THE EFFECT OF FRUSTRATION AND UNCERTAINTY ON DISCRIMINATION AND LEARNING

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued) Page

TABLE OF CONTENTS (Continued) Page

SUMMARY

Three sets of experiments, using rats as subjects, investigated the role of position responding in discrimination learning, the effect of two frustrating operations on subsequent discrimination and the role of errors in discrimination learning. The experiments were performed in a circular maze which allowed: (a) the study of visual discrimination learning under conditions of reduced spatial cues; and (b) the simultaneous presentation of multiple stimuli.

The role of position responding in discrimination learning. A review of the relevant literature revealed that position responding was usually assumed to be detrimental to discrimination learning. However, there was no support for this assumption in two experiments, an overtraining reversal study and a non-reversal shift study. In the former (Experiment 3.1), the presence of spatial cues to position actually facilitated the acquisition of a difficult discrimination. In the second experiment (Experiment 3.2) there was no difference in the rate of learning a non-reversal shift between subjects which learned to ignore spatial cues during the initial task and subjects which learned the initial task in the absence of spatial cues.

The effect of frustrative non-reward on discrimination learning. Since position responding is often assumed to be a reaction to or an expression of frustration, the effect of two frustrating operations on a subsequent learning task was studied in the presence and absence of spatial cues to position. Pilot studies (Experiments 5.1 and 5.2) supported the above assumption. In the main study (Experiment 5.3)rats under one condition were confronted with an insoluble task (uncertainty group) and in the other condition the insoluble task was preceded by a solvable

problem (Amsel-type frustration group). Both frustrating operations had a detrimental effect on subsequent discrimination learning, but the effect was more severe in the uncertainty group. Subsequent experiments eliminated the possibility that these results were due to the experimental groups being too small (Experiment 5.4) and showed that the advantage experienced by subjects which had mastered a discrimination task before confronting the insoluble problem depended on the presence, during random reinforcement, of a cue to which these subjects had learned a particular response. If such a cue was present subjects could cope with a severe random reinforcement schedule (Experiment 5.5), but in the absence of such a cue position responding was adopted and seemed to delay acquisition of the subsequent discrimination task (Experiment 5.6).

<u>The role of errors in discrimination learning.</u> Earlier research had indicated that responses to S-, or errors, were more important in discrimination learning than responses to S+ or correct responses (the Moss-Harlow effect). This conclusion was based on a variety of experimental designs each of which had basic methodological problems, usually involving novelty or order effects. The circular maze was used to study multiple stimulus discrimination learning with S+ and S- differentially weighted. The results of Experiment 8.1 confirmed the previous finding that variability in S- was more detrimental than variability in S+. However, the results also suggested that the presence of a constant stimulus was more critical than had been realised. This was confirmed by Experiment 8.2 in which the Moss-Harlow effect was not observed when S+ and S- were differentially weighted without one stimulus being constant. Experiments 8.3 and 8.4 weighted

S+ and S- by varying the number of S+'s and S-'s according to two ratios, but without stimulus variability being a factor. Experiment 8.5 also differentially weighted S+ and S- but without varying the frequency of occurrence of any one stimulus. The results of these three experiments supported the conclusion that errors are more important than correct responses.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge and belief, it contains no material previously published or written by another person, except when due reference is made in the text.

Signed . . . .

Gerald Patrick Mullins

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CHAPTER 1

THE ROLE OF POSITION RESPONDING IN SIMULTANEOUS VISUAL DISCRIMINATION LEARNING BY THE RAT.

Introduction

One of the most common phenomena occurring in the presolution phase of a symbol discrimination task involving simultaneous stimulus presentation, is a period of position responding. This is especially so if the subjects under study are rats. By "position responding" is meant a sequence of responses to one side or other of the apparatus. In a jumping apparatus, e.g. of the Lashley type, rats will consistently jump to the left or right stimulus display. In a T-maze, Y-maze, or Grice type discrimination box, the animals will run to the left or right alley irrespective of the colour or pattern of the doors, alleys, or goal boxes being used as discriminanda.

Position responding is but one of a wide range of systematic behaviour patterns or strategies which might be adopted by a subject. Some strategies which can be readily detected (cf. Harlow, 1959; Levine, 1959) are alternation, on consecutive trials, between the relevant stimuli or between the right and left positions; consistent responding to a preferred or previously correct stimulus; responding to the stimulus or position rewarded on the previous trial (win/stay: lose/shift); or responding to the stimulus or position not rewarded on the previous trial (lose/stay: win/shift). But so large is the proportion of presolution trials during which rats appear to be responding to spatial cues to position, that this form of behaviour has attracted more attention than any other.

Lovejoy (1968) provides some evidence of the magnitude of the phenomena. He quotes data from two groups of rats learning a horizontal-vertical discrimination: in one case 38 out of 49 subjects had runs of 20 or more to one side with a median longest run of 62; in the other case 30 out of 34 subjects had runs of at least 20 to one side with a median longest run of 104.

The reason for a particular rat having a left or right position preference has not been satisfactorily resolved. Peterson (1934) noted that side preference was stable in a given situation, but sometimes inconsistent in different situations. He eliminated a number of factors including sex, eye dominance, and heredity. Yoshioka (1928, 1930) opted for the curvature of the nasal bones. More recently Franken, Kolb and Wenger (1969) argued that position responding is related to initial exploratory responses, in that the occasional reward following such a response comes to cue further responses. In any case, the issue is not critical to the study of the role of position responding in visual discrimination situations, since position responding seems to develop during discrimination training and this development is not accounted for by pre-existing preferences. Mackintosh and Sutherland (1971) quote data from 204 subjects in several experiments requiring the learning of a brightness discrimination. By the 30th trial an average of 89 per cent of all responses were made to the preferred side, but during the first five trials only 68 per cent of responses were made to each subject's subsequently preferred side. Moreover, they quote Turner's (1968) unpublished data from 78 rats which developed position habits in acquisition: 35 developed their habit on the opposite side to that preferred during pre-training.

We are faced with the fact of position responding - even if it is regarded as no more than a nuisance. It requires, on the theoretical level, an explanation as to how it affects the course of discrimination learning, and on the experimental level, some form of control. As regards the latter, the usual procedure is to vary the discriminanda so that responses to spatial cues, and most other response strategies, receive 50 per cent non-differential reinforcement, and the subject cannot master the relevant discrimination without breaking its position habit. In other words, the position responding variable is randomised. Gellerman (1933) initially developed semi-random schedules for the ordering of the position of the discriminanda, and Fellows (1967) has improved these schedules. However, this procedure does not prevent the development of position habits - all that the experimenter can do is to record the amount of position responding and speculate upon its effect on the learning process. Sperling (1968, 1970) has developed methods of data analysis which distinguish between responses to stimuli and responses to the positions at which these stimuli appear. Sperling (1967) has also suggested the use of schedules which minimize position responding. The comparison of performance under these schedules with performance under the more conventional schedules (Sperling, 1967; Sperling and Yoder, 1969) will be discussed below.

An alternative method of controlling position responding is to manipulate the experimental situation so that position responding is just not possible, e.g. by the use of a single stimulus presentation procedure (Birch, Ison and Sperling, 1960). Such a manipulation was achieved in the experimental situations described in this thesis. The apparatus used throughout was a "circular maze" designed to reduce position responding. Subjects were placed on a starting platform surrounded by the discriminanda so that the visual cues to position were no longer available. Performance in this situation was compared with that of rats in a conventional two-choice situation. The circular maze is described in detail in chapter 2. The remainder of this chapter reviews various theoretical views of the role of position responding in discrimination learning. By far the most common view has been that position responding is detrimental to discrimination learning, although there is some evidence which raises doubt about this view. Finally, two experiments are described in chapter 3 which investigated the commonly held view of the detrimental effect of position responding in two situations : the effect of overtraining on discrimination and reversal learning with reduced cues to position responding, and nonreversal shift learning with cues to position responding as the irrelevant dimension.

The continuity versus noncontinuity controversy.

On the theoretical level, the most common view of position responding has been to regard it as a form of behaviour detrimental to the acquisition of the appropriate discriminative response. The most notable controversy involving position responding was that over the continuity or noncontinuity of the learning process. This is not surprising, since the debate was concerned with the nature of the learning process, and position responding is the most noticeable behaviour occurring during this process. Lashley (1929) suggested that,

> "...responses to position, to alternation, or to cues from the experimenter's movements usually precede the reactions to the light and represent attempted solutions that are within the rat's customary range of activity,"

and

> "...both the practice preceding and the errors following are irrelevant to the actual formation of the association." (page 135)

Lashley made these suggestions more on the basis of his informal observations than as a result of experimental work. His suggestions were developed by Krechevsky (1932) into a more complete theoretical statement, supported by experimental evidence. Krechevsky used a multiple discrimination apparatus in which rats successively encountered four Y-shaped choice points before reaching the goal box. At each choice point a brightness discrimination and a high-low hurdle discrimination were required. On the basis of individual learning curves and the development of position habits during the pre-solution period, Krechevsky argued that chance responding was not the basis of behaviour during the pre-solution period. In solving a problem a rat runs according to a set of integrated responses; this set of responses is preceded by other, just as integrated, responses.

> "Learning consists of changing from one systematic, generalised, purposive way of behaving to another and another until the problem is solved. The learning process at every point consists of a series of integrated, purposive behaviour patterns." (page 532)

Krechevsky called this systematic manner of behaving an "hypothesis" which he defined as,

> "(1) behaviour which is systematic; (2) behaviour which is purposive (displaying an "if-then" character); (3) behaviour which involves some degree of abstractness, and, finally, (4) behaviour which does not depend entirely on the immediate environment for its initiation and performance." (page 529)

The second classic paper in the controversy came from Spence (1936) who became the leading proponent of the continuity theory. Spence also denied that the behaviour of animals during the early stages of learning was due to chance.

> "Systematic responses at the beginning of learning are explained in terms of innate or acquired differences in the excitatory strengths of one of the position or spatial stimulus components" (page 439)

In his explanation of how a rat changes from position responding to the correct discriminative response Spence assumed that:

(a) trials at the beginning and at the end of learning do not add as much to the development of a response habit, or excitatory tendency, as do the intermediate trials;

(b) the weakening effect of non-reinforcement is directly related to the strength of the habit. If an animal brings a strong position habit to a brightness discrimination task, the position habit is only slightly increased when the correct stimulus (S+) is on the preferred side, but it is considerably decreased when the position response to the incorrect stimulus (S-) is not rewarded. Since the response tendency to S+ is low, it is strengthened and weakened in relatively small increments at first, but as the response tendency increases the effect of reinforcement also increases. Eventually the response to S+ will be greater than the tendency to go to the preferred side.

> "This systematic position habit will persist until the difference between the excitatory tendencies of these stimulus components becomes, through the action of reinforcement and non-reinforcement, more or less eliminated, or until the difference between the strength of the excitatory tendencies of the positive and negative cue components becomes sufficiently great to offset it." (page 438)

McCulloch and Pratt (1934) provided the first experimental test of the noncontinuity thesis with a presolution reversal study. The following 20 years saw a flood of theoretical and experimental papers, e.g.Krechevsky, 1937, 1938; Spence, 1940; Lashley, 1942; Ehrenfreund, 1948 . The controversy has been reviewed several times, e.g. Blum and Blum (1949), Osgood (1953, pages 446-451), Goodrich, Ross and Wagner (1961). Its resolution is not central to the present thesis. It is debatable if it ever was possible to resolve the controversy within the terms in which it was stated, although by 1950 the weight of evidence seemed to be in favour of the continuity hypothesis. What is important is the acceptance, by both sides in the debate, that position responding is a detrimental factor in the learning process. For the continuity theorists, position responding is a habit which will be maintained until it is offset by the growing strength of the excitatory tendency of S+; and for the noncontinuity theorists, position responding is evidence of an inappropriate hypothesis that, for the majority of subjects, must be discarded before the correct hypothesis can be adopted.

Moreover, since the 1930's and '40's was a period notable for general theories of learning, the views expressed in the continuity-noncontinuity controversy were incorporated into more comprehensive theories. Spence developed his position against a Hullian background. Tolman (1932, 1948), incorporated Krechevsky's "hypotheses" into his cognitive theory of learning - referring to them, rather grandiosely, as "sign-Gestalt-expectations". Hebb (1949), also integrated Krechevsky's views into his discussion of insight and perception.

Finally, the controversy led researchers to manipulate position responding in experimental situations. Spence (1945) used position habits as an example of a response to an irrelevant cue in an experiment to support his position. Rats were trained in grey runways to respond to their preferred side. The experimental group was then given 20 differentially rewarded trials in a black or white runway: the control group was given 50 per cent reinforcement for each colour. Position preferences were eliminated for both groups. Finally, the control subjects were given a brightness discrimination task and the experimental subjects were trained on the reversal of their original brightness training. This earlier training had a detrimental effect on subsequent reversal learning, even though the position training had ensured that the animals were responding according to what would be considered a spatial rather than a brightness hypothesis during the original brightness training. Ritchie, Ebling and Roth (1950) replicated Spence's (1945) experiment with certain changes, found similar results, and argued that since position habits were strong during the initial discrimination training, response tendencies to symbol cues were not exhibited until the position habits were eliminated. Our interest in these experiments is not in the support they are alleged to provide for the continuity position, but for what they reveal about the effect of position habits on discrimination learning and the assumption that this effect can be controlled by appropriate training.

Bitterman and Coate (1950) also offered evidence for the continuity theory in an experiment that manipulated position responding. While rats learned a brightness discrimination spatial cues were reinforced on either 80 per cent or 20 per cent of the trials. When the animals reached criterion on the brightness discrimination, they were transferred to a spatial discrimination. Those subjects whose new S+ was the position which had been more frequently rewarded during the brightness discrimination, learned the spatial discrimination faster than the subjects transferred to the position which was reinforced on only 20 per cent of the visual discrimination trials. Strong position preferences were evident before the differential reinforcement of spatial cues was introduced, and this may have biased the results. However, Bitterman and Coate found that, even though the differential reinforcement was on the preferred side for half the subjects and on the nonpreferred side for the other half, both groups learned the brightness discrimination at an identical rate.

The 1950's saw the development of several different lines of research in this field. Lawrence initiated a new phase of the continuity versus noncontinuity controversy with his work on the role of irrelevant cues and his theory of the acquired distinctiveness of cues. Reid's discovery of the overlearning reversal effect (ORE) sparked off an immense amount of experimentation and theorising. A great deal of work was done on other shift designs, for example the comparison of extra-dimensional and intra-dimensional shifts and serial reversal learning. Generalisation, probability matching, and partial reinforcement were areas of new research. These developments renewed argument about the course of discrimination learning, and assa consequence raised new questions about the role of position responding in that process.

Position responding as an irrelevant cue.

Lawrence (1949) showed that rats which had been trained to respond to a particular stimulus dimension (brightness, alley width or floor texture) in a simultaneous discrimination task were facilitated in learning a successive or conditional discrimination task involving that dimension, by comparison with subjects for whom the relevant dimension of the initial task was now irrelevant or absent. Lawrence argued that, since there was no basis for transfer via the instrumental response involved, the positive transfer must have been due to the "acquired distinctiveness" of the cues, i.e. during discrimination learning, a mediating process alters the relative discriminability of the stimulus cues in this situation. Lawrence (1950) trained rats on a successive discrimination (brightness, or presence or absence of chains) with one stimulus dimension relevant and the other irrelevant. The subjects then learned a simultaneous discrimination with both dimensions relevant. Testing with the two cues opposed indicated that subjects discriminated on the basis of the cue from the dimension that was relevant in the initial task. Relearning and reversal learning were faster with this cue than with the previously irrelevant cue. Lawrence's technique of shifting from successive to simultaneous discrimination tasks requires assumptions that have not gone unquestioned (cf. Weise and Bitterman, 1951; Bitterman and Wodinsky, 1953; Bitterman, Tyler and Elam, 1955; Siegel, 1967). However, Lawrence's work raised the problem of what subjects in a discrimination task are learning about irrelevant cues. Is it a matter of some cues becoming more distinct, or is it more a case of acquired non-distinctiveness of irrelevant cues? Mackintosh (1965 d) and Sutherland and Mackintosh (1966) found that rats pretrained on a successive brightness discrimination with orientation irrelevant, learned less about the orientation component of the subsequent brightness-orientation compound discrimination than subjects pretrained on brightness alone. Hence the suggestion is that subjects learned to ignore the orientation discrimination. Wortz and Bitterman (1953) had found that an irrelevant brightness cue retarded the learning of a form discrimination (upright versus inverted triangles). A more extensive study by Lawrence and Mason (1955) examined the maintaining of a habit during the reinforcement of an irrelevant dimension. They used 6 groups of rats: 4 groups learned a sequence of 8 brightness or high-low hurdle discriminations and reversals with one dimension relevant and the irrelevant dimension either set at a constant value or varying from trial to trial; 2 more groups (CD and CDR) learned 15 discrimination tasks involving a change of dimension on each task with (CDR) or without (CD) reversal of the stimulus values; finally, 2 groups learned 8 brightness or hurdle discriminations and reversals with position as the only irrelevant variable. Lawrence and Mason found that:

(a) difficulty of reversal was a function of the number of irrelevant dimensions involved. Moreover as the number of dimensions increased there was a marked increase in position responding.

(b) The CD group learned faster than the CDR group and showed less position responding. Hence reversal seemed to result in more systematic behaviour to irrelevant aspects of the situation, and, consequently, in greater difficulty in learning the relevant discrimination.

(c) The CDR group completed 16 tasks (8 hurdle and 8 brightness discriminations) faster than the group required simply to learn 7 hurdle reversals with brightness variable and irrelevant. This result might be explained in terms of a tendency of the CDR group to "displace" their behaviour when a familiar schedule of reinforcement was interrupted. Position responding was little use to the hurdle reversal group for hurdles were always relevant, but it might have facilitated the performance of the CDR group for whom a new task required a shift of response to a different aspect of the stimulus situation, i.e. from hurdle to brightness or vice versa.

Lawrence and Mason's experiment does not allow a simple conclusion, but the evidence indicates that the detrimental effect of responses to irrelevant cues may be more significant than any acquired distinctiveness of cues. The findings of Mackintosh and Holgate (1967) reinforce this view. They trained two groups of rats on a successive discrimination (brightness or orientation) with one dimension relevant and the other irrelevant. These groups and a naive control group were transferred to a simultaneous brightness discrimination (with a 75:25 ratio of reinforcement to provide a more sensitive measure of learning). The experimental groups differed, as in Lawrence (1950), but by comparison with the control group, the only significant difference was that the subjects pretrained to orientation with brightness irrelevant performed less well than both other groups. The experimental group which was given relevant pretraining, did not differ from the control group.

The assumption underlying all the above work is that position responding is behaviour that is under the control of an irrelevant cue or an irrelevant stimulus dimension, and that what can be shown about other irrelevant stimulus dimensions, e.g. orientation, as in Mackintosh and Holgate (1967), can be applied to position responding. This same assumption frequently appears in discussions of the next two topics to be considered - the ORE and nonreversal shifts.

Position responding and the ORE.

Reid (1953) initiated the present line of research and theory on the ORE. He found that rats overtrained on a black-white discrimination learned a reversal of this discrimination faster than subjects trained to a conventional criterion of 9/10 correct responses. Jackson (1932) had reported a similar paradox, but Reid's work embarrassed contemporary learning theories (e.g. Spence's) since increased learning might be expected to strengthen a learned response, make it more resistant to extinction, and so retard reversal.

Since there are several excellent and detailed reviews of the literature on the ORE - Paul (1965), Sperling (1965a, b), Mackintosh (1965a, 1969), Lovejoy (1966), Sutherland and Mackintosh (1971) - there is no point in repeating the exercise here. As far as the occurrence of the ORE is concerned, Sutherland and Mackintosh (1971) sum up the situation reasonably well,

> "(1) The ORE is more likely to occur with visual than with spatial discriminations.
> (2) The ORE is more likely to occur with difficult than with easy visual discriminations.
> (3) Even with difficult visual problems, the ORE is more likely to occur when a large reward rather than a small reward is used.
> (4) When the ORE does occur in visual studies (and sometimes when it does not), overtraining tends to increase the number of errors early in reversal, but leads to more rapid learning later in reversal.
> (5) The crossover in the learning curve of overtrained and non-overtrained subjects occurs because the latter develop more marked position habits." (page 287)

Recent reports indicate that another variable should be added to Sutherland and Mackintosh's list. Sperling (1970, 1972), Richman and Coussens (1970), Richman, Knoblock and Coussens (1972), and Sweller (1973) all present evidence that the amount of initial training or the strictness of the learning criterion on the initial task influence the occurrence of the ORE. If too much initial training is given, especially by setting too strict a criterion for the original discrimination, all subjects - both "criterion" and "overtrained" subjects - are in fact overtrained. Hence different amounts of initial training do not lead to faster reversal in one group relative to the other.

It would be rash even now to assume that the necessary and/or sufficient conditions for the ORE have been established. The theoretical explanation of the phenomena is even less a closed case. But, as with the continuity versus noncontinuity controversy, it is not the phenomena as such nor the theoretical explanation of it which is the focus of attention in this thesis. What is of interest is paragraph (5) of Sutherland and Mackintosh's list, i.e. the relationship between overtraining and the development of position responding in criterion and overtrained subjects. There is little doubt as to the empirical facts. Those studies which report the ORE consistently record more position responding by the criterion subjects: Reid (1953), Komaki (1961), Mackintosh (1962, 1963a,c, 1965c, 1969), Paul (1966), Siegel (1967), Hooper (1967) and Mandler (1968). Even studies which do not show the ORE report similar results: Mandler (1966). In the light of these facts it is not surprising that several explanations of the ORE depend heavily on the idea that overtraining somehow depresses position responding, thus counteracting the stimulus control of an irrelevant cue and so facilitating reversal learning.

Position responding figured in one of the earliest attempted explanations of the ORE. In Reid's (1953) paper, the author quoted a proposal by Spence that overtraining facilitates reversal by providing conditions for the equalisation of position habits. Criterion subjects commence reversal with the difference between response tendencies to S+ and S- only just greater than the tendency to position responding. During overtraining performance is almost errorless. Consequently, the rat responds to each side an equal number of times and so begins reversal with less tendency to adopt a response to a particular side i.e. it has less tendency to adopt a detrimental form of responding. Recently Wolford and Bower (1969) returned to Spence's model of discrimination learning for an explanation of the ORE. However, as Turner and Mackintosh (1970) point out:

(a) Pubols (1956) has shown that initial position preference has no effect on the ORE. Pubols attempted to equalise position responding before the initial brightness discrimination by position training his subjects to a criterion of no more than 11/20 responses to any one side. An indication of the effectiveness of this pretraining was that the proportion of responses to the initially preferred side during reversal was 0.45 and 0.55 for the criterion and overtrained groups respectively.

(b) Moreover, if position habits do <u>develop</u> in the course of the initial discrimination and are still present in the criterion subjects on reversal, Spence's case still does not hold. Turner and Mackintosh (1970) quote data from 99 rats (48 overtrained and 51 not overtrained subjects) which developed position habits in both acquisition and reversal. Only 57 per cent of the criterion subjects and 58 per cent of the overtrained subjects developed the same position habits in acquisition and reversal. Overtraining may reduce position responding, but not by reducing a specific position bias since these were not present even in criterion subjects.

Harlow (1959) proposed that his "error factor theory" could be used to explain the ORE. Harlow saw learning as an inhibitory process which consists in the elimination of error factors (incorrect response tendencies elicited by stimuli in the environment) rather than the development of correct responses. The dominant error factor in a visual discrimination problem is a responsiveness to spatial cues. Harlow argued that overtraining on the initial task could lead to the suppression of error factors during this stage of the task and so result in positive transfer on the reversal task.

Mandler (1966, 1968) and Mandler and Hooper (1967) have developed a more subtle explanation of the ORE based on a concept of position responding as a response strategy. Mandler (1966) described the effect of overtraining on reversal and transfer in a series of experiments in a Y-maze. She did not obtain the ORE but did observe large positive transfer when overtrained subjects were shifted to another visual task (from black-white to horizontal-vertical or vice versa). Mandler defined a position habit as,"the initial entry into the same alley (either left or right) for at least 8 out of 10 trials on any one day regardless of whether the animal makes an error or not." (page 191). This is a rather unusual definition of position responding in that a rat could be said to have a position habit and still be errorless in the performance of a visual discrimination task. However, it is consistent with the view expressed by Mandler and Hooper (1967),

> "Position responding has an anomalous status among the various 'irrelevant' behaviours found in a visual discrimination problem. A position habit is not a stimulus dimension; yet it is frequently suggested as an irrelevant 'hypothesis' or attempt at solution. It might be profitable to consider position habits not as attempts at problem solution but as types of learned goal approaching sequences which both affect and are affected by the discrimination to be learned." (page142f)

Mandler (1966) found that overtrained subjects, having eliminated position responding during the initial discrimination, rapidly reverted to position responding during reversal; but in a non-reversal shift situation, this reversion to position responding did not occur. In the light of these findings Mandler distinguished between a "detour strategy" and a "choice-point strategy". The former is a "go-first: choose-later" strategy whereby the subject runs to the same side of the maze on each trial and then either goes ahead or retraces to the other side on the basis of the relevant stimulus cues. A detour strategy is represented by Mandler's scoring of position responding. The choice-point strategy is a more efficient "choose-first: go-later" tactic whereby the rat pauses at the choice-point and chooses one side or the other, presumably on the basis of the relevant stimulus cues. Overtraining leads to the adoption of a choice-point strategy in most subjects, while criterion subjects retain a detour strategy. When overtrained subjects are transferred to a new discrimination task, their choice-point strategy facilitates learning. In a reversal situation, however, perseverative tendencies to the former S+ make a detour necessary on most trials so that, by the time such perseverative tendencies have been extinguished, the choice-point strategy has also been replaced by a detour strategy. This is how Mandler explained her failure to obtain the ORE. However, if some other factor, such as reward size, so affects the perseverative tendencies that position responding is effectively suppressed, the ORE will be obtained (Mandler, 1968).

