different groups of animals, the methods and results will be described separately for both experiments. The results are discussed in Section VIII.

B. Serial Multiple Visual Discrimination Apparatus I.

This first experiment was carried out largely in order to test the suitability of the apparatus for the problem in hand.

1. Apparatus:

The choice box opened into the reward box as before, but otherwise this apparatus differed in design from those described in Section VI. It was considerably larger, and each of the five panels contained five doors, making 25 doors in all. The reward box, as before, contained sawdust and "toys". (For diagram of apparatus, see Appendix F).

The choice box was illuminated by daylight, and, failing that, by artificial overhead lights. The whole apparatus rested on the floor of the laboratory at the beginning of the experiment, but was raised on a 3 foot dexion stand later, to make it easier for the experimenter to reach the doors. These doors could be opened from the approach end; each door was slung by two filing rings, and was prevented from opening the wrong way by a baton of wood stuck across the back; all the doors could be locked when necessary by fastening down these batons with butterfly catches. It was therefore impossible to tell which door was unlocked from the approach side.

Three types of stimuli were used, triangles, circles and blanks. The triangles were equilateral, and in three sizes, 2.0, 1.5 and 1.0 cms.; there were five sizes of circles, ranging from 2.0 cms. to 0.25 cms. in diameter; of the two blanks, one was brown (natural hardboard), and the other matt black. Of the ten stimuli thus obtained, the triangles were duplicated five times each, (one symbol for each panel), while the circles and blanks were each duplicated twenty times, thus giving four for each panel.

Each symbol was duplicated by a commercial photostatic process; the symbols were then stuck directly onto the doors, each figure being centrally placed and one centimetre from the door base. It was felt that matt surfaces were preferable to glass surfaces, so that any risk of confusing reflections was obviated. Therefore, spares were made of all the symbols, so that, in the event of any being chewed, torn or defaced in some way, they could be replaced. For copies of the symbols used in this experiment and the next see Appendix G .

2. Design of Experiment.

One series was given a day. Each series consisted of 4 or 2 trials, thus giving 20 or 10 choices respectively (a trial being one run through the five-panel apparatus); 2 trials were given less often, in circumstances where the experimenter's time was short, or the animals were too agitated to make it worth continuing.

The first two series had brown negative doors; in the following two series, the negative doors were matt black. In the succeeding three series, however, 2.0 cms. white circles in black backgrounds were introduced in every other panel in place of the plain black doors, to enable a gradual transition of negative stimuli to take place.

In the next eight series, all the negative stimuli were 2.0 cms. white circles. In the last eight series, the sizes of both positive and negative stimuli were varied, ranging from 2.0 cms. to 0.25 cms. for the circles, and from 2.0 cms. to 1.0 cm. for the triangle. These variations sometimes took place within the series, and sometimes between the series, so that all the sizes of triangle were played against all the sizes of circle. This was done in order to see whether discrimination learning was in any way affected by size variations.

A correct choice was recorded if an animal pushed the positive unlocked door first; if any of the locked doors were pushed first, the number of pushes was counted, and was recorded as the number of errors for that panel.

The numbers of the doors were randomised, so that the positive stimulus did not appear in the same door position on the five panels at any one time; neither did the stimuli appear in the same door position on the one panel during the trials in any one series.

Olfactory cues were partially controlled by exchanging the stimuli (and therefore the doors) at regular intervals; both the positive and negative stimuli were printed with the same type of ink, and so the chemical smells were presumably similar. Tactually identical paper was used for all stimuli.

Six male golden hamsters, aged 17 weeks, were used for this experiment. (For further details of these animals, see Appendix β). The animals had previously been trained in the two-choice five-panel apparatus (see Section VI), and were therefore accustomed to both handling and experimental situations.

3. Procedure.

As before, the animals were put into the open apparatus, so that they could explore it and learn their way about. The doors were replaced and left unlocked, until all the subjects were able to open them easily.

To facilitate the transition from the original learning situation, the original brown hardboard doors were retained as negative symbols for the first few series. Thus, in each panel, there was one 2.0 cms. white triangle (positive) on a black matt background, and unlocked, with four locked brown negative doors. The position of the triangle varied from panel to panel; one position was never repeated twice in one trial, so that all five possible positions were used; the order of these positions was randomised throughout the experiment.

For each trial, the animal was placed in the centre of the first choice box; all the negative doors were locked, and the positive doors open. The choices were observed by the experimenter and were recorded in terms of those correct and the number of errors per panel. On reaching the reward box, the animal was allowed to remain there for about two minutes, after which it was returned to its cage. The animals were tested in strict rotation, no animal doing two trials consecutively.

Both daylight and electric light were used, according to the time of day; the times of the experiment varied from 2.30 p.m. to 11.15 p.m., but on the whole, the experiment was performed in the late afternoon or early evening.

4. Results.

a. Treatment of Results. The levels of probability were calculated, using Pascal's Triangle and the Binomial Method; for the full range of these probabilities, see Appendix H . Adopting Fields' (1953) method, all probabilities were calculated on the basis that the chances of the first choice being correct on any one panel were 1 in 5; thus, 9 correct choices out of 20 are significant at the 0.007 level, and 7 out of 20 at the 0.05 level.

In the following description, results are referred to in terms of levels of probability, since, in the circumstances, this is more meaningful than merely stating the number of correct choices made at any one time. Therefore, references to, for example, "the 0.007 level" mean that $P < 0.007$.

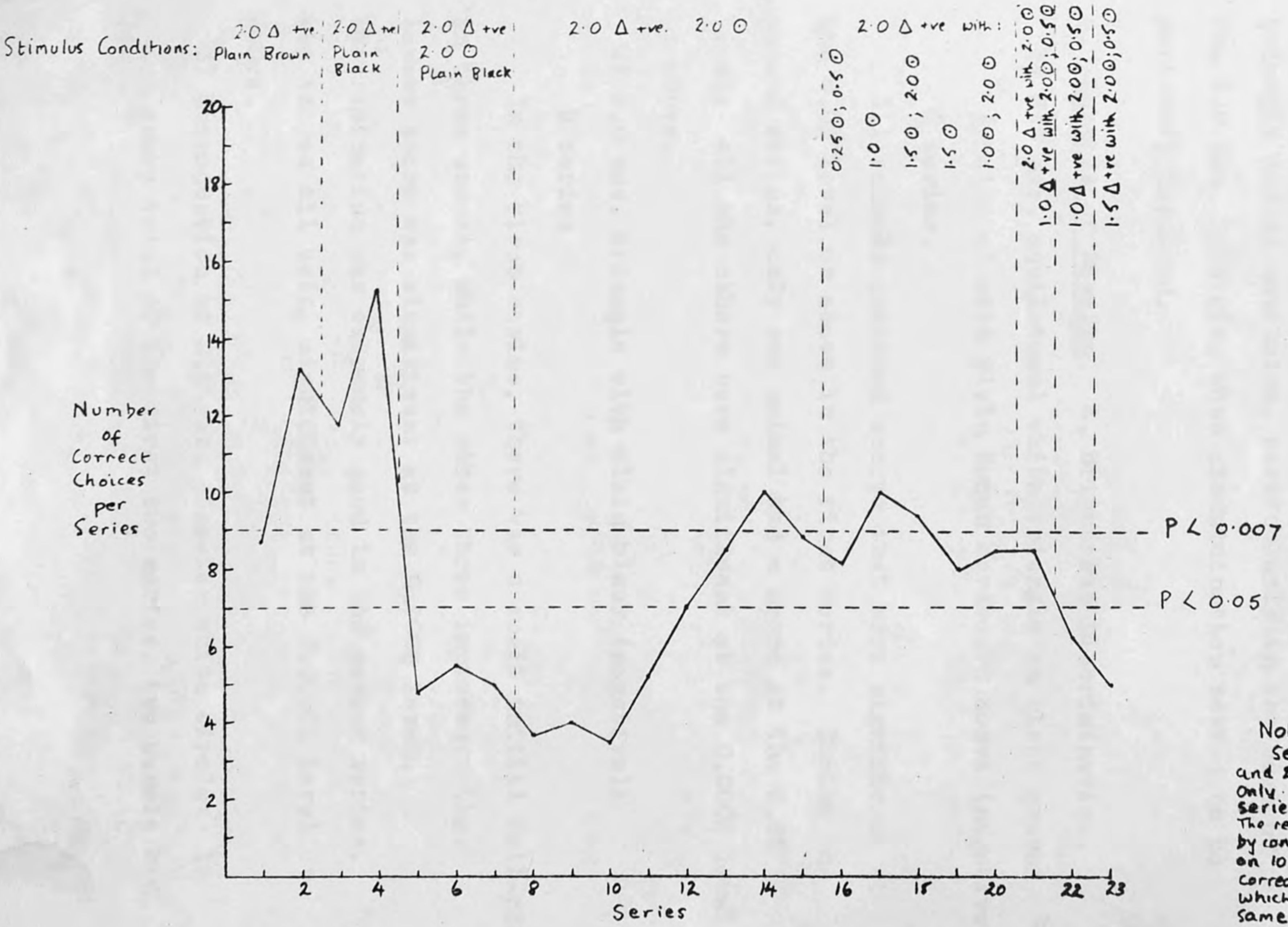
The average of the results is shown most clearly on the graph given as Figure 5. The graphs in Appendix I give the scores for each individual animal.

These results are described in detail in the following paragraphs.

b. Summary. In this preliminary multiple-choice investigation, it was found that, using this particular group of animals, brightness discrimination (2.0 cms. white triangle on black ground and negative blank) was learnt rapidly; replacement of a brown negative stimulus by a black did not affect discrimination to any great extent, and the average score in the final series was significant at the 0.00001 level.

There was a marked drop in scores when form discrimination (2.0 cms. triangle and 2.0 cms. circle) was presented in the same series with brightness discrimination, and a still further drop to chance level when form discrimination alone was given. However, after three series, scores improved rapidly, and the discrimination was learnt by the end of eight series.

Tests were then given to investigate generalisation of this learning to alterations in size of the stimuli. It appeared that alterations in the size of the circle disturbed discrimination slightly, but did not greatly



Note:
Series 9, 15, 17, 19, 22 and 23 contained 10 trials only. The remaining series series contained 20 trials. The results were equated by converting correct choices on 10 trials to the no. of correct choices at 20 trials which would occur at the same significance level.

FIGURE 5. SMVDA I: Average number of correct choices for six animals.

impair it. However, alterations in the size of the triangle caused confusion, particularly in the case of the 1.5 cms. triangle, when discrimination seemed to be seriously impaired.

c. Details of Results. A. Brightness Discrimination.

1) 2.0 cms. equilateral white triangle on black ground (positive) with plain brown hardboard doors (negative); 2 series.

All animals obtained scores that were significant at the 0.05 level or above in the first series. During the second series, only one animal had a score at the 0.05 level; all the others were significant at the 0.0005 level or above.

2) 2.0 cms. triangle with plain black (negative); 2 series.

In the first series, there was a small initial fall-off in three scores, while the other three improved; the lowest score was significant at the 0.0005 level. Discrimination was extremely good in the second series, the scores all being significant at the 0.00001 level or above.

3) Introduction of 2.0 cms. diameter white circle: in every trial of the first two series, two panels had

the black/white discrimination and three the form discrimination; in the third series, the black/ white problem was only presented three times.
3 series.

The results show a marked drop in the levels of the discrimination scores; the average score dropped to chance level. Examination of the individual results showed that the majority of correct choices were obtained on the brightness discrimination rather than on the form discrimination.

B. Form Discrimination: training. 2.0 cms. equilateral white triangle (positive), with 2.0 cms. diameter white circle (negative), both on black grounds; 8 series.

All scores dropped to chance level in the first series, and there was little evidence of discrimination. In the second series, two animals achieved scores which were significant at the 0.006 level, but this improvement was not maintained in the following series. However, series 4 showed an overall improvement, and all the scores, except one, increased steadily during the following three series. In the final series, the average discrimination score was close to the 0.007 level, and all the animals except one had achieved scores that were significant at the 0.05 level.

Several individual scores had been consistently above the 0.01 level for the last three series.

C. Form Discrimination: Transfer Tests. Size Generalisation.

1) 2.0 cms. triangle with 0.25, 0.50, 1.0, 1.5 and 2.0 cms. circle; 5 series.

The average score for all six animals remained on or above the 0.02 level of significance. Only four scores in the total of 30 obtained during these series were below the 0.05 level.

2) 1.0 cms. triangle with 0.25 and 2.0 cms. circle; 1½ series. (Standard 2.0 cms. symbols were given in the first half of the first series).

The alteration in the size of the triangle disturbed discrimination to some extent; three scores dropped to below the 0.05 level in the second series.

3) 1.5 cms. triangle with 0.25 and 2.0 cms. circles; 1 series.

This particular size of triangle appeared to produce an almost complete breakdown in discrimination. Only one animal achieved a score that was significant at the 0.05 level; all the others dropped to chance level.

These results are discussed together with those of the following experiment in the final section of the thesis.

C. Serial Multiple Visual Discrimination Apparatus II.

1. Introduction.

The results obtained with SMVDA I (see page 130) indicated that the basic design of the apparatus was satisfactory. Accordingly, the experiment was repeated, but with better controls, for example, a fixed reward time, and controlled illumination. The apparatus was also rebuilt to make it less clumsy.

2. Apparatus:

The apparatus was similar to that of SMVDA I (see p. 125) but was considerably smaller. The doors were smaller and closer together; they were permanently fixed with hinges, and had slide holders on the approach side for the symbols; they were locked by means of a bar which could be dropped into a retaining cup-hook on the opposite side. The locking bar was hidden by a baton of wood fixed across the back of the door; it was therefore impossible to tell which door was unlocked from the approach side. The whole apparatus, except for the reward box, was painted matt black throughout, and was placed on a 4 foot dexion stand.

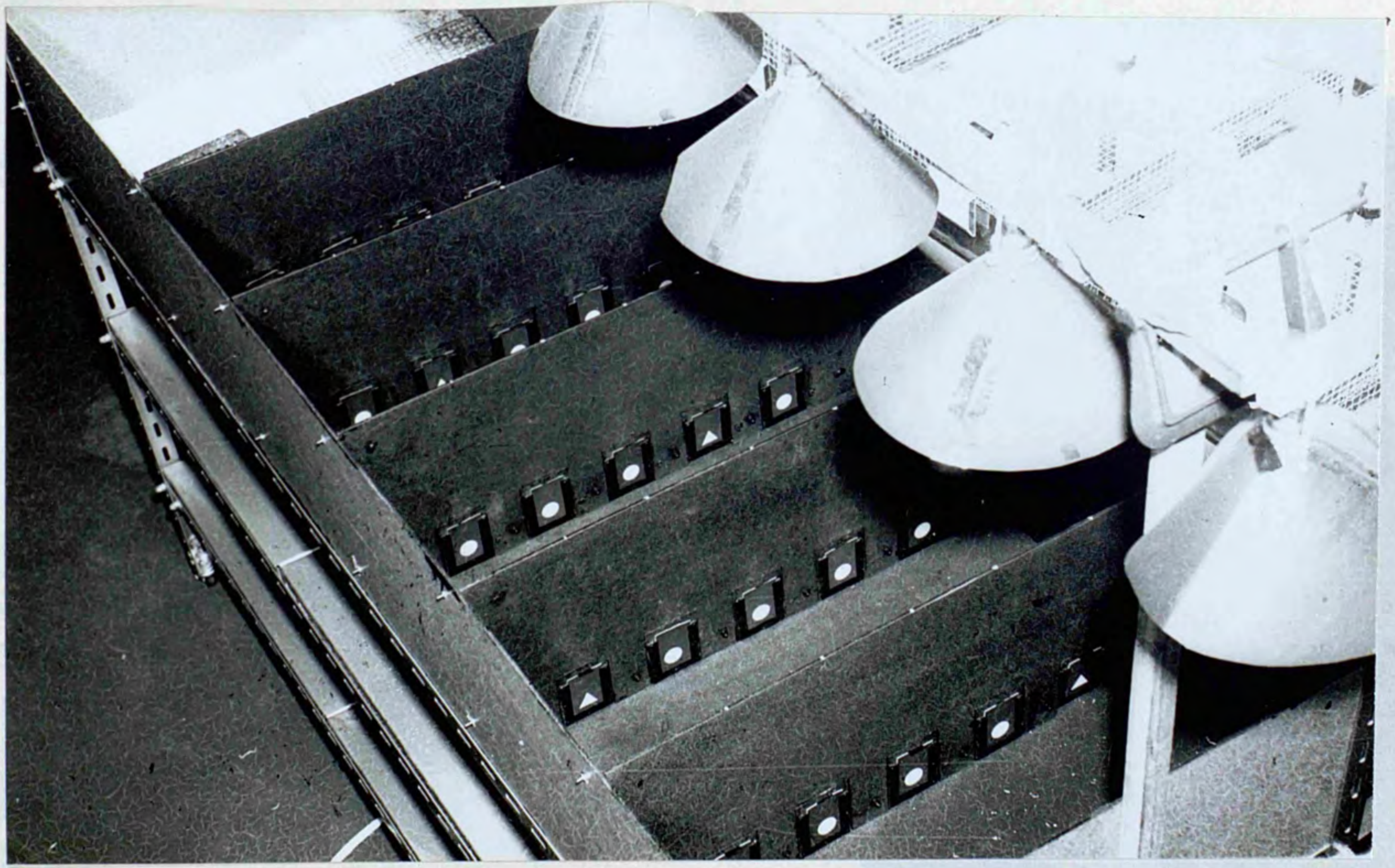
Illumination was provided by six 25 watt 240 volt bulbs suspended at a fixed distance (24" and 18") above the choice boxes; black shades above the bulbs helped to reflect the light downwards. The height of the bar holding the lights could be altered if required. Thus when the light bulbs were 24" from the floor of the choice box, the photometer reading for reflected light from the doors was 3.5 fc. When the lights were 18" away, the photometer reading was 4.5 fc. For further details of the apparatus, see Plates 9 and 10, and Appendix J.

The symbols were similar to those used in SMVDA I in size and type, but were stuck onto cards, so that they could be changed in the holders on the doors; each card had a black tab attached, so that it could be easily removed without touching the card itself.

3. Design of Experiment.

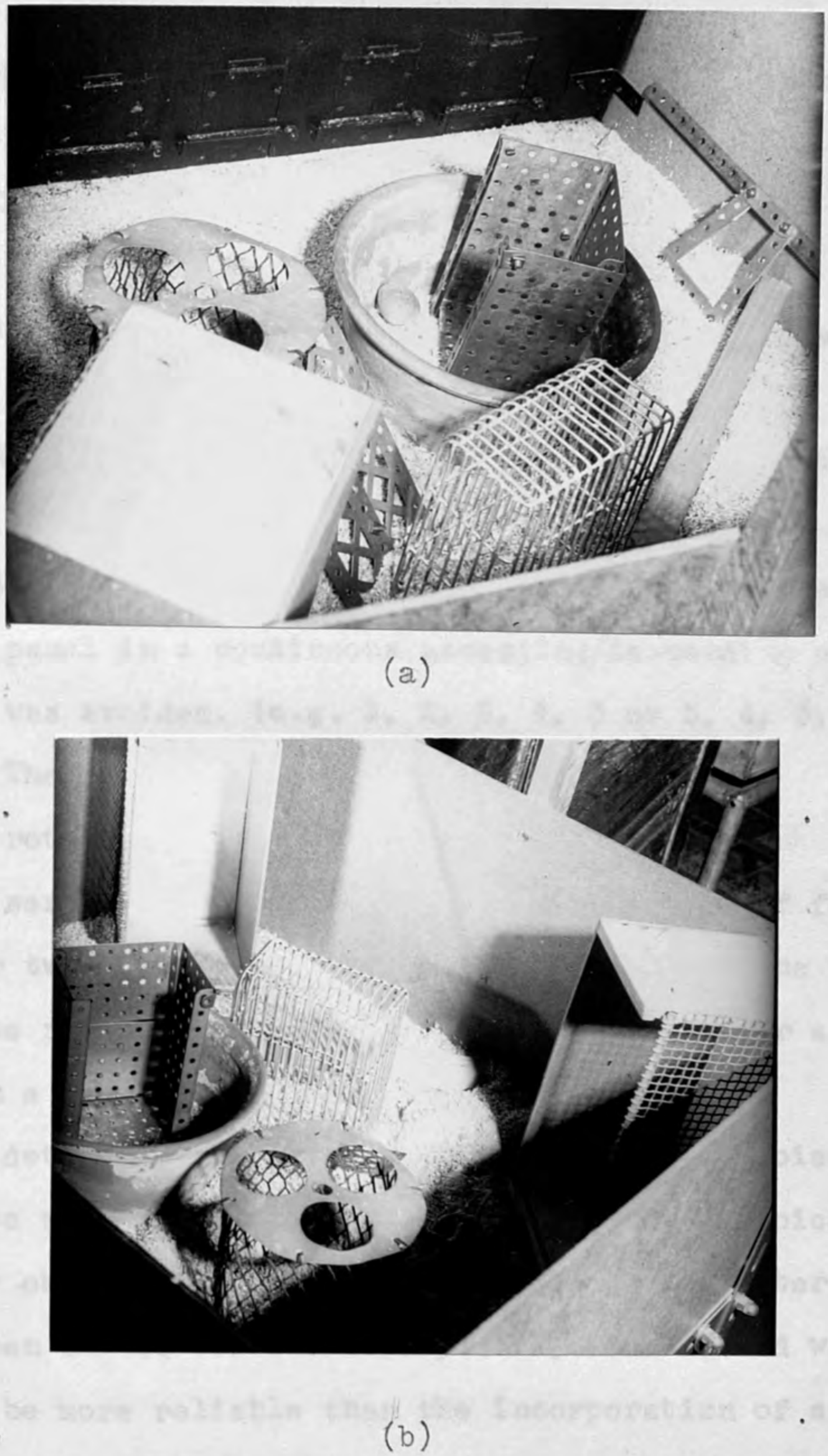
The reward time for this experiment was fixed at 2 minutes per trial for each animal; this length of time was chosen on the basis of the motivation study (see Appendix A).

As in SMVDA I, the position of the positive door in each panel during the different trials was randomised. The doors in each panel were numbered from 1 to 5; ten groups of figures for the presentation order of the positive stimulus were obtained, which complied with the following criteria:



SMVDA Apparatus II (modified from Fields 1953) from the starting end.

Plate 9.



(a)

(b)

Plate 10. SMVDA Apparatus II, reward area, a) showing back of the doors, b) other view of the reward area

a) No three figures in sequence in a trial, either backwards or forwards. (e.g. 1, 2, 3 or 5, 4, 3).

b) One door in one panel is never used twice in the same series.

c) A different door is used on every panel in each trial.

d) No one trial sequence is repeated in any of the ten groups of figures. (one group per series).

e) As far as was possible, change in the doors of one panel in a continuous ascending/descending order was avoided. (e.g. 1, 2, 3, 4, 5 or 5, 4, 3, 2, 1).

f) The groups of figures were used in strict rotation.

All series during this experiment consisted of four trials or twenty choices. Each animal completed the series before the next animal was started; one series per animal was given a day.

The determination of correct and incorrect choices was similar to that used in SMVDA I (see p.128); a choice was judged by observation on the part of the experimenter, since, as has been stated earlier (see p.110), this method was found to be more reliable than the incorporation of an electrical signalling circuit. The criterion for a push was the hamster actually touching the door with its nose.

The observation of a correct choice was assisted by the fact that it required a firm push to open the correct door, and the animals therefore tended to push a door hard rather than to brush it in passing.

The criteria of learning and the various levels of significance were, as before, based on Fields' (1953) suggested probabilities (see Appendix H).

Six male golden hamsters, aged 6 weeks, were used for this experiment. (For further details of these animals, see Appendix B).

4. Order and Rationale of Discrimination Training and Tests.

a) Brightness discrimination: plain white panel (positive) and plain black panel (negative). (3 series).

b) Brightness discrimination (cont.): 2.0 cms. white triangle (positive) and plain black panel (negative).

These series were given to test the transfer of brightness discrimination; they also introduced form into the problem, as there was a slight possibility that there might be a small amount of transfer when form discrimination training was begun. (3 series).

c) Form discrimination: training. 2.0 cms. equilateral white triangle (positive) and 2.0 cms. diameter white circle (negative).

These symbols were called the "standard". (42 series).

d) Alternative negative figures: 2.0 cms. triangle, with 2.0 cms. cross, rectangle, zigzag and square.

Alternative figures were substituted for the negative circle in order to see whether the discriminatory response was one of approach to the positive figure, or of avoidance of the negative figure. The bars of the cross were 2.0 cms. long; the height of the rectangle, the diagonal of the square and the cross-bar of the zigzag were all 2.0 cms. All four alternative figures were presented for one trial in each series; thus any difference in response to any one figure is less likely to be caused by uncontrolled external variables affecting one particular series. It was then possible to extract the results for each figure and compare them. (4 series).

e) Standard: the standard symbols were presented after each set of transfer tests, to act as a check on discrimination, to provide a comparison with the test results and to act as a "refresher course". (Either 1 or 2 series).

f) Size Generalisation: 2.0 cms. triangle with 0.25, 0.5, 1.0, 1.5 and 2.0 cms. circle (2 series); 2.0 cms. circle with 0.25, 0.5, 1.0, 1.5 and 2.0 cms. triangle (2 series); 1.5 cms. triangle and circle (1 series); 1.0 cms. triangle and circle (1 series); 0.5 cms. triangle and circle (1 series); 0.25 cms. triangle and circle

(2 series).

These series were designed to investigate the possible disturbances in discrimination caused by altering both stimulus sizes, or by altering one and not the other. Only sizes smaller than the training standard were investigated. (9 series).

g) Parts of figures: outline apex of 2.0 cms. triangle and upper arc of 2.0 cms. circle (1 series); outline base of 2.0 cms. triangle and lower arc of 2.0 cms. circle (1 series); 2.0 cms. solid triangle and 2.0 cms. diagonal diamond (1 series).