Siegel (1967, 1969) also emphasised the orientation of the subject in his analysis of the ORE. He used a T-maze in which subjects had to look behind doors at the arm of the T-maze in order to see the stimulus. Thus Siegel was able to separate the subject's observing or orienting response from its choice response. He found that performance on a transfer task was dependent on the subject's initial orientation, its reorientation when the initial observation revealed S- ("conditional reorientation"), and the approach responses rewarded during the pre-transfer task. Overtraining was seen as providing an opportunity for subjects to practice a conditional reorienting strategy and the transfer of the conditional response tendency facilitated performance on subsequent tasks.

Both Mandler's and Siegel's theories have been described as "observing-response theories" (Sutherland and Mackintosh, 1971) because of the emphasis on the learning of an appropriate orientation. With Mandler especially, an appropriate orientation follows the elimination of an inappropriate observing-response, i.e. position responding. Overtraining has its effect, facilitatory or detrimental, insofar as it affects position responding.

The most sophisticated explanation of the ORE is the attention theory of Sutherland and Mackintosh. The theory was initially proposed by Sutherland (1959, 1964). Over the next 10 years he, Mackintosh and several co-workers provided an impressive amount of experimental support for the theory, plus several theoretical statements (Mackintosh, 1965a, Lovejoy, 1965, 1966, 1968). Fortunately for this reviewer, Sutherland and Mackintosh (1971) have recently published a detailed statement of their theory and its application, supported by a summary of the experimental evidence gathered from several different species of subjects in many different experimental situations. While Sutherland and Mackintosh's attention theory is not the only theory to use attention as a basic concept (c.f. Mostofsky, 1970) it is the theory most frequently referred to in animal discrimination work and it does provide the most comprehensive and useful framework for discussion in that field.

The theory postulates that in a discrimination task part of what a subject learns is to attend to the relevant stimulus dimension. Subjects do not process the whole stimulus input to the same degree, but react selectively to the stimuli on the basis of the number and salience of the stimulus cues, and on the basis of the subjects' previous experience, pretraining, or response preferences. Attention to a dimension (or "analyser strength", as the more mechanistic statement of the model puts it) is increased when such attention results in correct predictions of future events of importance to the animal, i.e. when choice responses made on the basis of such attention are rewarded. When an analyser is strengthened, the total strength of other analysers is weakened by the same amount. Attention theory is a two-stage model in that while a subject learns to attend to a particular dimension (or to switch in the correct analyser) it develops choice responses to specific stimulus values ("response attachments") within that dimension. Response attachments are increased by reward and decreased by non-reward, and the size of the change is proportional to the strength of the relevant attending response or analyser strength. The rate of change of both response attachments and analyser strengths are different such that if the initial strength of an analyser is low it reaches asymptote more slowly than the strength of its response attachments.

According to attention theory position responding indicates that the subject is attending to the spatial dimension, since choices are determined by the responses attached to the strongest analyser. The cues representing the spatial dimension may be either external visual cues or internal proprioceptive stimuli (Mackintosh 1965b). Early in the task, in the case of a brightness discrimination, the relevant brightness analyser is low relative to the position analyser. Nevertheless, the initially weak brightness analyser increases in strength on all trials because its different outputs are consistently correlated with differences in reinforcement; while the initially strong position analyser gradually weakens because it predicts reinforcement on only 50 per cent of the trials. When the brightness analyser gets within a consistent amount of the position analyser choice behaviour depends upon both brightness and position response strength. If the position habit is broken under joint control then subjects break their position habit by a response to S+, the correct brightness value. After the break both analysers continue to control behaviour until the brightness analyser gains exclusive control.

As applied to the ORE, Mackintosh (1965a) puts the attention theory explanation quite precisely,

> "If overtraining increases the probability of subjects attending appropriately without causing a corresponding increase in choice response strength, then overtrained subjects will continue to attend to the relevant cue during reversal and will only have to extinguish their original choice responses and acquire new ones; while non-overtrained subjects will cease to attend to the relevant cue, attend to other irrelevant cues (during which time they will learn little about the correlation of the relevant cue with reward), and hence will take a long time to learn the reversal." (page 136)

Sutherland and Mackintosh (1971) are careful to distinguish their explanation of the ORE from those of Mandler and Siegel, although they do admit to certain common features.

> "Within the context of our theory, and of any other in which analysers sum to a constant value, strengthening of relevant analysers is necessarily accompanied by weakening of irrelevant analysers. We could, therefore, say that overtraining facilitates the reversal of a simultaneous brightness discrimination both because it strengthens the brightness analyser and because it weakens the position analyser. In this sense the possibility that overtraining facilitates reversal by suppression of irrelevant cues is not inconsistent with our theory. Analyses of discrimination learning have, however, been proposed which lay exclusive emphasis on the weakening of control by irrelevant stimuli."
> (page 229f)

The emphasis is clearly on the effect of overtraining as strengthening attention to brightness, and only secondarily on its effects of weakening attention to position. Mackintosh (1963a) found that the magnitude of the ORE was a function of the number of irrelevant cues - the addition of an irrelevant cue (horizontal-vertical) retarded reversal for criterion, but not for overtrained subjects. Moreover in a third group, for whom the irrelevant horizontal-vertical stimuli were introduced <u>after</u> reversal had begun (i.e. subjects for which overtraining cannot have weakened attention to the irrelevant cue), criterion subjects reversed slowly but overtrained subjects were unaffected by the presence of the irrelevant cue. Mackintosh concluded that overtraining had its beneficial effect on reversal more because it strengthened attention to brightness than because it weakened attention to orientation. Sutherland and Mackintosh (1971) assume that this evidence is applicable to position responding. However, they concede that because overtraining did not weaken attention to an already relatively weak cue, orientation, does not mean that it fails to weaken attention to a strong cue such as a spatial cue to position responding.

The overall conclusion as regards the ORE is much the same as that reached about the continuity versus noncontinuity controversy. Despite the variety of theoretical viewpoints, and the different roles assigned to position responding within these theories, position responding is almost universally regarded as an interfering factor. Its effect on discrimination and reversal is contrasted with the facilitating effect of overtraining.

Position responding and nonreversal shifts

Several examples of experimental designs incorporating shift have been mentioned already. Reversal learning, as in the ORE, is a special case of an intradimensional shift (IDS). Lawrence's work involved extra-dimensional shifts (EDS), e.g. from a brightness dimension to a hurdle dimension. It will be useful at this point to look at nonreversal shifts in a more systematic way. Nonreversal shifts are transfer tasks in which subjects are required to learn a second task, the relevant cues for which are either from a different stimulus dimension from the stimulus dimension used in the initial task (EDS), or they are of the same stimulus dimension (IDS). An important feature of shift paradigms is the manipulation of the irrelevant cue. The following table illustrates most of these experimental designs.

Type of Shift	Initial Task		Shift Task	
	Dimension 1	Dimension 2	Dimension 1	Dimension 2
Intradimensional	Relevant	Irrelevant	Relevant	Irrelevant
Pure reversal (1)	Relevant	Irrelevant	Relevant	Irrelevant
Pure reversal (2)	Relevant	Constant or Absent	Relevant	Constant or Absent
Extradimensional (1)	Relevant	Irrelevant	Irrelevant	Relevant
Extradimensional (2)	Relevant	Constant or Absent	Irrelevant	Relevant

Type of Shift	Initial Task Dimension 1	Initial Task Dimension 2	Shift Task Dimension 1	Shift Task Dimension 2
Extradimensional (3)	Relevant	Constant or Absent	Constant or Absent	Relevant
Extradimensional (4)	Relevant	Irrelevant	Constant or Absent	Relevant

Cf. Shepp and Turrisi (1966) or Slamecka (1968) for a full discussion of shift paradigms. It is rather arbitrary as to what is included in the EDS category: for example, Shepp and Turrisi (1966) would restrict extradimensional shifts to those designs in which the relevant cues become irrelevant and variable on the shift. Moreover, an irrelevant dimension may be variable between trials - only one value of it appears on each trial and is paired with both S+ and S- - or variable within trials - two values appear on each trial and each value is paired equally often with S+ and S-. Indeed Waller (1970a) found that subjects trained on a brightness discrimination with irrelevant texture cues varying both between and within trials learned both the brightness discrimination and a shift to a texture discrimination more slowly than subjects trained with the texture cues either constant or relevant; and they learned the texture discrimination more slowly than control subjects which were not trained on the brightness discrimination.

The point of considering research on nonreversal shifts springs from the manipulation of the irrelevant cue. The point made earlier is relevant here, namely, that spatial cues to position are the most common irrelevant cues in most visual discrimination tasks. It is necessary to ask whether what is true of other irrelevant cues is true of these cues.

Research on nonreversal shifts has tended to concentrate on comparisons of intradimensional with extradimension shifts and especially on the comparison of pure reversal with all nonreversal shifts. Much research has also been done on the effect of overtraining on extradimensional shifts. The former has been taken as a test of various theories of discrimination learning which propose some mediating process, for example Lawrence's theory; the latter is often useful as a test of various explanations of the ORE, for example Sutherland and Mackintosh's explanation.

Most comparisons of the speed of intradimensional and extradimensional shift have been done with human subjects, and usually the conclusion has been that humans (young children and adults) find a discrimination easier to learn if they have been pretrained to attend to the relevant dimension rather than to ignore it. As far as animal studies are concerned Shepp and Eimas (1964) trained rats on a shape discrimination (rectangle, triangle etc.) with the width and orientation of background black and white stripes irrelevant or vice versa. Subjects learned a subsequent intradimensional shift (from one shape discrimination to another with stripes still irrelevant) faster than an extradimensional shift (from a shape discrimination to a stripe discrimination or vice versa). However when Turrisi, Shepp and Eimas (1969) replicated this experiment, but with the irrelevant cue held constant rather than differing within trials, they found no intradimensional-extradimensional difference. Similarly, Sutherland and Andelman (1969) found that if subjects were transferred from a discrimination between black and white squares, or horizontal and vertical rectangles, to a discrimination between oblique rectangles, the intradimensional shift was no easier than the extradimensional shift. Sutherland and Mackintosh (1971) interpreted these results as indicating that the intradimensional-extradimensional difference occurs only when subjects must attend to a dimension that has previously been irrelevant. This explanation also covers the finding of Mackintosh (1964) that a group of rats trained on an absolute brightness discrimination (black or white squares versus a grey square) learn a conventional brightness discrimination faster than subjects trained on a square versus a diamond discrimination with black-white irrelevant. Even though both groups received equal exposure to brightness on the initial task, brightness was a relevant dimension for the first group and an irrelevant dimension for the second.

As regards the more specific problem of the comparison of the intradimensional shift of reversal with nonreversal shifts, the results are again complicated by the variety of shift designs available. If the irrelevant cue on the shift discrimination varies only between trials and not within trials, then reversals are learned more slowly than non-reversals (Kelleher, 1956, Tighe, Brown and Youngs, 1965). If the irrelevant cue of the initial discrimination remains irrelevant in the shift discrimination and varies within trials, the results are ambiguous: Kelleher (1956) found that the non-reversal shift was learned more rapidly than the reversal shift but Brookshire, Warren and Ball (1961) found no difference. Finally, if the shift design can be solved either as a reversal or as a nonreversal (i.e. an "optional" shift design e.g. a black-white discrimination with orientation irrelevant followed by a white vertical rectangle versus a black horizontal rectangle or vice versa) then rats solve the problem as a nonreversal (Kendler, Kendler and Silfan, 1964; Tighe and Tighe, 1966; Sutherland and Mackintosh, 1966).

The effect of overtraining on non-reversal shifts has received considerable attention over the last few years, because it has been seen as a test of theories initially formulated to explain the ORE. If, as proposed by Sutherland and Mackintosh (1971), the main effect of overtraining is to strengthen attention to the relevant stimulus dimension and, consequently, to weaken attention to other stimulus dimensions, then overtraining should retard, or at least not facilitate, an extra-dimensional shift. Once again, however, the experimental findings vary according to the shift paradigm used. If the relevant dimension of the initial task remains present but irrelevant and variable during the shift, overtraining retards reversal shift as predicted by attention theory (Mackintosh, 1963c) or has no particular effect (Brookshire et al., 1961; Mandler, 1966; Siegel, 1967). If the relevant dimension of the initial task is absent, is held constant, or varies only between trials on the shift task, the results are very confusing: Komaki (1961), Mandler (1966, 1968), Sutherland and Andelman (1969) and Waller (1970b, 1971) found that overtraining facilitated an extradimensional shift; Tighe et al.(1965) found that it had no effect and Mackintosh (1962) found that overtraining retarded an extradimensional shift. Clearly the evidence strongly suggests a facilitating effect. Sutherland and Andelman (1969) explained their results by reference to Wagner's (1969) work on selective attention - namely, that the effect of overtraining on the initial discrimination is to depress attention to position and other irrelevant cues so that during shift learning with the initial relevant dimension held constant, overtrained subjects attend predominantly to the new cue (e.g. orientation) and learn the discrimination faster than non-overtrained subjects whose attention to irrelevant cues has not been reduced by overtraining.

In Chapter 3, an experiment is described in which cues to position responding are manipulated as the irrelevant variable in a nonreversal shift design. This provides an opportunity to test some of the assumptions that have been made about the function of position responding as a form of responding to an irrelevant cue.

> "Clearly, the terms "incidental" or "irrelevant" are by no means indicative of the degree of importance that the cues so designated have in determining discrimination performance." (Wagner, 1969, page 110).

The range of experimental designs and theoretical views already covered in this chapter provide ample support for Wagner's comment. The list can be extended. Since Lashley and Wade (1946) it has been an issue as to whether the term "stimulus generalisation" describes anything more than the fact that a subject has failed to discriminate among the stimuli in question and has begun to respond to irrelevant stimulus cues in its environment (cf. Hoffman, 1969). Mackintosh (1970) argues strongly that as regards the performance of rats in probability matching tasks (where a ratio less than 100:0 describes the reinforcement contingencies for responses to S+: S-) subjects do not select the minority stimulus because of some momentary preference for it, but because they respond to an irrelevant cue - they select a particular position and the minority stimulus happens to be in that position. Several authors have recorded that in serial reversal learning an improvement in performance is a function of the elimination of position responding (Lawrence and Mason, 1955; Mackintosh, McGonigle, Holgate and Vanderver, 1968; Mackintosh and Holgate, 1969). Indeed Harlow's

(1959) error factor theory, mentioned above as an explanation of the ORE, was developed in the light of serial task improvement - as the number of problems increase, subjects learn to inhibit more error factors.

A different view of position responding

Depending on the theorist's point of view, position responding is an error factor (Harlow, 1959), an indication of attention to an inappropriate stimulus dimension (Sutherland and Mackintosh, 1971), a response tendency to an irrelevant cue (Spence, 1936), a misleading hypothesis that must be discarded before the appropriate hypothesis can be adopted (Krechevsky, 1932), or a goal approach strategy providing less efficient stimulus input (Mandler, 1966). Whatever the theoretical viewpoint position responding is detrimental to discrimination learning.

There is, however, some evidence to challenge this view. Goer (1958) provided such evidence in an experiment designed to test an early version of "Denny's "elicitation" theory (Denny and Adelman, 1955). Elicitation theory proposed that non-reward is more effective when the underlying response tendency is strong than when it is weak. Goer hypothesised that moderate strengthening of a position preference prior to a simultaneous brightness discrimination would facilitate discrimination learning, whereas strengthening of the position preference to a high level would impede such learning. He trained five groups of rats in a Grice-type discrimination box as follows:

Group C-0: position preferences were determined but not strengthened;

Group E-12: 12 trials of spatial discrimination training (with preferred side reinforced);

Group E-24: 24 trials of spatial discrimination training;

Group E-48: 48 trials of spatial discrimination training;

Group C-24: matched with Group E-24 as regards the number of trials and amount and pattern of reward, but reward was not related to position responding.

All subjects were then transferred to a black-white discrimination task. Groups E-12 and E-24 performed significantly better than did each of the other groups; and Group E-48 performed significantly worse than each of the other groups. There was no difference between Groups E-12 and E-24, or between Group C-0 and C-24. Hence, familiarity with the apparatus or the cues does not account for the difference between Group E-48 and E-12 and E-24. Irrespective of the support for elicitation theory what these results indicate is that position responding is not necessarily detrimental to subsequent discrimination learning and that position responding may actually facilitate that learning.

Further evidence of the need to qualify the assumptions that are made about position responding is presented in a study by Winefield and Jeeves (1969). These authors tested Mandler's (1966) suggestion that the negative transfer observed when rats were shifted from an insoluble or solvable problem to a brightness discrimination was due to the greater resistance to extinction of position habits acquired under 50 per cent random reinforcement, by comparison with position habits acquired under 100 per cent reinforcement. Winefield and Jeeves (1969) tested this hypothesis by systematically manipulating position habits. One group of subjects were given position habits which would be highly resistant to extinction by reinforcing their responses to one side of the maze on a 50 per cent basis (Group M). In another group, position responses were minimised by reinforcing a daily reversal of position preferences (Group E). The doors of the linear maze were grey during this pretraining. When both groups reached a stable level of responding (after 300 trials), they were transferred to a black-white discrimination task. Group M performed at a higher level than Group E during pretraining, but Group E did reach and maintain a high level of performance (8.5 out of 10 mean correct responses per day on the last 5 days). There was no difference between the two groups on the subsequent brightness discrimination task - the induced position habits seemed to have no effect on subsequent learning. The backward learning curves revealed no difference in the learning process. However, Group M displayed more position responding than Group E, which in turn showed less systematic behaviour during the presolution period.

In case the stimulus change, caused by the introduction of the discriminanda after pretraining, reduced the effect of position training, the experiment was repeated with the discriminanda present, but randomly associated with reward, during pretraining. The results were similar to those obtained in the first experiment. However, Group E did not attain a high, stable level of performance during pretraining (75 to 80 per cent correct, as against 85 to 90 per cent correct in the first experiment), and both groups took almost twice as long to learn the brightness discrimination. There was no difference between the two groups on the brightness discrimination. Winefield and Jeeves suggested that

> "...because the suppression of position responding is commonly associated with the emergence of a correct response, a causal relation has been erroneously inferred. A more likely hypothesis to explain the observed correlation involves the supposition that position responding represents a natural mode of responding for the rat, which is irrelevant to learning." (p.11).

This conclusion was seen as contrary to both continuity and non-continuity theories since both theories regard position responding as a source of interference. Winefield and Jeeves also suggested that a better explanation of Mandler's results was that it was frustration induced by random reinforcement which was transferred to the brightness discrimination, and which interfered with learning and that the position habits were merely manifestations of frustration and had no effect on learning.

Sperling (1967) tackled the problem of position responding, not by pretraining to manipulate position responding, but by varying the role of position responding in the course of the actual visual discrimination. She did this by the use of a special schedule of stimulus presentation designed to reduce the incidence of position responding in a visual discrimination task. This was a response contingent procedure whereby, on the first trial of the first day S+ was on the subject's preferred side and S- was on the non-preferred side. The positions of the two stimuli were maintained until the subject responded correctly - presumably on the first trial.

On the next trial the position of S+ and S- were reversed and remained so until the next correct response. The stimuli were then reversed again and this procedure was continued throughout the acquisition period. Sperling (1967) compared the performance of rats using this procedure (Group RC) with the performance of rats on a conventional, semi-random, simultaneous presentation procedure (Group NRC). Both groups were tested on a single-stimulus successive presentation of the same two discriminanda and their performance was compared with that of a control group which received only the single-stimulus training (Group C). An elevated Y-maze with striped and checkerboard stimuli was used and the same apparatus, with one arm blocked off, was used for the single stimulus training. During the acquisition of the simultaneous discrimination the amount of position responding in Group RC was immediately and persistently less than in Group NRC. However, there was no difference between the groups on the number or pattern of trials to criterion (84.0 trials for Group NRC and 77.7 for Group RC). Accuracy of performance increased with training and the rate of approach to criterion appeared to be the same for both groups. Although the number of subjects contributing to latency measures varied from 3 to 19, Sperling claimed that for Group NRC responses to the non-preferred side were made more slowly than responses to the preferred side, but this difference was not reliable for Group RC. By the end of the simultaneous training, the latency of response of both groups to S+ and S- was not significantly different.

On the single-stimulus transfer task, 50 per cent of the subjects from Group NRC and RC reached criterion on the first day of training. Moreover, the correlation between trials to criterion on the simultaneous task and on the single-stimulus task was not significant for either group. This might incline one to suspect the sensitivity of the single-stimulus task as a test of transfer. However, Group NRC did not differ from Group RC on trials to criterion (16.4 and 22.1 trials respectively) but both groups were faster than Group C (76.0 trials). For Groups NRC and RC, responses to S+ were faster than those to S- and this difference was significant from the beginning of the single-stimulus task - this is a surprising result since there was no evidence of a difference at the end of the simultaneous task. Sperling concluded that position responding does not affect the learning of a visual discrimination task. She regarded her results as evidence:

(a) against Mackintosh's (1965) attention theory;

(b) in favour of some form of continuity theory; and

(c) in favour of Sperling's (1965a, b) suggestion that the stimuli controlling position responding are proprioceptive, whereas those controlling visual discrimination are exteroceptive, and that these types of stimuli do not act in the same way or as a function of the same variables.

However, as Sperling admits, Group RC could have reached criterion on the simultaneous problem by learning to alternate position responses on each consecutive trial. As the number of correct choices increased, the presentation schedule approached trial by trial alternation and subjects were reinforced for responding to positional changes as much as they were reinforced for responding to visual stimuli as such. Consequently, it is possible that the visual discriminanda had less control over responding in this group than they had in Group NRC. Sperling may have compared two different tasks, alternation and visual discrimination, rather than manipulated the effect of position responding within the one visual discrimination task.

Sperling and Yoder (1969) continued Sperling's (1967) line of research. Two groups of rats were trained on a simultaneous visual discrimination task with the conventional semi-random presentation schedule. For Group NRC-NRC the discriminanda were reversed, with the same presentation schedule: Group NRC-RC was reversed with the stimulus positions being determined by the response contingent procedure. The mean trials to criterion and the pattern of position responding were similar for the two groups during acquisition. However, the mean trials to reversal were significantly different (124.5 for Group NRC-RC and 178.7 for Group NRC-NRC). Group NRC-RC displayed less position responding during reversal. Sperling and Yoder concluded that differences in the amount of position responding are not, by themselves, a sufficient condition for the observation of differences in trials to criterion. However, speed of learning is associated with less position responding. They suggested that reduced position responding permits a greater number of nonreinforced responses early in reversal and this leads to either a faster rate or a greater amount of extinction of the previously correct response early in reversal.

Despite the work of Goer, Winefield and Jeeves and Sperling, there is plenty of evidence indicating that position responding is often associated with poor visual discrimination performance. Efforts to determine more precisely the role of position responding have laboured under the difficulty of manipulating position responding independently of visual choice responding. The following chapter describes an apparatus developed by Winefield and Jeeves to study simultaneous visual discrimination independently of position responding.

CHAPTER 2

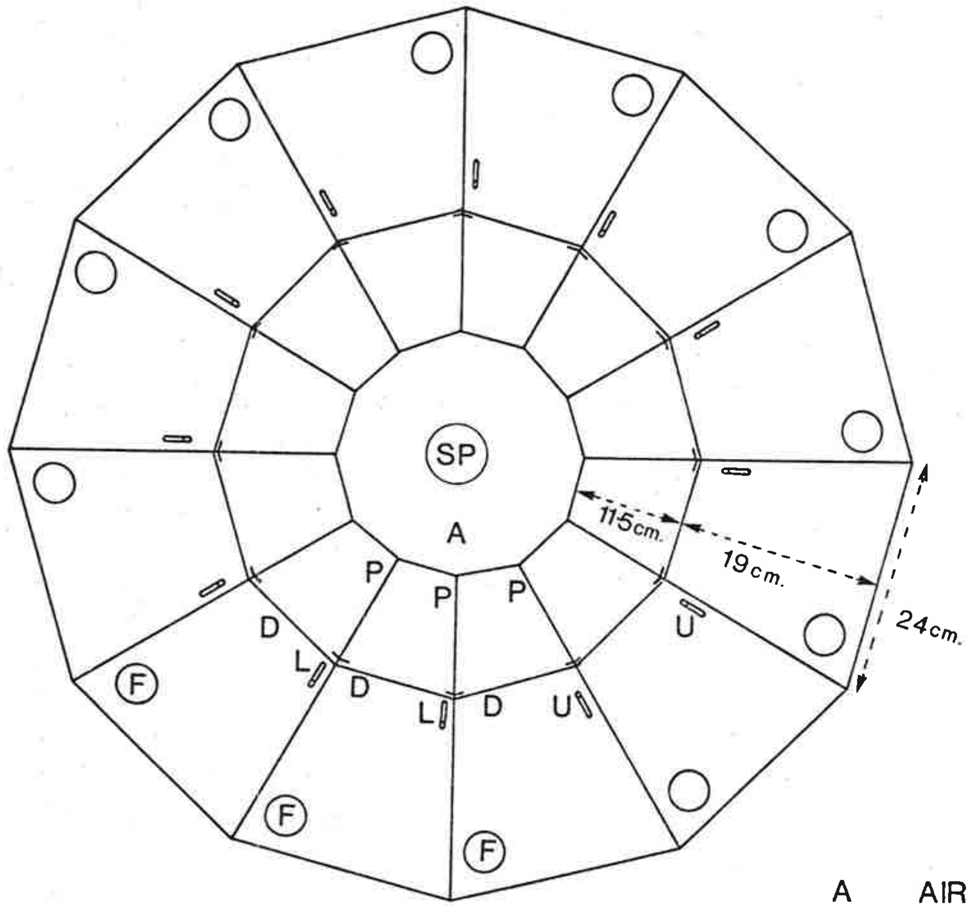
THE APPARATUS: THE CIRCULAR MAZE.

Despite attempts to manipulate position responding by pretraining or by special stimulus presentation schedules, the major problem in the study of position responding is the fact that,in almost all forms of apparatus used for the study of simultaneous visual discrimination learning in the rat, the visual discrimination task requires the subject to make a choice which involves going to the left or to the right, i.e. to make a position response. It is possible to study visual discrimination learning in situations where there is no position responding. Birch, Ison and Sperling (1960) studied reversal learning under single stimulus presentation using latencies as the response measure. Uhl (1964) studied the effect of overtraining on reversal and nonreversal shifts, also in a single stimulus successive discrimination situation, but using a free operant measure of response. However, comparisons between data gathered in situations such as these and data from two-choice simultaneous discrimination experiments are complicated by the fact that successive rather than simultaneous presentation of stimuli is used, and by the necessity to use some other response measure besides the number of choice responses.

Winefield and Jeeves (1970a) described a "circular maze" developed in order to enable simultaneous visual discrimination to be studied in a situation in which the cues that might elicit position responding are considerably reduced. Since this apparatus was used in all the experiments in this thesis it will be described in detail. There have been some minor changes in the apparatus since it was described in

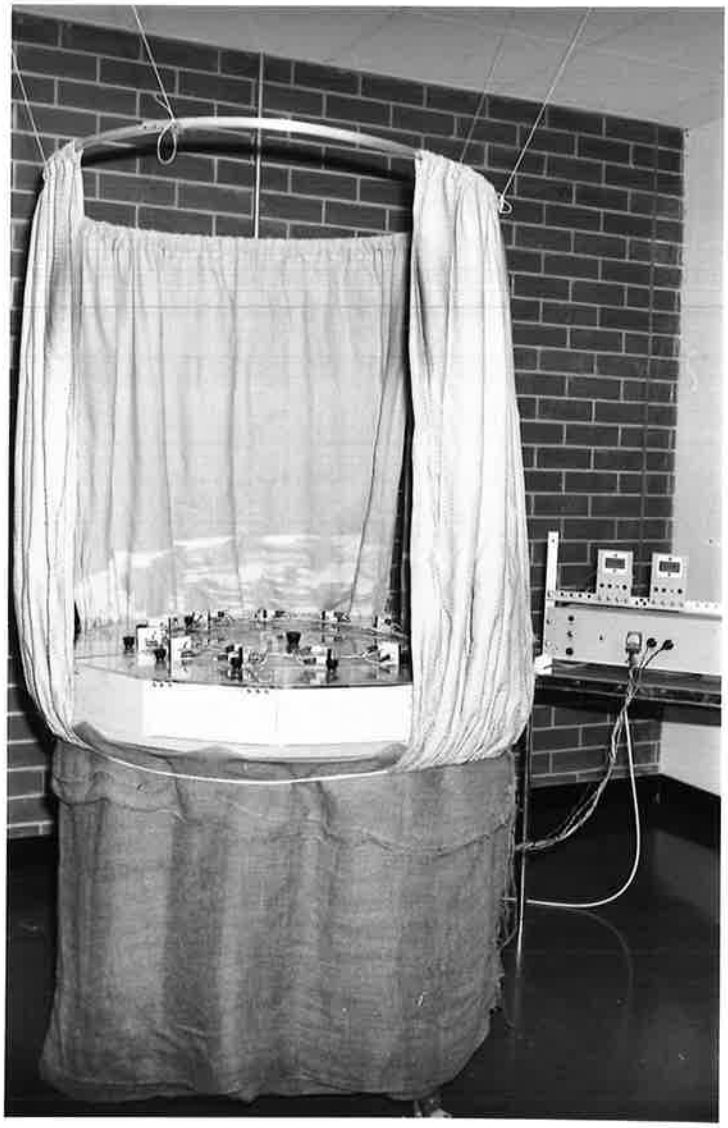
Winefield and Jeeves (1970a) due mainly to the need to alter the apparatus to measure latencies. A plan of the apparatus is shown in Figure 2.1 and photographs of the apparatus appear opposite.

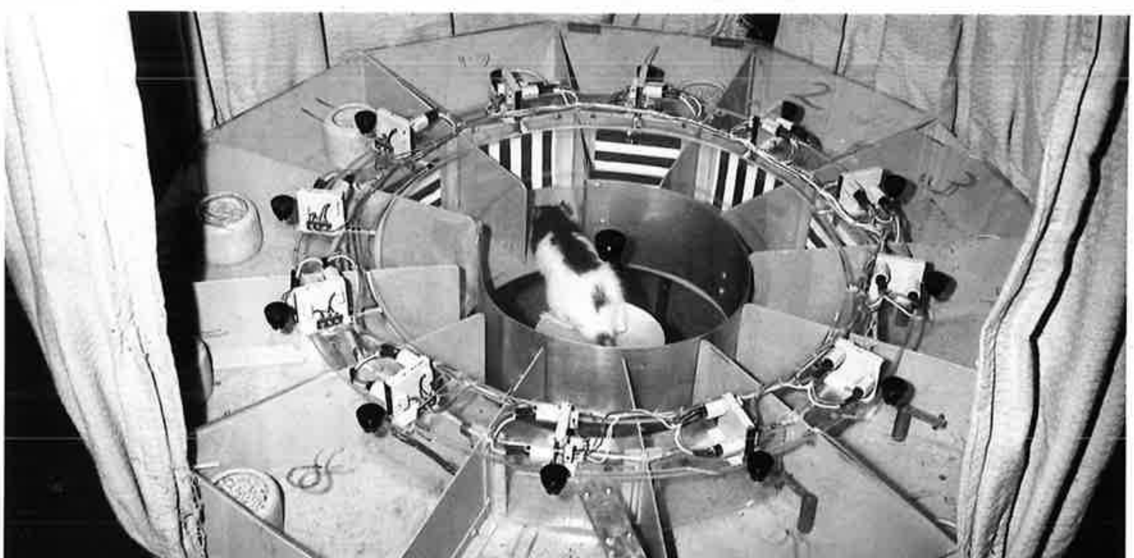
The circular maze consisted of a central starting platform surrounded by 12 goal compartments, the doors of which carried the discriminanda. The starting platform was a circular grey metal platform, 12.5 cms in diameter. The platform rested on a single metal rod rising from a heavy base, and stood about 70 cms from the floor. The starting platform was surrounded by the goal compartments, but was separated from them by a 7.5 cm air gap to discourage rats from "running on" without looking at the discriminanda. The 12 goal compartments were constructed of 16 gauge aluminium on a circular wooden base. Each compartment was 9.7 cms high, 30.5 cms deep, 12.5 cms wide at the open end facing the starting platform and 24.0 cms wide at the closed, outer end. Each compartment was separated into two parts by a grey aluminium top hinged door. The area behind the door, the "goal box", was 19.0 cms deep. The area in front of the door was 11.5 cms deep: this area formed a shelf in front of the door. The discriminanda were painted or stuck on to 9 x 7 cm metal plates which could be clipped on to the door. The doors could be locked from behind by means of a rotating arm so that the rat on the starting platform could not see whether or not the door was locked. When unlocked, the door could swing forward if pushed by the rat, but it was prevented from swinging backwards by small lateral extensions of the compartment walls which overlapped both sides of the door so that once the animal had entered the goal box it could not retreat. When locked the door swung forward a fraction before hitting the locking arm. In this case the rat was left sitting on the shelf before the door. The weight



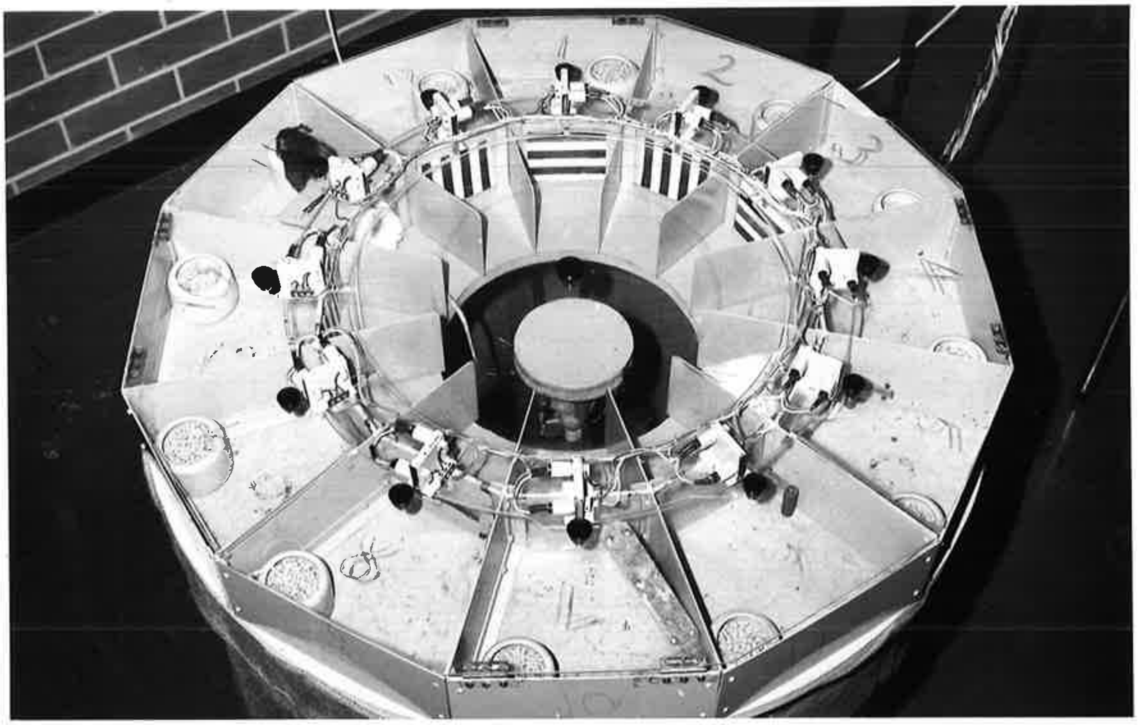
A	AIR GAP
D	DOOR
L	LOCKED
U	UNLOCKED
F	FOOD
SP	STARTING PLATFORM
P	PLATFORM

FIG. 2·1
CIRCULAR MAZE

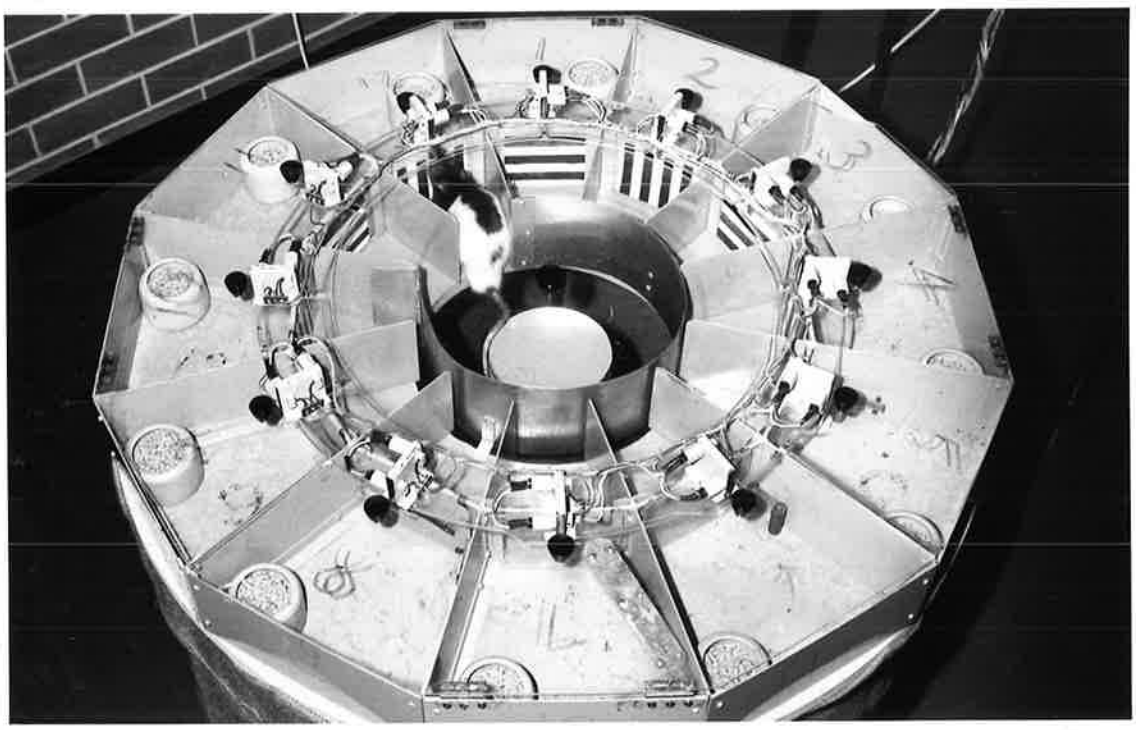




THE APPARATUS



12 DOOR



2 DOOR

of the rat on the starting platform triggered a microswitch which started two timers. A vane mounted on top of the door broke two light beams and turned off the timers. The breaking of the first light beam occurred just before the door hit the locking arm. Thus the latency of any response - correct or incorrect - could be measured as the time which elapsed from placement of the rat on the central platform to its touching a door. The second light beam was broken when the door was three-quarters open, which was about as far open as necessary to admit the rat to the goal box. This second timer provided a measure of the latency of a completed, or rewarded, response. The timers made a loud clattering noise, useful in itself as a masking noise. A food pot containing small pellets of dry, compressed food was placed in each goal box.

To allow comparisons between the 12-door situation and the more conventional 2-door situation, an unpainted, flexible, aluminium screen, 10 cms high, could be clipped on to two of the compartment dividing walls and curved around the inside of the apparatus. This screen blocked off any ten compartments, retained the air gap, and presented the rat with two adjacent compartments. The top of the apparatus was covered with clear perspex: hinged sections allowed access to the goal compartment by the experimenter, and a circular lid could be lifted up to allow the experimenter to place the rat on the starting platform. The whole apparatus was 90 cms in diameter and stood 80 cms off the ground. It was mounted on castors which allowed it to be moved or rotated. The apparatus was surrounded by grey curtains reaching over 100 cms up from the top of the maze to an aluminium circle attached to the ceiling of the experimental room. Four partitions in the curtains allowed access to the apparatus, but the partitions could be closed once the rat was on the starting platform. The lower part of the apparatus was surrounded by grey curtains to floor level. Illumination was provided by an ordinary electric globe situated immediately above the starting platform.

What Winefield and Jeeves attempted to do was to:

(a) eliminate as many irrelevant intra- and extra-maze cues as possible; and

(b) more specifically, eliminate cues to position responding, especially kinesthetic and visual cues.

Apparatuses with multiple stimuli have been used before. Fields (1935) used a five-stimulus apparatus which, he claimed, reduced position responding. Field (1935, 1954) reported data from experiments using this apparatus. However, the stimuli were on a panel 2 metres wide and the reduction in position responding seemed to be due to the fact that subjects ran along in front of the stimuli looking at each one in turn. Lachman and Brown (1957) also used a five-choice apparatus in which five paths radiated from a central starting platform. Lachman was interested in whether, in a multiple choice situation, rats would behave in a stereotyped manner, i.e. choose the same path on each trial, or whether they could be trained to select different paths on successive trials. Lachman and Brown (1957) and Lachman (1965, 1969a and b, 1971) reported data on this problem.

Something closer to Winefield and Jeeves' circular maze was proposed by Fujita and Ishihara (1963) who initiated a long series of studies in a semi-circular maze. The maze consisted of a starting box facing eight goal boxes in a semi-circular array 50 cms from the starting box. The authors studied a variety of factors in discrimination learning, including position responding (Fujita and Ishihara, 1964. Cf. also Fujita and Ishihara, 1966, Ishihara, 1962, 1965, 1966, 1967a and b, 1968 a and b).

Finally, Thompson (1962) and Barner, Smith and Latto (1970) did develop circular mazes. Thompson's apparatus consisted of a mobile centre circle surrounded by an outer stationary circle made up of 16 goal boxes. However, the inner circle was bisected by a screen in the centre of which was the starting box. Thompson was interested in separating stimulus alternation and response repetition and he found that reinforced subjects showed an increasing tendency to repeat responses and a decreasing tendency to alternate responses. The Barnes et al. apparatus consisted of a circular platform surrounded by 6 goal boxes. Subjects were trained to enter one dark compartment and to avoid the 5 illuminated compartments. The authors were interested in the effect of superior collicular lesions on orientation to visual cues. The apparatus was designed to ensure that subjects had to choose the correct stimulus from a distance and jump towards it, i.e. the task required accurate orientation. Although Barnes et al. did take advantage of the fact that position habits could be prevented by placing subjects on the starting platform in varying orientations, they did not place much stress on this aspect of the experimental design. Apart from Barnes et al. (1970) none of the multiple stimulus apparatuses described above prevented position responding - indeed none of the equipment was designed to eliminate such responding.

There have also been attempts to eliminate extraneous cues. The most serious of these attempts were made during the "place vs. response" controversy - a debate which was contemporary with that between the continuity and noncontinuity theories. The controversy was concerned with whether rats learn a specific sequence of responses, or whether they learn the location of the place where reinforcement can be obtained. Restle (1957) reviewed the question and his conclusion was,

> "...there is nothing in the nature of a rat which makes it a 'place' learner, or a 'response' learner. A rat in a maze will use all relevant cues, and the importance of any class of cues depends on the amount of relevant stimulation provided as well as the sensory capacities of the animal" (page 226).

In other words, the controversy was a non-issue. However, it did lead to efforts to control the cues available to subjects. Restle noted that when experimenters enclosed their mazes in a homogeneous visual surround (usually a muslin dome) subjects seemed to solve the problem on the basis of response cues (Blodgett and McCutchan, 1948; Hill and Thune, 1952; Scharlock, 1955; Thompson and Thompson, 1949). Place responding was more likely to occur when extra-maze cues were easily available, e.g. rat cages (Ritchie, 1947; Tolman, Ritchie and Kalish, 1946), windows (Blodgett and McCutchan, 1947; Blodgett, McCutchan and Matthews, 1949), objects in the room (Galanter and Shaw, 1954) or uneven room illumination (Tolman and Gleitman, 1949; Tolman, Ritchie and Kalish, 1947).

More recent researchers have utilised the techniques developed during the place vs. response debate. D'Amato and Jogoda (1960, 1961, 1962), for example, developed a semi-automated Y-maze. The arms of the maze were of equal length and the goal box on one trial became the starting box for the next trial. The maze was fully enclosed and white noise masked extraneous sounds. Position responding in this maze was claimed to be very nearly a pure "turning" response, i.e. responding based on kinesthetic rather than visual cues. The conventional Skinner box represents the most efficient development of the efforts to eliminate extraneous cues. However, it is only recently that the Skinner box has been developed in such a way that performance in this situation can be compared with simultaneous, two-choice visual discrimination performance.

The research described above highlights both the possibility and the difficulty of withholding any particular class of cue from the rat. What the circular maze is designed to do is to reduce, as much as possible, any cues that might be used as the basis for position responding. Table 2.1

lists most of the cues, besides the relevant discriminanda, which a rat might use. The table notes the conventional procedures used to eliminate or control such cues, and also any special aspects of the circular maze designed to do this.

TABLE 2.1

Irrelevant cues in visual discrimination learning.

Irrelevant cues	Conventional control measures	Special precautions in the circular maze
(1) Intra-maze:		
(a) Visual (e.g. sides of maze, accidental marks on maze)	Rotation of discriminanda; uniform colour within maze.	Subjects face two different compartments each trial. No visual cues to position.
(b) Tactile (e.g. feel of the floor)	Uniform floor texture.	
(c) Kinesthetic (i.e. from subject itself)	Rotation of discriminanda; interchangeable starting box/goal box.	
(d) Olfactory (e.g. odour of subject, other subjects, food, discriminanda).	Uniform placement of food; uniform stimulus material; sometimes, varied squad order.	Squad order varied; different compartments on each trial.
(2) Extra-maze:		
(a) Visual (e.g. from room fittings, cages)	Sometimes enclosure of maze and rotation.	Maze enclosed in curtains; lighting central; maze rotated daily.
(b) Olfactory (e.g. from other rats, experimenter)	None.	Maze rotated daily.
(c) Auditory (e.g. from equipment, air conditioning, other rats, experimenter)	Sometimes, masking noise.	Masking noise from timers; maze rotated daily.

One of the more difficult problems that must be faced in the assessment of behaviour in the circular maze is the possibility that the rats use odour - their own or that of other animals - as a discriminatory cue. The 12-door subjects may select any of the 12 goal compartments on any one trial, as distinct from the 2-door subjects who are restricted to 2 compartments on any one trial, and a different 2 compartments on subsequent trials of that day. Hence there is the possibility that 12-door subjects have more opportunity to use consistent odour cues.

The problem of the use of odour cues has received considerable attention over the last few years (Cf. Schultz and Tapp, 1973 for an excellent review). It has been shown that rats use odour cues in several experimental situations: spontaneous alternation (Douglas, 1966, Still and Macmillan, 1969); single and double alternation (Ludvigson, 1967; Ludvigson and Systma, 1967; McHose, Jacoby and Meyer, 1967); escape learning (King, 1969); latent extinction (Pratt and Ludvigson, 1970) and delayed reward (Ludvigson, 1970).

Looking specifically at the role of odour cues in visual discrimination tasks, Phillips (1968, 1970) showed that when visual and odour cues led to the same response, learning set formation was facilitated by comparison with situations in which visual and odour cues led to conflicting responses. It is not clear how the odour cues operate. Lester (1968a,b) suggested that they affect exploratory responses. There is strong evidence that after the early trials, when exploration is no longer a factor, the odour associated with nonreward or frustration (in the Amsel sense of non-fulfilment of expectancies) functions most strongly as a discriminatory cue (Morrison and Ludvigsen, 1970; Collerain and Ludvigsen, 1972; Wasserman and Jensen, 1969). This finding is of particular importance to the present thesis, since responses to the S- in general, and frustrated responses to the S- are central issues.

Attempts have been made to control odour cues, for example Prytula, Bridges, Anderson and Hayes (1972) used an exhaust fan and found increased running speed in partial reinforcement acquisition and extinction. King (1969) disassembled his apparatus, hosed it with hot water and dried it with hot air! From the point of view of the experimenter using a conventional apparatus, the only bright note comes from a study by Means, Hardy, Gabriel and Uphold (1971) who found that odour cues were less of a discriminatory cue in mazes with wooden floors. Presumably the floor either does not retain the odour as well as paper, or its permanent nature results in odours being confounded. However, Means et al. did find that the more rats there were providing an odour trail, the easier it was for subsequent rats to use the cue. They concluded, as did Phillips (1968, 1970), that odour is a weak cue but one sufficient to influence discrimination performance. As things stand, all that one can do is to accept this conclusion and attempt to infer the influence of odour cues from behaviour patterns in the course of learning.