The part-figures were in outline form, since it was felt that the results of these tests would possibly provide information both on the preferred part of the original figure, and on transfer to outlines from the solid figure. The solid figure was presented with the diamond to investigate the possibility of confusion being caused by the presence of two apices. (3 series).

h) Rotated figures: 45^o rotated 2.0 cms. triangle and 2.0 cms. circle (1 series); 90^o rotated 2.0 cms. triangle and 2.0 cms. circle (1 series); 45^o rotated 0.5 cms. triangle and 0.5 cms. circle (1 series); 90^o rotated 0.5 cms. triangle and 0.5 cms. circle (1 series); 90^o rotated 2.0 cms. triangle and cross (1 series); 90^o rotated 2.0 cms. triangle and square and diamond (2 series).

In view of the results obtained by Fields (1932; see Section II) and with one animal in the pilot study reported in Section VI, it was thought worthwhile to investigate this particular aspect of discrimination thoroughly. Accordingly, two sizes of triangles, each with two rotations, were presented, to see whether size played any part in the recognition of rotated figures. (It should perhaps be mentioned that a 90° rotation gives the appearance of an inverted figure, and is often thus referred to in the literature).

The remaining three series were given after a break, during which several standard series were presented, and figure-ground reversal was investigated. These last three rotation series were given in an effort to throw some light on the determining qualities of figure recognition. These particular negative symbols were chosen because a) although they had been seen previously by the animals, it was unlikely that there had been time for any marked avoidance response to be attached to them, and b) all three figures had some aspects similar to the inverted triangle, i.e.: cross: vertical axis; diamond: lower apex; square: upper base line. (7 series).

i) Figure-ground reversal: 2.0 cms. black triangle and 2.0 cms. black circle on a white ground.

This series was presented in order to see whether there was any transfer when the brightness relationship of the figure and ground was reversed. (1 series).

j) Control and breakdown measure: Five 2.0 cms. circles in every panel.

The purpose of this series was twofold: a) to ascertain whether previous discrimination had been dependent on any cues other than visual ones, b) to provide a chance base line against which other results could be compared. (1 series).

k) Black/white retention: plain white (positive) and plain black (negative) stimuli.

This series was given to see whether, after lengthy form discrimination training and testing, there was any evidence of the original brightness discrimination having been retained.

(Copies of the symbols used in this experiment are given in Appendix G).

5. Pre-training.

The group of animals used in this experiment were experimentally naive, so all animals were handled by the experimenter every day for 10 days before the experiment.

Every animal spent 10 minutes a day for the next three days in the apparatus, with all the doors wide open. On the fourth day, the doors were gradually closed, until by the last trial, they were completely closed; this was repeated on the fifth day. Finally, all animals were allowed to run through the apparatus several times, with all the doors closed but unlocked.

6. Procedure.

When two or three individuals began to show position habits in the pre-training, the experiment, involving simple black/white discrimination was started. The four negative doors of each panel, containing the plain black symbol, were locked; the one positive door, with the white symbol, was left unlocked.

At the beginning of each series, S was placed in the reward box for one minute, to give it time to wake up and to adapt to the situation. It was then coaxed into a plastic mug (see Section III), and transported to the first choice box, where it was released in the centre, at the back.

The choices for each panel were recorded in terms of those correct and the number of errors. On reaching the reward box, the animal was allowed two minutes, after which it was taken back to the first choice box for the next trial; the symbols were changed by the experimenter during this reward period. During some of the later series, it was found that the hamsters would sometimes accept a very small quantity of peanut, which they ate rapidly; at other times, the peanut was pouched, or refused altogether, so this behaviour was not constant.

When the black/white discrimination had been learnt, white 2.0 cms. triangles were substituted for the plain white positive symbol. When this, too, had been learnt, the plain black symbols were replaced by 2.0 cms. white circles on a black ground. Thus, the learning problem has changed from brightness discrimination to form discrimination.

Training on the standard figures (2.0 cms. triangle and circle) was continued until all animals had achieved the 0.01 level of confidence. A series of transfer tests was performed, in which alternative figures were substituted for the circle, the sizes of both the circle and triangle were altered, parts of the original symbols were presented, and the triangle was rotated. Check trials on the standard symbols were given after each set of transfer tests.

The experiment was normally performed in the early evening.

7. Results.

a. Treatment of Results. The levels of probability, based on Fields' (1953) method, are given in Appendix H; 9 correct choices out of 20 are significant at the 0.007 level, and

7 out of 20 at the 0.05 level.

As in SMVDA I, results are described in terms of levels of probability. Any reference to a certain level means that $P <$ than this level.

The graphs in Figures 6(a) and 6(b) show the average score for all six animals during the training and transfer tests. The graphs in Appendix K give the scores for each individual.

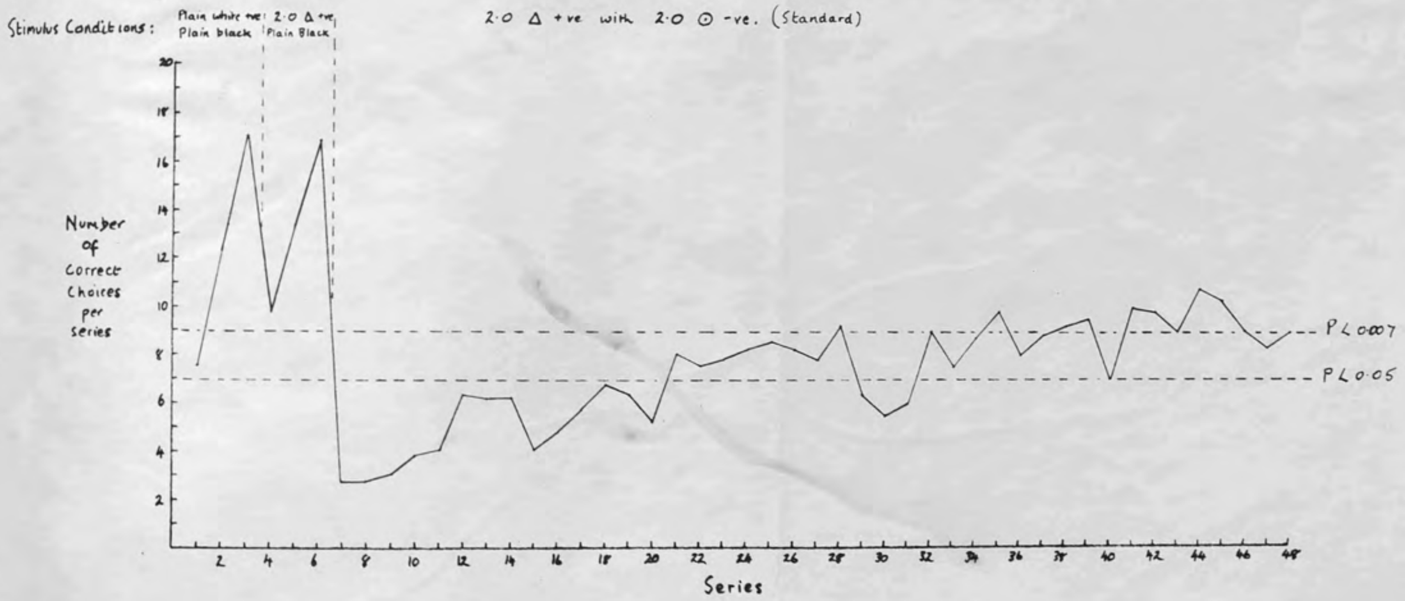
The various results are described in detail in the following paragraphs.

b. Summary of Results. From the results which are given in detail below it is apparent that golden hamsters are able to learn a brightness discrimination between black and white. They are also able to learn a form discrimination between a triangle and a circle, although this learning requires longer training.

Transfer tests showed that substitution of alternative negative figures (cross, rectangle, zigzag and square) for the circle did not impair discrimination. However, there was a significant difference ($P < 0.05$) between the results obtained for the rectangle and the square, the scores for the rectangle being lower. There were no significant differences between the other figures.

Generalization to size occurred when the standard 2.0 cms. symbols were substituted by 1.5, 1.0, 0.5 and

FIGURE 6a. SMVDA II: Brightness Discrimination and Form Discrimination Training.
Average number of correct choices for six animals.



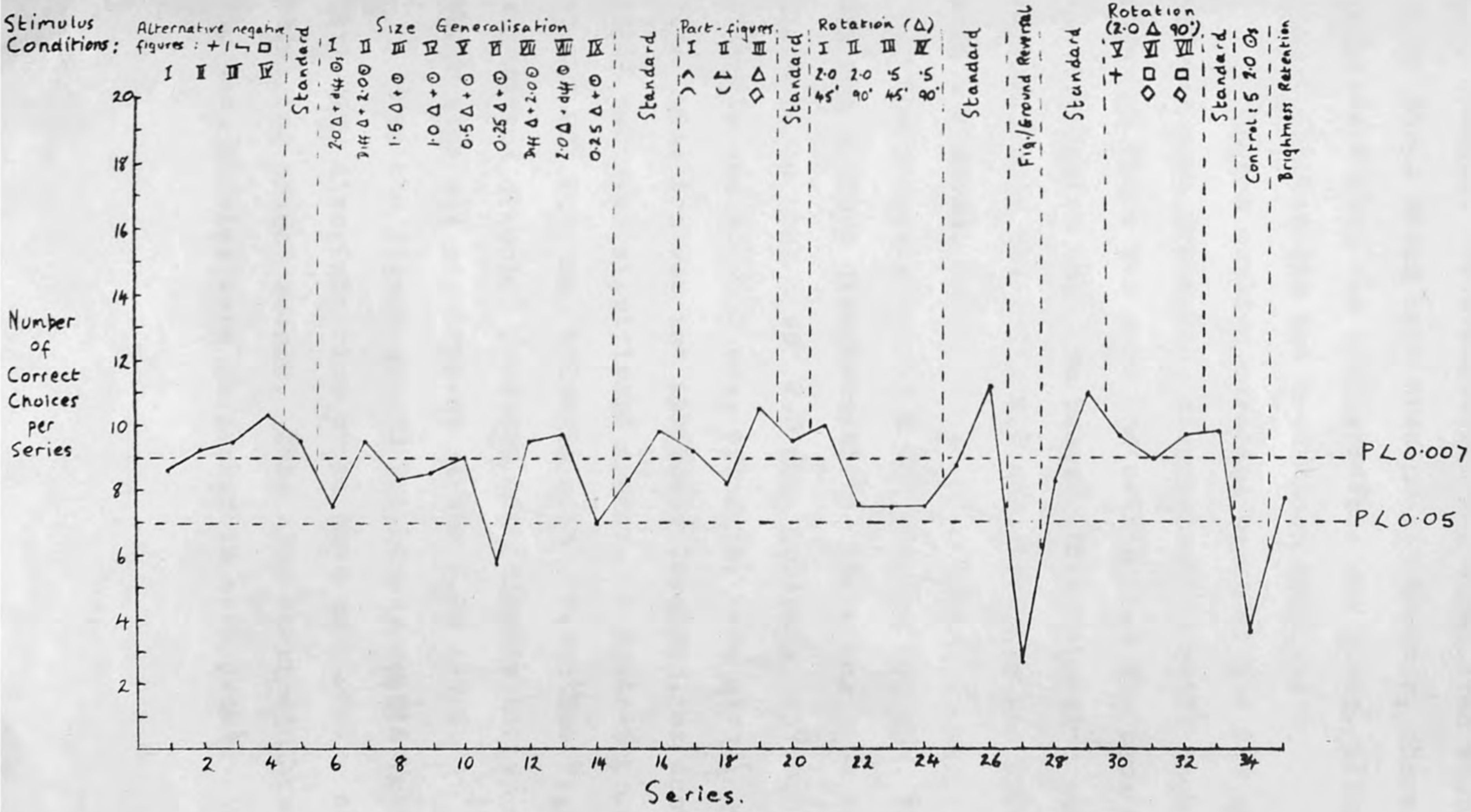


FIGURE 6 b. SMVDA II: Form Discrimination Transfer Tests.

Average number of correct choices for six animals.

0.25 symbols. Discrimination was unimpaired when the first three sizes were presented; however, there was some impairment when the smallest size was given, although discrimination did not break down completely.

When the outline tops and bases of the 2.0 cms. standard figures were presented, discrimination still took place, although there was some indication that the tops were easier to distinguish than the bases. Discrimination scores improved when the solid 2.0 cms. triangle was presented with a diamond.

The presentation of a 45° rotated 2.0 cms. triangle did not disturb discrimination; there was some slight disturbance when a 90° 2.0 cms. triangle, 45° 0.5 cms. triangle and 90° 2.0 cms. triangle, were given, but discrimination was not seriously impaired, as most animals still achieved significant scores. A further presentation of the 90° 2.0 cms. triangle with alternative figures (cross, square and diamond) produced high discrimination scores, which were all significant at the 0.02 level.

When the figure-ground brightness relationships were reversed, discrimination broke down completely, all animals obtaining chance scores. This also occurred when five 2.0 cms. circles were presented in each panel.

A final series to investigate the retention of the black-white brightness discrimination indicated that some discrimination was taking place, but the scores were not very high.

c. Details of Results. A. Brightness Discrimination.

1) Plain black (negative): plain white (positive) discrimination; 3 series.

During the first series, three animals achieved discrimination scores that were significant at the 0.007 level or above, while the score of a fourth animal was significant at the 0.05 level; the remaining two animals obtained chance scores. In the second series, all scores were significant at the 0.002 level or above, while in the third series, the lowest level of significance was 0.00001; in this last series, two animals made 19/20 and 20/20 correct choices.

2) Plain black (negative): white 2.0 cms. equilateral triangle on a black ground; 3 series.

There was a slight initial fall-off in the scores obtained in the first series; however, four animals were still achieving scores at the 0.007 level and above. The scores of all six animals were significant at the 0.007 level in the succeeding series, and in the last series, the lowest level of significance was 0.000002; again, one animal scored 20/20 and two animals 18/20.

B. Form Discrimination. Training.

1) White 2.0 cms. diameter circle on black ground: white 2.0 cms. equilateral triangle on black ground; 42 series.

The scores of all six animals dropped to chance level in the first series when form discrimination was introduced. There was a gradual improvement during the next 21 series, four animals obtaining scores at or above the 0.007 level of significance in series 23; the fifth animal's score was significant at the 0.05 level, and the score of the sixth animal dropped to just above chance level, although it had obtained significant scores in the series immediately preceding number 22.

There was then a break in training of three weeks, and it is thought that this accounts for the marked drop in scores in series 23, 24 and 25. From then on, however, the scores rose again to their original level, and although individual performances were a little erratic, the average scores for all six animals often rose well above the 0.007 level. Individual scores frequently reached the 0.00009 level and above.

During the last six series of this training procedure, all animals consistently achieved scores at or above the 0.05 level of significance; again, individual scores were frequently considerably higher. The introduction of a fresh set of symbols in the last three series did not impair discrimination, although they caused an increase in sniffing and general investigation.

Although further training might have produced a higher final overall rise, it was considered that, as the average score had been consistently above the 0.05 level for the last 17 series, and as all six animals had individually demonstrated that they had mastered the problem, further practice was superfluous. Training on the standard 2.0 cms. symbols therefore stopped after the 42nd series, and transfer tests were introduced.

C. Form Discrimination: Transfer Tests.

1) Substitution of alternative negative figures (cross, rectangle, zigzag and square) for the negative 2.0 cms. circle; 4 series. All four figures were presented in each series.

At no time during these four test series did any of the scores drop below the 0.05 level of significance; many rose well above to the 0.0005 level. The average score remained near or above the 0.007 level.

When the results for the different alternative figures were separated out, the average score for each figure was at the 0.02 level or above; nevertheless, using the Mann-Whitney U-test, the difference between the scores obtained on the rectangle (average 8.2) and those on the square (average 10.3) was found to be significant ($P < 0.05$). Behavioural observations suggested that the rectangle caused slightly more confusion than the other figures.

2) Size Generalisation, from 2.0 cms. symbols to 0.25 cms. symbols; 9 series.

The introduction of a variety of circle sizes (2.0, 1.5, 1.0, 0.5, 0.25 cms.) with the standard 2.0 cms. triangle in the first series caused a slight drop in the scores; however, five of the animals were still achieving scores at or above the 0.05 level of significance, and when the series was repeated in Series 8, all six animals obtained scores at the 0.02 level and above. In Series 2 and 7, the size of the triangle was varied from 2.0 to 0.25 cms., while the circle remained at 2.0 cms.; here, two out of the twelve scores were at the 0.05 level, while the remaining scores were above this level, many being above the 0.007 level.

In series 3, 4 and 5, 1.5 cms. triangle with 1.5 cms. circle, 1.0 cms. triangle with 1.0 cms. circle, and 0.5 cms. triangle with 0.5 cms. circle were given respectively. Discrimination of the symbols was still unimpaired, although one animal appeared to find some difficulty with the 1.0 cms. triangle and circle. However, the average score for all six animals still remained about the 0.01 level of significance.

A 0.25 cms. triangle and a 0.25 cms. circle were presented in series 6 and 9; in series 6, discrimination was impaired to some extent, only two animals achieving scores that were significant at the 0.05 level; the average score was considerably lower. In series 9, two animals obtained scores at the 0.007 level of significance, and one at the 0.02 level; however, three animals were below the 0.05 level. Behavioural observations of both series indicated that there was some confusion.

3) Part-Figures: series 1: apex of 2.0 cms. triangle
and upper arc of 2.0 cms. circle.
series 2: base of 2.0 cms. triangle
and lower arc of 2.0 cms. circle.
series 3: complete 2.0 cms. triangle,
and substitution of diamond (2.0 cms.
diagonal) for circle.

Five animals achieved scores well above the 0.05 level for both the upper and lower parts of the figures; the sixth animal's score fell to just below the 0.05 level. The average for both series was, for series 1, just above, and for series 2, just below, the 0.007 significance level.

There was some indication, from behavioural observations, that the bases of the figures were slightly more difficult to discriminate than the tops, but the only indication of this in the results is that each animal's score (except one) fell by either one or two points; even then, a significant level of discrimination was maintained.

The presentation of the 2.0 cms. triangle with the diamond produced scores that were all at the 0.02 level of significance or above; the average for this third series was significant between the 0.002 and the 0.0005 levels.

4) Rotated figures: 2.0 cms. and 0.5 cms. triangles rotated through 45° and 90°; 7 series.

The presentation of the 45° rotated triangle with a 2.0 cms. circle caused no impairment in discrimination. All animals achieved scores that were significant at the 0.02 level and above; the average score for the series was significant at the 0.002 level.

In the second series, when a 90° rotated 2.0 cms. triangle with a 2.0 cms. circle was given, there was some disturbance of discrimination, but all the scores (except one which was just below) were significant at the 0.05 level, although none reached the 0.01 level.

A 45° rotated 0.5 cms. triangle presented with a 0.5 cms. circle in the third series produced similar results, although one animal's score was significant at the 0.002 level.

In the fourth series, a 90° rotated 0.5 cms. triangle with a 0.5 cms. circle produced four scores significant at the 0.05 level and above, and two just below the 0.05 level. The average score for these last three series was identical, and was between the 0.05 and 0.02 levels.

Therefore, although discrimination was disturbed, it was not seriously impaired by rotation of the triangles. However, presentation of the standard 2.0 cms. upright triangle and 2.0 cms. circle immediately after these four rotation transfer tests produced results that soared to the 0.007 level and above.

In the remaining three rotation series, a 90° rotated 2.0 cms. triangle was presented, in the first series, with a cross, and in the second two series, with a diamond and a square. In all three series, all the scores were significant at the 0.02 level and above. The average score for all six animals did not fall below the 0.007 level. Comparison of the results obtained with the diamond and square showed that there was no difference, the averages being identical.

5) Figure-ground Brightness Relationship Reversal: 2.0 cms. black triangle and 2.0 cms. black circle on white

grounds; 1 series.

The presentation of this series caused a complete breakdown in discrimination. No animal achieved a score above chance level. Behavioural observations showed that there was marked confusion and agitation among all six animals.

6) Control and Breakdown Measure: five 2.0 cms. circles per panel; 1 series.

This series was preceded by a check series, in which the standard 2.0 cms. triangle and circle were given; all animals achieved scores that were significant at the 0.02 level and above.

When five circles were presented, however, discrimination broke down completely; all scores dropped to chance level. Once again, behavioural observation indicated that the animals were disturbed, although not so agitated as in the figure-ground reversal series; the tendency was for each animal to examine all the doors in a panel thoroughly several times, and then to push indiscriminately.

This series therefore checked that previous discrimination had been dependent on visual cues only.

7) Brightness Discrimination Retention: plain black (negative) and plain white (positive); 1 series.

Only two animals achieved scores at the 0.007 level or above; three more reached the 0.05 level, and one remained at chance level. The general impression was one of confusion at first, but the scores improved as the series progressed.

These results are discussed in the final section.

D. Preference Tests.

1. Introduction.

In view of Lashley's (1938) results with rats, in which he demonstrated that these animals appear to have a pre-existing preference for horizontal stripes, it was decided to conduct a short series of preference tests on golden hamsters who had (a) been trained to discriminate between shapes, and (b) who had not. In this way, it was hoped to demonstrate that, if a similar preference existed in hamsters, it was either inherent or due to experimental training.

Further tests were conducted with the experimentally naive group of animals, using black/white and triangle/circle stimuli. It was felt that, if any preference was shown by these animals for a particular stimulus, then this apparent pre-existing preference in hamsters might have influenced the speed of discrimination learning in the visual discrimination experiments.

2. Procedure.

Four doors in each panel of SMVDA II were used for these tests; the fifth door was blocked off. Each panel had two negative and two positive stimuli, thus equalising the chances of either stimulus being chosen.

Three pairs of stimuli were tested for preference: horizontal and vertical 0.4 cms. black and white stripes; 2.0 cms. equilateral white triangle and 2.0 cms. diameter white circle, both on black backgrounds; plain black and plain white stimuli. One series per animal was given for each pair.

The order of presentation of the stimuli were randomised over the panels and throughout the series to control for position habits.

Two groups of animals were used:

a) a control group (C) of six animals, who had not been used for either brightness or form discrimination before; these animals were trained to open the doors of the apparatus previous to being tested.

b) the experimental group (E) of six animals trained on both brightness and form discrimination in the final experiment SMVDA II.

Both groups of animals were of the same age (16 weeks), sex (male) and strain (wild agouti). For further details of these animals, see Appendix B .

Group C was tested on all three pairs of stimuli; Group E was tested on the horizontal and vertical stripes only, since they had been trained on the other two pairs previously.

3. Results.

Group C:

i) Black and white: one animal showed a preference for white, significant at the $P < .025$ level. One other animal showed a slight, but not significant preference for white, while the remaining four showed no preference for either shade.

ii) Triangle and circle: one animal showed a slight, but not significant preference for circles, while the others obtained equal scores on both symbols. Four animals had by now adopted position habits to the first door.

iii) Horizontal and vertical stripes: no preference was shown by any animal for either stimulus.

Group E:

Horizontal and vertical stripes: one animal showed a slight but not significant preference for vertical stripes, while two other animals showed slight but not significant preferences for horizontal stripes. The remaining three animals showed no preference for either.

4. Summary of Results.

Of the six animals in the control group C, who were presented with three different pairs of stimuli, only one animal showed a significant preference for white. The remaining animals showed no preference for any of the six stimuli.

In the experimental group E, who were given horizontal and vertical stripes, one animal showed a preference (P = not significant) for the vertical stripes; the other five animals showed no significant preference for either stimulus.

VIII DISCUSSION.

A. Methods and Apparatus

The results described in the last section are important not only in their own right but for the attention that they draw to methodology.

The solution to the methodological problems encountered in this study proved in the end to lie in successfully focusing the animal's attention on the discrimination task itself. Since the object of the experiment is to test the animal's capacity for visual discrimination and generalisation, it is important that the learning involved should be as easy for the animal as possible and that the method should make the optimal use of the animal's capacity. It is perhaps particularly interesting that the problem was ultimately solved not by increasing the strength of motivation, but by making the best use of it. Alterations in the testing procedure, which remove from the animal's field of visual attention virtually all other stimuli but those to be differentiated, elicit rapid learning, as can be seen from the experiment (described in Section VI) where an animal learnt a black/white discrimination to a 100% efficiency level in 30 trials on the circular apparatus. The same animal showed no evidence of having learnt anything in 150 trials on a more traditional type of two-choice apparatus.

The same point is brought out, though in a slightly different way, when the results of the six animals trained in the 5-unit 2-choice apparatus (see page 108) and then on the serial multiple visual discrimination apparatus I (see page 130) are compared. In the first experiment, each animal made 380 choices on a form discrimination problem and there was little or no evidence of learning in any member of the group. Yet, when these same animals were trained some weeks later on the SMVDA I apparatus, form discrimination was achieved at the 0.05 level of significance in less than 100 trials. The rapidity with which this learning took place in the second apparatus by comparison with the experimentally naive group who were trained in SMVDA II, suggests that a large amount of latent learning had in fact occurred during the first experiment. Yet this learning was not obvious until a suitable apparatus was designed to elicit it. Here, the success of the second apparatus depends not on surrounding the animal with unavoidable visual stimuli, (with form discrimination this would be very difficult), but on a slight shift in the task which confronts the animal, so making the learning of the form discrimination the easiest thing for it to do with the situation.

The difference between the two methods as regards learning success may be interpreted in terms of the phenomenological approach (Snygg 1935); the latter would suggest that in the two-choice apparatus, the easiest way out of the situation is not to use the symbols as signs, whereas in the 5-choice apparatus the situation is reversed. In fact the stimuli come to have a sign value for the animals in this situation, which, in view of the rapidity with which errors can be corrected, they do not have in the two-choice situation. The experiment is thus adjusted to the animal and makes the optimal use of its desire to escape from the choice boxes.

The form discrimination results show this phenomenon equally clearly. In other words, although training on the 5-panel 2-choice apparatus was continued for 380 choices, there was little or no evidence of learning. In SMVDA II, on the other hand, the average score had reached the 0.02 level of significance after 280 choices; the learning curve showed a marked rise after 80 choices and continued to rise steadily, although somewhat erratically.

The conclusion from the evidence is that it is important to adjust the balance of the available motivation in such a way that the most efficient learning situation is established.

In connection with the question of motivation strength, it is quite clear from the results obtained during this investigation that exploratory drive as a source of motivation is adequate for the learning of a complex discrimination task. It might be argued that stronger motivation, of the classical type, would perhaps produce quicker learning or higher overall scores. However, although some animals may learn more quickly under strong motivation, once they have grasped the problem, others are likely to adopt a rigid pattern of behaviour in an attempt to reduce the incomprehensible punishment. In addition, it is not necessary to obtain 100% correct choices from each animal, since in the multi-choice apparatus the probability levels are sensitive enough to indicate whether the task has been learned without demanding compulsive efficiency from the animals.

Of particular relevance to this question is the fact that in this study all 12 animals used in SMVDA I and II learned the problem set them; yet Lashley (1938) and Dodwell (1957) both admit to having discarded animals who did not reach the necessary learning criterion.

The chief conclusion that is reached about the question of motivation is that, with hamsters at least, the exploratory drive is quite adequate, provided that the animal's attention is properly focused on the discrimination problem. The theoretical interest of this lies in two directions:

first this source of motivation is commonly used with monkeys but is unusual with rodents; secondly, for these animals it is entirely effective, and incomparably simpler to use than techniques which require elaborate feeding schedules and expensive apparatus.

B. Form Discrimination and Generalisation.

With the results of SMVDA I and II (given in Section VII), a good deal has been established about the visual capacities of the golden hamster. Since the only existing evidence is the experiment by Rensch and Rahmann (1960), in which hamsters are reported to have discriminated horizontal from vertical stripes,[1] this has some general value. The basic work on this species can now be said to have been done, since both brightness and form discrimination have been established together with an approximate measure of acuity. With the modified Fields apparatus, it should be possible to extend this knowledge fairly rapidly. However, most of the previous work done in this area on rats has been carried out for its theoretical interest rather than for strictly comparative purposes. The comparison of the results obtained

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[1] Since Rensch and Rahmann used 1.5 mm. vertical striae and 2.5 mm. horizontal striae as stimuli without giving any data on acuity, a certain doubt arises as to whether this was a form or brightness discrimination. If, as the results reported in this thesis suggest, 2.5 mm. figures are marginal for acuity, it seems possible that Rensch and Rahmann's 1.5 mm. striae were seen as grey, and hence the possibility exists that the discrimination was one of brightness rather than of form.

here with those of other workers is interesting because of its theoretical importance rather than as a matter of interspecies comparison. It could be argued that some of the discrepancies can be explained by species differences, but the species are closely enough related for it to be possible to suggest that the disparity arises from differences in method rather than in visual capacity.

Since the main object of the study was form rather than brightness discrimination the latter was not investigated fully but used rather as a buffer for the more difficult form learning. However it is perhaps worth noting that a simple brightness discrimination is very easily learnt in the right situation. Form discrimination is much more difficult, taking 300 choices to establish as against the 20 or 40 choices for brightness.

The more rapid discrimination learning apparent in SMVDA I was thought, as suggested earlier, to be due to latent learning, and the results obtained in this particular experiment would appear to support the theory that learning takes place in situations which do not elicit any evidence that it has occurred.

It is necessary here to discuss SMVDA I and SMVDA II separately, in view of the different procedures used in each experiment. Since SMVDA I was in the nature of a methodological test, generalization of discrimination was not pursued very far. Thus as soon as the animals showed evidence of having learnt the standard problem of discriminating a triangle from a circle, a short series of size generalisation tests was given. These suggested that alteration in the size of the negative symbol discrimination was not disturbed, whereas alteration in the size of the positive symbol caused some impairment, and, in the case of the 1.5 cm. triangle, quite a considerable amount. However, for reasons to be given below, these results were not considered to be as informative as those obtained in SMVDA II.

In this second experiment (SMVDA II) overlearning was deliberately introduced into the situation, since it was considered that the introduction of a new symbol in the form of transfer tests would possibly then cause less disturbance to the discrimination set, and the results might therefore provide a better measure of generalisation per se. Therefore training was continued until all the animals were obtaining scores considerably above the 0.05 level of probability, and the average score was on or about the 0.007 level.

The introduction of alternative negative figures at this point produced no disturbance in discrimination, and clearly demonstrated that the response was made to the positive rather than to the negative figure. The results also showed that the aspects of the negative figures which were similar to the triangle, such as the base of the square, did not cause confusion. However, one interesting discrepancy was observed: a significantly greater number of correct choices was made when the square was presented than when the vertical bar was presented. This lends support to Lashley's theory that the vertical axes of figures are more important in discrimination than the horizontal axes; however, it is worth noting that the presentation of the bar did not <u>impair</u> discrimination, and it seems likely that this question of the vertical axes was not as important as his work suggested. It is also worth noting that the vertical bar of the cross did not have the same effect. The horizontal top of the square in contrast to the apex of the triangle may have accounted for the greater number of correct choices in this case, and it also suggests that the reaction to the figures is <u>not</u> in terms of the base line, as Lashley, Munn and others found it to be with rats. Since the average scores of both approached the 0.007 level of significance, it is perhaps unwise to place too much weight on the differences in the results for the two symbols.

Three tentative conclusions arise from the first set of results: first, that the approach is to the positive figure; secondly, that discrimination is not in terms of the base line only; thirdly, it is possible that the tops of the figures are important.

The second series of transfer tests were concerned with size generalisation. These results showed that variation in the size of one symbol while the other remained constant did not cause any impairment of discrimination. Neither was there impairment when the sizes of both symbols were reduced from 1.5 cms. to 0.5 cms. However, there was marked impairment when 0.25 cms. triangle and circle were presented. Although scores rose slightly in the second presentation of this size, there was still difficulty, which was apparent in the behaviour of the animals: they were more confused. This last result is particularly interesting in that it suggests that a behavioural measure of visual acuity has been reached, since it appeared that if the size of the symbols was reduced any further, discrimination would break down completely. It also shows that visual acuity in the golden hamster is considerably better than might have been expected in a semi-nocturnal animal.

There is a slight contradiction in the results obtained with the SMVDA I and II; results from the former group of animals had suggested that alteration in the size of the positive figure impaired discrimination, whereas this did not occur in the second group. It is thought that this is due to the over-learning which was allowed in the second group, and that the results of the first group were caused not so much by the lack of <u>ability</u> to generalise, but by the disturbance of expectancies and set caused by the introduction of the different positive figure. The results of the second group were therefore considered more valid.

Thus it has been shown that golden hamsters can generalise to sizes smaller than the symbols on which they have been trained, but that discrimination is impaired when a size as small as 0.25 cms. is given, suggesting that a behavioural measure of acuity has been obtained.

The transfer tests on part-figures indicated that, not only could golden hamsters generalise to the outlines of a figure, but that they could discriminate between parts of figures as well. The first finding is in accordance with results found in the literature on rats. The second is not, for the following reasons: the hamsters were able to discriminate easily between the upper parts of the figures, but not quite as easily between the lower parts, although the results for the latter were still clearly significant at the 0.05 level. Nevertheless behavioural observations suggested that the second series caused slightly more difficulty. However, discrimination was much better than either of these two series when the whole figure was presented with a diamond. Since these part-figures were outlines only this result also suggests that Dodwell's contention that the learning of solid figures was due to brightness rather than to shape discrimination, is a little superfluous.

These results suggest three things: first, that hamsters are able to discriminate between either the tops or the bases of the figures; secondly, that it is slightly easier to discriminate between the tops than the bases; thirdly, that the whole figure is easier to discriminate than either of its parts. This last point is supported by a) the higher results obtained in this series and b) by the lack of confusion between the two apices of the triangle and the diamond. Therefore, although the tops appear to be fairly important in discrimination, the whole figure predominates.

These results are in direct contradiction to those on rats, in which it was found that apparently the base line dominated discrimination, and when the tops of the figures were given, discrimination broke down completely (Munn 1930). It is suggested that the results obtained with golden hamsters differ from those of rats because of the technique of investigation; this point is discussed in detail later.

The results from the rotation tests were particularly interesting in view of the rat findings. In this investigation, it was found that hamsters were able to generalise not only to 45° rotated 2.0 cms. and 0.5 cms. triangles, but to inverted triangles of the same sizes. The best results were obtained with the 45° 2.0 cms. triangle, in which discrimination was quite undisturbed. Some disturbance occurred in the successive three series, but there was no serious impairment, and the majority of scores were at the 0.05 level of significance and above. A further three series, in which an inverted 2.0 cms. triangle was presented with a cross, square and diamond, showed no disturbance in discrimination at all, although the results were slightly lower than in a preceding trial with the standard.

It is suggested that, in view of these later results, the fall-off in scores obtained during the first four series was due to disturbance of set introduced by a major alteration to the positive figure, and that it was not due to an inability to generalise to rotated figures.

Two conclusions can be drawn from these results: the first lends support to the part-figure test results, in that the response appears to be to the whole figure and not to its parts, since there is no confusion with the apex of the diamond, the base line of the square or the axes of the cross. The second, and more important, conclusion is that there is evidence of formation of at least a limited concept of triangularity; the stimulus has meaning outside the presented Gestalt formed by the symbol and the door. According to Lashley (1938) his rats were discriminating in terms of the Gestalt formed by the triangle and the edges of the card; this was clearly not happening in this case.

In connection with this aspect of form discrimination, it is worth referring back to Fields' (1932b) results. He states: first, that a 10° rotation of a triangle caused a disturbance in discrimination; secondly, that it required nearly as many trials for a rat to learn each new orientation of the triangle as it did to learn the original upright figure; thirdly, that orientations of the triangle are only recognised after prolonged training with the figure-ground brightness relationships reversed, and that a concept of triangularity could only be said to be formed after about 40,000 trials. In view of this, it would seem that the results obtained with rotated figures in this investigation are worthy of attention.

The hypothesis that the concept of triangularity is limited is supported by the results of the figure-ground brightness relationship reversal, in which discrimination broke down completely, and there was no transfer. This finding is in agreement with previous rat studies. Together with the five-circle breakdown series, this series is also of value in demonstrating that previous discrimination had been in terms of visual signs alone. The results in the case of the part-figures and the rotated figures are therefore less likely to be experimental artifacts.

The results of the final black/white retention series mean little, since it is impossible to tell whether the discrimination that did occur was based on memory or on learning within the series; in view of the ease with which brightness discrimination can be learnt, the latter is quite possible. The results are very similar to those of the first brightness discrimination training series, and it is probable that retention of the original task was slight, or that the change in the nature of the discrimination problem caused confusion, masking any retention there was.

The preference tests suggested that there was no pre-existing preference for any of the stimuli, except possibly for white; this finding may possibly be caused by the experimental situation, since the white panel was the only easily distinguishable object in an area of black. The result also occurred with only one animal, so the preference can not be said to be very dominant.

The lack of preference for either horizontal or vertical striations is interesting when Lashley's results are considered. He states that there was a pre-existing preference among his rats for horizontal striations, but it seems possible that this preference is an artifact induced by the use of/the jumping stand. Horizontal striations resemble the level of the landing platform, and perhaps suggest a measure of safety to the animal. Dodwell (1958), on the other hand, finds no such preference, although Deutsch (1958) does; the point is obviously debateable.

A brief inspection of the form discrimination results shows an interesting increase in the scores obtained on the standard symbols presented after the later transfer tests. This suggests that a discrimination set (comparable to Harlow's (1953) learning set) has been formed; thus, although there is an initial fall-off in transfer test scores, due to a disturbance of this set, the recovery is quick, and the better performance on successive trials shows an overall improvement. Thus the animal orientates itself to the discriminatory aspects of the problem.

The marked difference between the results of this study and the findings of previous work with rats suggests that the actual technique of investigation is more important than is often credited. It is considered that the successful discrimination shown by hamsters in the rotation and part-figure tests is due to the absence of a fixed scrutiny distance, and the small size of the symbols. Former studies with rats seem to be heavily weighted with experimental artifacts, for example, the predominance of the base-line in discrimination. This base line receives the greatest attention by the rat in a jumping stand, since it is (a) nearest the landing platform, (b) on eye-level and (c) within the field of vision. The experimental method is responsible for all three determinants, and therefore the result cannot be taken to have any general validity. The results obtained in the part-figure series in this investigation with hamsters supports the hypothesis: the animals tended to favour the tops rather than the base of the figure, since, in this case, it is the top of the figure which is on eye-level. However, the tendency was to respond to the whole, and this was made possible both by the small figure coming within the field of vision and by the freedom of scrutiny. It seems possible that a marked preference for any particular part of the figure is an artifact produced by the experimental situation.

The results of the rotation and size generalisation tests are affected by the same factors; the impairment of discrimination when the 0.25 cms. symbols are presented is not necessarily an accurate measure of visual acuity, but it is a truer measure than any discrimination performed from an arbitrary fixed distance. It seems likely that if this method was repeated with rats, similar results would be obtained.

The outcome of all this may be reduced to two main points. First, it is felt that the results obtained in this study are possibly more indicative of the real nature of visual discrimination in rodents than previous work on rats has been. Secondly, whether or not this is so, experimental method is critically important; the wrong situation will produce no result, and therefore the wrong assumption as to the animal's learning capacity; the right situation will produce rapid learning, and therefore a more accurate measure of abilities.

C. Conclusion.

According to this investigation, golden hamsters are able to learn both a brightness and a form discrimination. This form discrimination can be generalised to alternative figures, to changes in size, to parts of the figures and to rotated figures, but not to a reversal of the figure-ground brightness relationships.

The source of motivation, namely exploratory drive, was adequate and in many ways appears to be preferable to the stronger, artificially induced types of motivation which are commonly used.

The difference between the results of this study and of other studies with rats is discussed. It is suggested that these differences are due to the type of methodological approach used, which appears to be important for determining the results that are obtained. The success of this particular investigation seems to have depended on the freedom of scrutiny and the small size of symbols, and it is thought that the results obtained by other workers in this field have been affected by not taking these two factors fully into account.

REFERENCES

Berlyne, D.E. and Slater, J., 1957. Perceptual curiosity, exploratory behavior and maze learning. J. Comp. Physiol. Psychol. 50, 228-232.

Bernstein, L., 1952. A note on Christie's "Experimental naivete and experiential naivete." Psychol. Bull. 49, 38-40.

Bernstein, L., 1957. The effects of variations in handling upon learning and retention. J. Comp. Physiol. Psychol. 50, 162-167.

Bovard, E.W., 1958. The effects of early handling on viability of the albino rat. Psychol. Rev. 65, 257-271.

Braun, H.W., Russell, R.W. and Patton, R.A., 1949. Duration of decrements in learning and retention following electroshock convulsions in the white rat. J. Comp. Physiol. Psychol. 42, 87-106.

Brazier, M.A.B., 1960. The electrical activity of the nervous system. London: Pitman Medical Publishing Co. Ltd.

Deutsch, J.A., 1958. Shape recognition: a reply to Dodwell. Brit. J. Psychol. 49, 70-71.

Dodwell, P.C., 1957. Shape recognition in rats. Brit. J. Psychol. 48, 221-229.

Dodwell, P.C., 1958. Shape recognition: a reply to Deutsch. Brit. J. Psychol. 49, 158-159.

Duke-Elder, S., 1958. System of Opthalmology. Vol. I: The eye in evolution. London: Henry Kimpton.

Duncan, C.P., 1945. The effect of electroshock convulsions on the maze habit in the white rat. J. Exp. Psychol. 35, 267-278.

Ellermann, J.R., 1940. The families and genera of living rodents. Vol. I: Rodents other than Muridae. London: British Museum. 22, 39, 51.

Fields, P.E., 1928. Form discrimination in the white rat. J. Comp. Psychol. 8. 143-158.

Fields, P.E., 1929. The white rat's use of visual stimuli in the discrimination of geometric figures. J. Comp. Psychol. 9. 107-122.

Fields, P.E., 1932 a. Studies in concept formation. I. The development of the concept of triangularity in the white rat. Comp. Psychol. Monog. 9. 1-70.

Fields, P.E., 1932 b. Concerning the discrimination of geometrical figures by white rats. J. Comp. Psychol. 14. 63-77.

Fields, P.E., 1953. The efficiency of the serial multiple visual discrimination apparatus and method with white rats. J. Comp. Physiol. Psychol. 46. 69-76.

Gellermann, L.W., 1933. Chance orders of alternating stimuli in visual discrimination experiments. J. Genet. Psychol. 42. 206-208.

Gentry, E., 1934. Methods of discrimination training in white rats. J. Comp. Psychol. 18. 227-258.

Gibson, E.J. and Walk, R.D., 1956. The effect of prolonged exposure to visually presented patterns on learning to discriminate them. J. Comp. Physiol. Psychol. 49. 239-242.

Gibson, E.J. and Walk, R.D., 1960. The "visual cliff". The Scientific American. 202. 6. 64.

Grassé, P.P. and Dekeyser, P.L., 1955. Orde des rougeurs. (pages 1357 and 1439). In Grassé, P.P. (Ed.) Traite de Zoologie. Tome XVII. fasc. II.

Greenhut, A. and Young, F.A., 1953. Visual depth perception in the rat. J. Genet. Psychol. 82. 155-182.

Grether, W.F. and Wolfle, D.L., 1936. The relative efficiency of constant and varied stimulation during learning. II. White rats on a brightness discrimination problem. J. Comp. Psychol. 22. 365-374.

Grice, G.R., 1948. The relation of secondary reinforcement to delayed reward in visual discrimination learning. J. Exp. Psychol. 38. 1-16.

Hall, C.S., 1934. Emotional behavior in the rat. I. Defecation and urination as measures of individual differences in emotionality. J. Comp. Psychol. 36. 338-360.

Hall, C.S. and Martin, R.F., 1940. A standard experimental situation for the study of abnormal behavior in the rat. J. Psychol. 10. 207-210.

Hall, C.S. and Whiteman, P.H., 1951. The effects of infantile stimulation upon later emotional stability in the mouse. J. Comp. Physiol. Psychol. 54. 61-66.

Harlow, H.F., 1953. Primate learning. In Stone, C.P. (Ed.) Comparative Psychology. London: Staples Press Ltd., 183-238.

Hindle, E., 1947. The golden hamster. In Worden, A.N. (Ed.) The UFAW handbook on the care and management of laboratory animals. London: Baillière, Tindall and Cox. 196-202.

Hindle, E. and Magalhaes, H., 1957. The golden hamster. In Worden, A.N. and Lane-Petter, W. (Eds.) The UFAW handbook on the care and management of laboratory animals. London: UFAW. 324-335.

Humphrey, G. and Marcuse, F., 1939. New methods of obtaining neurotic behavior in rats. Amer. J. Psychol. 52. 616-619.

Jenkins, M., 1928. The effect of segregation on the sex behavior of the white rat as measured by the obstruction method. Genet. Psychol. Monog. 3. 6. 455-568.

Karli, 1954. C. R. Soc. Biol. (Paris), 148, 575, 1111. In Duke-Elder, S., 1958. System of Opthalmology. Vol. I: The eye in evolution. London: Henry Kimpton. 664.

Lashley, K.S., 1930 a. The mechanism of vision. I. A method for rapid analysis of pattern vision in the rat. J. Genet. Psychol. 37. 453-460.

Lashley, K.S., 1930 b. The mechanism of vision. III. The comparative visual acuity of pigmented and albino rats. J. Genet. Psychol. 37. 481-484.

Lashley, K.S., 1932. The mechanism of vision. V. The structure and image-forming power of the rat's eye. J. Comp. Psychol. 13. 173-200.

Lashley, K.S., 1938. The mechanism of vision. XV. Preliminary studies of the rat's capacity for detail vision. J. Genet. Psychol. 18. 123-193.

Lawlor, M.M., 1959. Dominance relationships in the golden hamster with special reference to the influence of heredity. Unpublished Ph.D. thesis. University of London Library.

Lawlor, M.M., 1961. Activity patterns in the golden hamster. Proceedings of the London Conference of the British Psychological Society. Dec. 1961. 5a.

Levine, S., 1960. Stimulation in infancy. The Scientific American. 202. 5. 80-86.

Morgan, C.T., 1939. Studies in vision. I. A technique for the study of visual discrimination in the rat. J. Comp. Psychol. 28. 73-79.

Morgan, C.T., 1942. Studies in vision. II. Dark-adaptation in normal and A-avitaminotic rats. J. Genet. Psychol. 60. 109-119.

Moroney, M.J., 1957. Facts from figures. London: Pelican, A236. 90.

Muenzinger, K.F. and Fletcher, F.M., 1937. Motivation in learning. VII. The effect of an enforced delay at the point of choice in the visual discrimination habit. J. Comp. Psychol. 23. 383-392.

Munn, N.L., 1930. A note on Lashley's method for studying vision in the rat. J. Genet. Psychol. 37. 528-530.

Munn, N.L., 1931. An apparatus for testing visual discrimination in animals. J. Genet. Psychol. 39. 342-358.

Munn, N.L., 1932. An investigation of color vision in the hooded rat. J. Genet. Psychol. 40. 351-362.

Munn, N.L., 1950. Handbook of psychological research on the rat. Boston: Houghton Mifflin Co.

O'Day, K., 1947. Visual cells of the guinea pig. Nature. 160. 648.

Poiley, S.M., 1950. Breeding and care of the Syrian hamster. In Farris, E.J. (Ed.) The care and breeding of laboratory animals. New York: Wiley. 118-152.

Porter, P.B. and Stone, C.P., 1947. Electroconvulsive shock in rats under ether anaesthesia. J. Comp. Physiol. Psychol. 40. 441-456.

Reetz, W., 1957. Unterschiedliches visuelles Lernvermögen von Ratten und Mäusen. Z. Tierpsychol. 14. 347-361. In Sutherland, N.S., 1961. Shape discrimination by animals. Exp. Psychol. Soc. Monog. 1. 30, 43, 47, 52, 57.

Rensch, B. und Rahmann, H., 1960. Einfluss des Pervitins auf das Gedächtnis von Goldhamstern. Pflügers Archiv. 271. 693-704.

Selye, H., 1950. Stress. Montreal: Acta, Inc.

Sgnonina, 1936. Z. Wiss. Zool. 148. 350. In Duke-Elder, S., 1958. System of Opthalmology. Vol. I: The eye in evolution. London: Henry Kimpton. 618.

Smith, K.U., 1933. Apparatus for the study of discrimination in the higher vertebrates. J. Genet. Psychol. 43. 462-466.

Smith, K.U., 1937. The post-operative effects of removal of the striate cortex upon certain unlearned visually controlled reactions in the cat. J. Genet. Psychol. 50. 137-156.

Snygg, D., 1935-1936. Mazes in which rats take the longer path to food. J. Psychol. 1. 153-166.

Snygg, D., 1936. Maze learning as perception. J. Genet. Psychol. 49. 231-239.

Stone, C.P., 1953. Comparative psychology. London: Staples Press Ltd.

Sutherland, N.S., 1961. Shape discrimination by animals. Exp. Psychol. Soc. Monog. 1.

Takatsuki, R., 1937. Vision as a factor of distance discrimination in the white rat. Acta Psychol. Keijo. 3. 1-31. Psychol. Abst. 1938. 707.

Tolman, E.C., 1954. Presidential Address: Proceedings of the International Congress of Psychology, Montreal.

Waddell, D., 1951. Hoarding behavior in the golden hamster. J. Comp. Physiol. Psychol. 44. 383-388.

Weininger, O., 1956. The effects of early experience on behavior and growth characteristics. J. Comp. Physiol. Psychol. 49. 1-9.

Williams, J., 1926. Experiments with form perception and learning in dogs. Comp. Psychol. Monog. 4. 70.

Yerkes, R.M., 1907. The dancing mouse. New York: Macmillan.

APPENDIX A.

Effect of reward time and delay time on the speed of emergence from choice box into a reward area.

This experiment was designed by Dr. Lawlor and Mrs. Hitchcock, and carried out by Miss I. Dugmore as an undergraduate research project. Only a brief summary is given here, for which I am indebted to Miss Dugmore.

Six male golden hamsters were used in this experiment, aged 10 weeks. The reward and delay times were each presented with one another to each animal, using a modified greco-latin square design.

Each animal had five consecutive runs with each combination of reward and delay time. The sets were given at the rate of two a day with a three- or four-hour break between each.

Delay times used were

(a) minimal: the animal was taken from its cage, placed in the delay box and allowed to get out as soon as this was in place.

(b) 30 seconds: as for (a) except that the sliding door of the delay box was kept in place for 30 seconds.

(c) 60 seconds: as for (b) except that the delay was 60 seconds.

Reward times (the time allowed in the reward area between runs) were 30", 60", 90", 120", 150", and 180".

<u>Results</u>.