Buxton (1968) performed the first experiment in the Winefield and Jeeves apparatus. He compared the discrimination and reversal performance of two groups of rats on a black-white discrimination task. One group was run with 12 doors available; the control group was run with only 2 doors available. In the light of the generally held view that position responding is a source of interference in discrimination learning, Buxton predicted that the 12-door subjects would learn both the initial discrimination and the reversal more quickly than the 2-door subjects. In fact, there was no difference between the two groups on the initial discrimination in terms of trials to criterion (mean trials to criterion were 34.8 for the 12-door subjects and 33.8 for the 2-door subjects) or in errors to criterion

(11.5 for the 12-door subjects and 16.0 for the 2-door subjects). The ease with which the rats learned the discrimination was surprising when their performance is compared with the 64.8 trials required for a black-white discrimination in a linear maze (Winefield and Jeeves, 1968) and 86.8 in a Y-maze (Mandler, 1966). This rapid learning made a comparison on the basis of the process of learning rather difficult. On reversal, there was a clear difference between the two groups, but in exactly the opposite direction to that predicted by Buxton. The mean trials to criterion were 61.8 for the 12-door subjects and 44.8 for the 2-door subjects. The error scores were 38.5 for the 12-door subjects and 27.5 for the 2-door subjects. The explanation of these results proved a problem. The learning curve showed no difference between the groups in the course of learning. Position responding on the part of 2-door subjects was slight (a mean of 1.0 days on the initial discrimination and 0.9 days on the reversal task) and there was high correlation between position responding and trials to criterion. Buxton concluded that the disadvantage of position responding in the 2-door subjects was offset by a more serious disadvantage in the 12-door subjects. He suggested that the procedure used in placing subjects on the starting platform may have affected the results. The 2-door subjects were placed on the starting platform with their backs to the discriminanda: the 12-door subjects were placed facing a negative stimulus in order to prevent them "running on" without discriminating. Not only did this procedure establish a difference between the groups, it might have encouraged perseverative responding in the 12-door subjects. On reversal, the S- was now the former S+ and it had a former S- on either side of it. In fact the 12-door group did perseverate more than the 2-door subjects (2.3 days as against 1.4 days). However, Buxton noted that his subjects typically changed their orientation to the stimuli before responding: hence this procedural flaw may not have distorted the results.

Winefield and Jeeves (1970b) replicated Buxton's experiment with a slight procedural modification. The 2-door subjects were placed in the apparatus so that they faced the partition between the two doors. The 12-door subjects were placed in the apparatus facing a partition such that they faced a stimulus configuration similar to that faced by the 2-door subjects on that trial (i.e. S+: S- or S-: S+). The results of Winefield and Jeeves (1970b) agreed with Buxton's results in some respects but not in others. As in Buxton's study, there was no difference between the 2-door subjects and the 12-door subjects on the initial discrimination task (mean trials to criterion for the 2-door subjects was 29.5 and for the 12-door subjects it was 35.3). On reversal, three 12-door subjects showed no sign of reaching criterion after more than 260 trials, and training was discontinued. Apart from these 3 subjects the slowest learner to reach criterion took 125 trials. Although the difference in medians favoured the 2-door subjects (55.0, as against 74.0 for the 12-door subjects) the difference between the groups was not significant.

Winefield and Jeeves discussed their results in terms of Maier's theory of frustration (Maier, 1949, 1956). Since Maier's theory will be discussed in greater detail in Chapter 4., it is not proposed to discuss it fully here. Suffice it to say that Winefield and Jeeves argued that perseveration in reversal involves frustration in the sense of a "failure in the fulfilment of expectancies" and that this failure occurs on 100 per cent of the trials. The 2-door subjects can develop position habits which gain 50 per cent reinforcement, whereas the 12-door subjects are not able to adopt such a form of behaviour. Moreover, they argued, position responding may facilitate learning in the 2-door group by reducing the tension in the frustrating situation which exists after reversal.

Buxton (1968) had concluded his thesis with the comment,

> "It is suggested that the study could be profitably repeated with a more difficult discrimination. This would have two effects: (a) it would make the learning more protracted thus permitting a better comparison of the course of learning than is possible in our case; and (b) it would increase the probability that strong position responses would develop and allow a more adequate analysis of their role in discrimination and reversal learning" (page 46f).

The present author attempted to take up this suggestion by using a horizontal-vertical discrimination (Mullins, 1969; Mullins, Winefield and Levy, 1973). This was presumed to be a more difficult discrimination than the black-white task used by Buxton and by Winefield and Jeeves.

The main results of this experiment are summarised in Table 2.2.

TABLE 2.2

Trials to criterion on the initial discrimination task (H/V) and its reversal, Mullins (1969).

Group:	N:	Discrimination (H/V)	Reversal:
2- door	12	$\bar{X}$: 31.8 S.D.: 11.0	$\bar{X}$: 97.4 S.D.: 56.3
12-door	12	$\bar{X}$: 27.7 S.D.: 7.4	$\bar{X}$: 95.8 S.D.: 35.0

The most surprising aspect of the results was that the vertical-horizontal discrimination task was learned very quickly. The speed of acquisition of the initial discrimination was as fast as in Buxton's experiment, although the reversal took longer. There was no difference in the rate of learning between the 12-door subjects and the 2-door subjects on either the discrimination or the reversal task. Nor did strong position preferences develop. In the 2-door group, the mean number of days of position responding was 1.9 days for the initial discrimination and 2.8 days for the reversal. The results of Mullins (1969) supported earlier findings using the circular maze insofar as very rapid learning of the initial discrimination occurred, and there was no difference in the rate of learning between the 2-door subjects and the 12-door subjects. However, the discrimination task chosen was less difficult than had been anticipated and the suggestion made by Buxton was not really put to the test.

The possibility that frustration was a factor in the explanation of Buxton's and Winefield and Jeeves' (1970b) results was tested by Levy (1969, Mullins, Winefield and Levy, 1973). Levy provided deliberate frustration training by using the classic frustration inducing technique of Maier (1949), i.e. random reinforcement of the discriminanda to create an insoluble problem. 2-door subjects and 12-door subjects were given 19 days (190 trials) of random reinforcement to give all subjects a chance to develop stable response stereotypes. In fact, 50 per cent of the 2-door subjects developed stable position stereotypes and 50 per cent developed symbol stereotypes: of the 12-door subjects, 50 per cent developed symbol stereotypes and the remaining subjects showed no sign of developing stereotyped responding.

The main results of Levy (1969) are summarised in Table 2.3. On neither task was there a significant difference between the two groups of subjects. As expected, the frustration training produced slower learning on the initial discrimination for both groups. Similarly, the variance was much greater than had been observed in earlier experiments. On the other hand, the frustration training did not apparently impair the learning of the reversal task. The difference in trials to criterion on

TABLE 2.3

Trial to criterion on the transfer task (H/V) and its reversal, Levy (1969).

Group:	Transfer task (H/V)	Reversal
2-door	$\bar{X}$: 57.0 Median : 50.0 S.D. : 33.6 N : 12	$\bar{X}$: 106.1 S.D.: 53.0 N : 12
12-door	Median*: 63.0 N : 12	$\bar{X}$: 127.5 S.D.: 46.0 N : 11

* One subject failed to reach criterion and was subsequently discarded.

the reversal task between the 2-door subjects and the 12-door subjects was not significant. As in Mullins (1969), there was no significant difference between the 2- and 12-door subjects with regard to the amount of perseveration to the former positive stimulus in the early stages of reversal training. However, there was more position responding on the part of the 2-door subjects in this experiment than in Mullins (1969).

The experiments done in the circular maze to this point, left several questions unanswered. The suggestion of Buxton (1968) that a more difficult discrimination should be used had still not been put to the test. The relationship between position responding and frustration was also unclear. The experiments to be described subsequently are efforts to answer some of these questions.

Finally there is the overall question of whether the circular maze does what it was designed to do, i.e. does it significantly reduce position responding? The earlier experiments in the circular maze raised this question since a tendency, on the part of certain 12-door subjects, to prefer some doors to others regardless of the symbol displayed was noticed. A satisfactory test of the extent to which the design of the apparatus and the procedure followed were successful is difficult to achieve.

What it is proposed to do in subsequent experiments in which there is a critical 2- versus 12-door comparison is to record on each trial, both the initial orientation of the subject with respect to the doors and the actual door chosen by the rat. Thus it is possible to determine the amount of "position responding" displayed by the 12-door subjects in the sense that when placed facing the partition between two doors the rat could go consistently to the left or right door, i.e. it could ignore the other ten doors and act as if it were in a 2-door situation. Comparison with the behaviour of the 2-door subjects is then possible. Certainly this is not the only form of position responding available to the 12-door subjects, for example, a rat could consistently go to the door on the left of the pair of doors it was facing. The possibilities are endless, but at least it will be possible to take a measure of position responding which compares, in a meaningful way, with the measure of position responding applied to the 2-door subjects.

Another form of systematic behaviour is a preference for one particular door - irrespective of the subject's initial orientation. This is a pattern of responding which one would expect if subjects were using auditory, olfactory or tactile cues which were not apparent to the experimenter. In the light of the rat's poor visual ability relative to ours, the existence of visual cues which can be used by the rat and not detected by the experimenter is unlikely. However the same cannot be said of auditory, tactile and, especially, olfactory cues. Of course such a pattern of behaviour is not possible for the 2-door subjects, since they face a different pair of doors on each trial and the remaining doors are shut-off by the aluminium screen. Hence appropriate comparisons cannot be made between 2- and 12-door subjects. All that one can do is to note the extent of the behaviour and make an overall assessment of its importance. The measure of door preference which will be reported is the mean number of responses to the most preferred or most frequently chosen door on each day. This is but one of a number of possible measures, e.g. one could record the number of different doors chosen or the number of times each door was chosen. All these measures are distorted by the fact that the probability of any particular door being chosen changes as the subject learns the task and narrows its choice from the full range of 12 doors to the 6 doors displaying S+.

The "post hoc" nature of this investigation of the effectiveness of the circular maze has its drawbacks - if the maze does not reduce position responding the whole exercise has been fruitless. On the other hand, the economies achieved by simultaneously testing the effectiveness of the maze and carrying out a programme of research on the interaction of frustration, position responding and learning make this risk worthwhile. This decision is reinforced by the fact that the earlier experiments in the circular maze did not reveal extensive systematic behaviour by the 12-door subjects.

CHAPTER 3

EXPERIMENTS ON DISCRIMINATION LEARNING WITH REDUCED CUES TO POSITION RESPONDING.

Experiment 3.1. The effect of overtraining on discrimination and reversal learning with reduced cues to position responding

The function assigned to position responding in visual discrimination learning by most theorists is reflected in the theories developed to explain the ORE. The relevant literature has been reviewed in Chapter 1, pages 11 to 20. Two aspects of this literature are worth recalling:

(a) The well established fact that overtrained subjects have less tendency to revert to position responding during reversal learning;

(b) Despite the variety of theoretical viewpoints, this position responding is almost universally regarded as an interfering factor. For example, Spence (in Reid, 1953), Harlow (1959), Mandler (1966, 1968), and Sutherland and Mackintosh (1971) all explain the ORE, in toto or in part, by assuming that the reduced position responding of the overtrained subjects underlies their improved performance in reversal. In this sense the work on the ORE accurately reflects the general assumptions made about the role of position responding in discrimination learning. Consequently, it seemed reasonable to carry out a study of the effect of overtraining on reversal learning in a situation in which visual cues to position were drastically reduced or abolished, i.e. in the 12-door situation in the circular maze, and to compare performance in this situation with performance in the more conventional discrimination learning situation.

The precise predictions which might be made by various theorists differ. Let us consider three examples. On the basis of Harlow's "error factor" theory, one might expect that overtraining the 12-door subjects would inhibit more error factors than training to criterion in the 12-door situation. However, it is not clear whether or not overtraining the 2-door subjects would more or less compensate for the absence of position responding as an error factor in the 12-door non-overtrained subjects. So Harlow might predict an ORE for the 12- and 2-door groups separately, and expect the worst performance from the 2-door, non-overtrained group.

From Mandler's point of view, the 12-door subjects are not able to adopt a detour strategy. Consequently, she would not predict an ORE for the 12-door groups since overtraining would not induce a change of strategy, and indeed the increased perseverative tendencies of the overtrained subjects might result in the opposite effect, a reverse ORE. Given the fulfilment of the necessary conditions, such as adequate reward magnitude, Mandler would expect an ORE for the 2-door subjects. As with Harlow, it would be difficult to predict whether overtraining the 2-door subjects would result in their adoption of a choice point strategy to the extent that these subjects would perform as well as the 12-door subjects. On the whole then, Mandler would also predict the worst performance from the 2-door non-overtrained subjects.

Finally, Sutherland and Mackintosh might expect, given the necessary conditions, a conventional ORE for the 2-door subjects and a reverse ORE for the 12-door subjects. For the 12-door subjects there are few irrelevant dimensions available and the most obvious irrelevant dimension, visual cues to position responding, is not available. Hence, neither overtrained nor non-overtrained subjects should switch out the relevant stimulus analyser. Presumably overtraining will increase the response strength to the particular values of the relevant dimension, consequently non-overtrained subjects should find it easier to reverse their response attachments. Both 12-door groups should reverse faster than the 2-door groups, again due to the reduction of irrelevant dimensions in the 12-door situation. Hence the speed of reversal predicted will be: 12-door non-overtrained, 12-door overtrained, 2-door overtrained, and, worst of all, 2-door non-overtrained.

On the other hand, the work already carried out in the circular maze, as described in Chapter 2, indicated that the assumptions made about the role of position responding are not as well founded as had been previously thought. Consequently an experimental study on the effect of overtraining in a situation with reduced cues to position responding should furnish a further test of these assumptions.

In order to maximise the possibility of obtaining an ORE in the conventional situation, i.e. with the 2-door groups, the necessary conditions, as determined by previous research (Cf. Chapter 1, page 12), were fulfilled. A difficult discrimination and a relatively large reward were used. Non-overtrained subjects were trained to both a strict and a more lenient criterion and all subjects were reversed to both a strict and a lenient criterion.

The use of a difficult discrimination made possible the testing of Buxton's (1968) suggestion. If position responding facilitates discrimination learning by some mechanism - perhaps relief of the tension involved in a choice situation - then the 2-door subjects should learn both the initial discrimination and the reversal faster than the 12-door subjects. On the other hand, if position responding provides rats with the means of breaking a perseverative habit - by providing an alternative response - the 2-door subjects should perform better than the 12-door subjects only on the reversal task.

METHOD

Experimental Design

The experimental design was a 2 x 3 one with 2- or 12-door groups given initial training to a lenient criterion (10/12), to a strict criterion (22/24), or to the strict criterion plus 120 trials of overtraining. All groups were given reversal training and were compared on the basis of the number of trials taken to reach a lenient (10/12) or a strict criterion (22/24).

Subjects

The subjects were 34 male, Wistar strain, hooded rats. They were approximately 100 days old at the start of pre-training and were experimentally naive. The subjects were houses individually in cages, with water available at all times.

Apparatus

The apparatus was the circular maze described in Chapter 2. The discriminanda used in this experiment were light and dark grey plates which were clipped onto alternate doors of the maze. Pilot studies had indicated that it took about 100 trials for rats to learn this light grey-dark grey discrimination task.

Procedure

Since essentially the same procedure, especially as regards pre-training, was used for all subsequent experiments, it will be described in detail here and only briefly referred to hereafter.

Pretraining. Subjects were handled for approximately five minutes each day for about a week. During this time the ad lib. weight of each rat was determined and gradual reduction to 85 per cent of this ad lib. weight was initiated. Subjects were maintained at 85 per cent of their ad lib. weight for the remainder of the experiment. Subjects were fed compressed dry food 30 minutes after the experimental session on each day.

During pre-training the 12-door subjects were trained in the 12-door situation: the 2-door subjects were pre-trained with only 2 compartments available. Subjects were allotted to 2- or 12-door conditions according to random number tables. During pre-training the doors of the maze were mid grey. For the first two days, subjects were trained to leave the starting platform and enter a goal box with the doors of the goal compartments propped three-quarters open. Subjects were left in the goal box until they would eat, or at least show no anxiety at such close confinement. On the next three days, the doors were only a quarter open so that subjects had to push through the door in order to reach the goal box. The doors were then closed, but not locked, for a further three days until subjects would, fairly confidently, leave the starting platform, push open a door and eat in the goal box. Any position preferences shown by the 2-door subjects were noted. On the final three days, subjects encountered occasionally locked doors to ensure that they would continue to respond after such an experience. At the same time the door locked for the 2-door subjects on two thirds of the trials was that on an animal's preferred side so that the 2-door subjects began the experiment with their position tendencies more or less equalised, as indicated by the tendency of subjects to respond to the opposite side on the trial following an encounter with a locked door. On the day following the completion of pre-training subjects began discrimination training.

Discrimination and reversal training. During discrimination training 6 light and 6 dark grey plates were clipped onto the doors in an alternating pattern. Half the subjects had light grey as S+ and half had dark grey as S+. Subjects were run in squads of 2 or 3 with an inter-trial interval of about 4 minutes. The within-squad order of subjects varied systematically from day to day, utilizing the various possible combinations of within-squad order. The order in which groups were run was alternated between 2- and 12-door groups from day to day.

Subjects were given 12 non-correction trials per day with S- always locked - although there was food behind both locked and unlocked doors. The 12-door subjects were placed on the starting platform facing a different partition on every trial. Thus 12 trials ensured that each of the 12 partitions (or 12 pairs of doors) would be encountered once a day. For the 2-door subjects this procedure involved moving the screen on every trial so as to expose a different pair of doors. The order in which the partitions were faced varied from day to day according to Fellow's (1967) series. There was no limit to the time allowed for subjects to respond. Correct responses were rewarded by 30 seconds access to the container of pellets of dry compressed food which was in all 12 compartments. In the case of an incorrect response - indicated by the subject pushing the locked door far enough to turn off the first timer - the subject was immediately taken from the maze and returned to the home cage until the next trial. The orientation of the maze in the experimental room was altered daily.

Subjects were run to a criterion of 10/12 correct responses on one day. On the basis of their attainment of this criterion, one third of the subjects were allotted to the lenient criterion group (6 12-door and 6 2-door) and the remaining subjects continued to a criterion of 22/24 correct responses over two consecutive days. On the basis of their attainment of this stricter criterion, a third of the subjects were allocated to the strict criterion group (5 12-door and 5 2-door) and the remainder were given ten days (120 trials) of overtraining.

On the day following the end of discrimination training for each subject, the discriminanda were reversed, and subjects were run to a criterion of 22/24 correct responses over two consecutive days. The number of trials taken to attain a criterion of 10/12 correct responses on one day in the course of reversal learning was noted.

RESULTS

Initial discrimination.

The performance on the initial discrimination task is summarised in Table 3.11

TABLE 3.11

Trials to criterion on the initial discrimination.

Group:	Trials to criterion 10/12:	22/24:
12 door		
Lenient criterion	$\bar{X}$: 87.2 S.D.: 34.8 N : 6	-
Strict criterion	$\bar{X}$: 91.8 S.D.: 26.8 N : 5	$\bar{X}$: 114.2 S.D.: 16.6 N : 5
Overtrained	$\bar{X}$: 87.5 S.D.: 60.1 N : 6	$\bar{X}$: 120.7 S.D.: 34.6 N : 6
All 12-door subjects	$\bar{X}$: 88.7 S.D.: 41.1 N : 17	$\bar{X}$: 117.7 S.D.: 26.8 N : 11
2 door		
Lenient criterion	$\bar{X}$: 86.8 S.D.: 28.2 N : 6	-
Strict criterion	$\bar{X}$: 75.0 S.D.: 24.6 N : 5	$\bar{X}$: 87.0 S.D.: 26.7 N : 5
Overtrained	$\bar{X}$: 84.7 S.D.: 22.5 N : 6	$\bar{X}$: 92.0 S.D.: 23.2 N : 6
All 2-door subjects	$\bar{X}$: 82.6 S.D.: 24.2 N : 17	$\bar{X}$: 89.7 S.D.: 23.7 N : 11

Subjects were allotted to different experimental groups (lenient criterion, strict criterion and over-trained) on the basis of their attainment of a criterion of 10/12. There was no overall difference between

2- and 12-door groups at this criterion level ($t < 1$ $p < .05$), nor was there any difference between the three experimental groups (for both the 12-door subjects and the 2-door subjects, $F < 1$, $p > .05$). When the remaining subjects reached a criterion of 22/24 they were allotted to the strict criterion group or the overtrained group. The 2-door subjects reached this stricter criterion significantly faster than the 12-door subjects ($t(20) = 2.594$, $p < .01$). *

Reversal

The results of reversal training are summarised in Table 3.12 and Figure 3.1.

These results are very difficult to interpret. The first complication arises from the fact that, in the 2-door situation, the conventional situation, the ORE was not obtained. Indeed, the very reverse was indicated. When one looks at the 12-door groups the situation is even more complex. There is an ORE in that the overtrained group reversed faster than the strict criterion group. However, the lenient criterion group reversed even faster. If the 12-door and 2-door groups are compared a complex picture again emerges. The over-trained 12-door group reversed faster than the overtrained 2-door group; the opposite happened with the strict criterion groups; and for the lenient criterion groups the 2-door group reached the lenient reversal criterion faster than the 12-door group, but it reached the strict reversal criterion slower than the 12-door group.

* Since in most of the tests in which it was appropriate, a clear directional prediction was made, the tests are one-tailed unless the contrary is specified. Parametric tests were employed in all cases where the distribution of raw scores was approximately normal so as to give maximum power. However, if the distribution was clearly skewed or truncated nonparametric tests were employed.

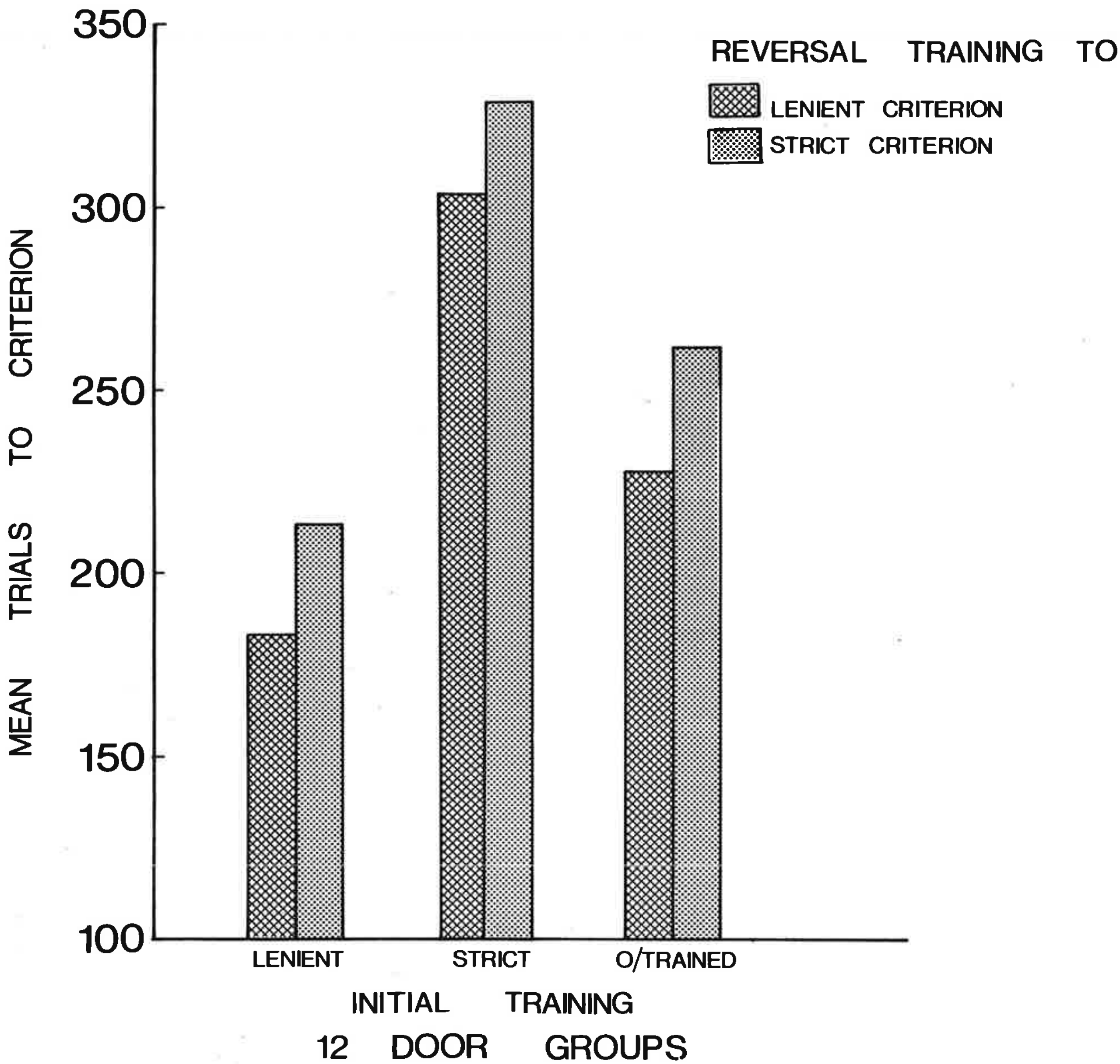

350
300
250
200
150
100
MEAN TRIALS TO CRITERION
REVERSAL TRAINING TO
LENIENT CRITERION
STRICT CRITERION
LENIENT
STRICT
O/TRAINED
INITIAL TRAINING
12 DOOR GROUPS