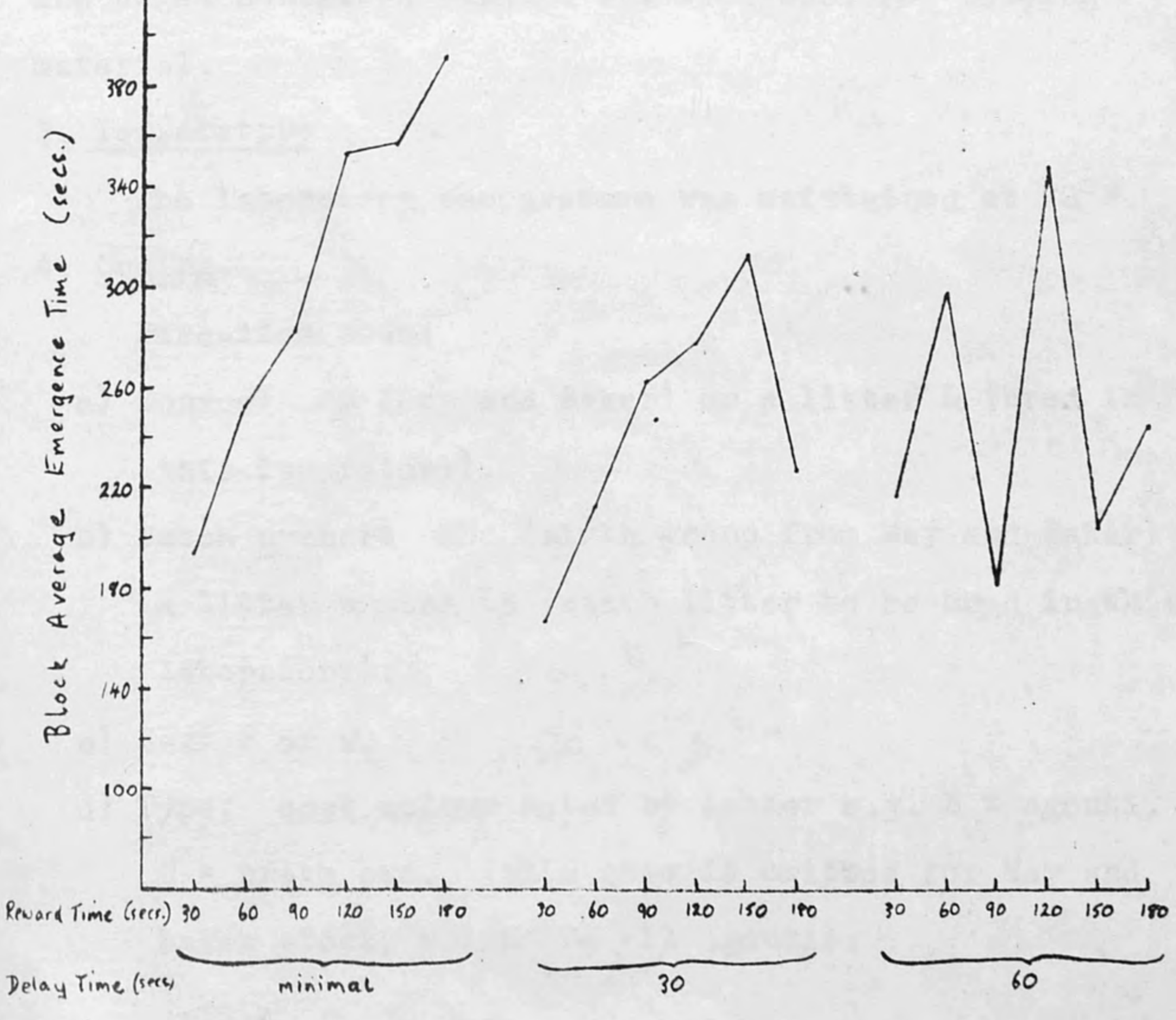
The average lengths of emergence time for each combination of conditions is given in Figure 1. The main findings were:-

1. The emergence time for the first trial of each block was significantly longer than for succeeding trials in the same block.
2. The graph shows that, with the minimal delay time, there is a positive linear relationship between reward times and emergence times.
3. There are significant differences between the animals.
4. There are no significant overall effects when all runs are taken into consideration.
5. When the results for the first run of each block are considered separately there are significant effects for reward and delay times.

FIGURE 1. (APPENDIX A.)

The relationship between time of emergence from the choice box and variations in delay and reward time.

Average results for six animals.



APPENDIX B.

Details of Animals used in Experiments.

1. Diet.

All animals were fed on MRC 41B and SGI pellets ad lib., water ad lib. and one ounce of fresh green food a day per animal.

2. Cages.

The cages were of the solid shoe-box or dish-type, measuring 16" x 12" x 6" deep. The lids were of mesh. The cages contained sawdust and wood wool for nesting material.

3. Temperature.

The laboratory temperature was maintained at 72°F.

4. Coding.

Five-item code:

a) Source: MB (May and Baker) or a litter L (bred in this laboratory).

b) Batch number: MB6 (sixth group from May and Baker) or a litter number L6 (sixth litter to be bred in this laboratory).

c) Sex: ♂ or ♀.

d) Type: coat colour noted by letter e.g. B = agouti, C = cream etc. (this item is omitted for May and Baker stock, which are all agouti).

e) Individual: either i) cage letter and dye mark code
letter e.g. AB (Cage A; marked
on back)
AO (Cage A; not
marked)
or ii) dye code letter only, where groups
or individuals are used. e.g.
(a) LS = left side etc. Code
from 1-10: B, M, N, H, LS,
RS, LC, RC, O, T.
(b) A = cage number (using rest of
alphabet).

5. <u>Experiments.</u>

a. Eye investigation.

Three male golden hamsters aged eleven weeks from May and Baker strain. These animals were being trained currently in the five-unit two-choice apparatus.

b. Visual acuity.

Three male golden hamsters, one aged 17 months, and two aged six months, from May and Baker strain. Previous experimental experience in observational experiments.

c. Depth perception: visual cliff.

The sample of 42 animals was composed as follows:

a) Sex: 34 male; 8 female.

b) Age: 4 weeks, 18 ; 2½ mths, 8; 10-13 mths, 12; 20 mths, 4.

c) Coat colour: 35 agouti; 4 cream; 3 albino.

10 animals had been used previously on the visual cliff.

d. Pilot Study.

Six male golden hamsters aged six weeks, from May and Baker strain. No previous experimental experience.

e. Five-unit two-choice apparatus.

Six male golden hamsters aged nine weeks, from May and Baker strain. No previous experimental experience.

f. One-unit two-choice apparatus.

One male golden hamster aged twenty-one weeks, from May and Baker strain. Previous experimental experience in simple observational experiments, for example, open field and visual cliff.

g. Circular apparatus.

Two male golden hamsters aged thirty weeks, from May and Baker strain. One animal had been trained previously in the one-unit two-choice apparatus (f). The other had been used for simple observational experiments.

h. SMVDA I.

Six male golden hamsters aged 4 mths from May and Baker strain. All animals had been trained previously in the five-unit two-choice apparatus (e).

i. SMVDA II.

Six male golden hamsters, aged nine weeks, from May and Baker strain. Previous experimental experience on the visual cliff only.

APPENDIX C.

VISUAL ACUITY EXPERIMENT.

1. Aim.

The aim of this experiment was to determine whether a golden hamster has sufficient visual acuity to discriminate 2 degree stripes at a distance of 28.6 cms., and, if so, the optimal value of illumination necessary for this discrimination.

2. Method.

a. Subjects: The subjects were three male golden hamsters.

b. Apparatus: The apparatus consisted of a drum which could be rotated independently of a centrally placed perspex box, under even illumination. The inside of the drum was painted with uniform vertical black and white stripes, each stripe measuring 1.0 cms.; the frame was 30 cms. high, 57.25 cms. in diameter and 180 cms. in circumference.

A narrow perspex box, open at the upper end, was suspended over the centre of the drum, and extended into it for a distance of 20 cms. The apparatus was illuminated by a 230 volt 60 watt bulb placed 65 cms. vertically above the bottom centre of the drum; this light was connected to a Variac resistance, which in turn was connected to the mains.

The kymograph was set to rotate at a speed of 37 mm/sec.

(9F); it rotated uniformly.

For all further details of the apparatus, see Plate 1. page 81 and figure 1. App.A.

c. <u>Dependent Variable</u>: S's response to the movement of black and white stripes by head movements and the focussing of attention. The tendency to become lethargic was a further possible result of stimulation (Smith 1937).

d. <u>Independent Variables</u>:

i) The size of the stimulus: 2° stripes at a distance of 28.6 cms.

ii) The levels of illumination, controlled by the Variac resistance.

e. <u>Control of Variables</u>:

i) External illumination: this was controlled by performing the experiment in a dark room.

ii) Drum rotation: this was kept at a constant 37 mm/sec.

iii) Order of presentation of different illuminations: these were presented in a random order.

iv) Position of S's head: the distance of S's head from the sides of the drum was kept equidistant by only taking readings when the animal was facing the centre of the drum.

Figure 1. (appendix C)

Diagram of acuity testing apparatus

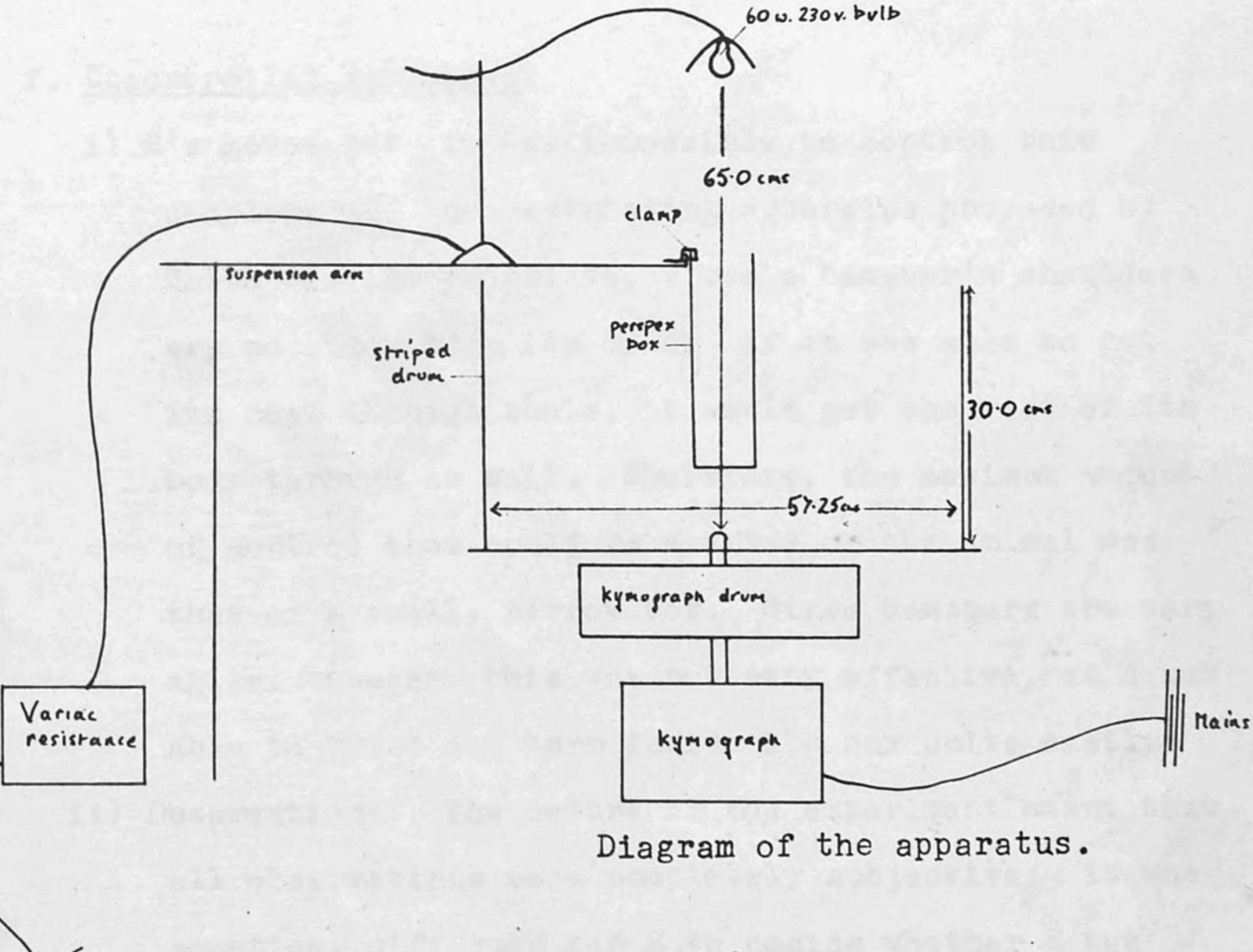
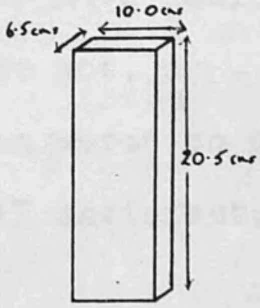


Diagram of the apparatus.



The perspex box.

v) Handling: all three animals were handled for several weeks prior to the experiment. They were also trained for a short time to become used to being confined in a small space.

vi) Sound: to prevent S reacting to the sound of the kymograph switch, the drum movement was controlled from the mains wall point.

f. <u>Uncontrolled Variables</u>:

i) S's movement: it was impossible to control this completely. The restricting apparatus proposed by Smith was inappropriate, since a hamster's shoulders are no wider than its head; if it was able to get its neck through a hole, it would get the rest of its body through as well. Therefore, the maximum amount of control that could be exerted on the animal was that of a small, narrow box. Since hamsters are very agile, however, this was not very effective, as S was able to twist and turn inside the box quite easily.

ii) Observations: the nature of the experiment meant that all observations were completely subjective; it was sometimes difficult for E to decide whether S was reacting to the drum or not.

iii) Eye movements: the eyes were too dark to distinguish the iris from the pupil satisfactorily; it was therefore almost impossible to observe the reflex eye movements that should have occurred when the animal responded to the moving stripes.

3. Procedure.

S was given three trials per series, several series being given a day. Different levels of illumination were used for each series.

At the beginning of the first series, the perspex box was removed, and S placed inside. The box was then firmly clamped in position, so that the animal's head was equidistant from the sides of the drum.

As soon as S had settled down and was facing the centre of the drum, the latter was rotated and S's reactions noted and recorded. The drum was then stopped.. Two further observations were made under the same strength of illumination. The light value was then altered by means of the Variac resistance, and three further observations made as before. In each case, it was necessary to wait until S was facing in the right direction and was reasonably quiet. Not more than five series was given in any one day; S was usually allowed two short rest periods during the experiment.

4. Summary of Results.

Illumination in volts.	Reactions of Animals (see dep.variables above)		
	Positive.	Negative.	Doubtful.
80	1	3	1
100	3		3
110		2	4
120	1	1	1
130	1	1	
140	1	3	2
150	2		
160	2		
180	1		2
220	1	1	
240	1	3	2

The results are for three animals over varying conditions of illumination. No animal was tested on all levels of illumination.

Conclusion.

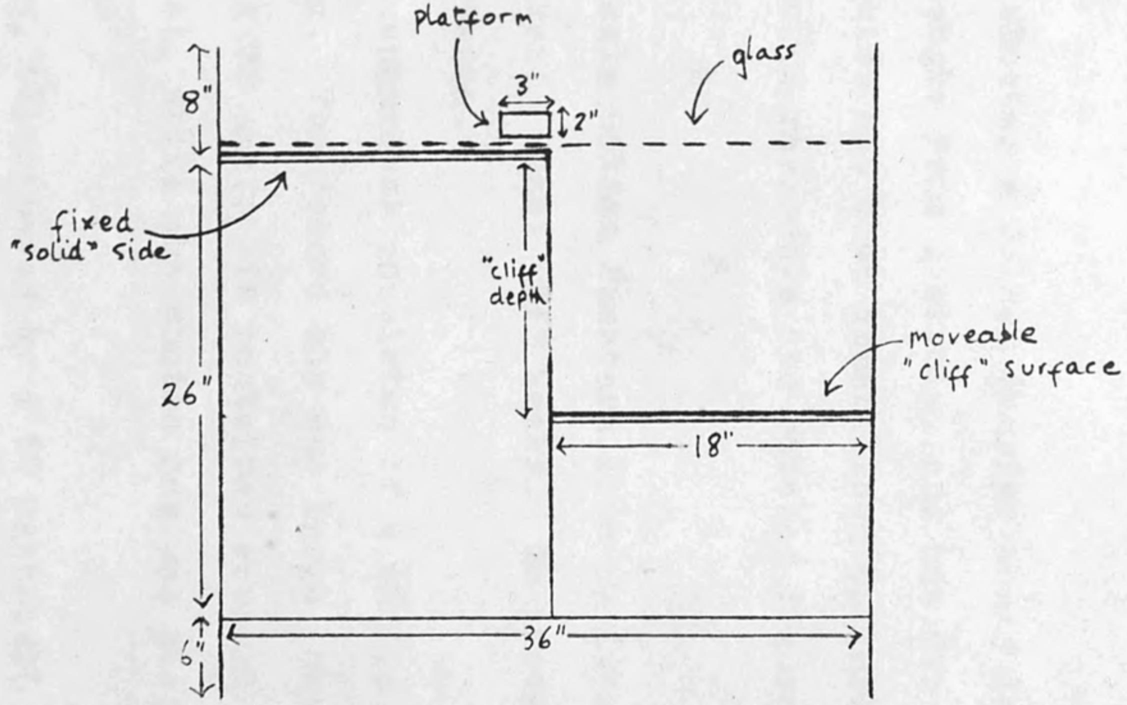
Illumination varying from 100 to 220 v. appears to be adequate for discrimination of 2° stripes at 27.6 cms., but the method is essentially unsatisfactory, accurate observations being almost impossible.

APPENDIX D

Design of visual cliff apparatus

DEPTH PERCEPTION.

Diagram to show the Visual Cliff.



APPENDIX E.

PILOT STUDY.

1. Problem.

To determine whether a Golden Hamster would learn to discriminate a triangle from a circle, and how far this initial discrimination was then generalised to include other symbols, figure-ground reversals and rotated figures.

2. Method.

a. Subjects: Six male Golden Hamsters from an inbred strain (May and Baker). Age: six weeks. No previous experimental experience.

b. Apparatus: The apparatus consisted of a choice box placed inside a reward box. The reward box was large, measuring approximately 110 x 75 cms.; it contained sawdust and a small activity wheel, while the choice box was placed across one corner.

The choice box, illuminated by a 60 watt bulb at 100 volts, was raised about 15 cms. from the floor of the reward box, which was reached by means of a ramp. The hamster could leave the choice box by one of two doors, which were opened by being pushed from the inside; the doors then slid upwards by means of a pulley-weight system. Each door could be locked at will by the experimenter; when a locked door was pushed, an electrical circuit was completed, causing a small light to flash.

Both doors were constructed to hold symbol cards, which were visible from the inside of the choice box. Each card was placed between two pieces of glass, and could be removed from the door when necessary.

Twenty-two symbol cards were used in all; these consisted of triangles and circles ranging from 2.0 cms. to 0.5 cms., together with a square, zigzag, bar, diamond and cross, all measuring 2.0 cms. Three rotated triangles, a triangle apex, base and circle arcs were also used. Except for two, all symbols were white on a black background.

For all further details of the apparatus, see plates 3-6 for photographs in the text pages 97(a)+ 97(b)

c. Dependent Variables:

Number of correct choices made by hamster.

d. Independent Variables:

- i) Triangle versus circle. Standard: white triangle and circle on black background, both symbols measuring 2.0 cms.
- ii) The experimenter.
- iii) Symbols used:
  - (a) Different sizes: △ and ○ in 2.0, 1.5, 1.0, 0.5 cms. Triangle: positive stimulus. Circle: negative stimulus.

(b) Different shapes instead of circle: □ ┌┘ | + ◇

(c) Background reversal: black on white and white on black.

(d) Part figures: ∧ ⏢ ◡ ◠

(e) Rotation: 2.0 cms. △ through 90° and 45°.
0.5 cms. △ through 90°.

e. <u>Control of Variables</u>:

i) The strength of illumination used in the discrimination apparatus was 1 ft. candle at the stimuli (This was based on results from acuity experiment described in Appendix C .)

ii) Motivation of S: Desire to escape from a confined space, together with a tendency to explore.

iii) Randomisation of the doors: the numbers of the doors were randomised, so that the positive symbol did not appear in one door in any particular order, in an attempt to prevent position habits and any prediction that might occur. The randomisation order was adjusted slightly so that each door was used five times in each series of ten trials, and one door was not used consecutively more than twice, e.g. 2121121221. This again prevented any position habit from occurring.

iv) Criterion of correct and incorrect choices: an incorrect choice occurred when S pushed the locked (wrong) door hard enough to cause the contact light to flash. (It also required a fairly hard push to open the positive door). E also observed each choice.

v) Handling: all the animals were handled for three weeks prior to the experiment; they were also allowed to become used to the apparatus, and taught how to open the doors. They were therefore not faced with a new situation when the experiment began.

vi) Criterion for learning: learning efficiency was taken to be 80% correct on the standard.

vii) Olfactory and tactual clues: each symbol was placed between two pieces of glass, which could be washed. Olfactory and tactual clues were therefore prevented to some extent. The animals were also unable to chew the symbol card.

viii) Number of trials: a definite number of trials (usually ten) were given each day. Too many trials at once made S very nervous.

ix) Experimenter: E stood in the same position behind the choice box for each trial, in order to keep the environment as stable as possible.

x) Positioning for each trial: S was always placed in the centre back of the choice box; it was therefore equidistant from both doors. This helped to eliminate the animal's tendency to dash for the nearest door.

xi) When the animal had learnt the standard, any symbols that differed from these two were only presented for one series of ten, so that generalization was being tested rather than new learning.

f. Uncontrolled Variables:

i) Conditions: there was a great deal of loud, irregular external noise, due to building operations.

ii) Experimenter: a change of experimenters during the experiment was unfortunately unavoidable; this change took place for series 23 - 28 inclusive.

iii) Differences between the animals: it was naturally impossible to control this completely; variables were eliminated as far as possible, however, by ensuring that all six animals belonged to an inbred strain, and were of the same age.

iv) Temperature: the temperature of the room fluctuated considerably during the first part of the experiment. This was then corrected so that the temperature was a steady 70°F.

v) Omission of series No.17: owing to the very bad conditions (noise of building operations) under which this particular series was performed, it was felt that it would be advisable to omit the results, as being invalid.

g. Variables Measured:

i) Choice time: the period that elapsed between the time S was placed in the choice box and the time it pushed one of the doors, was known as the choice time. This was measured for each trial.

ii) Exit time: the total time spent by S in the choice box was known as the exit time, and was measured for every trial throughout the experiment. For correct choices, this measurement was, of course, synonymous with the choice time.

3. Procedure.

Since the animals on arrival were six weeks old and unused to handling, each hamster was handled every day for a period of three weeks prior to the experiment. This helped to eliminate, to some extent, the nervousness caused by being faced with a new situation, and made it used to being transferred from place to place.

During the experiment, each series consisted of ten trials; one series was given each day. Throughout all the series, the triangle was taken as positive, and the circle or substituted symbol as negative. The positive door was therefore open and the negative door locked.

At the beginning of each series, after allowing the animal a few minutes to wake up, S was put straight into the choice box for the first trial. A stopwatch was started at the same moment, and both exit and choice times were noted. S was allowed to remain in the reward box for about a minute, during which the exit door was closed, and, if required, the symbols changed; if they were not changed and a wrong choice had been made, the locked door was pressed back to break the light circuit. S was then returned to the choice box for the second trial, and the same procedure used. Except when the animal was actually making a choice, E talked to it throughout the series, particularly when handling it; this seemed to prevent the animal being disracted by external noise to some extent. The symbols were presented in the following order: (See Plate 1: App.E).

Series.	Symbols.	Measurements.
1 - 15	Standard ○ & △ .	2.0 cms.
16 & 18	○ & △ .	1.5 cms.
19 - 23	○ & △ .	1.0 cms.
24 & 25	○ & △ .	0.5 cms.
26	○ & △ , 45° rotated.	2.0 cms.
27	○ & △ . 90° rotated.	2.0 cms.
28	Standard ○ & △ .	2.0 cms.
29	○ & △ .	0.5 cms.

Series.	Symbols.	Measurements.
30	○ & △ , 90° rotated.	0.5 cms.
31	△ & □ .	2.0 cms.
32	△ & + .	2.0 cms.
33	△ & | .	2.0 cms.
34	△ & ┌┘ .	2.0 cms.
35	△ & + .	2.0 cms.
36	Standard △ & ○ .	2.0 cms.
37	△ & ○ , both backgrds. reversed.	2.0 cms.
38	△ black on white & ○ white on black.	2.0 cms.
39	△ white on black & ○ black on white.	2.0 cms.
40 - 42	Standard △ & ○ .	2.0 cms.
43	△ apex & ○ .	2.0 cms.
44	△ apex & ○ upper arc.	2.0 cms.
45	△ base & ○ .	2.0 cms.
46	△ base & ○ lower arc.	2.0 cms.
47	△ apex & △ .	2.0 cms.
48	△ & ◇ .	2.0 cms.

For the last two series, both doors were left unlocked, to act as a check on external clues provided by locking, and to ensure that the former results were not dependent on cues other than those afforded by the symbols. In both sets, the complete triangle was taken as positive, for ease in recording results.

E made qualitative observations on each series throughout the experiment.

4. Results.

a. Treatment of Results. The average result per series of ten trials from S's performance on the first 100 trials was taken as the criterion of expected performance when the animal was not discriminating between the symbols. This was 45% correct, or between 4 and 5 correct choices in each series.

b. Quantitative Results. The results for only one animal are treated, because, of the remaining five animals, four did not reach the criterion for efficient learning on the standard, and one became ill during the experiment.

Results of S_A

The number of trials correct in each series of the independent variables was as follows:

i) Sizes.

(a) Standard. 4 series of 8: 5, 6, 7, 6.
5 series of 10: 8, 8, 6, 6, 8.

(b) 1.5 cms. 2 series of 10: 7, 7.

(c) 1.0 cms. 5 series of 10: 6, 6, 6, 6, 6.

(d) 0.5 cms. 2 series of 10: 6, 8.

ii) Shapes. All series of 10.

(a) △ & □ . 6.
(b) △ & ┌┘ . 6.
(c) △ & | . 7.
(d) △ & + . 4, 5.

iii) Rotation. All series of 10.

(a) 45^o 2.0 cms. △ . 8.
(b) 90^o 2.0 cms. △ . 5.
(c) 90^o 0.5 cms. △ . 6.

iv) Background reversal. All series of 10.

(a) 2.0 cms. △ & ○ both black on white. 4.
(b) 2.0 cms. △ black on white, ○ white on black. 4.
(c) 2.0 cms. △ white on black, ○ black on white. 6.

v) Gestalt. All series of 10.

(a) ∧ & ○ . 6.
(b) ∧ & ⌒ . 6.
(c) ⊔ & ○ . 6.
(d) ⊔ & ∪ . 3.
(e) ∧ & △ . 7.
(f) △ & ◇ . 6.

Chance level could be taken to be 50%, but this is arbitrary, and it seemed more logical to take the actual criterion from the animal's own performance before the initial discrimination was learnt.

Qualitative Results.

Observations were made by E throughout the experiment. These were as follows:

	Comments.
i) Sizes.	
(a) Standard △ & ○ .	Knows it.
(b) 1.5 cms. △ & ○ .	No comment.
(c) 1.0 cms. △ & ○ .	Seen; slightly uncertain.
(d) 0.5 cms. △ & ○ .	No comment.
ii) Shapes.	
(a) △ & □ .	No comment.
(b) △ & ⌐ .	Certain
(c) △ & ǀ .	No comment.
(d) △ & + .	No indecision over correct choice.
iii) Rotation.	
(a) 45° 2.0 cms. △ .	No comment.
(b) 90° 2.0 cms. △ .	Cannot do it.
(c) 90° 0.5 cms. △ .	Sees it; apparent recognition.
iv) Background reversal.	
(a) 2.0 cms. △ & ○ both bl. on wh.	Confused.
(b) 2.0 cms. △ bl. on wh., ○ wh. on bl.	Some confusion.
(c) 2.0 cms. △ wh. on bl., ○ bl. on wh.	Some confusion; reaction mainly positive.

v) Part figures.

(a) ∧ & ○ .	Confused at first.
(b) ∧ & ∩ .	Recognition.
(c) ◺◿ & ○ .	Can see it.
(d) ◺◿ & ∪ .	No recognition.
(e) ∧ & △ .	Positive reaction to complete figure.
(f) △ & ◇ .	Most are definite; a bit confused at times.

It was found that S usually examined the symbols from a distance of 1 to 3 cms. The animal also tended to look at the doors sideways, and appeared to use only one eye at a time; no particular preference was shown for either eye. The cards were not often examined from a head-on position. Several times during the experiment, when S made a correct choice, it appeared to examine the positive symbol <u>only</u>, and paid no attention to the negative one at all.

5. <u>Findings.</u>

It was found from this experiment that a Golden Hamster is able to discriminate between two forms, namely, a triangle and circle of 2.0 cms. size. It is able to generalise this discrimination, to some extent, and can differentiate between similar symbols of smaller sizes, that is, triangles and circles of 1.5, 1.0 and 0.5 cms. size.

This generalisation does not include figure-ground relationships; if the colouring of the figure and its background is reversed, the animal is apparently confused, and unable to make accurate choices. The exception to this is in the case of the white triangle and the black circles; here, although there was some confusion, a greater number of correct choices was obtained.

With different shapes substituted for the circle, and with the 2.0 cms. triangle remaining, S had no difficulty in distinguishing between them, except with the cross. Thus, generalisation was also transferred to distinguish between a triangle and square, triangle and bar, and triangle and zigzag; it is doubtful whether it was transferred to the triangle and cross, however. With rotated shapes, S recognised the 45° 2.0 cms. triangle, and the 90° 0.5 cms. triangle, but showed a total inability to recognise the 90° 2.0 cms. triangle.

In the final part figure series, S seemed able to discriminate between the apex of the triangle and the circle and its arc, but showed confusion when faced with the triangle base. When given the triangle apex and the complete triangle, it tended to react positively to the complete triangle.

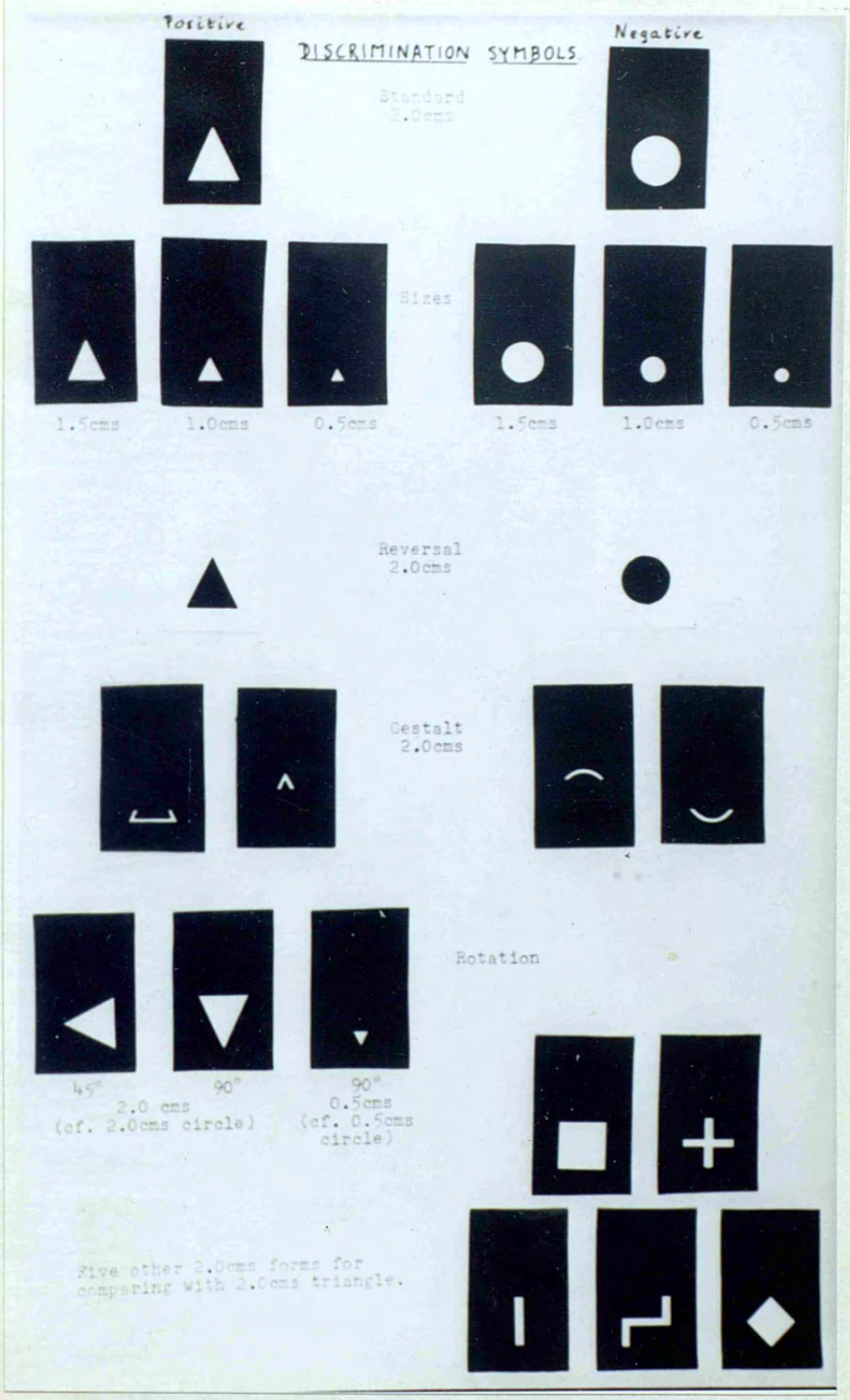


Plate 1. (Appendix E)

APPENDIX F
Diagram of SMVDA I

APPENDIX F.
Serial Multiple Visual Discrimination Apparatus I.

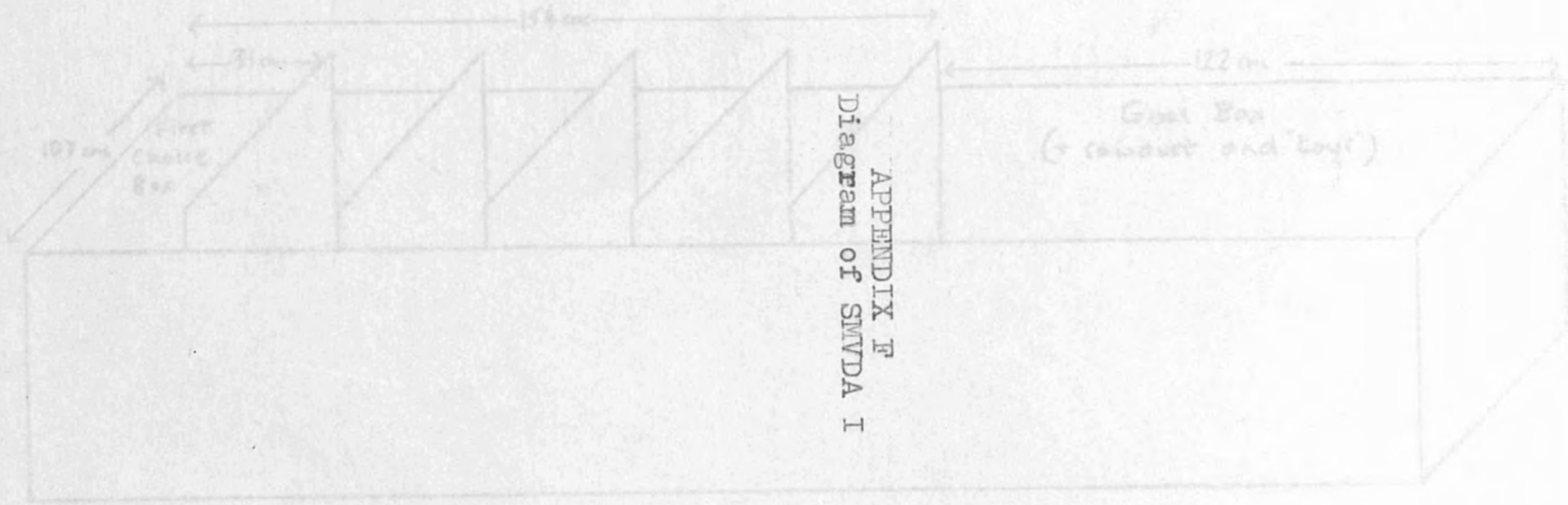


Figure 1: The choice boxes and goal box

Figure 2: One choice panel

APPENDIX F.

Serial Multiple Visual Discrimination Apparatus I.

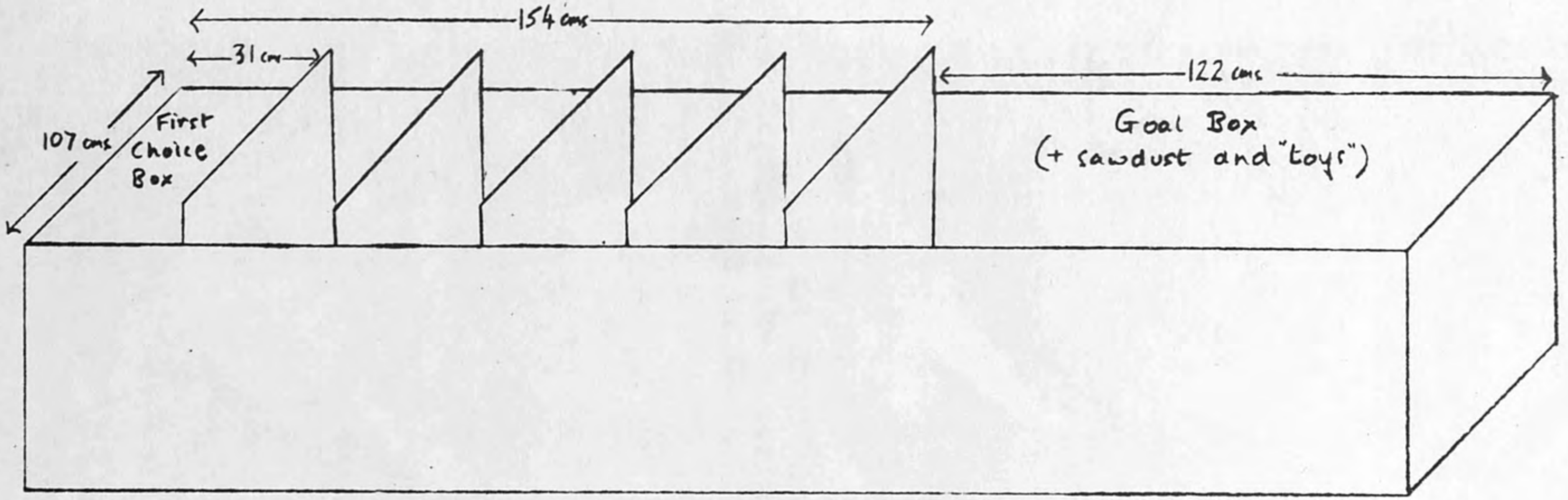


Figure 1: The choice boxes and goal box.

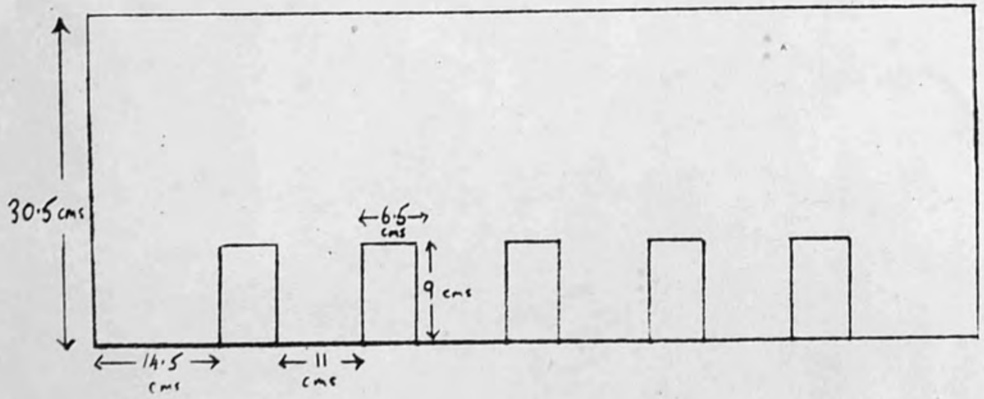
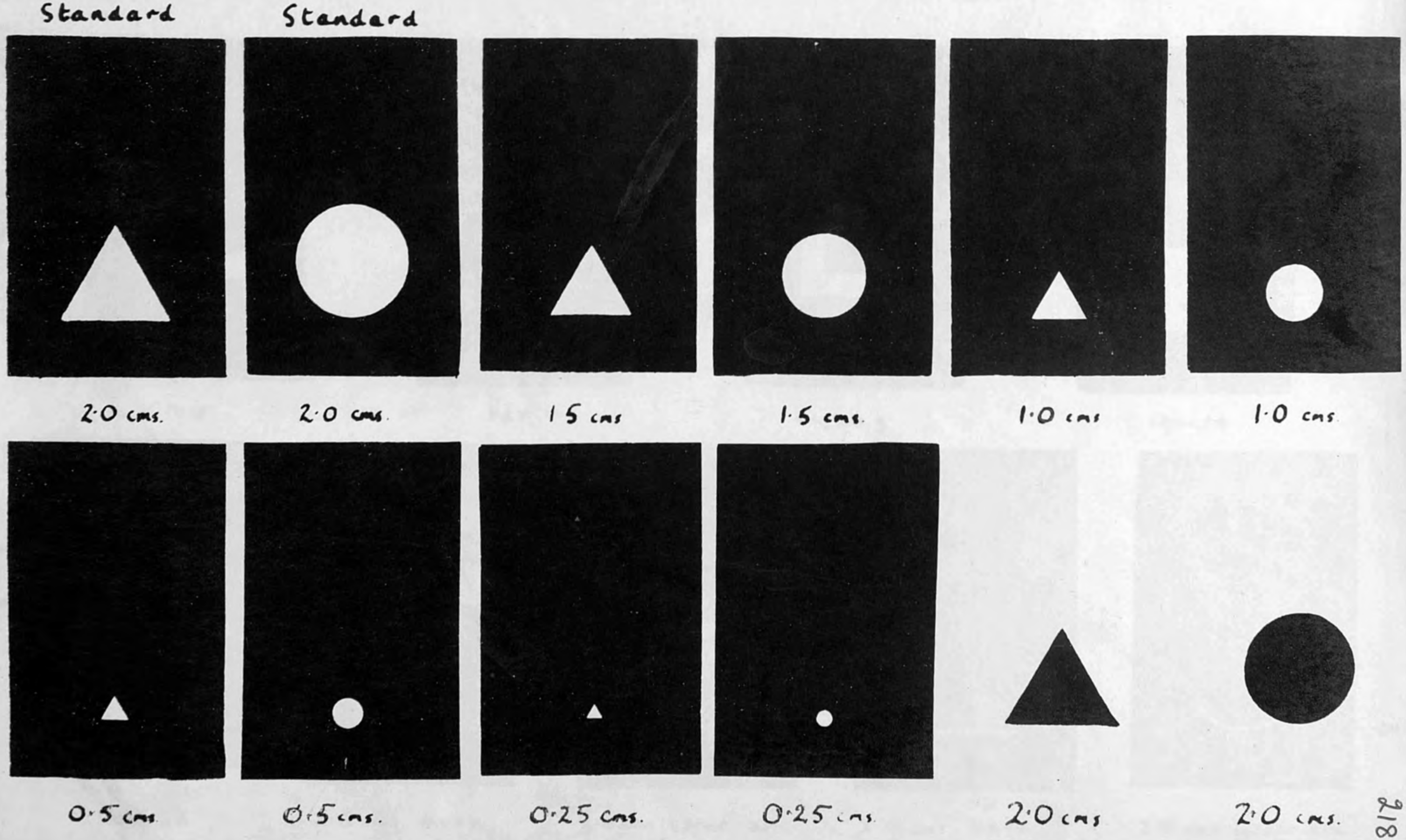


Figure 2: One choice panel.

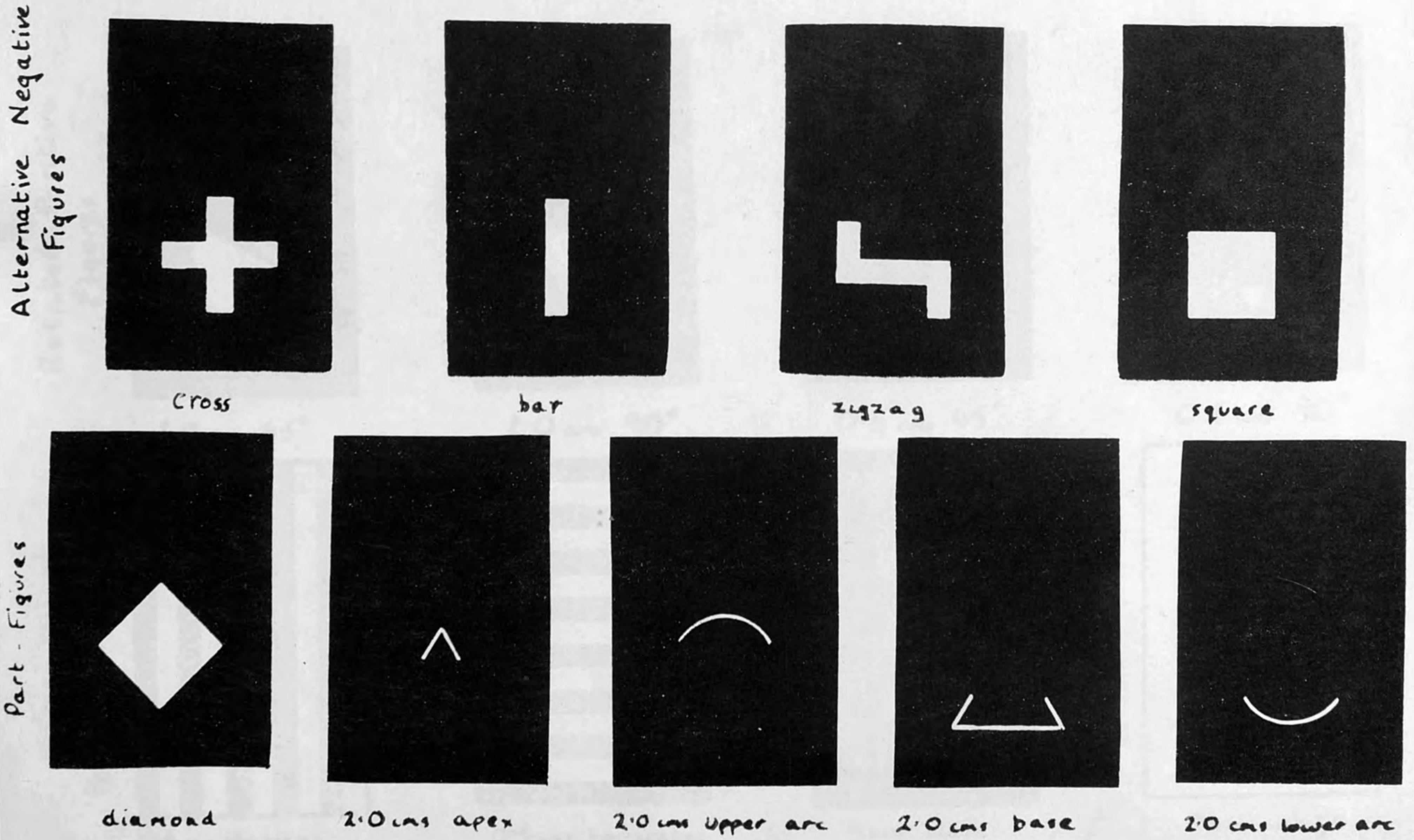
APPENDIX G

Copies of the discrimination stimuli used in SMVDA I and II

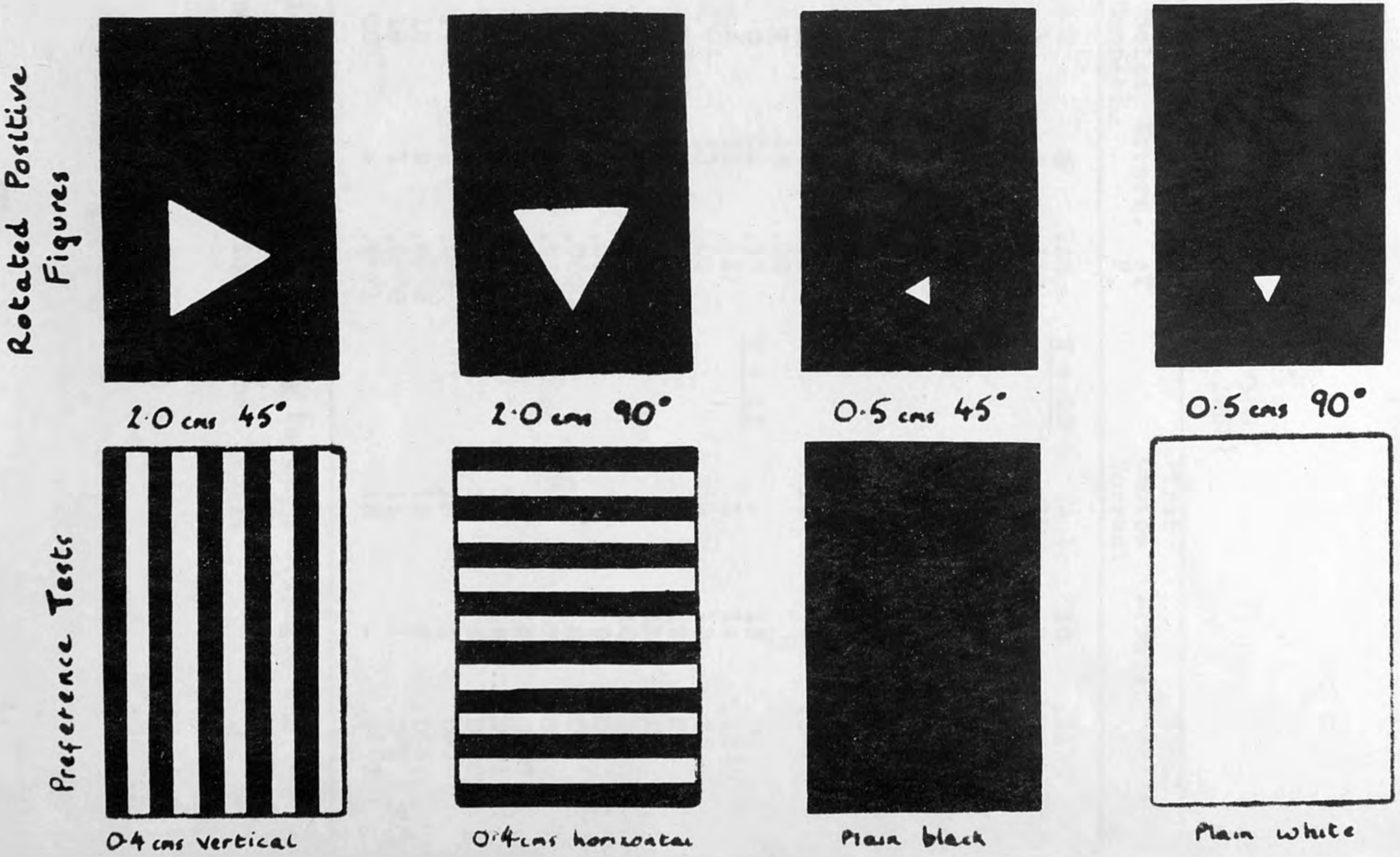
Symbols used in Size Generalisation and Figure - Ground Reversal. (Δ = +; ⊙ = −).



Symbols used as Alternative Negative Figures and as Part - Figures.



Symbols used as Rotated Positive Figures and for Preference Tests and Brightness Discrimination.