FIG. 3·1

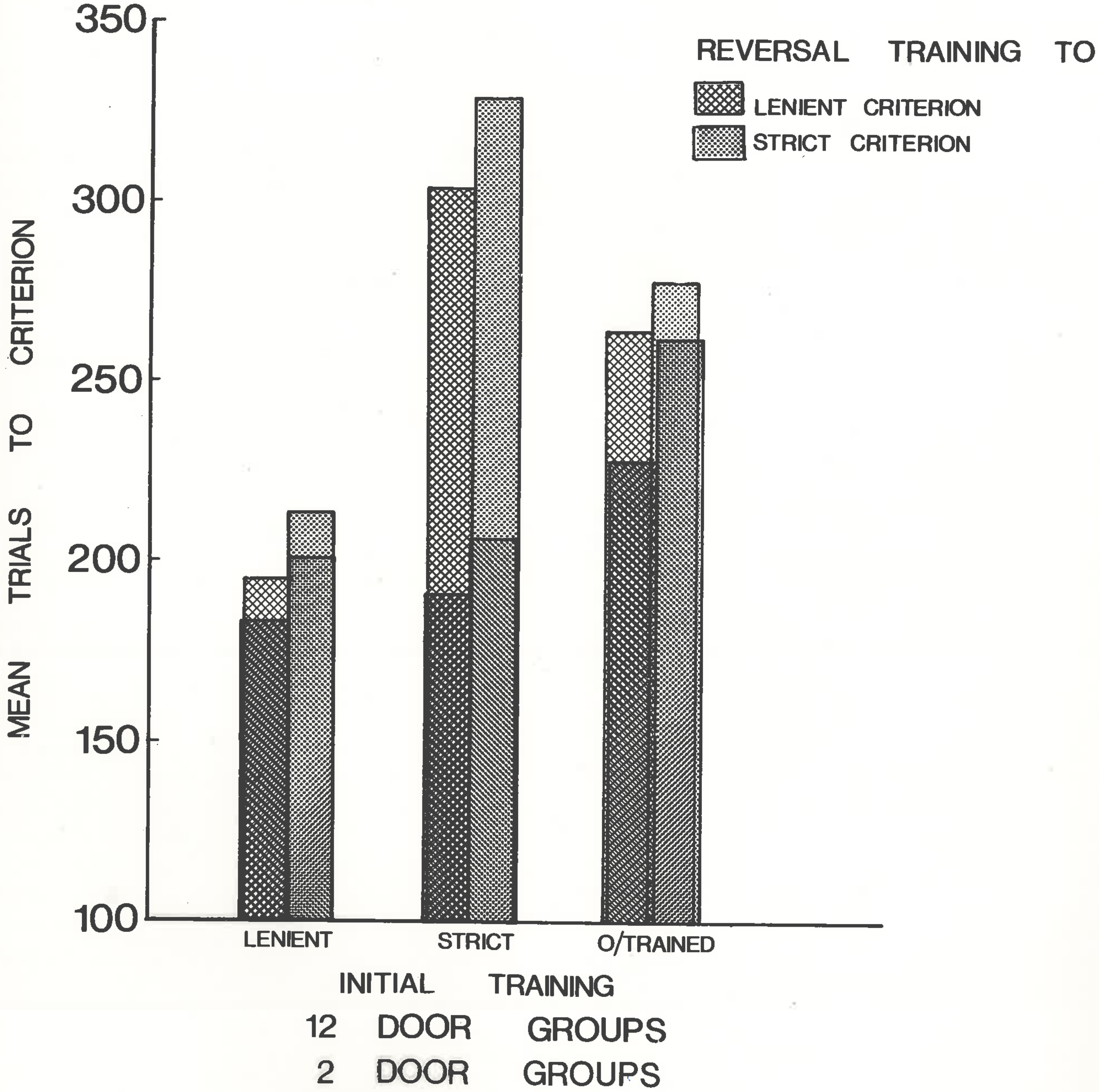

350
300
250
200
150
100
MEAN TRIALS TO CRITERION
REVERSAL TRAINING TO
LENIENT CRITERION
STRICT CRITERION
LENIENT
STRICT
O/TRAINED
INITIAL TRAINING
12 DOOR GROUPS
2 DOOR GROUPS

FIG. 3·1

TABLE 3.12

Trials to criterion on reversal.

Group:	Trials to criterion 10/12:	22/24:
12 door		
Lenient criterion	$\bar{X}$: 183.2	$\bar{X}$: 215.5
	S.D.: 85.2	S.D.: 63.7
	N : 6	N : 6
Strict criterion	$\bar{X}$: 329.6	$\bar{X}$: 334.2
	S.D.: 106.3	S.D.: 111.5
	N : 5	N : 5
Overtrained	$\bar{X}$: 232.8	$\bar{X}$: 261.8
	S.D.: 61.4	S.D.: 65.3
	N : 6	N : 6
2 door		
Lenient criterion	$\bar{X}$: 196.5	$\bar{X}$: 204.5
	S.D.: 67.7	S.D.: 74.5
	N : 6	N : 6
Strict criterion	$\bar{X}$: 189.2	$\bar{X}$: 211.5
	S.D.: 75.3	S.D.: 74.5
	N : 5	N : 5
Overtrained	$\bar{X}$: 262.8	$\bar{X}$: 281.7
	S.D.: 108.9	S.D.: 104.4
	N : 6	N : 6

In an effort to salvage something from the data, a Duncan Multiple Range test was done on both the trials to the lenient reversal criterion and the trials to the strict reversal criterion. As regards trials to the lenient reversal criterion, the 12-door strict criterion group was significantly different from all other groups except the 2-door overtrained group. No other comparisons were significant. As regards trials to the strict reversal criterion, the 12-door strict criterion group was significantly different from the 2-door strict and lenient criterion groups and the 12-door lenient criterion group. No other comparisons proved significant.

The data on perseveration and position responding do not throw much more light on the matter. This data is presented in Tables 3.13 and 3.14,

TABLE 3.13

Perseverative responding during reversal training.

Group:	Days of $>$ 9/12 responses to former S+ :	No.of trials before a correct response :
12 door		
Lenient criterion	$\bar{X}$: 2.2	7.0
Strict criterion	$\bar{X}$: 19.6	15.6
Overtrained	$\bar{X}$: 8.7	14.0
2 door		
Lenient criterion	$\bar{X}$: 3.3	8.3
Strict criterion	$\bar{X}$: 3.4	9.0
Overtrained	$\bar{X}$: 6.5	27.7

TABLE 3.14

Position responding in the 2-door subjects (as days of $>$ 9/12 responses to one side).

Group:	Initial discrimination: to 10/12	Initial discrimination: to 22/24	Reversal: to 10/12	Reversal: to 22/24
Lenient criterion	$\bar{X}$: 3.7	-	$\bar{X}$: 9.8	$\bar{X}$: 9.8
Strict criterion	$\bar{X}$: 3.4	$\bar{X}$: 3.4	$\bar{X}$: 10.2	$\bar{X}$: 10.4
Overtrained	$\bar{X}$: 3.8	$\bar{X}$: 3.8	$\bar{X}$: 12.8	$\bar{X}$: 12.8

The difference between the 12-door strict criterion group and the 2-door strict criterion group in terms of days of perseveration was significant, ($t(8) = 3.649$, $p < .01$, two-tailed). There was no difference between the 2-door groups in terms of days of position responding ($F < 1$, $p > .05$).

As regards the effectiveness of the circular maze in reducing position responding (Cf. pages 45 f.), the amount of "position responding" in the 12-door subjects is summarised in Table 3.15. Obviously there was very little. The degree of door preference, again as described above, is summarised in Table 3.16. At this point it is too early to draw a definite conclusion, but the tendency of the 12-door subjects to go to the same door no more than three or four times per 12 trials reflects favourably on the effectiveness of the apparatus.

TABLE 3.15

Position responding in the 12-door subjects (as days of $>$ 9/12 responses to one particular side of the partition)

Group:	Initial discrimination	Reversal
Lenient criterion	$\bar{X}$: 0.5	$\bar{X}$: 1.3
Strict criterion	$\bar{X}$: 0.6	$\bar{X}$: 0
Overtrained	$\bar{X}$: 1.2	$\bar{X}$: 0

TABLE 3.16

Door preferences in the 12-door subjects
Mean no. of trials per day on which most preferred door was chosen

Group:	Initial discrimination	O.T.	Reversal
Lenient criterion	$\bar{X}$: 3.2	-	$\bar{X}$: 2.7
Strict criterion	$\bar{X}$: 2.8	-	$\bar{X}$: 4.0
Overtrained	$\bar{X}$: 3.2	$\bar{X}$: 3.4	$\bar{X}$: 3.5

The data on latencies on both the initial discrimination and the reversal revealed no systematic differences. It appeared that the distance between the starting platform and the doors was too short to allow any differentiation between experimental conditions. This problem beset all the subsequent experiments. However, the timers did provide a background noise which effectively masked all other auditory cues in the room.

DISCUSSION

This experiment must be counted as another failure to replicate the ORE. The numbers used in the experiment were small because it was intended to repeat the experiment and so obtain a respectable number of subjects in each group. The results, however, indicated that this would be a waste of time. The conditions specified as a result of previous research as being necessary for the occurrence of the ORE were fulfilled in this experiment. Although, with hindsight, one might suspect that the reward size was not large enough. However, a more reasonable conclusion might be that the necessary and sufficient conditions for the ORE are still inadequately determined. Overall the results of the experiment were disappointing. This is not so much because the results were not as expected but rather because they were so difficult to interpret in a meaningful way. The 2-door situation, since it resembled the conventional situation for overtraining studies, was to provide a control situation which would allow comparisons to be made with previously published research. Since the ORE was not observed in this situation the performance of the 12-door groups became difficult to interpret. Consequently, the fact that there was an ORE as regards the strict criterion and the overtrained group cannot be given much weight. This is especially the case in the light of the fact that the lenient 12-door group reversed faster than the strict criterion group.

The most interesting finding in the experiment was the fact that on the initial discrimination, in terms of trials to the strict criterion, there was a significant difference between the 2-door and 12-door groups in favour of the 2-door subjects. The light grey-dark grey discrimination did prove to be a difficult problem. There was considerable position responding by the 2-door subjects, with a mean of 3.4 days for the initial discrimination and 10.4 days for the reversal task. The difference between the 2-door subjects and the 12-door subjects in trials to criterion on the initial discrimination was maintained on the reversal task by those subjects which were not overtrained. The difference on the initial discrimination suggested that subjects which were able to adopt a position response during the pre-solution period were not only not disadvantaged in the learning of the task by their position responding but they may have been positively assisted. The difference between the 2- and 12-door groups on reversal was in agreement with the earlier work of Winefield and Jeeves (1970b); the most obvious explanation of this difference is that the 12-door subjects continued to respond to the former S+ whereas the 2-door subjects were able to adopt a position response.

Overall the experiment provided no support for the idea that position responding is necessarily detrimental to discrimination or reversal learning. Another test of the assumption was made in the next experiment.

<u>Experiment 3.2. Nonreversal shift learning with cues to position responding as the irrelevant dimension.</u>

Current discrimination learning theories assume that visual cues to position control behaviour in much the same way as any other irrelevant stimulus dimension. The literature relative to this issue is reviewed in

Chapter 1, pages 8-11 and 20-25. If this is the case, then one might expect that:

(a) as a subject learns a visual discrimination task in which cues to position are irrelevant to the solution of the problem, the subject will learn to ignore these cues;

(b) having learned to ignore cues to position on one task, the subject will continue to do so on a subsequent task. Hence one might expect that these subjects will solve a subsequent task faster than subjects which have not learned to ignore cues to position.

As regards (a), it is true that some theories, e.g. Sutherland and Mackintosh (1971), put less stress on the subject's learning to ignore cues for stimulus dimensions than on the subject's learning to respond to relevant cues or stimulus dimensions. But even Sutherland and Mackintosh concede that a subject does learn to ignore a stimulus dimension.

As regards (b), the proposition is difficult to test. The subsequent task may be a reversal of the initial discrimination or a nonreversal shift. The former is complicated by perseverative tendencies to the former S+. For the latter, it is difficult to arrange an appropriate control condition such that the initial discrimination is learned without the subject learning to ignore position cues. In conventional 2-choice apparatuses, position responding is an unavoidable component of any discrimination learning task. If the control subjects do not learn the initial discrimination, it is not possible to control, in the experimental group, for positive transfer due to learning other than learning to ignore cues to position responding. However, the 12-door situation of the circular maze does allow subjects to be trained on the initial discrimination without their learning to ignore spatial cues. The subjects can then be transferred to a new discrimination task in the 2-door situation and their performance can be compared with subjects which have learned the initial discrimination in a 2-door situation, i.e. subjects which have learned both to ignore spatial cues and to respond appropriately to the symbol discrimination.

METHOD

Experimental Design

The experimental design was a cross-over design in which two groups of subjects were trained on an initial discrimination under the 2-door or 12-door condition. On their attainment of the learning criterion half the 2-door subjects were transferred to another discrimination task under the 12-door condition (Group 2 → 12) while the remainder of the 2-door subjects were transferred to the new task under the 2-door condition (Group 2 → 2). Similarly, half the 12-door subjects were transferred to the new task under the 2-door condition (Group 12 → 2) and half the 12-door subjects were transferred to the new task under the 12-door condition (Group 12 → 12). The initial discrimination was a patterned discrimination and the transfer task was a brightness discrimination. The transfer task chosen was a relatively difficult brightness discrimination which was intended to minimise any effect of novelty when subjects were transferred to this task under a 2- or 12-door condition after initial training with a 12- or 2-door condition. Groups 2 → 12 and 12 → 12 might also be considered as control groups to assess any novelty effect.

Subjects

The subjects in this experiment were 40 experimentally naive male, Wistar strain, hooded rats which were approximately 100 days old at the beginning of pretraining. They were maintained at 85 per cent of their ad lib. body weight throughout the experiment but had water available at all times.

Apparatus

The apparatus was the circular maze described in Chapter 2. The stimuli used in the initial discrimination were black and white patterns of horizontal or vertical stripes. The discrimination to be learned in the transfer task was between light grey and dark grey. The horizontal stimulus pattern consisted of 3 black and 3 white stripes 1.2 cm wide; the vertical stimulus consisted of, from left to right, 1 white stripe 0.6 cms wide, 3 white and 4 black vertical stripes 1.2 cms wide and on the other side of the pattern 1 white stripe 0.6 cms wide. The horizontal and vertical stimuli are among those illustrated in Figure 8.1. The light and dark grey stimuli used in the transfer task were the same as the stimuli used in experiment 3.1. The results of Experiment 3.1 had shown that this discrimination was relatively difficult.

Procedure

Pretraining. The pretraining procedure used in this experiment was the same as that used in Experiment 3.1. On the day following the end of pretraining subjects were transferred to the initial discrimination task.

Discrimination and reversal training. The details of discrimination and reversal training were the same as those described in the previous experiment, except for the following details. Subjects were run in groups of 4 with an inter-trial interval of 2 to 3 minutes. A correct response gained the subjects 15 seconds access to food. Following an incorrect response the subject was taken from the maze and replaced in the home cage until the next trial. Half the subjects had the horizontal stripes as their S+, and half the subjects had the vertical stripes as their S+. When the subjects reached a criterion of 22/24 correct responses over two consecutive days on the horizontal-vertical discrimination they were transferred to the light grey-dark grey discrimination in such a way as to balance both learning ability and symbol preferences. Due to an administrative error one of the 2-door subjects was transferred to the 12-door condition instead of the 2-door condition resulting in slightly unequal experimental groups. Subjects were run to a criterion of 22/24 correct responses over two consecutive days on the light grey-dark grey discrimination.

RESULTS

The number of trials taken to attain criterion on both the initial task and the transfer task are shown in Table 3.21.

There was no difference between the 4 experimental groups on trials to criterion on the initial task ($F < 1$, $p > .05$). Nor did the 2-door and 12-door subjects, when grouped together, differ ($t < 1$, $p > .05$).

On the transfer task the absence of any great difference between the means of the four groups was striking. The critical comparison for the purposes of this experiment, was between Groups 2 → 2 and 12 → 2. In fact this was the largest difference between any pair of means, but the difference was not significant ($t < 1$, $p > .05$).

Since the role of position responding was the point of the experiment, the amount of position responding displayed by Groups 2 → 2 and 12 → 2 is shown in Table 3.22.

TABLE 3.21

Trials to criterion on the initial discrimination (H/V) and the transfer task (Light/dark grey).

Group:		Initial discrimination (H/V)	Transfer task (Light/dark grey)
2 → 12	$\bar{X}$	49.7	106.9
	S.D.	36.7	38.4
	N	11	11
2 → 2	$\bar{X}$	50.56	101.0
	S.D.	28.0	31.1
	N	9	9
All 2 door subjects	$\bar{X}$	50.2	
	S.D.	31.8	
	N	20	
12 → 2	$\bar{X}$	48.1	109.2
	S.D.	28.8	39.3
	N	10	10
12 → 12	$\bar{X}$	46.1	102.6
	S.D.	21.8	45.5
	N	10	10
All 12 door subjects	$\bar{X}$	47.1	
	S.D.	24.2	
	N	20	

TABLE 3.22

Position responding in Groups 2 → 2 and 12 → 2 (Days of > 9/12 responses to one side).

Group:		Initial discrimination	Transfer task
2 → 2	$\bar{X}$	1.9	2.7
	S.D.	2.4	2.9
	N	9	9
12 → 2	$\bar{X}$	-	3.7
	S.D.		3.4
	N		10

In Group 2 → 2 the increase in position responding from the initial task to the transfer task was not significant ($t < 1$, $p > .05$). On the transfer task, Group 12 → 2 displayed more position responding than

Group 2 → 2, but again this difference was not significant ($t < 1$, $p > .05$).

There was no evidence that the results obtained were due to stimulus preferences. On the initial discrimination the 2-door subjects found it easier to learn the task with horizontal as S+ than with vertical as S+ but the difference between the mean trials to criterion (39.9 and 16.3 respectively), was not significant. There was no striking evidence of symbol preferences either on the initial task or on the transfer task.

The response pattern of the 12-door subjects in this experiment was similar to that in Experiment 3.1. Only 4 days of "position responding" were recorded throughout the experiment. The frequency of response to the most preferred doors is summarised in Table 3.23.

TABLE 3.23

Door preferences in the 12-door subjects
Mean no. of trials per day on which most preferred door was chosen

Group:	Initial discrimination	Transfer task
12 → 12	$\bar{X}$: 3.2	$\bar{X}$: 2.9
12 → 2	$\bar{X}$: 3.2	-
2 → 12	-	$\bar{X}$: 3.2

DISCUSSION

The results of Experiment 2 provided no support for the proposition that position responding is a detrimental factor in discrimination learning. The same conclusion was reached on the basis of the results of Experiment 3.1, but those results were, admittedly, difficult to interpret. This cannot be said of the results of this experiment. There was no difference in the rate at which the 2- and 12-door subjects learned the initial horizontal-vertical discrimination. Thus the four experimental groups could be considered to have entered the transfer task on equal terms. This made comparisons between their performance on the transfer task relatively simple. The rate of learning the transfer task was remarkably similar for all groups.

The transfer task chosen for this experiment was a relatively difficult one in order to allow time for the effect of novelty in the 12 $\rightarrow$ 2 group to dissipate. As a matter of observation, apart from the first few transfer trials, the subjects' behaviour gave no indication that they were upset by the change from the 12-door situation to the 2-door situation or vice versa. Moreover no novelty effect was indicated by comparisons between the performance of the 12 → 12 and the 2 → 12 groups.

The 2 → 2 group displayed little position responding on the initial task. This was not surprising since the horizontal-vertical discrimination was not a particularly difficult task. What was interesting was the fact that the group did not display significantly more position responding in the course of the transfer task, despite the fact that the light grey-dark grey discrimination was a much more difficult task. The relative difficulty of the initial and transfer tasks was indicated by the mean trials to criterion for the 2 → 2 group, 50.6 and 101.0 respectively. The most obvious interpretation is that the 2 → 2 group did learn to ignore cues to position responding and that it transferred this learning to the new task. However, the 12 → 2 group did not display all that much position responding on the transfer task despite its initial training in a 12-door situation. Certainly the group responded to position cues more than the 2 → 2 group, as expected, but the difference, as measured by days of position responding, was not significant. If there was positive transfer from the initial task to the transfer task for the 2 → 2 group, it was not large and it did not play a significant role in that group's performance on the transfer task. Nor was there any evidence that the results were due to symbol preferences.

We are left with the conclusion that there was no difference between the experimental groups on the transfer task, and that the absence or presence of visual cues to position on the initial task made no difference to performance on the subsequent nonreversal shift. It might be considered rash to accept too readily the hypothesis of no difference at this stage, but the possibility that this is the best explanation of the data must be considered seriously. Experiments 3.1 and 3.2 raised serious doubts about the assumption that position responding is necessarily detrimental to discrimination learning and indeed the data from the initial discrimination in Experiment 3.1 suggested the possibility that the presence of cues to position may facilitate learning. This conclusion will be discussed further in Chapter 6 when additional, relevant data from the experiments described in Chapter 5 can be considered.

CHAPTER 4

THE ROLE OF FRUSTRATION AND INCONSISTENT REINFORCEMENT IN DISCRIMINATION LEARNING.

"Everyone today is some kind of frustration theorist" (Bolles and Moot, 1972). This wry comment occurred in the course of a review of the literature on derived motivation. It is not an unsubstantiated remark and it does imply that yet another discussion of frustration ought to be justified. The purpose of this review is to introduce a series of experiments which investigated:
(a) two different frustrating operations - one derived from Maier's paradigm and the other derived from Amsel's concept of frustration - both of which involved random or inconsistent reinforcement, and their effect on subsequent discrimination learning.
(b) the interaction of position responding with both frustration and learning.

Winefield and Jeeves (1969, 1970b) discussed their work on the role of position responding in discrimination learning in terms of Maier's (1949, 1956) theory of frustration. This was quite a reasonable thing to do in the light of the relationship established by Maier between stereotyped position responding and frustration. Influenced by Winefield and Jeeves' and Maier's work Levy (1969) studied the effect of frustration on behaviour in the circular maze. She used Maier's technique of presenting the subject with an insoluble task to induce frustration and her results indicated that this line of investigation was worth further research. Moreover, the fact that the experiments described in Chapter 3 of this thesis supported the previous research done in the circular maze suggested that frustration could be an important variable interacting with both discrimination learning and position responding. Consequently, research into the role of frustration became a major concern of the present thesis.

Maier's theory of frustration is not the only such theory. Consequently if we are to research the role of frustration in discrimination learning it is necessary to consider other conceptions of frustration and different experimental paradigms for the study of frustration and its effect on learning. Moreover, some authors, e.g. Yates (1962) and Seward (1969), would consider Maier's experimental situation to be one of conflict rather than frustration. Hence the latter part of this chapter considers work that would be regarded more as the study of conflict or uncertainty than of frustration.

The task of reviewing the literature on frustration is not undertaken lightly. Few concepts in psychology have been used with as much ambiguity and by workers in such diverse fields. Fortunately there already exist several reviews of the literature. Lawson and Marx (1958) presented a very comprehensive review of the work done until 1956. Some idea of the variety of work which might be considered under the heading of frustration is indicated by listing the independent variables considered by Lawson and Marx. These included:

altered amount of reward or delay of reward; extinction (including the partial reinforcement effect); failure with the implied possibility of success; the blocking or prevention of the completion of a response sequence; interruption of a response aroused by goal stimuli; failure on a task on which subjects had previously succeeded; punishment and conflict situations: Yates (1962) and Lawson (1965) presented excellent reviews of the work done on frustration, although these authors often achieved their clarity of exposition by confining themselves to the main lines of research. The literature since Lawson's book is not well reviewed and discussion is, for the most part, confined to Amsel's theory of frustration (Appley, 1970; Bitterman and Schoel, 1970; Bolles and Moot, 1972; Strongman, 1973; Scull, 1973). This chapter will not be an attempt to improve on the earlier reviews, a difficult and pointless exercise, but will summarise their findings, bring the discussion up to date, and attempt to see how the current work in this field might be applied to the present research. It should be borne in mind, in this context, what the present research topic is; namely, the extent to which frustration is a factor in discrimination learning, especially in visual discrimination learning by rats. Topics such as the frustration-aggression theory in first year college students are unlikely to throw much light on this problem and, consequently, will not be discussed.

Maier's theory of frustration

Maier's work on frustration is an obvious starting point, both historically, as he was one of the earliest systematic investigators of the problem, and logically, within the context of this thesis. Maier began his work with the study of reasoning in rats (Maier, 1929). He soon became involved with the abnormal aspects of animal behaviour, including seizures (Maier and Glaser, 1940a), fixations (Maier, Glaser and Klee, 1940), and abortive responding (Maier, 1940). The Maier et al (1940) paper introduced the elements which were to become basic in Maier's theory: namely, the concept of an insoluble problem as a frustrating situation, the all or nothing nature of the fixation developed in this frustrating situation, and the quantitative distinction between systematic responding to symbol or position cues which characterises a learned response and the fixated responding produced by frustration.

Further studies by Maier and his associates considered hereditary factors affecting frustration (Maier and Glaser, 1940b), the effect of drugs (Maier and Sacks, 1941) or diet (Maier and Ellen, 1951a) on fixated behaviour, the relationship between fixations and convulsions, (Maier and Klee, 1941a and b, Maier and Longhurst, 1947) and between fixations and punishment (Maier and Klee, 1943), and the effect of guidance on fixations (Maier and Klee, 1945, Maier and Ellen, 1952). A synthesis of Maier's work during the 1940's was presented in his book Frustration: the study of behaviour without a goal (1949).

The basic experimental design used by Maier was a two stage procedure based on a two choice discrimination using the Lashley jumping stand. In the first stage (160 trials) the two choice problem was insoluble in the sense that 50 per cent of responses to any cue were randomly rewarded by access to food and 50 per cent were punished by impact with a locked door followed by a fall into a net below the apparatus. This was Maier's definition of a frustrating situation.

The behavioural result, in about 80 per cent of the subjects, was a stereotyped response to one particular side of the apparatus and, in most other subjects, to a particular symbol. In the second stage the problem was made solvable by differential reinforcement of the symbol cues. In a typical experiment only 15 to 20 per cent of the rats solved the discrimination problem within 200 trials. The remainder persisted in the stereotyped response adopted during the insoluble problem. Maier characterised this behaviour as "fixated".

The basis of Maier's explanation of this behaviour was that behaviour adopted in a frustrating situation became fixated and that this fixation could not be explained in terms of reinforcement contingencies or motivation. Fixated behaviour was seen as an end in itself. Fixated behaviour and goal oriented behaviour were considered qualitatively different. However, the longer subjects were in a frustrating situation the stronger were the fixations produced (Maier and Feldman, 1948).

Two points of particular relevance to the present thesis are the effect of previous performance on the consequences of frustration and the possibility that position fixations have some beneficial effects. Maier and Klee (1943) found that when rats were returned to an insoluble problem after solving a previous discrimination (by guidance if necessary), most subjects persisted in the kind of response adopted just before the introduction of the insoluble problem. There was no disorganisation of the response in progress and no tendency to return to previously acquired responses. Moreover, when the subjects were again shifted from the insoluble task to a soluble problem the subjects which had fixated in the earlier phase of the experiment showed fewer fixations in the current phase, i.e. a history of previous fixation, which had been broken by guidance, conferred some degree of immunity to the effect of subsequent frustration. Maier and Ellen (1952) showed that rats which learned a difficult discrimination with guidance were less inclined to fixate when subsequently transferred to an insoluble problem than rats which had learned the initial discrimination without guidance. Secondly, Maier and Klee (1941a and b) showed that the incidence of seizures in rats decreased when fixations appeared. However, Maier (1949, p.81) stressed that although this may indicate that fixations serve as an adjustment, or a relief of tension, this relief is not rewarding in the sense of being drive reducing. Tension reduction merely accompanies fixation as an incidental by-product.

Maier's (1949) book was greeted with sceptism by classical learning theorists (e.g. Mowrer, 1950; Hilgard,1950) and it was followed by a lively debate. The main issue was whether Maier's findings on frustration could be adequately explained by the current theories of learning without the need to resort to a separate category of behaviour, i.e. fixated behaviour (Farber, 1948; Russell and Pretty, 1951; Knopfelmacher, 1952, 1953a and b; Eglash, 1951, 1952, 1954; Wilcoxon, 1952; Wolpe, 1953). These challenges to Maier's theory have been well reviewed by Russell (1954), Staats (1959) and Yates (1962, pp. 36-56).

Maier and his associates attempted to answer these criticisms, to provide further evidence in support of the theory (Maier and Ellen, 1951b, 1952, 1954, 1956; Ellen, 1956; Feldman, 1957; Feldman and Waite, 1957) and to initiate a vigorous counterattack on what Maier called "premature crystallisation" of learning theory (Maier, 1954, 1960, 1964). This work included three papers which developed the theory quite considerably (Maier 1956, Maier and Ellen, 1955, 1959). The main points of the modification were:

(a) Maier and Ellen (1955) found that a ratio of 80:20 or 20:80 of reward: punishment caused more fixations in groups of rats with position stereotypes than a ratio of 50:50 and they argued that whether or not a given ratio produces fixation depends upon the subject's expectations, i.e. it depends on how different a subsequent pattern of reward and punishment is from the preceding pattern.

(b) Maier (1956) and Maier and Ellen (1959) further developed the concept of a threshold for frustration to explain why some animals developed fixations and other animals, in the same frustrating situation, did not.

(c) Maier and Ellen (1955) listed what they considered to be frustrating situations: an insoluble problem, pressure to respond, prevention of escape, punishment, and the nonfulfillment of expectancies. As Yates (1962) points out, frustration, once strictly defined, is now generalised to almost any experience of failure.

(d) Maier and Ellen (1959), under the heading of "principles of availability" list the factors which determine which response is fixated: physical nearness, biological ease, the response in progress, simplicity of the response, training, sex, body structure, personality, social and cultural influences. Such a list does make prediction either difficult or so easy as to be ridiculous.

The recent work of Maier's associates has tended to prescind from theoretical issues and has been largely concerned with using fixated behaviour as a dependent variable in studying the behavioural effects of such things as ECS (Feldman and Neet, 1957, 1960), various drugs (Feldman, Ellen, Liberson and Robins, 1959; Feldman and Liberson, 1960; Liberson, 1967; Liberson and Karczmar, 1969; Houser and Feldman, 1971) and brain lesions (Smith and Feldman, 1969). Liberson's (1967) work is particularly interesting in that the motivational aspects of Maier's experimental situation have been simplified by doing away with food as a source of motivation and making subjects jump to avoid shock applied to the starting platform. Also very persistent position responses are induced without the need for a preliminary insoluble phase, merely by consistent reinforcement of one side or the other.

However, the development of Maier's theory of frustration as such has continued. For example, Feldman and Green (1967) attempted to identify more precisely the antecedent conditions of fixation and to describe the way in which they operate in terms of a double approach-avoidance conflict model. Secondly, Tanner (1967) returned to the problem of the effect of prefrustration training on subsequent behaviour. Tanner found that 30 per cent of subjects faced with a symbol discrimination were incapable of solving the discrimination even when they had not previously been exposed to frustration. Maier and Ellen (1952) had found similar results indicating that the difficulty of the discrimination is a more important factor than Maier's earlier work had suggested. Moreover, there was no significant difference between frustration and nonfrustration subjects in terms of fixations when both groups were given pretraining on a soluble discrimination. This suggests the "prophylactic" effect of a successful discrimination against the effects of subsequent frustration.

The situation studied by Maier was so complex that one suspects that the last word has yet to be said as regards his work. If his theory does not survive his data will still require explanation, and so far no one has accounted for all aspects of the data in one simple explanation. Moreover, it can hardly be denied that Maier's work threw a great deal of light on the relationship between position responding and frustration. However, the aversive factors operating, especially during the insoluble phase, ensured that position responding in Maier's typical situation would not be regarded as typical of behaviour during any discrimination task. Maier may have conceded that any reasonably difficult task is frustrating, but this does not mean that his view of frustration can therefore be applied as an explanation of behaviour in any discrimination task.

Amsel's theory of frustration

As Lawson (1965) pointed out there appeared during the late 1930's and 40's a number of independent theories of frustration which shared several features in common with Maier's theory (Rosenweig, 1934, 1938, 1944; Dollard, Doob, Miller, Mowrer and Sears, 1939; Barker, Dembo and Lewin, 1941). In all these approaches to the study of frustration, frustration was defined by a relatively simple set of operations, it was identified as a unique topic in its own right, and the problem was seen as one of determining the behavioural effects of frustration. The therories proposed were ingenious but were not tested thoroughly by extensive programmes of research. A more significant development was the integration of the study of frustration with more general theories of learning and motivation (Rohrer, 1949; Sheffield, 1949, 1950; Brown and Farber, 1951; Child and Waterhouse, 1952, 1953; Waterhouse and Child, 1953).

Currently the most influential theory of frustration is that proposed by Abram Amsel. In recent years research reports in which data is discussed in terms of frustration are usually referring to the model developed by Amsel - certainly the definition of frustration used by him, and in many cases his actual theory of frustration. Like Child and Waterhouse and Brown and Farber, Amsel's theory was a two factor theory in the sense that frustration was considered both to increase drive level and to arouse unique stimulus-response connections. Like Brown and Farber, the theory was firmly embedded in the Hullian tradition.

Amsel defined frustration as "a state which results from the non-reinforcement of an instrumental response which previously was consistently reinforced" (Amsel and Roussel, 1952, p.363); or as "the absence of or delay of a rewarding event in a situation where it had been presented previously" (Amsel, 1958, p.102). Amsel and his associates have produced an impressive amount of experimental support for the theory. Several theoretical papers summarise their work and develop the theory and its application to various learning phenomena (Amsel, 1958, 1962, 1967, 1972 a and b).

Amsel's theory proposes that:

(a) The nonreinforcement of a previously reinforced response produces an immediate frustration reaction (R_F) which has a motivating effect on ongoing behaviour because it is a source of generalised drive.

(b) A fraction of the primary frustration reaction is classically conditionable and the conditioned fractional anticipatory form of the frustration reaction (r_F) is aversive in the sense that the subject avoids, by withdrawal or by making a competing response, stimuli which elicit r_F. (c) There are stimulus consequences of r_F (s_F) which can enter into associative control of behaviour. If an instrumental response is subsequently reinforced then the aversiveness of the r_F and s_F may be overcome so that eventually s_F becomes a source of associative strength for the response.

Amsel's account of discrimination learning posits four discrete stages in the formation of a discrimination. During the first three stages the discriminanda do not operate differentially. In the first stage, the developing, yet weak strength of expectancy (r_R-s_R) is insufficient to elicit primary frustration on nonrewarded trials. After R_F is elicited on nonrewarded trials during the second stage, a conditioned form of the frustration reaction (r_F-s_F) develops during the third stage and produces conflict: both S+ and S- elicit r_R-s_R and r_F-s_F, the former signalling approach to the goal and the latter signalling avoidance of it. This conflict is resolved and the discrimination formed in the final stage. Now only r_R-s_R and approach are elicited by S+ and a r_F-s_F and avoidance are elicited by S-. The frustration effect is measured in a double runway apparatus in which performance in the second runway is contrasted after reward and nonreward in the first runway. The characteristic finding is one of faster running, presumably due to the nonspecific energising effect of R_F after nonrewarded first runway trials. In discrimination studies S+ and S- trials are given in the first runway and the frustration effect measured in the second. The magnitude of the frustration effect should increase at first, as the strength of r_R-s_R on S- trials becomes sufficient to elicit R_F and then becomes stronger resulting in a more intense R_F. Later on the magnitude of R_F should be reduced since S- no longer elicits the expectancy required for nonreward to be frustrating. This prediction has been confirmed by Amsel and Ward (1965) for a black-white discrimination.

Amsel's work has had enormous influence. Phenomena for which explanations have been proposed in terms of his frustration theory include the partial reinforcement effect, negative contrast effects, the effect of delay of reward and the effect of overtraining on extinction and reversal (cf Amsel, 1967; Sutherland and Mackintosh, 1971, chapter 10; Scull, 1973; Black, 1968; Dunham, 1968; Bitterman and Schoel, 1970, for reviews of these issues). However, most of this research does not involve discrimination learning and is not relevant to the present thesis. The main concern at this point is Amsel's <u>concept</u> or <u>definition</u> of frustration rather than his experimental paradigms which have been largely concerned with runway situations.

Amsel's position has not gone unchallenged. The most embarrassing contrary evidence has been the demonstration of the "small trials" partial reinforcement effect (Capaldi and Hart, 1962; Capaldi and Deutsch, 1967; Capaldi, Capaldi and Kassover, 1970; Capaldi and Waters, 1970; McCain and Bowen, 1967; McCain, 1968). From a theoretical point of view Amsel's position has been weakened by attacks on the r_F-s_F mechanism (Rescorla and Solomon, 1967; Brown and Farber, 1968) and by several very strong alternative explanations of the partial reinforcement effect (Logan and Wagner, 1965; Capaldi, 1966, 1967; Sutherland and Mackintosh, 1971).

As far as the "frustration effect", the partial reinforcement effect and associated phenomena are concerned, an explanation in terms of frustration must be considered seriously, but as only one of a number of alternatives. Scull (1973) assessed the situation quite well when he pointed out, in reference to the "frustration effect", that the double runway, in which most of the data has been gathered, is more complex than had been realised. Consequently, the theories developed to explain that data are either too simple to cover all the facts or they are so complex that it is impossible to choose among them at the present time. Before the topics of Amsel's theory of frustration and of the partial reinforcement effect (which has been so closely associated with Amsel's theory) are closed two lines of research ought to be discussed, both of which are relevant to this thesis by virtue of their concern with discrimination learning.

Child and Waterhouse (1952, 1953) and Waterhouse and Child (1953) analysed the effect of frustration on the performance of a complex task. Schmeck and Bruning (1970) attempted to do the same, but within a Hullian framework - just as Amsel did for simple runway performance. They distinguished between the specific and the non-specific effects of frustration. The specific effect is produced by the interaction of the competing responses elicited by s_F and the response under observation (usually latency). The effect facilitates or interferes with the measured response depending on whether the response elicited by s_F is compatible or not. The non-specific effect results from frustration-produced increments in general drive, i.e. frustration increases the probability of competing responses elicited by stimuli other than s_F. The effect of such drive changes depends on the level of training and on the number and strength of competing respones. Hence, frustration early in training should be more detrimental than frustration late in training when the difference between the strengths of competing and correct respones will be large.

Schmeck and Bruning (1968) tested the assumption that the effects of frustration are a function of the number and strength of the competing responses. Their apparatus, for rats, consisted of a simple runway (as used by Amsel) and a complex linear maze with four consecutive choice points each having five possible responses. Frustration improved the performance of subjects on the simple task and interfered with it on the complex task. Schmeck (1970) demonstrated the same effect in human subjects and he also found evidence to suggest that incorrect responses themselves produce frustration reactions, i.e. errors increased the probability of future errors. Finally, Bruning, Schmeck and Silver (1971) found that if rats are taught a discrimination and its reversal, the introduction of frustration impairs performance by comparison with non-frustrated subjects or with subjects which have learned only the initial discrimination and have no readily available competing response. Wookey, Joyce and Strongman (1972), however, continued the line of research initiated by Schmeck by replacing the second alley of an Amsel-type double runway with a complex 4-unit T-maze. They found that the variance, but not the average number of errors, increased after frustration. Moreover, in contrast to Schmeck (1970), there was no evidence that errors early in the maze led to frustration-induced errors. However, they agreed that, in a complex situation, frustration is disruptive, but its effects are multi-directional.

The second line of research is Sutherland and Mackintosh's (1971) explanation of the partial reinforcement effect in terms of their own theory of attention. Their explanation assumed that continuously reinforced subjects learn to attach their responses only, or mainly, to outputs from analysers which consistently predict reward; whereas partially reinforced subjects attach their responses to the outputs from many different analysers, since no analyser can consistently predict reinforcement. During extinction the series on nonreinforced trials leads to the weakening of responses attached to any analyser which is switched in and this weakening continues to a level at which the response will no longer be performed even though the analyser still controls behaviour. At this point the continuously reinforced subjects stop running. Since partially reinforced subjects have their responses attached to the outputs from many different analysers, no analyser is firmly switched in and so that response is weakened slowly to each of them. Thus the partial reinforcement effect occurs. Sutherland and Mackintosh presented evidence in support of their theory from experiments on the "breadth of learning", showing that subjects learn about more cues under partial reinforcement than under continuous reinforcement (Sutherland, 1966, McFarland, 1966); and on the effect of varying the number of relevant cues in an attempt to show that a partial reinforcement effect occurs only when there are several possible cues in the environment. This latter evidence is inconclusive. A third type of experiment quoted in support of the theory is interesting in that it considered the sequential effect of giving both partial and continuous reinforcement. If during partial reinforcement subjects learn to attach their responses to many different cues subsequent continuous reinforcement training should not alter these response attachments. Theios (1962) and Jenkins (1962) found a partial reinforcement effect despite a block of continuously reinforced trials inserted between the partial reinforcement training and extinction. If continuous reinforcement training strengthens a few dominant analysers, the insertion of a block of partial reinforcement trials will have little effect in terms of causing the attachment of responses to analysers switched in to other stimulus dimensions. Consequently, Sutherland and

Mackintosh would predict no significant partial reinforcement effect in this situation. On the other hand, Sutherland, Mackintosh and Wolf (1965) found that a group given continuous reinforcement after partial reinforcement extinguished at the same rate as subjects given partial reinforcement only. What we have then is an explanation of the partial reinforcement effect without any reference to frustration. A similar point will be discussed in the next section - a review of a number of studies in which random reinforcement is used without reference to frustration.

Non-differential reinforcement as frustration

Most of the theories of frustration discussed so far have been concerned with the effect of the nonfulfilment of expectancies on performance. Maier's approach was an exception in the sense that he studied the effect on subsequent discrimination learning of prior experience with an insoluble problem. The study of behaviour in a situation of non-differential or inconsistent reinforcement has been undertaken by other researchers, but without reference to frustration. Because random reinforcement was used as a means of studying other effects rather than for its own sake, the research tends to be scattered and unsystematic.

Krechevsky (1932) studied the effect of random reinforcement as a means of highlighting hypotheses adopted by or originating from the rat, as distinct from those imposed by the experimental design. He found that even though no response gained more than 50 per cent reinforcement, all subjects adopted one or more systematic or uniform patterns of response. He concluded,

> The rat, when placed in an unsolvable situation, does not respond in a helter skelter chance fashion, but makes a series of integrated unified attempts at solution (page 61).

Krechevsky (1933) subjected rats to a period of random reinforcement until a persistent response was adopted (on the average, after 34 trials). He found that when the rats were transferred to a solvable task the hypothesis necessary to solve the new task was readily adopted, irrespective of whether the hypothesis adopted under random reinforcement was appropriate in the solvable phase. Witkin (1940, 1941), however, criticised Krechevsky on two important points;

(a) "In the last analysis no situation is truly insoluble unless it is impossible for the animal to learn anything at all about it" (p.459). If subjects cannot learn a specific sequence of responses, they may at least learn about the situation during random reinforcement.

(b) Behaviour in an insoluble situation is not necessarily the same as behaviour during the presolution period of a solvable observation. Witkin found that if all responses are reinforced during the pre-training period, i.e. quite a different form of non-differential reinforcement to that used by Krechevsky, rats behave in a different manner than when they learn a differential brightness or spatial discrimination. He concluded that choice-point complexity, not goal attainment, is the determinant of systematic behaviour patterns.

A decade later Bitterman and his associates took up the technique of non-differential reinforcement (in the sense of reinforcing all responses) to test the Hullian principle that perceptual learning cannot occur without differential reinforcement (Hull, 1952). Bitterman, Calvin and Elam (1953) gave rats 120 trials of non-differential reinforcement either with grey doors or with horizontal-vertical discriminanda presented simultaneously or successively. The three groups were then transferred to a conventional simultaneous or successive discrimination task with horizontal-vertical as the discriminanda. Subjects trained on one presentation method and tested on another learned no faster, but made fewer errors than subjects trained with the grey doors - evidence contrary to Hull's proposition. Subjects trained and tested with the same presentation method learned fastest of all. Bitterman, Elam and Wortz (1953) compared the effects of non-differential reward and punishment. To avoid the non-differential punishment constituting an insoluble problem situation (of the type used by Maier), with concomitant emotional effects, the non-differential reward and punishment were given in the context of a task in which the horizontal-vertical discriminanda were irrelevant. Nondifferential reward did not facilitate performance on a subsequent task, but neither nondifferential reward nor non-differential punishment retarded subsequent discrimination learning. It does not follow that non-differential reinforcement has no effect on subsequent discrimination, since reward and punishment may give rise to significant but opposite effects which cancel each other. Bitterman and Elam (1954) further showed that with increased amounts of non-differential reinforcement (from 3 up to 12 days) performance on a subsequent horizontal-vertical task deteriorated, indicating that the transfer effect of non-differential reinforcement is predominantly negative, but the deterioration was even worse for subjects pretrained with grey doors. The effect was not due to the afferent consequences of the response, e.g. goal box colour (Billingsley, Feddersen and Bitterman, 1954), and it was not due to the stimuli used (Crawford Mayes and Bitterman, 1954). Bitterman and Elam (1954) argued that:

(a) The retardation factor was due to attentional modification (in terms of perceptual selectivity or an orienting response). It was not due to position habit strength since position responding was fairly constant for the first nine days and during the last three days it increased for the horizontal-vertical subjects and decreased for the grey door subjects.

(b) The superiority of the horizontal-vertical subjects was due either to the early perceptual differentiation by the horizontal-vertical subjects surviving the adverse effects of continued non-differential reinforcement, or to perceptual differentiation occurring concurrently with the negative effect of non-differential reinforcement.

Further support for Bitterman's discrimination hypothesis was provided by Elam and Tyler (1958), using monkeys, and Grosslight, Hall and Scott (1954), using rats, who showed that non-differential reinforcement of the discriminanda during training led to faster reversal than partial reinforcement. Calvin (1953), with rats, and Calvin, Perkins and Hoffman (1956), with children, showed that subjects which received non-differential reinforcement on all trials learned a subsequent discrimination faster than subjects which had two punishment trials randomly interspersed among the twelve rewarded trials. Calvin et al (1956) concluded that the amount of positive transfer is inversely related to the number of solutions possible during non-differential reinforcement and directly related to the degree to which these had been, or could be, explored. Positive transfer occurs during non-differential training when a solution is available; if there is no available solution, then negative transfer occurs. They found that non-differential reward and non-reward were no different as regards the effect on the performance of subsequent tasks and both conditions led to better performance than a control condition consisting of transfer from one task to another.

In a second experiment, Calvin et al found no difference between a group given non-differential training with the discriminanda of a subsequent discrimination task and a control group, even though another group given non-differential training with stimuli other than those used in the subsequent task did perform better than the controls.

Krechevsky's ideas have been continued by Levine. Over several years Levine (1963a, 1966, 1969) has examined human discrimination learning in terms of the testing of hypotheses, where "hypothesis" is defined in Krechevsky's sense of the word, and a non-continuity theory of learning has been developed. In support of this theory, Levine studied the effect of random reinforcement on discrimination learning. Levine (1962, 1963b) had subjects classify simulus patterns over a series of trials where responses were correct or incorrect at random. The subjects were then shifted to a problem where some cues were consistently paired with reinforcement. Levine found that, regardless of the number of random reinforcement trials (which varied from 4 to 60), random reinforcement always produced a decrement in subsequent performance and this negative transfer was constant. This finding was replicated by Holstein and Premack (1965) using six as well as two dimensions, so the result was not due to subjects' ability to remember the hypotheses disconfirmed during random reinforcement. Levine, Yoder, Kleinberg and Rosenberg (1968) and Glassman and Levine (1972) established the similarity between seven-dimension, insolvable problems and eight-dimension problems which are too difficult to solve. In an effort to throw more light on the learning process Trabasso and Staudenmayer (1968) tackled the question of within and between problem effects of random reinforcement. They found that when subjects were given differential training before the random reinforcement, negative transfer was problem specific, i.e. it occurred only when cues relevant to the solvable task were identical with cues occurring during random reinforcement. They concluded that subjects rejected hypotheses based on irrelevant cues, but that this rejection was temporary and occurred only if the problem or dimensions remain unchanged.

The physiological effects of stress induced by random reinforcement have been studied in some detail (e.g. Boles and Russell, 1970, Mikhail, 1971, Pare, 1972). However, noxious stimulation is almost always used in the studies, making comparison with food motivated discrimination learning difficult. The exception is a study by Lovibond (1969) who looked at changes in the frequency of gastric lesions in ulcer susceptible rats as a function of various combinations of a light and a buzzer which had been associated in previous training with food and shock respectively. At 90 second intervals, during 24 hours of restraint, different groups received: the light and buzzer simultaneously, the light followed by the buzzer, the buzzer followed by the light, the light alone, the buzzer alone, or neither the light nor the buzzer (control group). The greatest number of lesions was associated with the simultaneous presentation of light and buzzer (the "conflict" situation) and the least number of lesions was associated with the light alone (the conditioned stimulus for feeding). The light seemed to act as an inhibitor of anxiety since there were very few lesions associated with the light followed by the buzzer condition. Lovibond concluded that conflict phenomena generated in a stimulus pattern tended to elicit incompatible responses and no response was able to achieve dominance. The incompatible responses did not need to be of equal strength, as implied by most conflict studies.

One interesting development in the area of aversive stimulation is the work done on the phenomena of "learned helplessness" (Overmier and Seligman, 1967, Seligman and Maier, 1967, Overmier, 1968, Maier, Seligman and Solomon, 1969, Seligman, Maier and Solomon, 1971). Most of the initial work was done with dogs and it was found that if the animals were subjected to a period of random unavoidable shock whilst strapped into a Pavlovian type harness, two-thirds of the subjects were unable to master a subsequent task, usually an escape-avoidance shuttle-box task. The authors argued that their subjects learned that they were helpless in the random, unavoidable shock situation and that they transferred this learned helplessness to the solvable escape-avoidance task. However, the dogs could be taught the escape-avoidance task using a guidance method or they could be "immunised" or "inoculated" against the effect of unavoidable shock by experience with a solvable task (Seligman and Maier, 1967). Seligman, Maier and Geer (1968) pointed out the similarity of these results to those found by Maier (1949). However, the explanation of the phenomena, in this case, is entirely in associative terms, whereas Maier explained his data by reference to a quite separate category of behaviour, fixated behaviour. The phenomena of learned helplessness has been observed in human subjects (Foseo and Geer, 1971, Thornton and Jacobs, 1971, 1972, Dweck and Reppucci, 1973). However, it does not appear as clearly when rats are used as subjects and seems to be affected by factors such as the strain of rat and the type of test situation (Anisman and Waller, 1971, 1972).