APPENDIX H.

PROBABILITY LEVELS
(based on Fields 1953)

	First Choice Correct.	Errors.	Level of P.		First Choice Correct.	Errors.	Level of P.
N = 5	-	5	.33	N = 10	-	10	.11
	1	4	.41		1	9	.27
	2	3	.20		2	8	.30
	3	2	.05		3	7	.20
	4	1	.006		4	6	.09
	5	-	.0003		5	5	.03
					6	4	.006
N = 20	-	20	.01		7	3	.0008
	1	19	.06		8	2	.00007
	2	18	.14		9	1	.000004
	3	17	.21		10	-	$.0^{6}1$
	4	16	.22				
	5	15	.17	N = 15	-	15	.04
	6	14	.11		1	14	.13
	7	13	.05		2	13	.23
	8	12	.02		3	12	.25
	9	11	.007		4	11	.19
	10	10	.002		5	10	.10
	11	9	.0005		6	9	.04
	12	8	.00009		7	8	.01
	13	7	.00001		8	7	.003
	14	6	$.0^{5}2$		9	6	.0007
	15	5	$.0^{6}2$		10	5	.0001
	16	4	$.0^{7}1$		11	4	.00001
	17	3	$.0^{9}8$		12	3	$.0^{6}9$
	18	2	$.0^{10}3$		13	2	$.0^{7}6$
	19	1	$.0^{12}8$		14	1	$.0^{8}2$
	20	-	$.0^{13}1$		15	-	$.0^{10}3$

These levels were obtained using Pascal's Triangle and the Binomial Distribution (Moroney 1957).

APPENDIX I

SMVDA I

Individual results for six animals

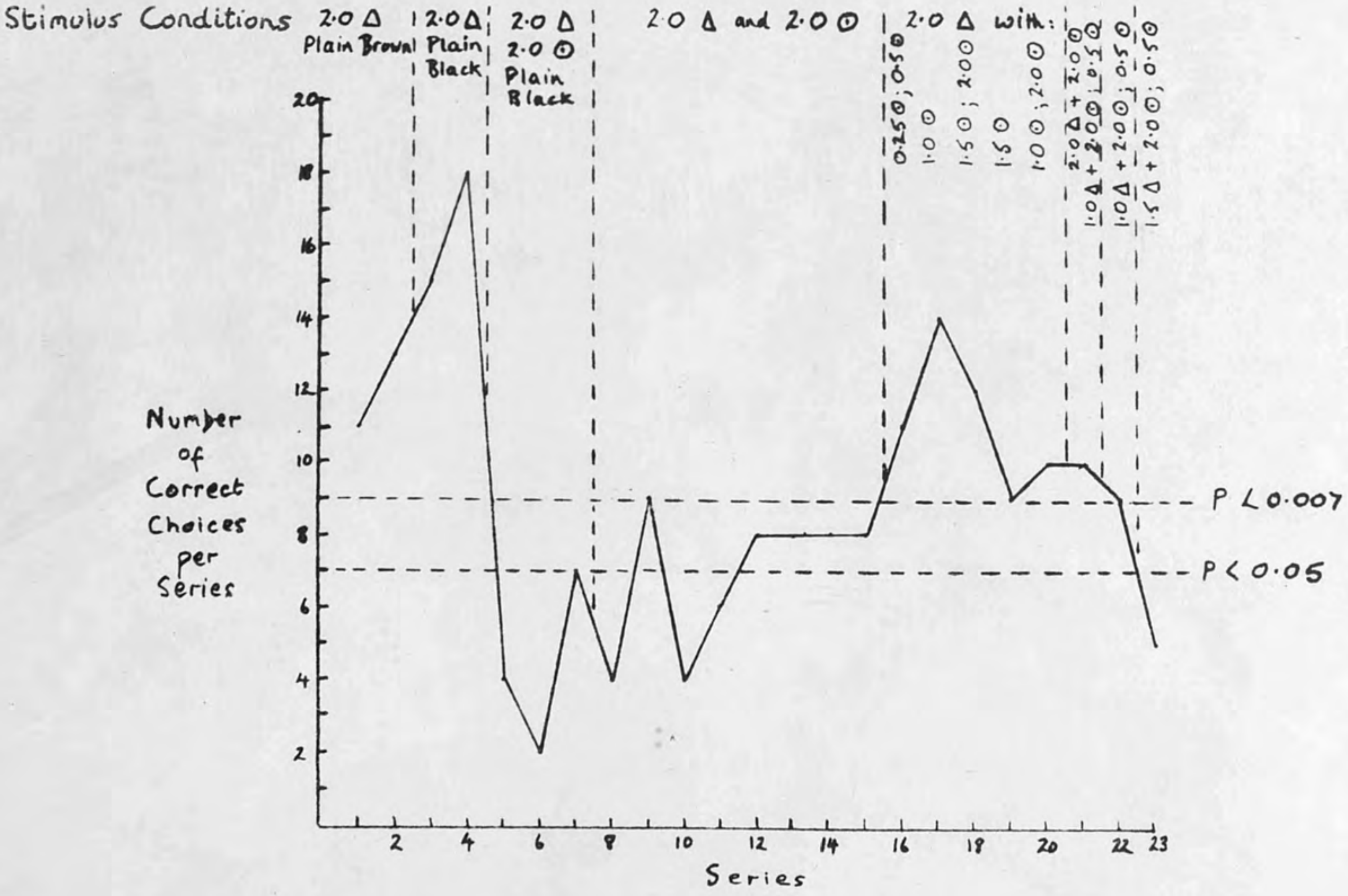
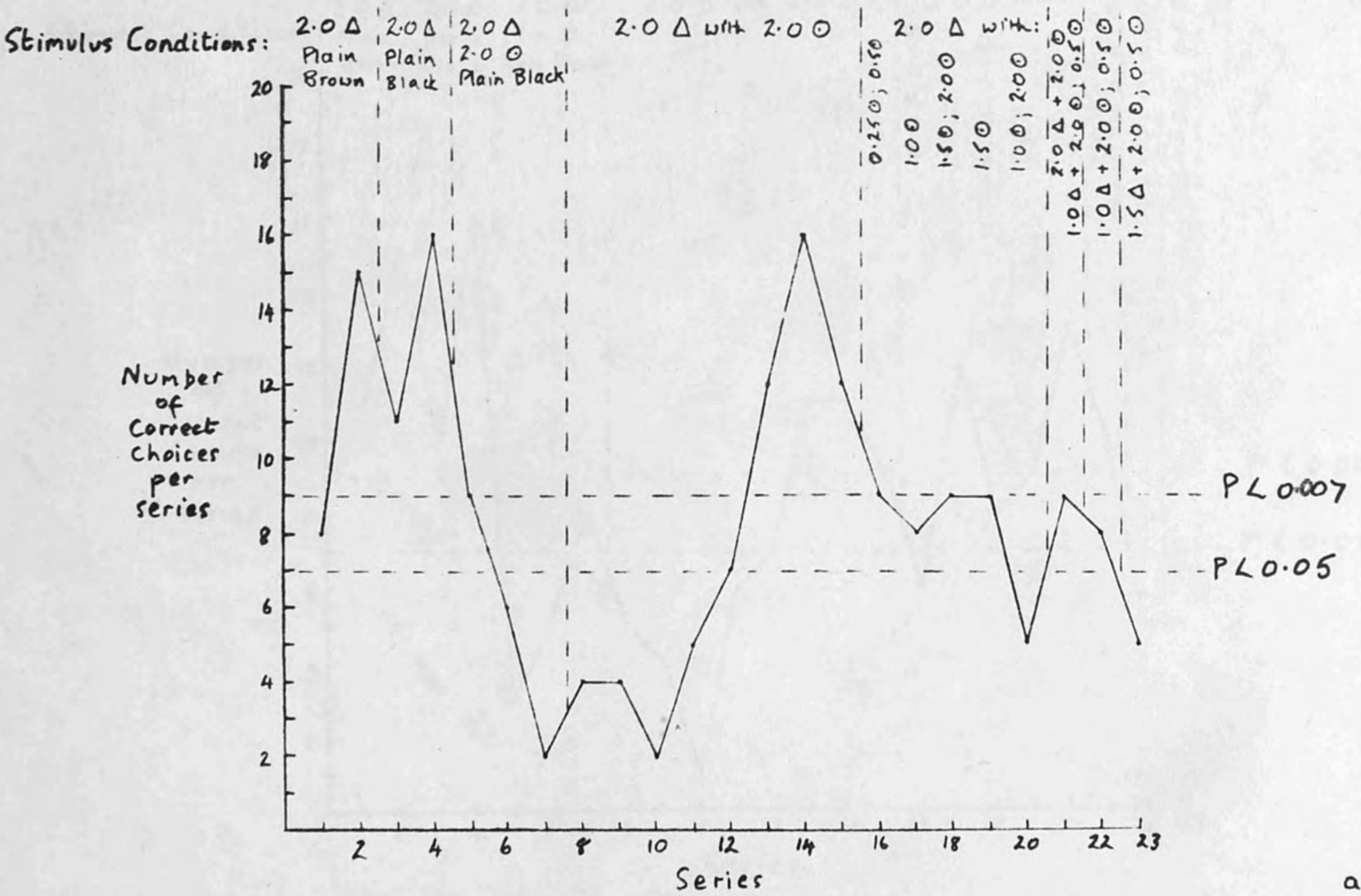


FIGURE 1. SMYDA I: Number of correct choices for Animal MB2♂ LS.

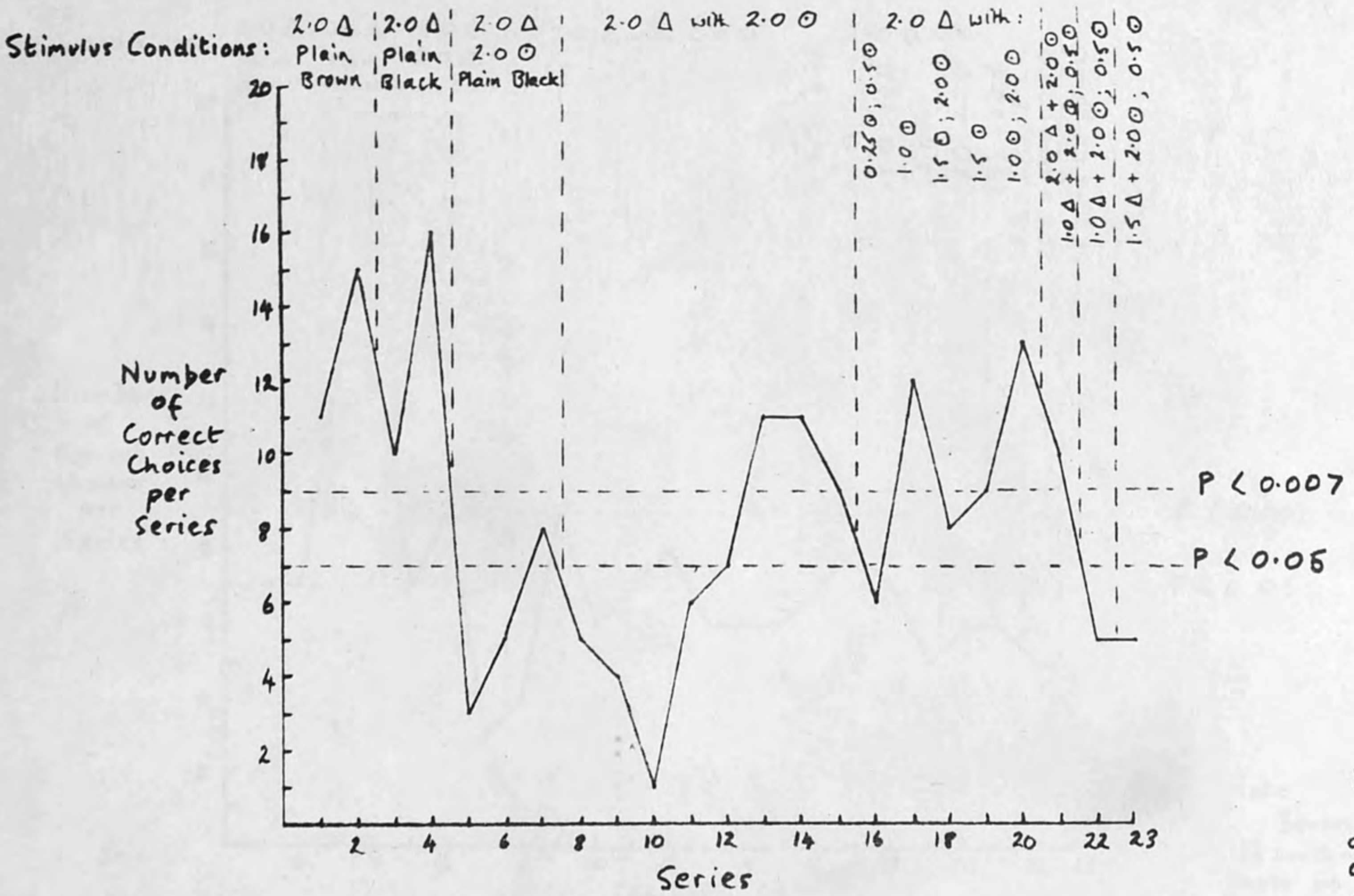
Note:

Series 9, 15, 17, 19, 22 and 23 contained 10 trials only. The remaining series contained 20 trials. The results were equated by converting correct choices on 10 trials to the no. of correct choices at 20 trials which would occur at the same significance level.



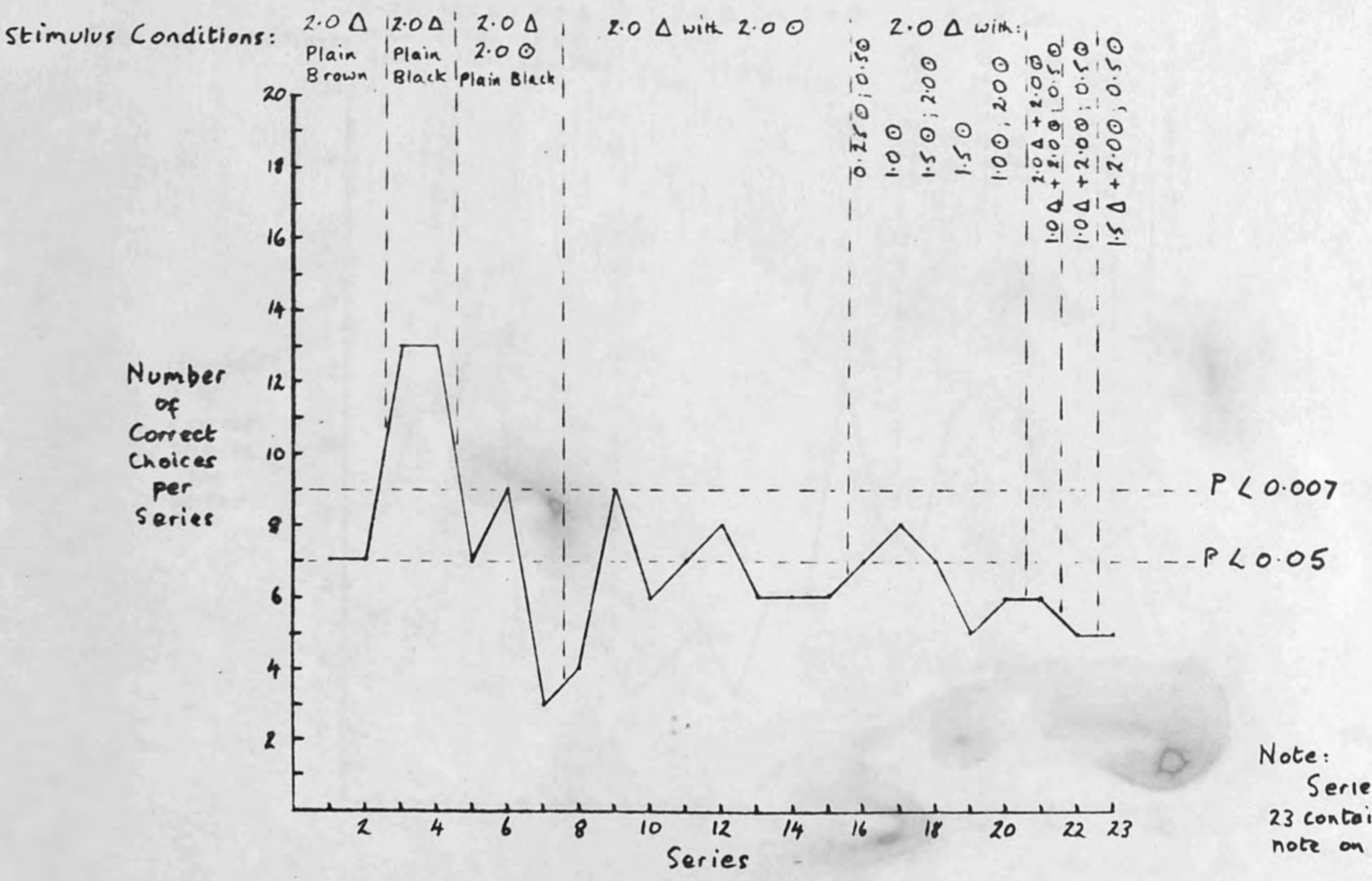
Note:
Series 9, 15, 17, 19, 22 and 23 contained 10 trials only. See note on Figure 1 of this appendix.

FIGURE 2. SMVDA I. Number of correct choices for Animal MB2♂O.



Note:
Series 9, 15, 17, 19, 22 and 23 contained 10 trials only. See note on Figure 1 of this appendix.

FIGURE 3. SMVDA I. Number of correct choices for Animal MB2 ♂ M.



Note:
Series 9, 15, 17, 19, 22 and 23 contained 10 trials only. See note on Figure 1 of this appendix.

FIGURE 4. SMVDA I. Number of correct choices for Animal MB2♂N.

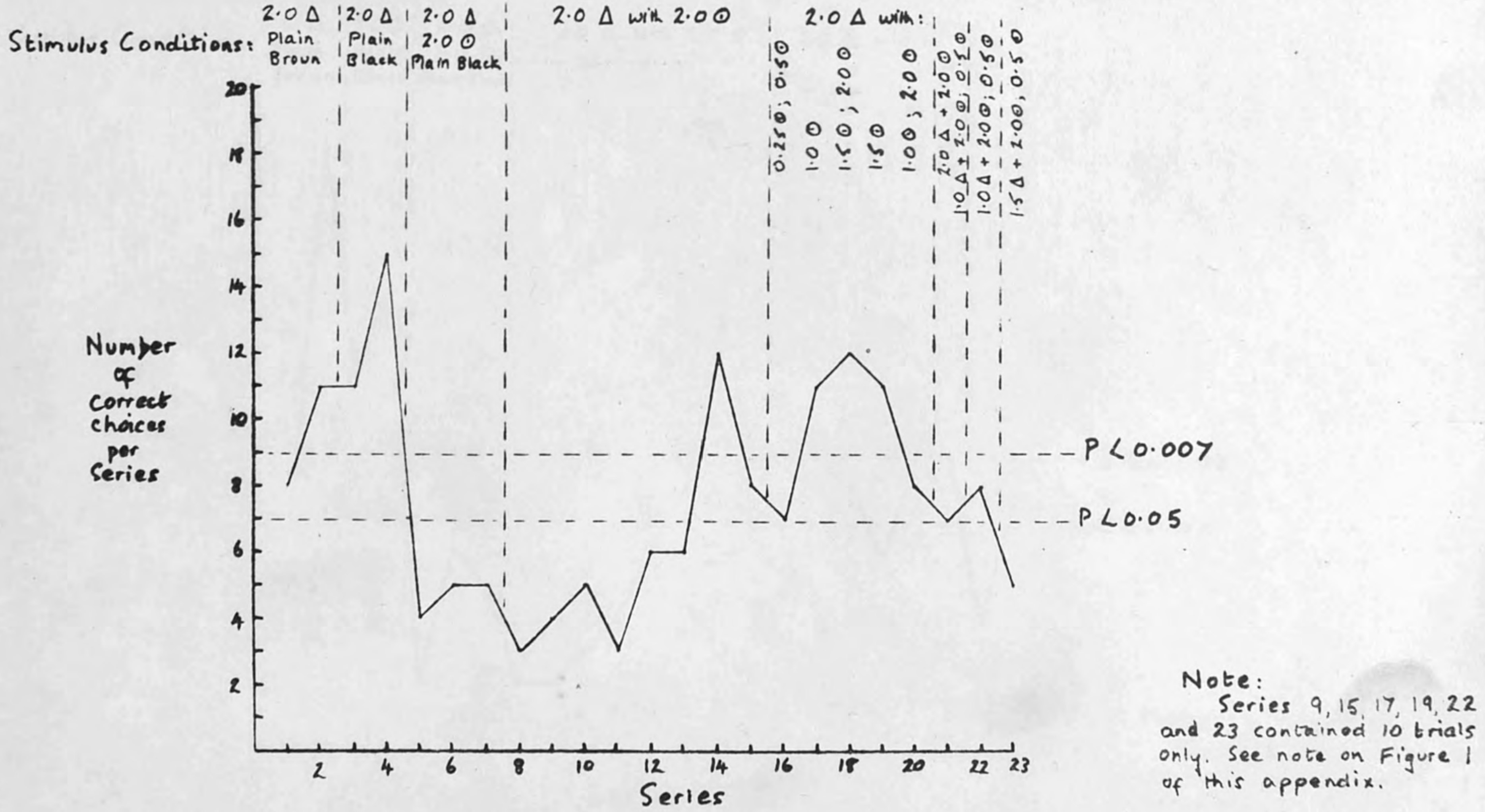
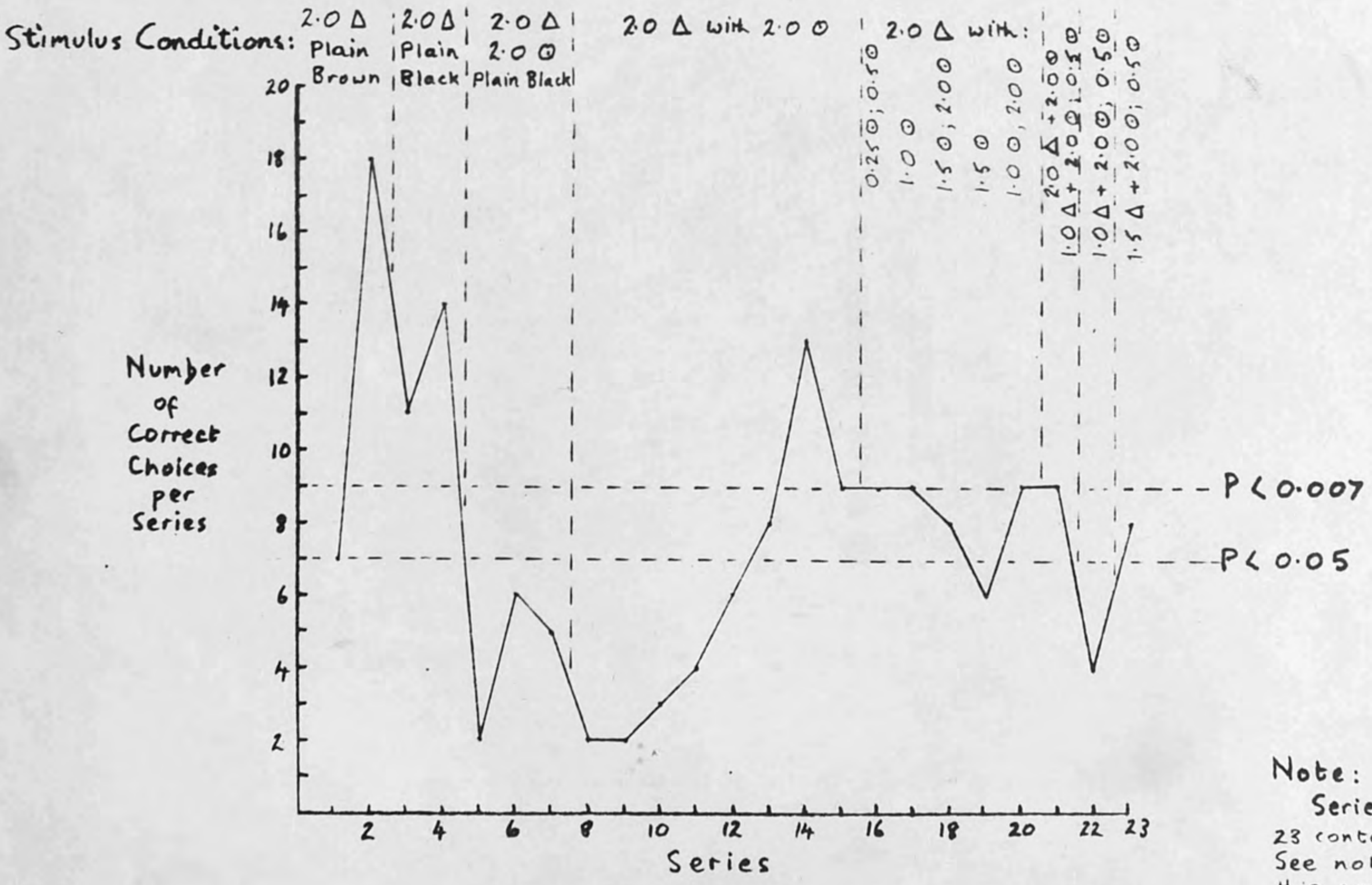


FIGURE 5. SMVDA I. Number of correct choices for Animal MB2♂ RS.

Note:
Series 9, 15, 17, 19, 22 and 23 contained 10 trials only. See note on Figure 1 of this appendix.



Note:
Series 9, 15, 17, 19, 22 and 23 contained 10 trials only. See note on Figure 1 of this appendix.

FIGURE 6. SMVDA I. Number of correct choices for Animal MB2♂T.