Another experiment relevant to this review is a study by Mandler (1966) who used a period of random reinforcement (70 or 220 trials) followed by transfer to a black-white discrimination task to study the relationship between position habits and errors in discrimination learning. By comparison with naive subjects, the randomly reinforced subjects showed negative transfer, their performance was highly variable from day to day and three-quarters of them maintained position habits developed during random reinforcement for the first 70 trials of the transfer task. Mandler argued that this overall impairment of learning was partly accounted for by the carry-over of position habits (a detour based strategy according to Mandler: cf. Ch. 1 pages 15 and 16) from the random reinforcement stage to the black-white discrimination. However the impairment is not ascribed to frustration but to the resistance to extinction of habits acquired under partial reinforcement conditions or to "some temporary deterioration in the discriminative process" (p.199) produced by random reinforcement.

A number of other studies have shown that inconsistent reinforcement during acquisition retards the reversal of a simultaneous brightness discrimination in rats (Grossleight, Hall and Scott, 1954, Grosslight and Radlow, 1956, 1957, Kendler and Latchburn, 1958, Wise, 1962, Erlebacher, 1963).

The final issue to be discussed in this chapter concerns the effect of random reinforcement on selective attention in discrimination learning. The work has been done in operant situations but it is considered here because it is notable for a very closely argued discussion about what is learned about relevant and irrelevant cues in a discrimination task. The question was raised by an experiment of Wagner, Logan, Haberlandt and Price (1968). Two groups of rats, in a discrete-trial operant situation, either learned a tone discrimination (the "true discrimination" or TD group) or were subject to an equivalent number of trials during which responses to tones were randomly reinforced (the "pseudodiscrimination" or PD group). A constant stimulus, a light, was consistently presented with each tone for both groups. However, when the light was presented alone, it had acquired greater stimulus control over PD subjects than over TD subjects. After the first test session, half the subjects in each group received further true or pseudoconditioning on the tone discrimination and the remainder were switched to the opposite condition. A second test session followed this training. For the subjects which continued in this original condition response tendencies to the light were similar to those existing after Stage 1 and responses to the tones, presented alone, were either very accurately differentiated (TD group) or undifferentiated (PD group). Subjects which changed from the TD to the PD condition increased their responses to the light and their discrimination between the tones deteriorated badly, but not as badly as the consistently randomly reinforced group. Those subjects which were switched from the PD to the TD condition dramatically decreased their responses to the light and learned the tone discrimination, but not as well as the consistently reinforced group.

Wagner et al argued that a partially reinforced cue is much less likely to be an effective stimulus in isolation when it has been experienced in compounds containing elements more highly correlated with reinforcement than when experienced in compounds which do not contain more valid elements. They saw their results as supporting theories, such as Sutherland and Mackintosh's attention theory, which assume that the extent to which an analyser is switched in depends on the validity of its outputs, or theories such as Restle's (1955) theory of discrimination learning in which cue neutralization is assumed to occur in proportion to the number and validity of cues more highly correlated with reinforcement. Throughout the discussion there was no suggestion that frustration was a possible reaction of subjects being randomly reinforced or being switched from true to pseudodiscrimination.

Thomas (1969) proposed an alternative interpretation of Wagner et al's results. He argued that discrimination training produces a "set to discriminate" or a "general attentiveness" which encourages differential responding along all stimulus dimensions, including those not involved in such training. Subjects are assumed to learn a rule of the game - that there is reward to be gained in the experimental situation and that exteroceptive stimuli can assist in the pursuit of that reward. Such learning transfers to new problems despite changes in the relevant stimulus dimensions or response requirements. By the same token non-differential reinforcement teaches subjects either the insignificance of a stimulus or the futility of responding on the basis of such stimuli. Thomas's approach contrasts with selective attention theories which view attention as a selective process narrowing the range of stimuli which control responding. According to these theories increased attention to one dimension implies reduced attention to another. Thomas did not deny that pre-discrimination experience could enhance the distinctiveness of a particular stimulus dimension but he emphasised those effects which transcend the specific values of the training stimulus.

Eck, Noel and Thomas (1969) and Eck and Thomas (1970) found, with pigeons, that successive discrimination training with two line angles resulted in positive transfer to discrimination performance on dimensions orthogonal to the initial dimension - wavelength and brightness. Frieman and Goyette (1973) found transfer of training effects when both stimulus modality and response class (key press or chain pull) were changed between the two problems.

In the Eck et al paper, TD subjects were trained on a line-tilt discrimination followed by a wavelength discrimination, with the S+ from the initial discrimination superimposed on both S+ and S-. The subjects were then returned to the initial discrimination and, finally, they were shifted to a brightness discrimination, again with the S+ of the initial discrimination present. The TD group learned the wavelength and brightness discriminations as fast as a control group for which the initial S+ was not present during these discriminations, and more rapidly than a PD group which was randomly reinforced on the line-tilt discrimination. Thomas, Freeman, Svinicki, Burr and Lyons (1970) reported five experiments which showed, with pigeons, that successive discrimination training along one dimension sharpened generalization gradients along a second test dimension, by comparison with non-differentially trained groups. In separate experiments, the test dimension was either present but irrelevant during training, or it was introduced later. The study also demonstrated a sharpening of generalization gradients irrespective of whether the training and test dimensions were from the same or different sense modalities. Thomas, Miller and Svinicki (1971) found similar results with rats. Subjects were shifted from a light intensity discrimination to a tone discrimination - so far from preventing the acquisition of control by a constant, irrelevant stimulus, TD training appeared to have enhanced such control.

Thomas, Burr and Eck (1970) extended the alternative interpretation of Wagner et al's (1968) results. Since both groups in that study were trained to respond to a compound (tone and light) stimulus, the light alone constituted a generalized stimulus. Since discrimination training leads to sharper generalization gradients than non-differential training, the change from the compound training stimulus to the generalized, light-only stimulus produced a greater decrement in the gradient of the TD group. This lower response strength to the light by the TD group simply reflected heightened stimulus control by the compound training stimulus. The PD group, since its gradient around the compound stimulus was flatter, showed relatively less decrement in stimulus control when shifted from the compound stimulus to the light-only stimulus. The PD subjects had been taught to ignore stimulus differences. The TD subjects were more discriminating and so responded less to any generalized stimulus than the PD subjects. Thomas, Burr and Eck replicated Wagner et al's first experiment, with the exception that the rats were tested for response strength in the presence of both the original light intensity and a novel, dimmer light. This test provided a generalization gradient measure of stimulus control by light intensity and it showed that TD training produced a sharper generalization gradient than PD training.

An explanation which attempted to reconcile the findings of Wagner et al and of Thomas and his associates was suggested by Turner and

Mackintosh (1972). Honig (1969) had found that PD training with wavelength discriminanda after TD training on a line-tilt discrimination led to a flattening of the line-tilt generalization gradient. Similarly if there were strong but unidentified, irrelevant stimuli present in the Thomas et al (1970) situation they would have been suppressed by TD training but would have gained control during PD training. Since these stimuli would have been present on the test trials, the TD group would have demonstrated what control had been acquired by the experimenters' constant, irrelevant stimuli but the PD group would have remained under the control of the unidentified, irrelevant stimuli. Turner and Mackintosh extended Honig's experiment by counteracting the effect of PD training by giving subsequent TD in the absence of the constant irrelevant stimulus. They found that, although control TD and PD groups (replicating Thomas et al, 1970) differed in respect to the generalization gradient around the irrelevant stimulus, this difference was eliminated by the insertion of TD training between the initial task and generalization testing. Turner and Mackintosh argued that Thomas et al's finding can be explained as a test effect of PD training. PD subjects in both experiments had been noticed to be responding at a high absolute rate. This responsiveness is quite consistent with the proposition that there were unidentified and irrelevant stimuli in the experimental situation which exercised quite strong stimulus control.

Since Turner and Mackintosh's first experiment merely found no difference between PD and TD conditions and did not reverse the difference found by Wagner et al, they repeated the experiment in a discrete trial situation instead of the free operant situation used in the first experiment. They found that PD training resulted in a sharper gradient than did TD training and they suggested that, in the free operant situation, response-produced stimuli may have been the irrelevant stimuli. Their overall conclusion was,

> PD animals do not <u>learn</u> less about the constant, irrelevant stimulus, therefore TD training does not establish a general set to attend to all stimulus dimensions. (p.8)

<u>Conclusion</u>

This review of the literature on frustration and inconsistent reinforcement in discrimination learning will have achieved its purpose if it has given an idea of the variety and complexity of the research which has been done in this area. The work has ranged from the precisely defined situation investigated by Maier, Amsel and their associates to the study of the effect of frustration on complex behaviour carried out by Schmeck and his associates. Frustrating operations have been imposed on on-going behaviour or they have preceded learning tasks. Many studies involving random or inconsistent reinforcement have been performed with no suggestion of frustration being involved (e.g.Krechevsky, 1932, 1933; Levine, 1962, 1963b; Seligman, Maier and Solomon, 1971; Mandler, 1966; Wagner et al, 1968).

In the following chapter a series of experiments is described which investigated: (a) different frustrating operations and their effect on subsequent discrimination learning, and (b) the interaction of position responding with both frustration and learning.

Note: The following chapter 5 commences on page 106. Page numbers 98 to 105 inclusive are not used, as a result of textual revision.

CHAPTER 5

EXPERIMENTS ON THE EFFECT OF FRUSTRATION ON SUBSEQUENT DISCRIMINATION LEARNING.

Reference has already been made to the experiment of Levy (1969) which investigated the possibility that frustration interacts with position responding and thereby affects discrimination learning (Ch.2, p.44f). In the second experiment of Winefield and Jeeves (1970b), three subjects out of ten from the 12-door group had failed to reach the learning criterion on a reversal task after 260 trials. Apart from these subjects the slowest learner in the group took 125 trials to reach criterion. This bi-modality in the data suggested to Winefield and Jeeves an explanation in terms of Maier-type frustration, and Levy investigated this suggestion. She adopted Maier's technique of inducing frustration by a period of random reinforcement, and studied the effect of this frustration on subsequent acquisition and reversal learning. Levy found no difference between 2- and 12-door subjects on either task. In other words there was no support for the predictions that: (a) the 2-door subjects would learn faster than the 12-door subjects on both tasks; and (b) some of the 12-door subjects would fail to learn to reverse through developing symbol fixations. However, the pattern of responding in both groups did seem to be affected by frustration. By comparison with the performance of rats in earlier experiments in the circular maze, which involved simple discrimination acquisition and reversal learning, the frustration training produced slower learning in acquisition for both groups but had little effect on reversal learning. Moreover, the 2-door subjects displayed more position responding in acquisition and reversal, but both 2- and 12-door subjects displayed less perseverative responding in reversal. The proportion of 2-door subjects adopting a stereotyped position response in reaction to the insoluble problem (50 per cent) was much less than one might have expected from reading Maier, who found that typically about 80 per cent of his subjects developed position stereotypes (Cf. Mullins, Winefield and Levy (1973) for the details of Levy's (1969) results.)

The failure of the period of random reinforcement to produce a difference between 2- and 12-door groups was surprising. Previous research had shown that position responding was not necessarily detrimental to discrimination learning and the exaggerated position responding which random reinforcement tends to induce was expected to highlight the difference between the 2- and 12-door conditions. The fact that fewer 2-door subjects than expected adopted position habits may have influenced the results. The overall conclusion adopted by Mullins, Winefield and Levy (1973) was that these results supported the earlier conclusions of Winefield and Jeeves (1969) that position responding is a natural response to frustration, but it has no direct effect on subsequent learning. This one experiment, however, left the issue unresolved and served to indicate how complex was the relationship between position responding, frustration and learning. The experiments reported in this chapter were designed to throw more light on the matter.

The most critical issue revolved around the definition of frustration. Levy adopted Maier's definition of frustration, or more correctly, of a frustrating situation, and assumed that a task is frustrating if there is no way in which it can be solved. An alternate definition of frustration, one which is associated with the work of Amsel, is in terms of the non-fulfilment of expectancies. There is a real distinction between Maier- and Amsel-type frustration since it can hardly be assumed that rats expect to be able to solve any discrimination task in which they find themselves. A rat in Maier's situation of random reinforcement is under a condition of stress, which may be labelled frustrating, but it is not necessarily frustrated in the sense of not having its expectancies fulfilled. Besides extending the work initiated by Levy, the following experiments examined the effect on learning of two different frustrating operations.

In both operations the subjects were placed under a schedule of random reinforcement - they were confronted with an insoluble problem. In one situation naive subjects received this frustration training. This is analogous to Maier's frustrating situation. However, it ought to be noted that the situation did not involve aversive stimulation to the same degree as used in Maier's experiments - animals were not encouraged to jump by an air blast and nonreinforced responses did not involve a fall into a net below the apparatus. Moreover, assessment of the effect of frustration training was made on the basis of performance of a nonreversal shift task. This differs from Maier's practice of transferring subjects from an insoluble task to a solvable one with the same discriminanda present in both phases of the experiment. A nonreversal shift design allowed the use of appropriate control groups without any group being at an advantage or disadvantage as a result of pre-exposure to the test discriminanda. In the second situation, subjects mastered an initial discrimination task before frustration training. The effect of such pre-training was assumed to be the development of an expectation that reward would be systematically and differentially provided. The transfer to an insoluble problem resulted in the nonfulfilment of this expectation. This situation is analogous to that defined as frustrating by Amsel. Certainly, Amsel was interested in the effect of partial reinforcement on behaviour, especially as measured by speed of response.

However, Amsel's definition of frustration (Cf. page 78) need not be restricted to this situation.

On the basis of a wide range of experimental research, apart from that of Maier and his associates, one might expect experience with random reinforcement to have a detrimental effect on subsequent learning (Bitterman et al, 1953; Calvin, 1953; Calvin et al, 1956; Levine, 1962, 1963b; Holstein and Premack, 1965; Overmier and Seligman, 1967; Overmier, 1968; Maier et al, 1969; Seligman et al 1971; Mandler, 1966; Wagner et al, 1968; Eck et al, 1969). On the other hand many of these same workers report that the introduction of an initial discrimination lessens the detrimental effect of random reinforcement (Maier and Klee, 1943; Tanner, 1967; Trabasso and Staudenmayer, 1968; Seligman and Maier, 1967; Wagner et al, 1968). Hence one might expect: (a) different effects of these frustrating operations on subsequent discrimination learning, and (b) different interactions between position responding and these frustrating operations.

The previous work done in the circular maze, especially by Levy, suggests that as far as the interaction between frustration and position responding is concerned, subjects for which position responding is possible will not be at a disadvantage. A clear prediction as regards the comparison between Amsel- and Maier-type frustration is not possible on the basis of previous research in the circular maze.

To determine whether the above questions were worth further research, two pilot studies were performed. The first of these looked at the effect of Amsel-type frustration on subsequent discrimination and reversal learning in the same way in which Levy (1969) had looked at the effect of Maier-type frustration. The second pilot study compared the two types of frustration within the one experiment.

For the sake of ease of exposition, hereafter Amsel-type frustration - defined, operationally, as the development and nonfulfilment of an expectancy - will be referred to as "frustration", and Maier-type frustration - defined as inconsistent or random reinforcement, or an insolvable problem - will be referred to as "uncertainty". This terminology is a matter of convenience and is not intended to imply that one operation is more accurately described as frustrating than another.

EXPERIMENT 5.1. The effect of the nonfulfilment of expectancies on subsequent discrimination learning under conditions of reduced spatial cues: a pilot study.

METHOD

Experimental Design

There were four stages in the experiment and they were as follows:

Phase 1: a black-white discrimination, learned to criterion by both 2- and 12-door groups in order to ensure that subjects did have definite expectations.

Phase 2: frustration training - 120 trials of random reinforcement with the black-white discriminanda present.

Phase 3: a non-reversal shift to a horizontal-vertical discrimination in order to assess the effect of the frustration training.

Phase 4: reversal of the horizontal-vertical discrimination.

Subjects

The subjects were 12 experimentally naive, male, Wistar strain, hooded rats, which were approximately 100 days old at the beginning of pretraining. They were maintained at 85 per cent of their ad lib. body weight throughout the experiment but had water available at all times.

Apparatus

The apparatus was the circular maze described in Chapter 2. The discriminanda used in Phases 1 and 2 were plain black or white. The discriminanda used in Phases 3 and 4 were the horizontal-vertical discriminanda used in Experiment 3.2.

Procedure

Pretraining. The pretraining procedure used in this experiment was the same as that used in Experiments 3.1 and 3.2. On the day following the end of pretraining subjects were transferred to the initial discrimination task.

Phase 1: initial discrimination training. The procedure used in the initial black-white discrimination was the same as that used in discrimination training in Experiment 3.2. When subjects attained a criterion of 22/24 correct responses over two consecutive days they were transferred, on the following day, to the random reinforcement situation.

Phase 2: frustration training. Each subject was given 120 trials (10 days) of frustration training during which reinforcement was randomly dispensed. On half the daily trials, the white doors were locked and the black doors were unlocked and vice versa. For the 2-door subjects the door on the right was locked on half the daily trials and the door on the left was unlocked and vice versa. Both random reinforcement and the position of the unlocked door were determined by Fellows' (1967) series, i.e. the random reinforcement was not truly random but was such that no response pattern could gain reinforcement on more than 50 per cent of the daily trials. Where possible, subjects were run in groups of 3.

The fact that subjects completed Phase 1 training at different rates meant that it was not always possible to run them in groups of 3, but the inter-trial interval of 2-3 minutes was always retained. Apart from the random reinforcement schedule, the subjects were treated in the same way as they were in Phase 1. On the day following completion of the 120 trials of random reinforcement, subjects were transferred to Phase 3.

Phase 3: transfer task. Subjects were transferred to a horizontal-vertical discrimination and trained to a learning criterion of 22/24 correct over two consecutive days. For half the subjects horizontal was the S+ and for the remainder vertical was the S+. Subjects were allotted to these two groups on the basis of Phase 1 scores in order to control for individual differences regarding stimulus preference and learning ability. As far as possible subjects were run in groups of 3, but, in any case, the intertrial interval of 2-3 minutes was maintained. On the day following attainment of the learning criterion subjects were transferred to Phase 4. All other details of the procedure were as in the previous experiments.

Phase 4: reversal learning. Following reversal subjects were trained to a criterion of 22/24 correct responses over two consecutive days. The procedure used for reversal training was the same as that used in previous tasks. One 12-door subject had not attained the learning criterion on the reversal task after 240 trials, whereas the next slowest subject reached criterion in 192 trials. Since this experiment was only a pilot study, this subject's training was terminated.

RESULTS

The results of Experiment 5.1 are summarised in Table 5.1.

TABLE 5.1

Trials to criterion on the initial discrimination task (B/W), the transfer task (H/V) and its reversal

Group	Phase 1 (B/W)	Phase 3 (H/V)	Phase 4 (Reversal)
2-door (N:6)	$\bar{X}$: 48.8 S.D.: 16.9	$\bar{X}$: 47.3 S.D.: 37.6	$\bar{X}$: 111.7 Median 92.5 S.D.: 60.0
12-door (N:6)	$\bar{X}$: 49.0 S.D.: 20.7	$\bar{X}$: 41.0 S.D.: 17.9	Median: 119.5 (1 S failed to learn)

There was no difference between the 2- and 12-door subjects on the initial black-white discrimination or the subsequent horizontal-vertical transfer task. ($t < 1$, $p > .05$ in both cases). In this sense the pilot study supported the finding of Levy (1969) that the presence or absence of spatial cues was not critical.

During frustration training (Phase 2) all the subjects continued to respond to the stimulus which had been their S+ in Phase 1, so the initial discrimination learning had led them to expect differential reinforcement. However, the 120 trials of random reinforcement seemed too long a period of frustration training. Initially subjects showed distress and vigorous responding, and then they appeared to habituate to the new 50:50 schedule. On the basis of this observation a shorter period of random reinforcement was used in later experiments to ensure that when subjects were transferred to the solvable task the effect of the nonfulfilment of their expectancies would still be strong, and they would not have had time to change their expectancies.

By comparison with the previous experiments done in the circular maze, with horizontal and vertical stripes as the discriminanda, the transfer task in Experiment 5.1 was acquired more slowly by the frustrated subjects than by naive subjects (Mullins, 1969, Cf. Table 2.1, p.43 of this thesis) and more rapidly than by subjects subjected to Maier-type frustration (Levy, 1969, Cf. Table 2.2, p.45 of this thesis). However, different experimental conditions (e.g. stimulus size, deprivation level, criterion level, and trials per day) make these comparisons unreliable except as indications for later research.

EXPERIMENT 5.2. A comparison of the effect of two frustrating operations on subsequent discrimination learning: a pilot study.

METHOD

Experimental Design

The experimental design was a 2 x 2 design with 2- or 12-door groups subjected to two different frustrating operations - either 60 trials of random reinforcement alone (uncertainty group) or random reinforcement preceded by the acquisition of a black-white discrimination (frustration group). The 4 groups were compared on the basis of their acquisition of a subsequent horizontal-vertical discrimination. Hence there were three stages in the experiment: Phase 1, an initial black-white discrimination. Phase 2, 60 trials of random reinforcement; Phase 3, transfer to a horizontal-vertical discrimination.

Subjects

The subjects in this experiment were 14 experimentally naive, male, Wistar strain, hooded rats which were approximately 100 days old at the beginning of pretraining. They were maintained at 85 per cent of their ad lib. body weight throughout the experiment, but had water available at all times.

Apparatus

The apparatus was the circular maze. The discriminanda used in this experiment were the black-white and horizontal-vertical discriminanda used in Experiment 5.1.

Procedure

Pretraining. The procedure for pretraining in this experiment was the same as that used in previous experiments, except that on the day following the completion of pretraining half the subjects began training on the initial discrimination (frustration group) and the remainder (uncertainty group) were kept in their home cages until the first frustration subject was ready to begin frustration training (4 days).

Phase 1: initial discrimination. Three 12-door subjects and four 2-door subjects were trained to a criterion of 22/24 over two successive days on a black-white discrimination as in Experiment 5.1.

Phase 2: frustration training. All subjects, a total of six 12-door subjects and eight 2-door subjects, were given 60 trials (5 days) of frustration training as in Experiment 5.1. For all groups the black-white discriminanda were present during the random reinforcement. On the completion of frustration training subjects were transferred to the horizontal-vertical task.

Phase 3: transfer training. All subjects learned the horizontal-vertical discrimination to a criterion of 22/24 correct over two successive days. The procedure used was the same as that used in Experiment 5.1.

RESULTS

The results of Experiment 5.2 are summarised in Table 5.2.

TABLE 5.2

Trials to criterion on the initial discrimination task (B/W) and the transfer task (H/V) of Experiment 5.2.

Group :		Phase 1 (B/W)	Phase 3 (H/V)
Frustration Group	2-door	$\bar{X}$: 39.25 N : 4	$\bar{X}$: 33.0 N : 4
	12-door	$\bar{X}$: 58.3 N : 3	$\bar{X}$: 37.7 N : 3
Uncertainty Group	2-door	-	$\bar{X}$: 46.0 N : 4
	12-door	-	$\bar{X}$: 56.0 N : 3

During frustration training (Phase 2) the frustration groups continued to respond to the stimulus which was their S+ in Phase 1, as was observed in Experiment 5.1. As regards the uncertainty group, the 2-door subjects adopted position habits and the 12-door subjects appeared to respond randomly in the sense that they did not systematically choose any particular door or symbol. The results of this experiment were promising in the sense that they indicated the usefulness of further research. Looking at the means, the different frustration operations seem to have had different effects. The Maier-type frustration was more detrimental to subsequent performance on the horizontal-vertical task. Secondly, the 2-door subjects consistently performed better than the 12-door subjects. Since this was a pilot study, the numbers in each group were small and statistical significance was not to be expected. In fact, the difference between the 2- and 12-door subjects on the initial black-white discrimination was not significant ($t(5) = 1.369$, $p > .1$). A 2 x 2 analysis of variance, by the method of unweighted means for unequal cell frequencies (Winer, 1971, p.402), of the trials to criterion on the horizontal-vertical transfer task indicated a nonsignificant effect for the 2- versus 12-door variable ($F < 1$, $p > .05$) and a nonsignificant effect for the pretransfer treatment variable ($F(1,10) = 2.865$, $p > .05$).

On the basis of the results of Experiments 5.1 and 5.2 it was decided that a full scale experiment, with appropriate control groups, was worth performing.

EXPERIMENT 5.3. The Effect of different frustrating operations on subsequent discrimination learning with and without reduced spatial cues.