APPENDIX J

Diagram of SMVDA II

APPENDIX J

Serial Multiple Visual Discrimination Apparatus II

Figure 1: The choice boxes and goal box

Figure 2: One choice panel

APPENDIX J.

Serial Multiple Visual Discrimination Apparatus II.

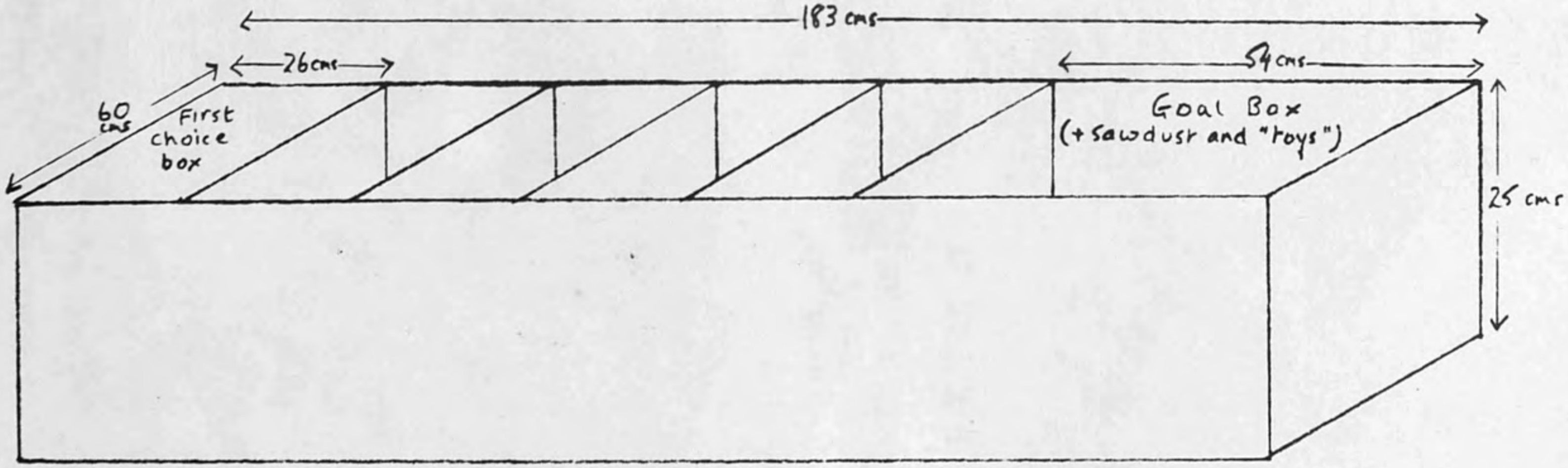


Figure 1: The choice boxes and goal box.

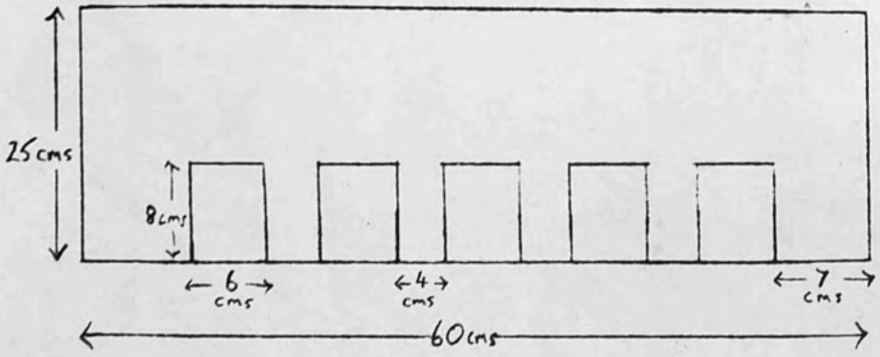
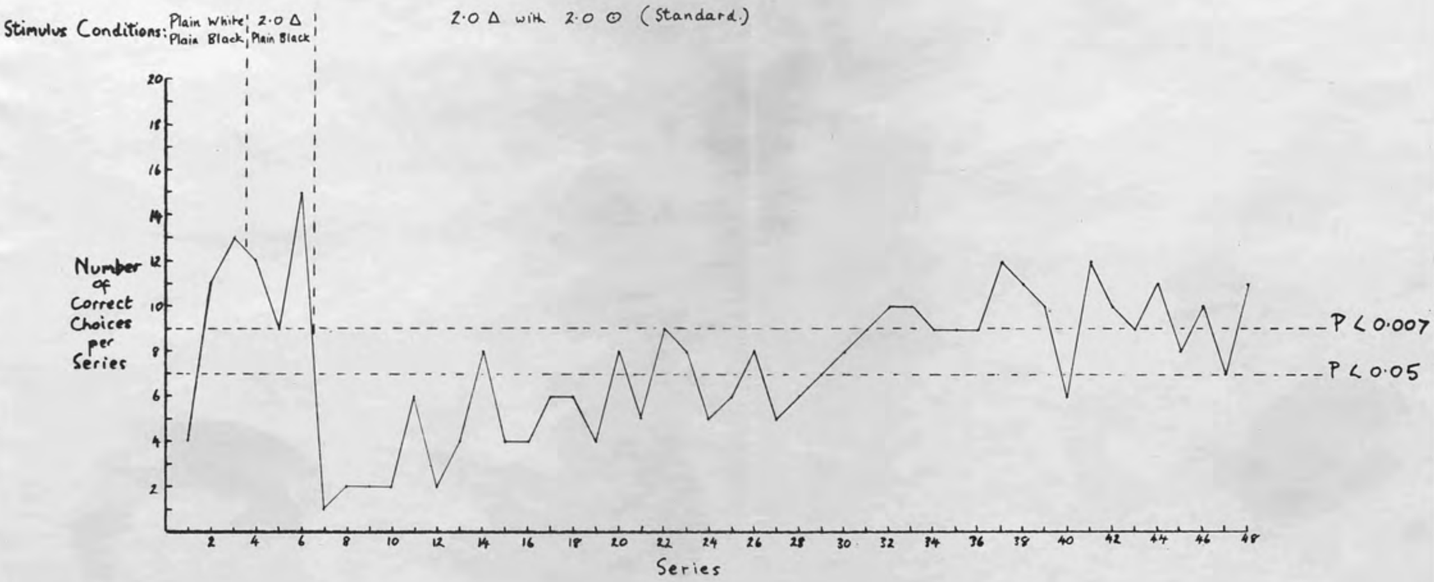


Figure 2: One choice panel.

APPENDIX K

SMDVA II
Individual results for six animals

FIGURE 1. SMVDA II. Brightness Discrimination and Form Discrimination Training.
Number of correct choices for Animal MB7♂N.



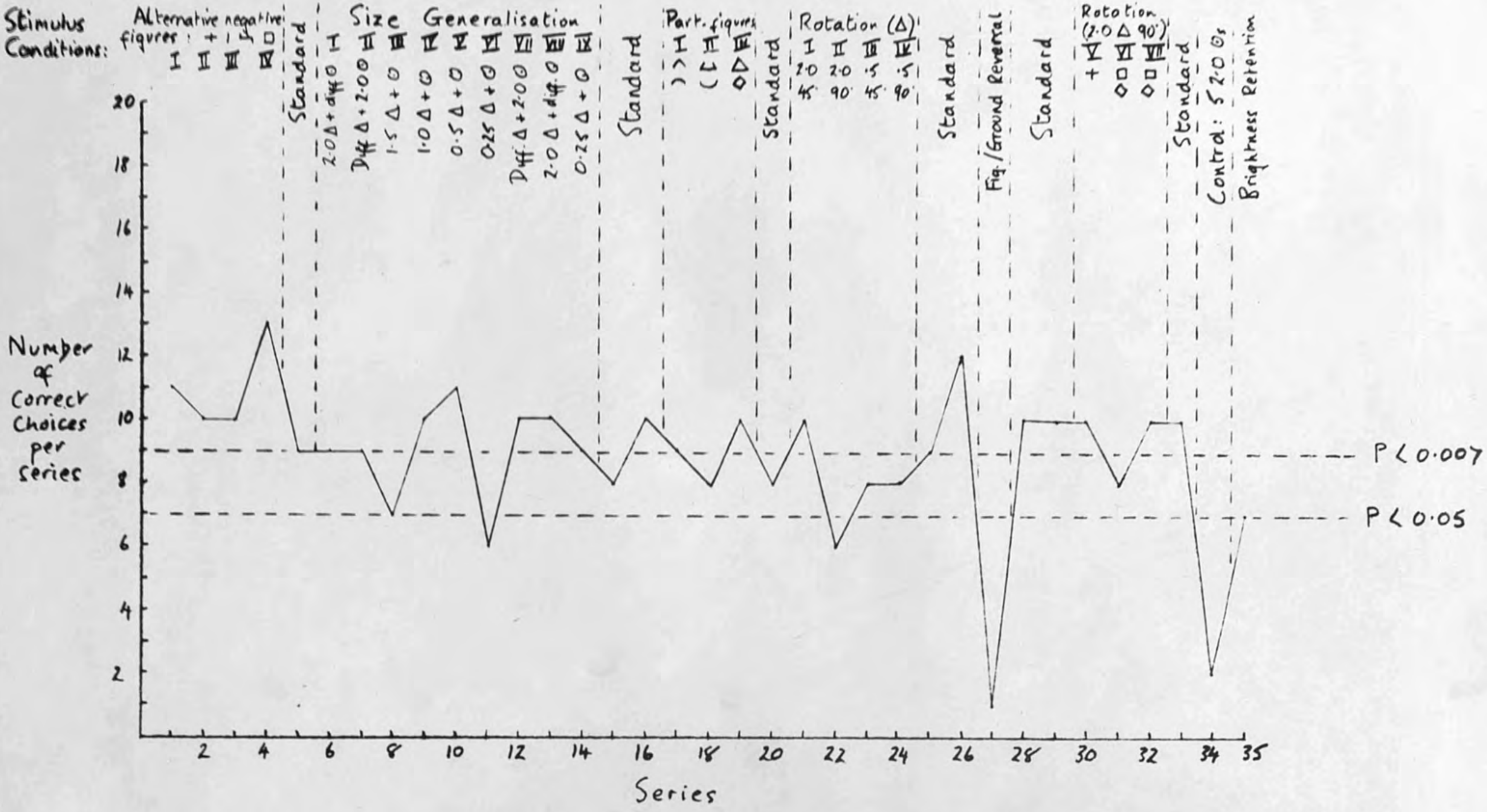
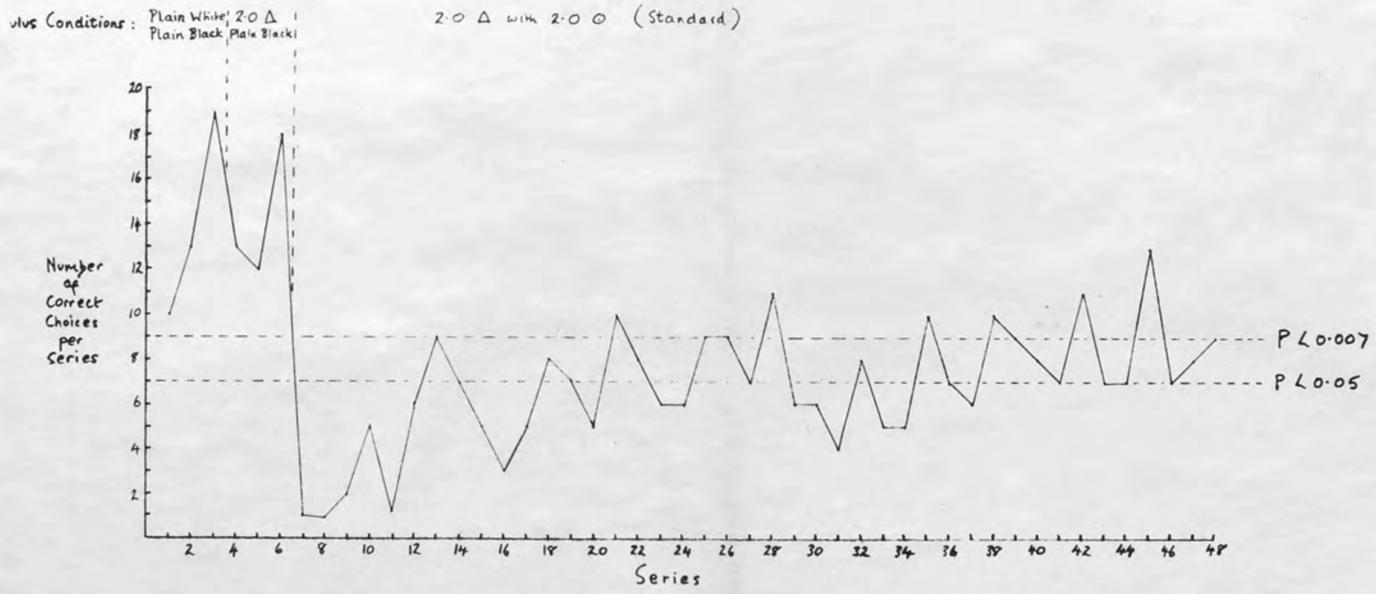


FIGURE 2. SMVDA II. Form Discrimination Transfer Tests.

Number of correct choices for Animal MB7♂N.

234.

FIGURE 3. SMVDA II. Brightness Discrimination and Form Discrimination Training.
Number of correct choices for Animal MB7♂T.



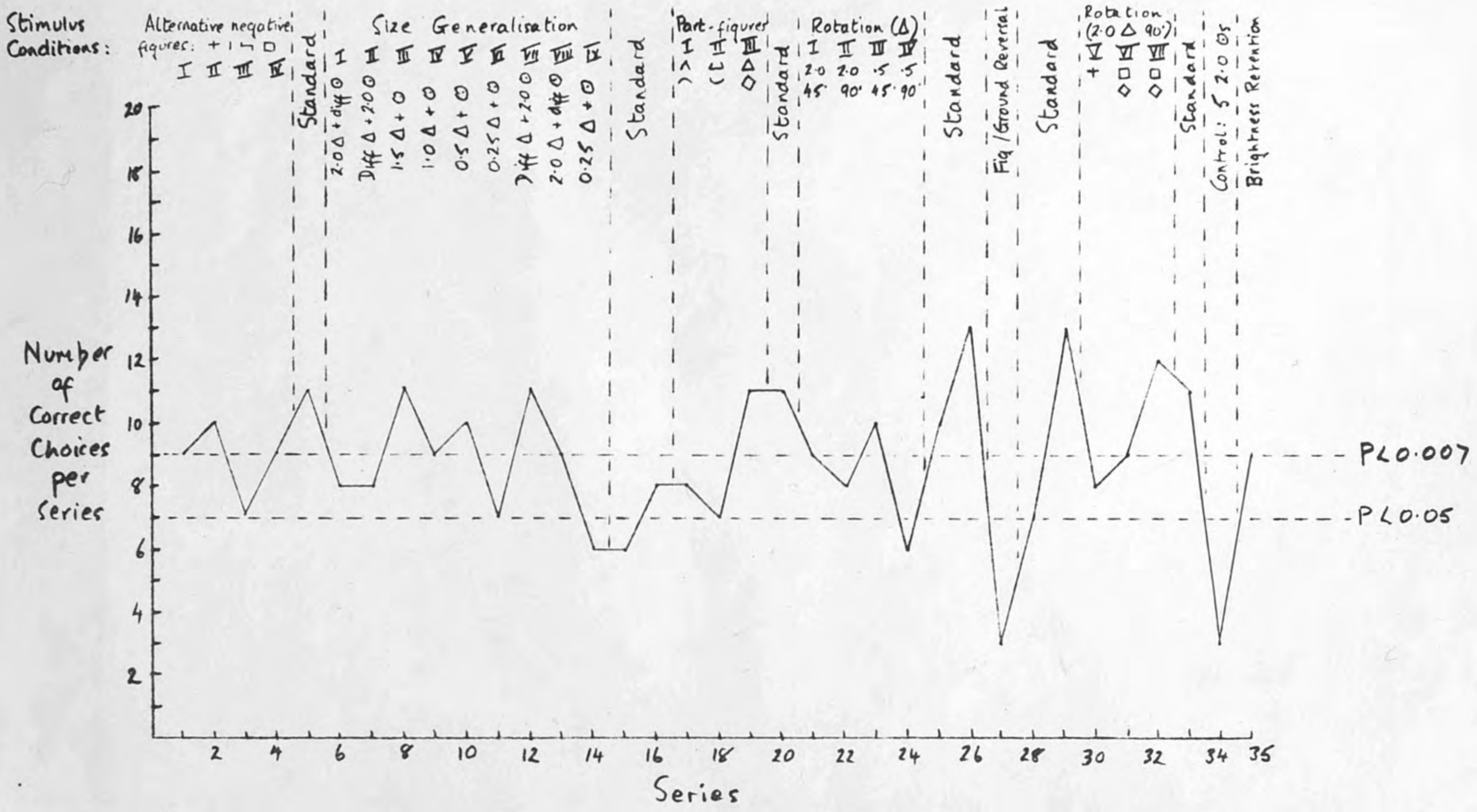
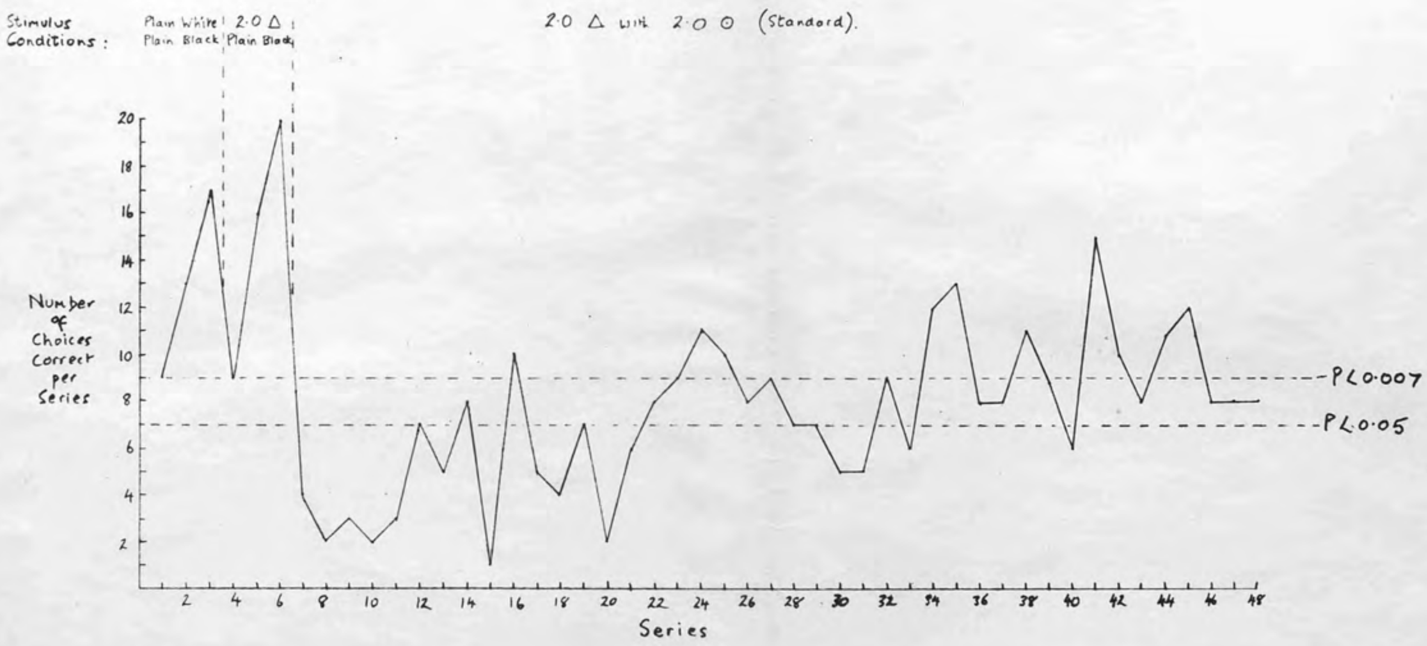


FIGURE 4. SMVDA II. Form Discrimination Transfer Tests.

Number of correct choices for Animal MB7♂T.

FIGURE 5. SMVDA II. Brightness Discrimination and Form Discrimination Training.
Number of correct choices for Animal MB7♂LS.



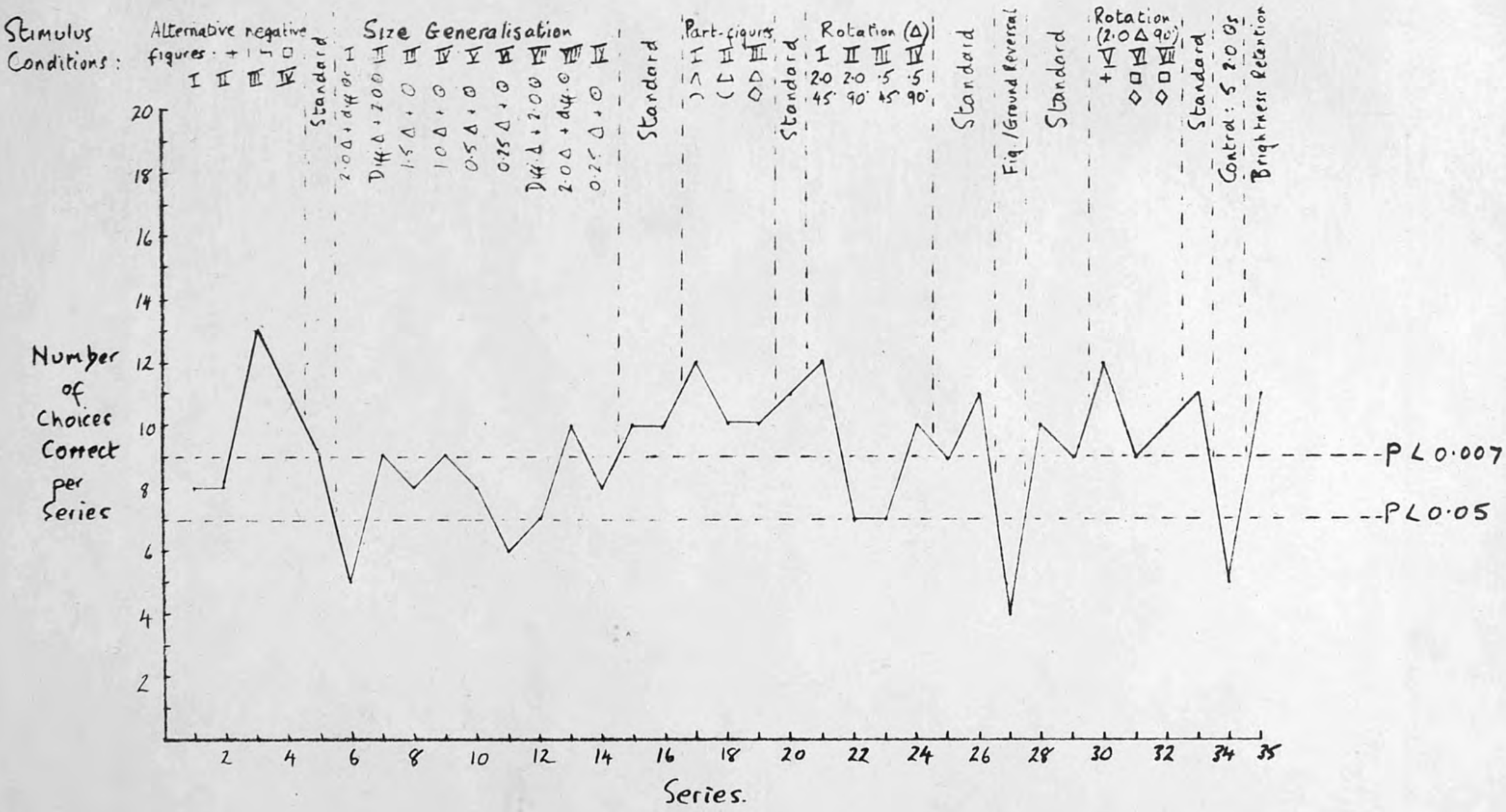
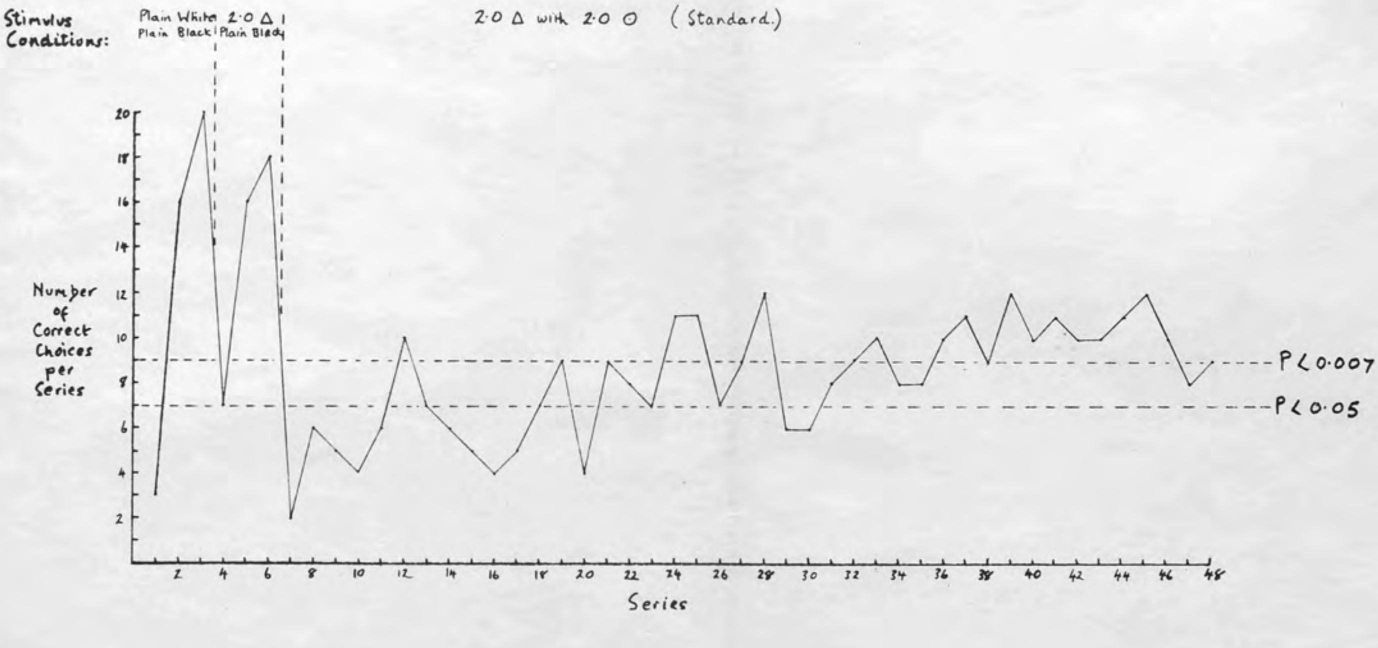


FIGURE 6. SMVDA II. Form Discrimination Transfer Tests.

Number of correct choices for Animal MB7♂LS.

FIGURE 7. SMVDA II. Brightness Discrimination and Form Discrimination Training.
Number of correct choices for Animal MB7♂RS.



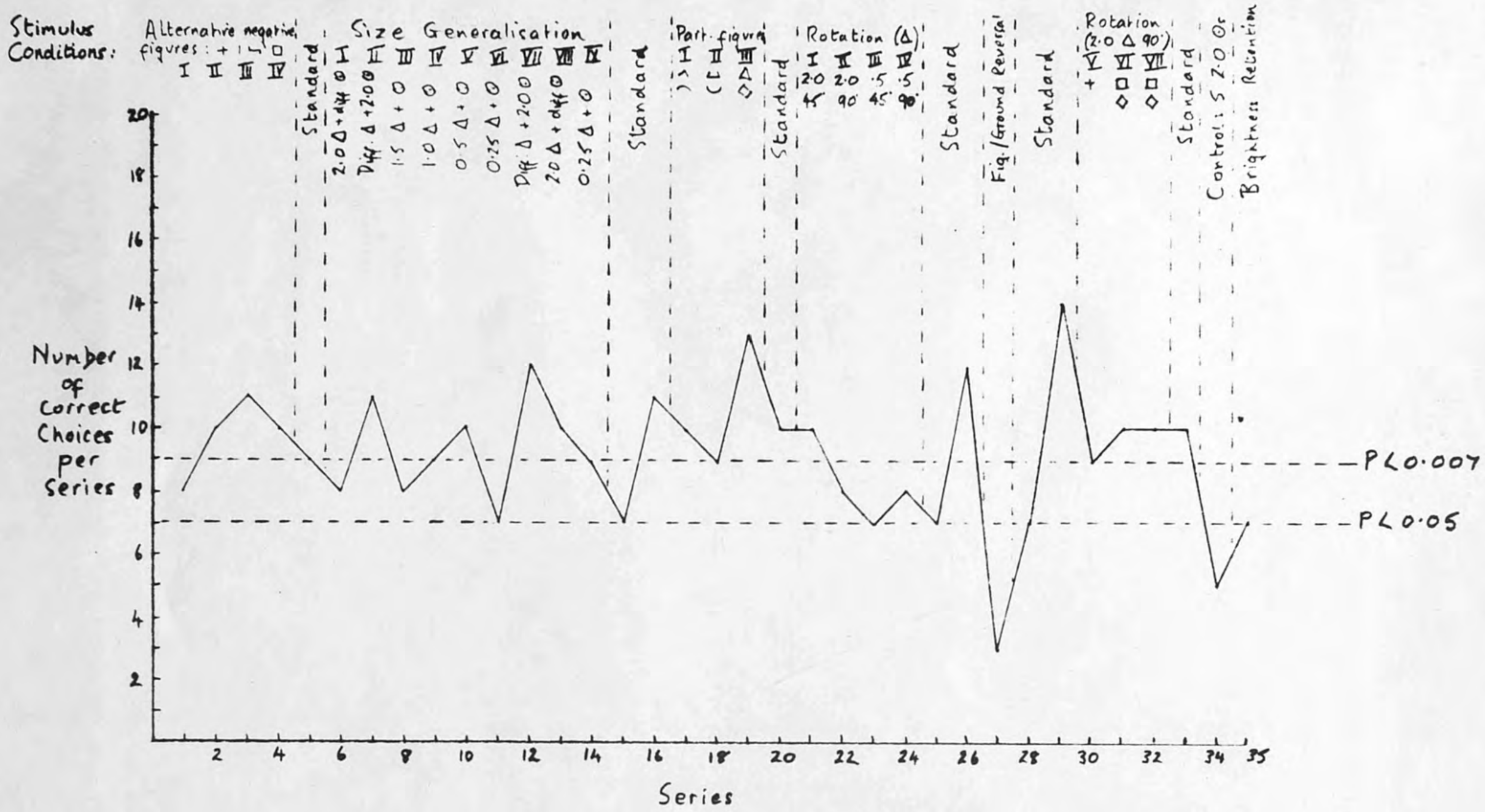
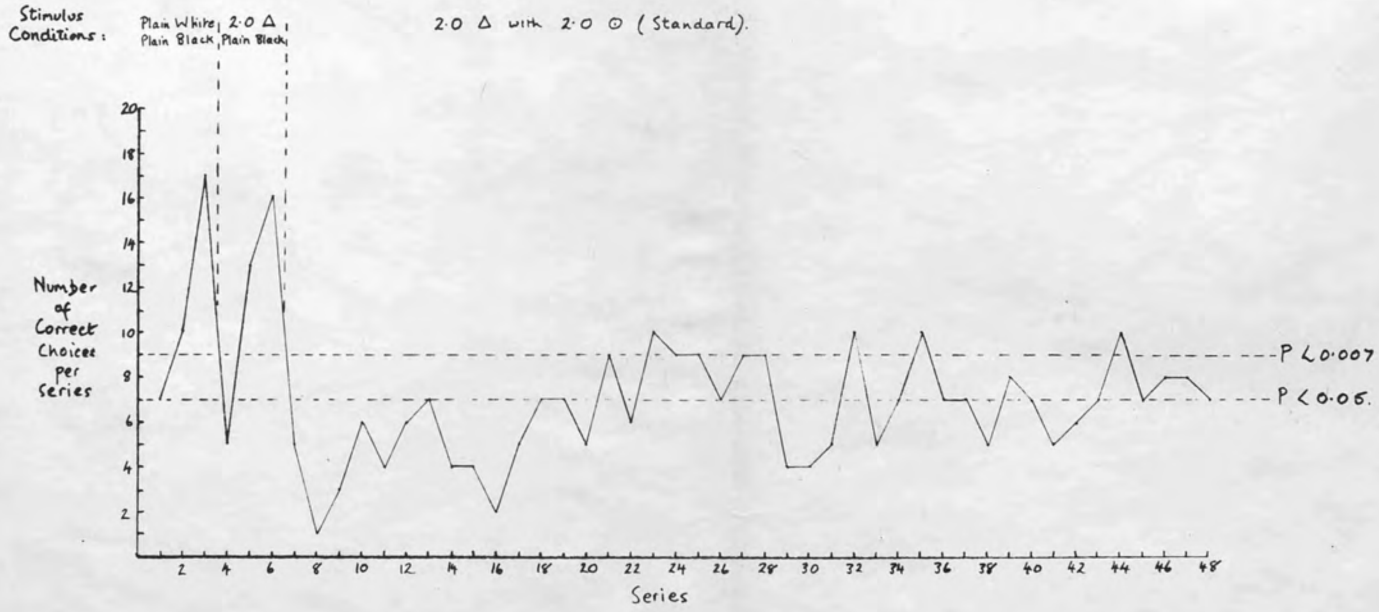


FIGURE 8. SMVDA II. Form Discrimination Transfer Tests.

Number of correct choices for Animal MB7♂ RS.

FIGURE 9. SMVDA II. Brightness Discrimination and Form Discrimination Training.
Number of correct choices for Animal MB7♂ O.



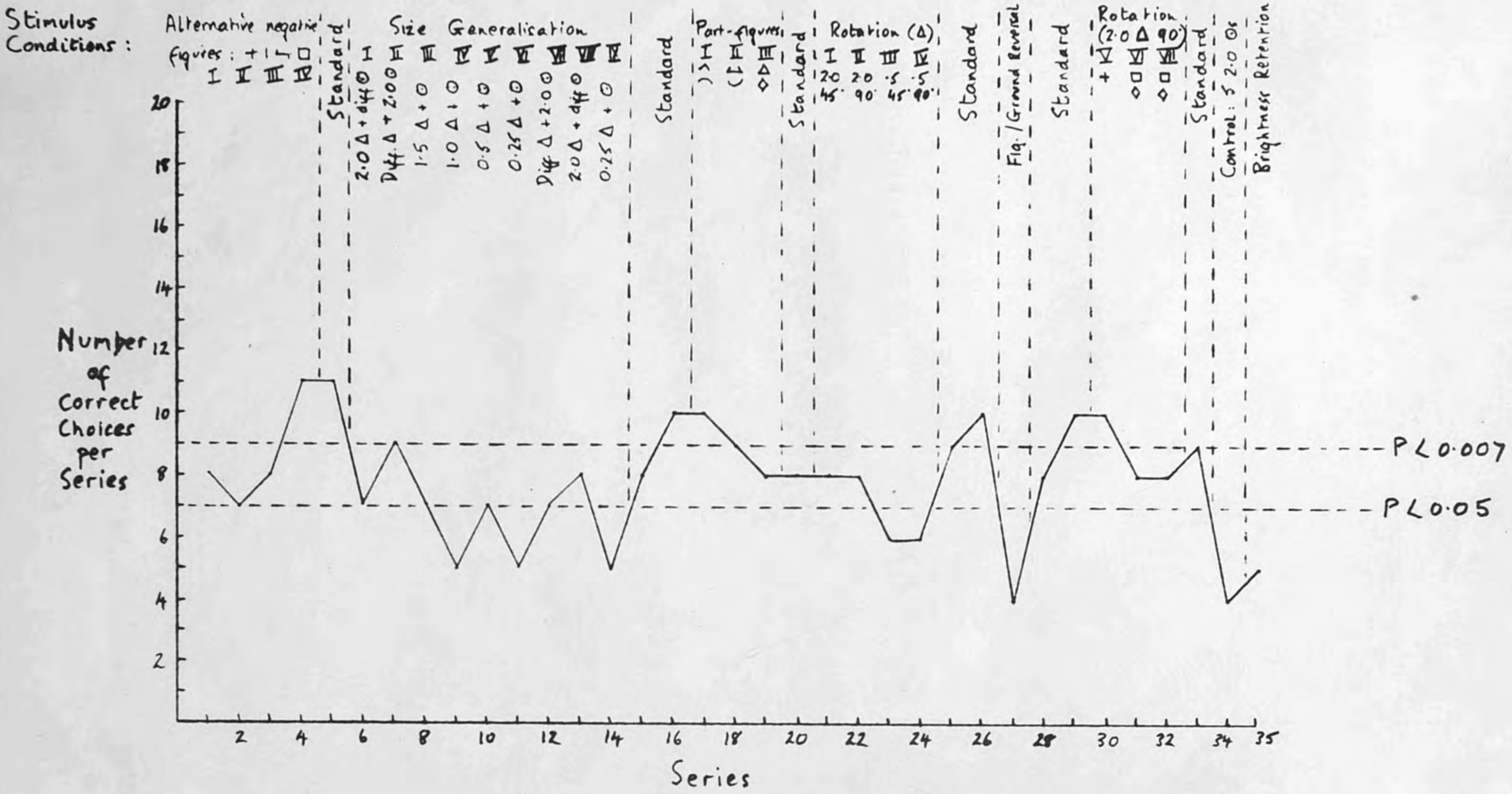
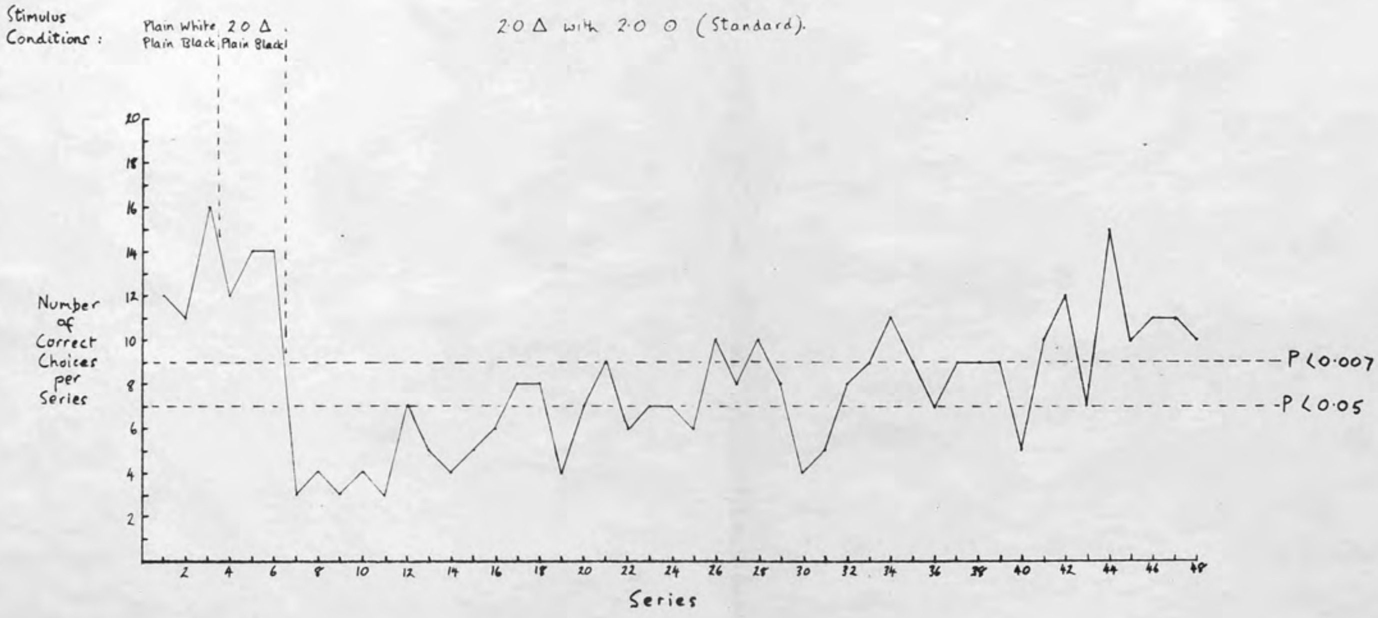


FIGURE 10. SMVDA II. Form Discrimination Transfer Tests.

Number of correct choices for Animal MB7♂O.

FIGURE 11. SMVDA II. Brightness Discrimination and Form Discrimination Training.
Number of correct choices for Animal MB7♂M.



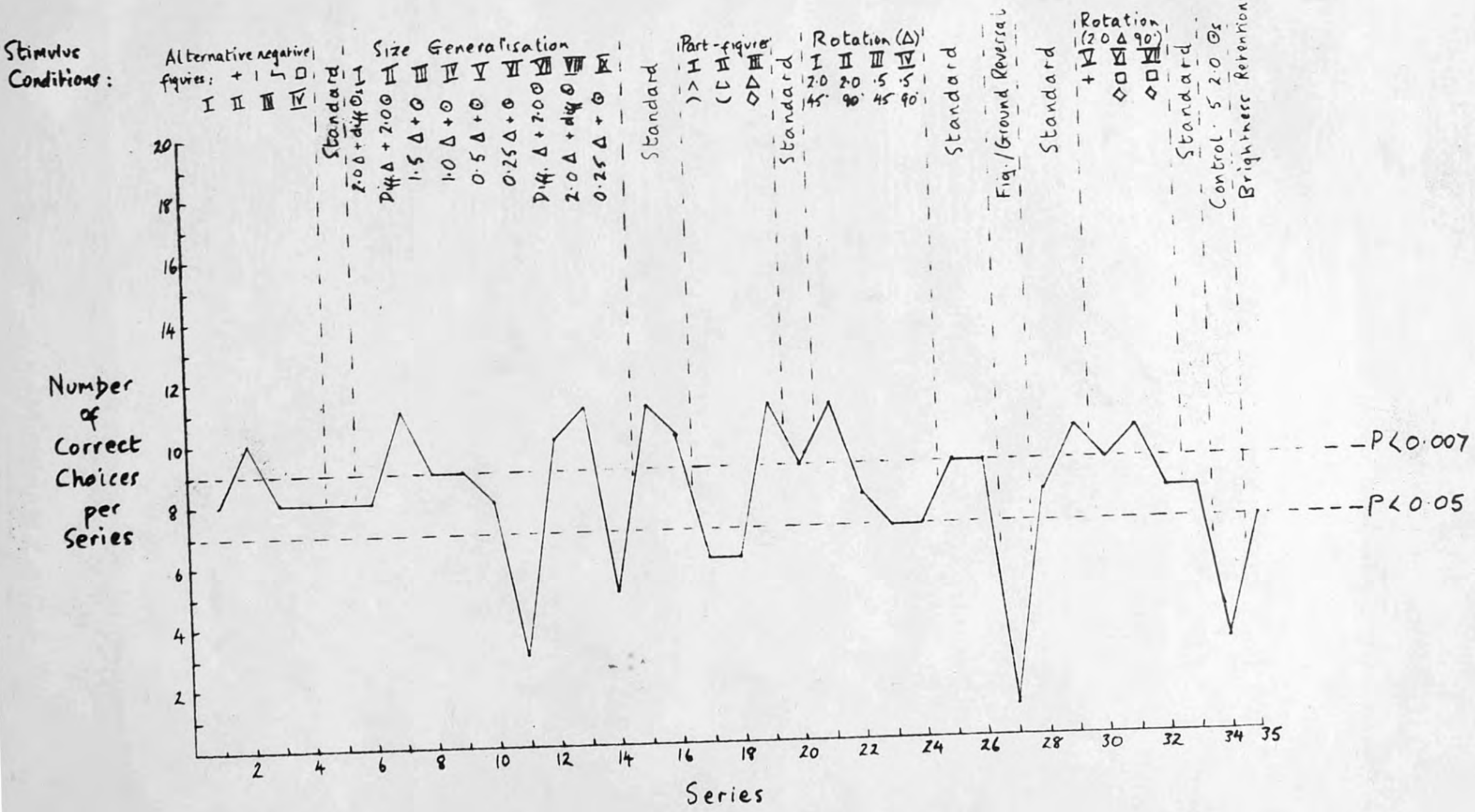
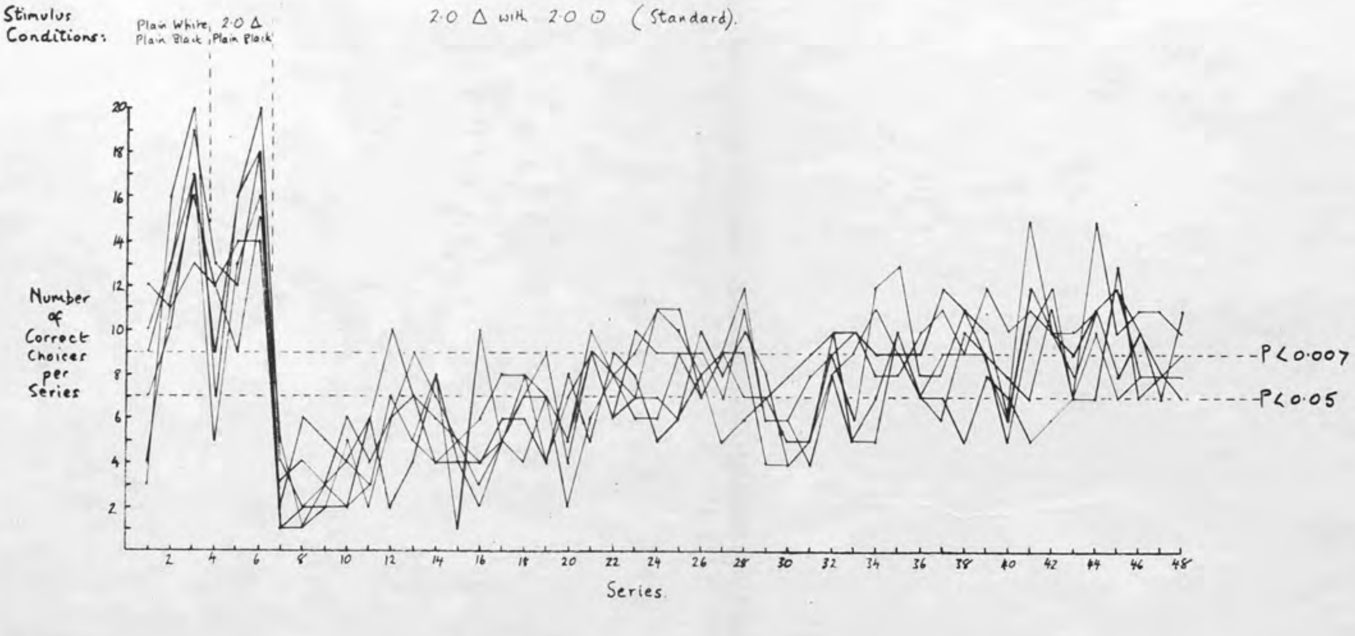


FIGURE 12. SMVDA II. Form Discrimination Transfer Tests.

Number of correct choices for Animal MB7♂M.

FIGURE 13. SMVDA II. Brightness Discrimination and Form Discrimination Training.
Number of correct choices for all six animals.



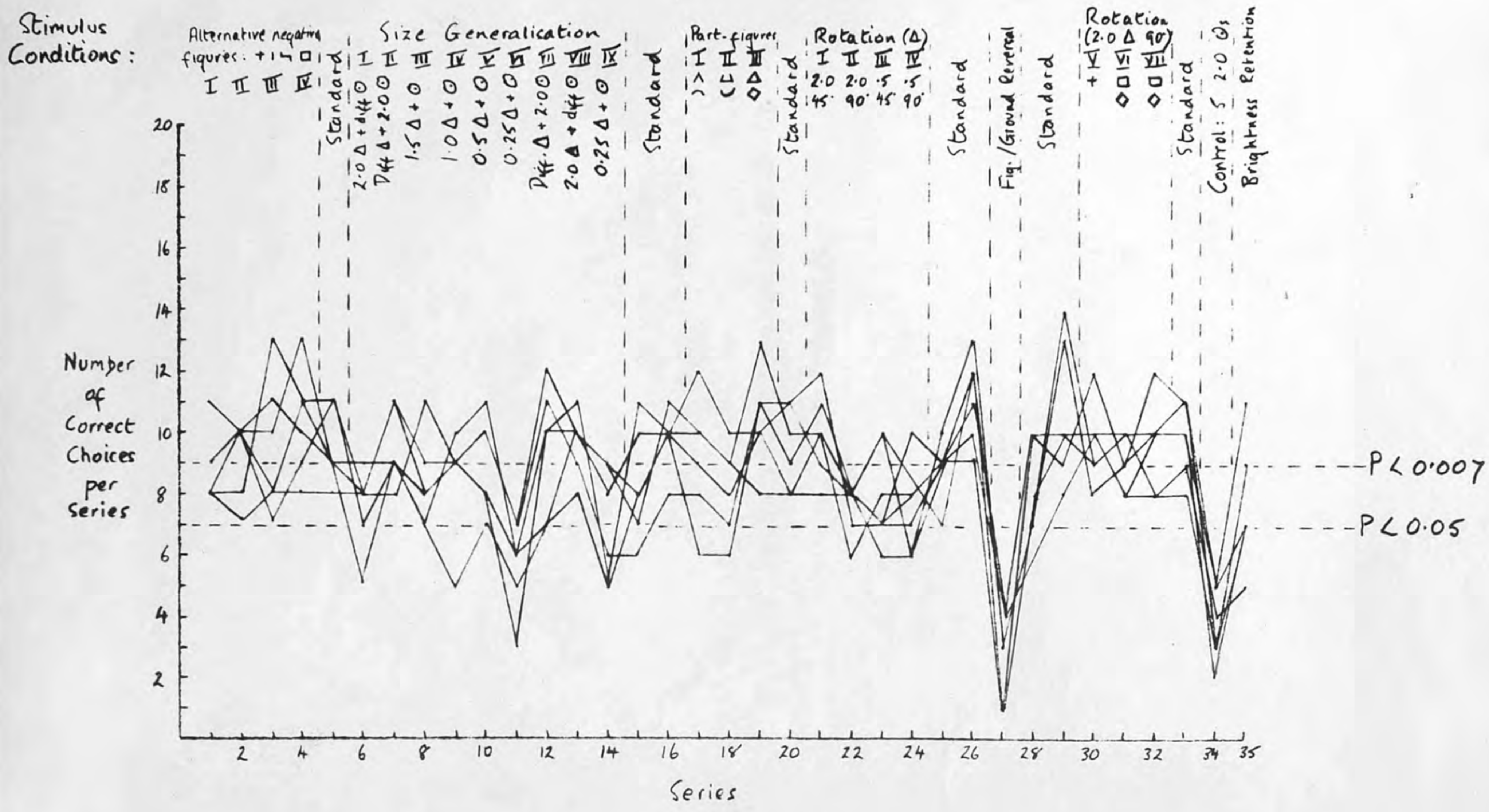


FIGURE 14. SMVDA II. Form Discrimination Transfer Tests.

Number of correct choices for all six animals.

APPENDIX L.

Diagram of circular apparatus.

CIRCULAR APPARATUS.

Diagram To Show Dimensions.

Note.
The apparatus is attached to the base board by a central pivot in the choice cylinder