The indications from Experiments 5.1 and 5.2 were that different frustrating operations had quite different effects on subsequent discrimination performance. It remained to be seen what these effect were relative to each other. This could be done only by comparing the effect of both operations within the one experiment, under the same experimental conditions, and with the appropriate control conditions. Thus the two experimental conditions were:

(a) a frustration group which learned an initial discrimination, was subjected to a period of random reinforcement, and was then transferred to another solvable discrimination;

(b) an uncertainty group which was transferred from an insoluble problem to a solvable discrimination.

The control groups considered appropriate were:

(a) a control for learning-to-learn, which consisted of a simple non-reversal shift from a black-white discrimination to a horizontal-vertical discrimination. There was the possibility of positive transfer from the initial black-white discrimination to the subsequent horizontal-vertical discrimination and this transfer could either cancel out the detrimental effect of the intervening random reinforcement or add to any facilitating effect of frustration training. Hence this learning-to-learn control group was appropriate, primarily, for the frustration condition;

(b) a naive control group which learned only the horizontal-vertical discrimination and its reversal. This group was appropriate, primarily, for the uncertainty condition.

Despite the previous research done in the circular maze, i.e. the experiments reported so far in this thesis and those reported in Winefield and Jeeves (1970b) and Mullins, Winefield and Levy (1973), the role of position responding in discrimination learning remained obscure. In none of the experiments performed to date had the rats with reduced spatial cues learned a discrimination more quickly than those with spatial cues available, and there were some situations (a difficult initial discrimination and, occasionally, reversal learning) in which the presence of spatial cues seemed to facilitate learning. Despite Levy (1969), who looked at only one form of frustration, the possibility remained that there was a critical relationship between position responding and frustration. Consequently the 2- versus 12-door comparison was retained in the present experiment in the hope that there would be revealed either an interaction between position responding and different types of frustration or a consistent relationship between the presence and absence of spatial cues across the four conditions.

The experiment was considered to be a test of the following predictions:

(a) that any difference between 2- and 12-door groups would be in favour of the 2-door subjects, irrespective of the frustrating operation;

(b) random reinforcement would have a detrimental effect on subsequent discrimination learning, so that the frustration groups would compare unfavourably with their appropriate controls;

(c) Amsel-type frustration would not have as deleterious an effect as Maier-type frustration, or uncertainty, on subsequent learning.

METHOD

Experimental Design

The design of this experiment was a 2 x 4 design with 2- or 12-door groups subjected to various pretransfer treatments and compared on the basis of performance on a subsequent horizontal-vertical transfer task and its reversal. The design of the experiment is summarised thus:

Condition:	Treatment:			
	Phase 1	Phase 2	Phase 3	Phase 4
Frustration	B/W	Random reinft.	H/V	Reversal
Learning-to-learn Control	B/W	-	H/V	Reversal
Uncertainty	-	Random reinft.	H/V	Reversal
Naive control	-	-	H/V	Reversal

Subjects

The subjects in this experiment were 71 experimentally naive, male, Wistar strain rats which were approximately 100 days old at the beginning of pretraining. These were maintained at 85 per cent of their ad lib. body weight throughout the experiment but had water available at all times.

Apparatus

The apparatus was the circular maze. The discriminanda were the same as those used in Experiment 5.2.

Procedure

Because of the number of subjects involved the experiment was run in two stages with 39 subjects run in the first stage and 32 subjects run in the second stage. However, all experimental conditions were represented in each stage.

Pretraining. The procedure for pretraining was the same as that used in the previous experiments.

Phase 1: initial discrimination. Half the subjects from both 2- and 12-door groups, 18 rats from each, were trained to a criterion of 22/24 correct responses over two successive days on a black-white discrimination, as in Experiments 5.1 and 5.2. On the day following attainment of the learning criterion, 9 12-door subjects and 9 2-door subjects were transferred to the horizontal-vertical discrimination (phase 3) and the remainder began frustration training (Phase 2). Subjects were allotted to these conditions on the basis of their attainment of the initial learning criterion.

<u>Phase 2: frustration training</u>. Nine 12-door subjects and 9 2-door subjects from Phase 1 and 9 12-door and 9 2-door naive subjects were given 60 trials (5 days) of random reinforcement as in Experiment 5.2.

<u>Phase 3: transfer training</u>. All subjects were trained to a criterion of 22/24 correct responses over two consecutive days on the horizontal-vertical discrimination with the same procedure as had been used in the previous experiments. As far as possible subjects

were run in groups of 3 or 4 with an intertrial interval of 2-3 minutes. Subjects were allotted to groups with horizontal as S+ or vertical as S+ as equitably as possible in order to balance stimulus preferences and individual differences in learning ability.

Phase 4: reversal training. On the day following attainment of the transfer training criterion, all subjects were trained to a criterion of 22/24 correct responses over two consecutive days on the reversal of the horizontal-vertical discrimination.

RESULTS

Rate of learning

The results of Experiment 5.3, in terms of trials to criterion, are summarised in Table 5.31.

There was no difference in terms of trials to criterion between the four groups which learned the initial black-white discrimination ($F < 1$, $p > .05$). This was convenient in that these groups could be more easily compared on performance in the transfer task.

During frustration training (Phase 2) the frustration groups continued to respond to the stimulus which had been their S+ during the initial discrimination. The mean number of responses to the former S- was 4.1 and 4.6 for the 2-door and 12-door frustration groups respectively over the 60 random reinforcement trials.

A 2 x 4 analysis of variance, by the method of unweighted means for unequal cell frequencies (Winer, 1971), of the trials to criterion on the horizontal-vertical transfer task indicated a nonsignificant main effect for the 2- versus 12-door variable ($F(1,63) = 2.617$, $p > .05$) but there was a significant effect for the pretransfer treatment variable ($F(3,63) = 11.120$,

TABLE 5.31

Trials to criterion on the initial discrimination task (B/W), the transfer task (H/V) and its reversal in Experiment 5.3.

Group:		N	Phase 1 (B/W)		Phase 3 (H/V)		Phase 4 (Reversal	
Frustration	2-door	9	$\bar{X}$	: 54.2	$\bar{X}$	: 29.9	$\bar{X}$	: 97.1
			S.D.	: 26.2	S.D.	: 9.6	S.D.	: 17.1
	12-door	9	$\bar{X}$	: 58.1	$\bar{X}$	: 26.7	$\bar{X}$	: 133.8
			S.D.	: 21.6	S.D.	: 17.5	S.D.	: 27.1
Learning-to-learn	2-door	9	$\bar{X}$	: 53.3	$\bar{X}$	: 17.6	$\bar{X}$	: 95.3
			S.D.	: 20.5	S.D.	: 16.7	S.D.	: 32.7
	12-door	9	$\bar{X}$	: 57.4	$\bar{X}$	: 24.0	$\bar{X}$	: 110.3
			S.D.	: 22.0	S.D.	: 17.4	S.D.	: 54.4
Uncertainty	2-door	9	-		$\bar{X}$	: 47.3	$\bar{X}$	: 134.2
					S.D.	: 19.4	S.D.	: 70.8
	12-door	9	-		$\bar{X}$	: 60.8	$\bar{X}$	: 144.0
					S.D.	: 25.3	S.D.	: 39.7
Naive Control	2-door	8	-		$\bar{X}$	: 36.1	$\bar{X}$	: 100.0
					S.D.	: 15.1	S.D.	: 31.3
	12-door	9	-		$\bar{X}$	: 48.1	$\bar{X}$	: 151.5
					S.D.	: 15.3	S.D.	: 78.3

$p < .005$). The interaction effect was not significant ($F < 1$, $p > .05$).

Orthogonal planned comparisons (as in Winer, 1971, page 449) were made between the means of the 2- and 12-door groups but the differences were not significant ($t(63) < 1$, $p > .05$ for the frustration and learning-to-learn groups; $t(63) = 1.545$, $p > .05$ for the uncertainty groups; $t(63) = 1.312$, p .05 for the naive control group). However, the frustration groups, with the 2- and 12-door subjects combined, were significantly slower to reach criterion than the learning-to-learn control groups ($t(63) = 2.427$, $p < .01$) and the uncertainty groups differed significantly from the naive control groups ($t(63) = 3.799$, $p < .005$). Finally the groups which had learned the initial black-white discrimination acquired the horizontal-vertical discrimination faster than the groups which did not learn this initial task ($t(63) = 21.338$, $p < .005$). The course of transfer acquisition by the different groups is illustrated in Figures 5.31 and 5.32.

An analysis of variance of the trials to criterion for the reversal task revealed a significant effect on the 2- versus 12- variable ($F(1,63) = 5.299$, $p < .05$), a nonsignificant effect on the pretransfer treatment variable ($F(3,63) = 1.577$, $p > .05$) and a nonsignificant interaction effect ($F < 1$, $p > .05$). The same planned comparisons as were made on the horizontal-vertical acquisition scores were made on the reversal scores, i.e. between

2- and 12-door frustration ($t(63) = 1.515$, $p > .05$), learning-to-learn ($t < 1$, $p > .05$), uncertainty ($t < 1$, $p > .05$) and naive control groups ($t(63) = 2.033$, $p < .05$); between the frustration groups and the learning-to-learn control groups ($t(63) = 1.474$, $p > .05$) and between the uncertainty groups and the naive control groups ($t(63) = 1.536$, $p > .05$). The only significant differences were between the 2- and 12-door naive control groups and between the groups which learned the initial black-white discrimination and those which did not ($t(63) = 7.626$, $p < .005$). The course of reversal learning for the different groups is illustrated in Figures 5.33 and 5.34. The pattern of errors throughout the experiment corresponded closely with that of the trials to criterion.

Position responding

The amount of position responding observed in the 2-door groups is summarised in Table 5.32 in terms of the number of days on which subjects chose one side on more than 9 out of 12 trials.

FIGURE 5·31
ACQUISITION OF HORIZONTAL - VERTICAL TRANSFER TASK.
(Exp. 5·3 Phase 3) 2 - Door Groups.

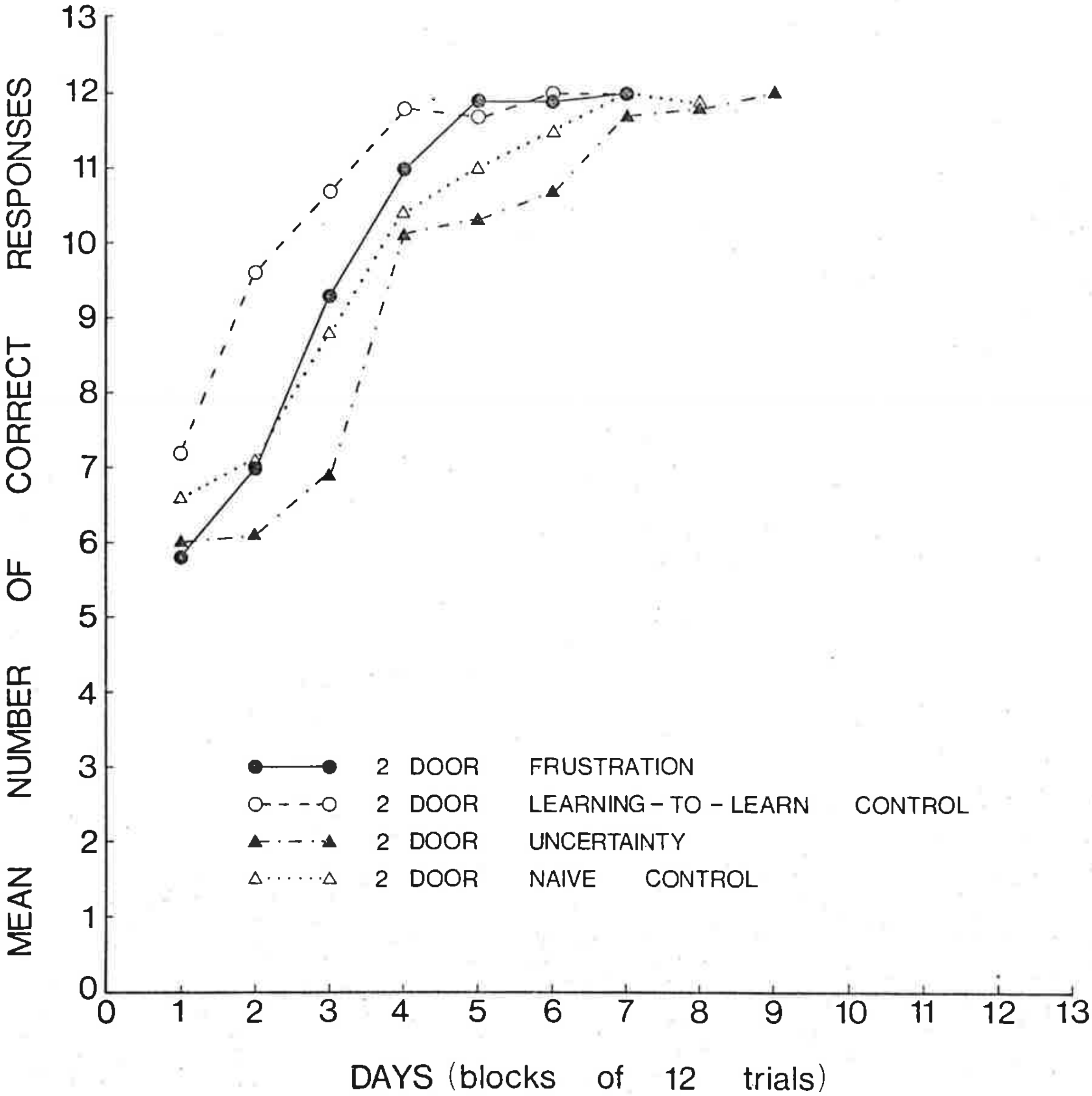


FIGURE 5·32

ACQUISITION OF HORIZONTAL - VERTICAL TRANSFER TASK.

(Exp. 5·3 Phase 3) 12 - Door Groups.

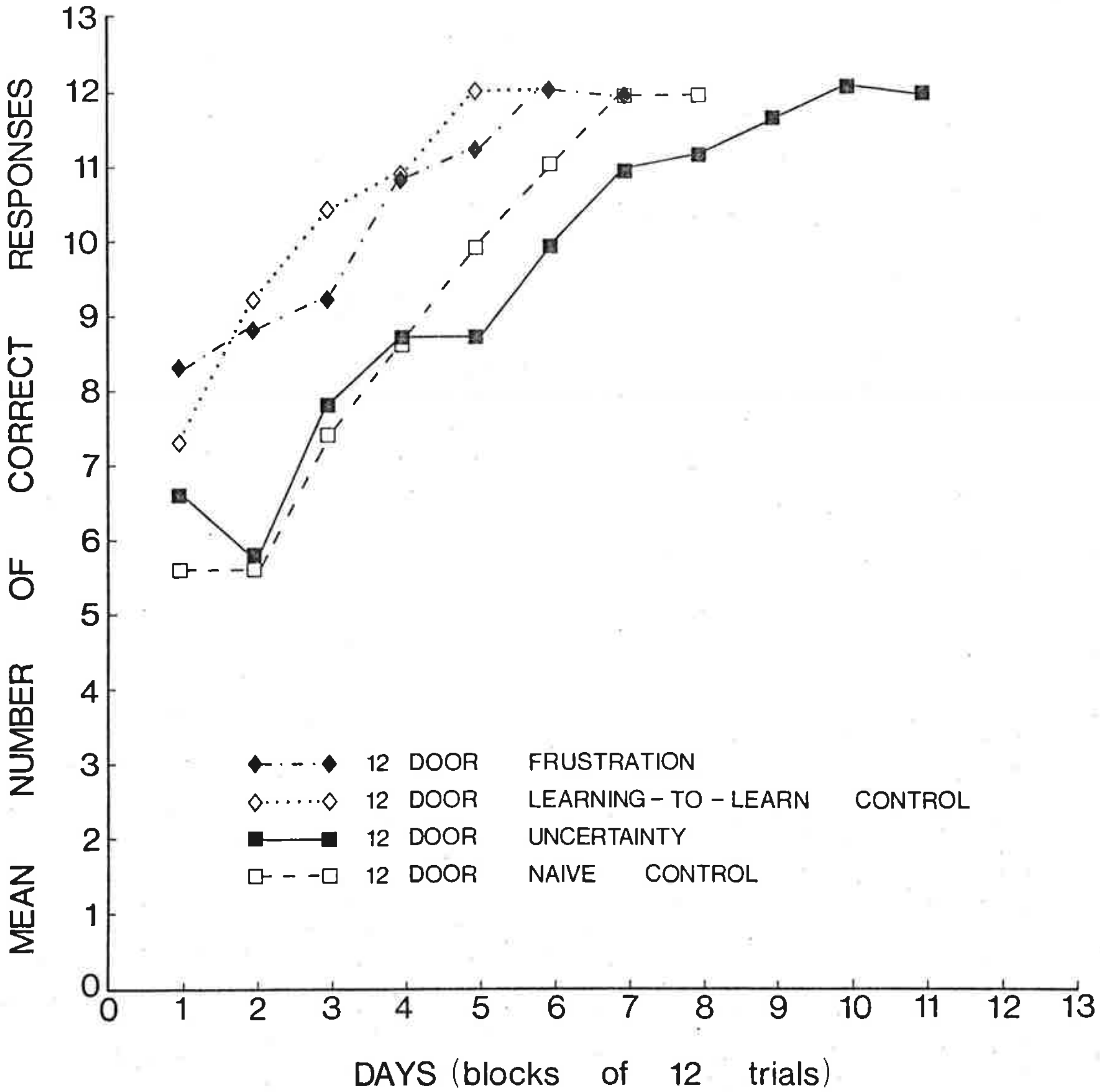
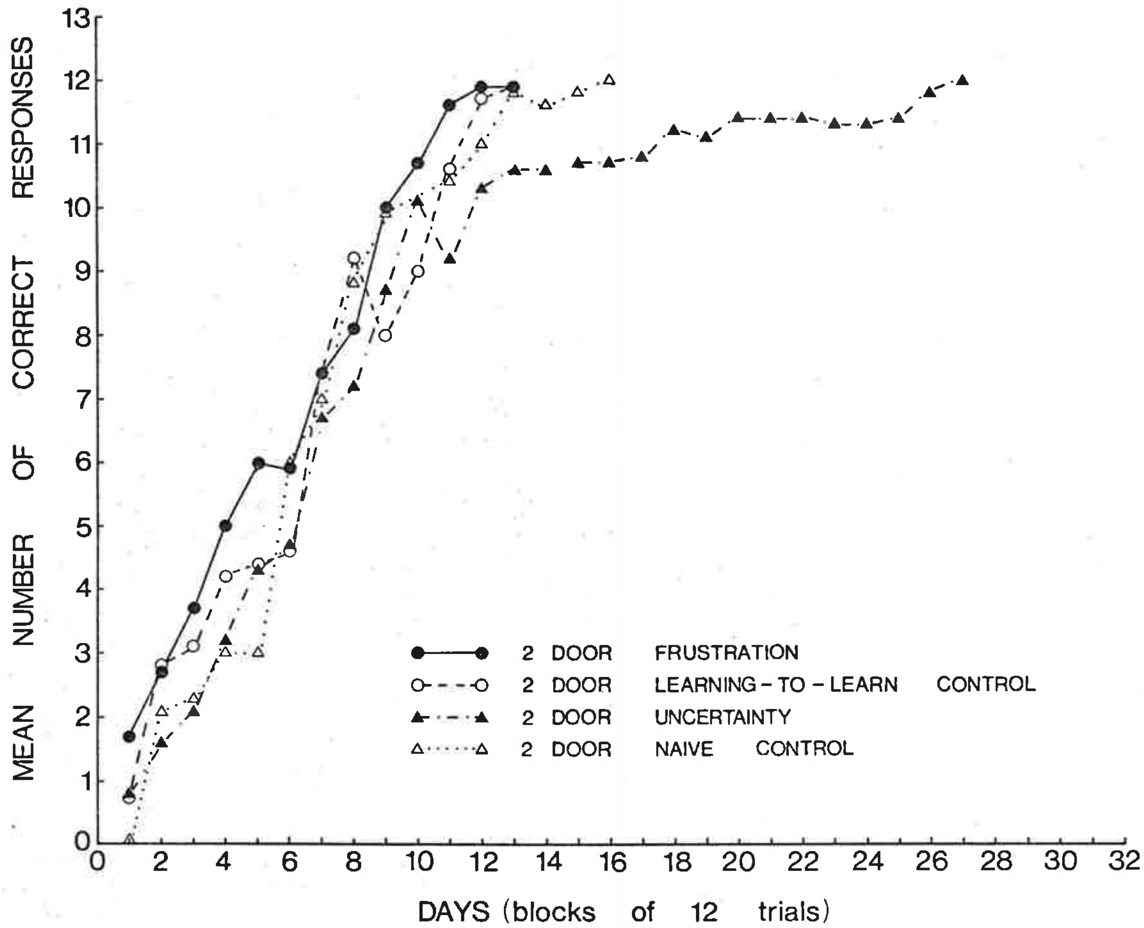


FIGURE 5·33

REVERSAL LEARNING OF THE HORIZONTAL – VERTICAL DISCRIMINATION.
(Exp. 5·3 PHASE 4) 2 – Door Groups.



REVERSAL LEARNING OF THE HORIZONTAL - VERTICAL DISCRIMINATION.
(Exp. 5·3 PHASE 4) 12 - Door Groups.

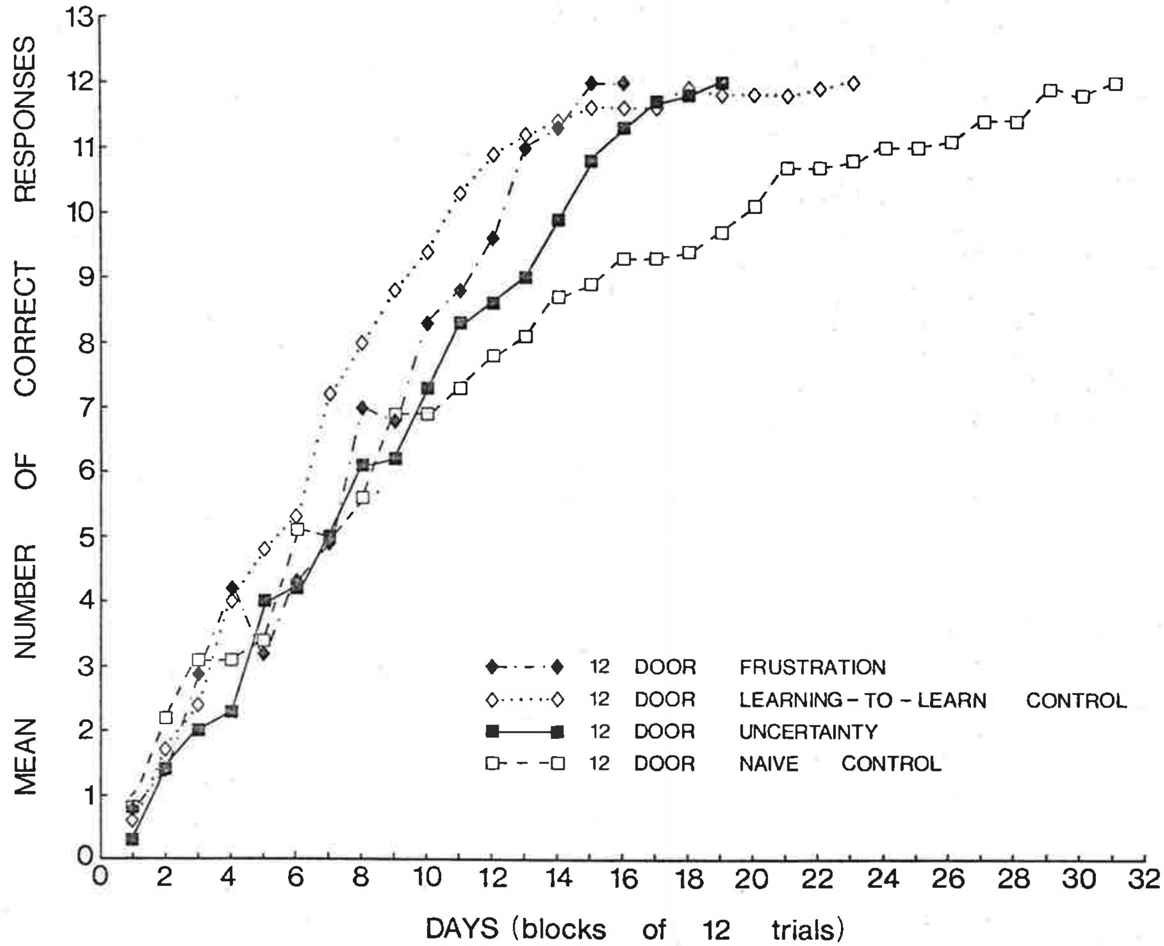


TABLE 5.32

Position responding by 2-door groups
(Days of more than 9/12 to one side)

Group	Phase 1 (B/W)	Phase 2	Phase 3 (H/V)	Phase 4
Frustration	$\bar{X}$: 1.7	$\bar{X}$: 0	$\bar{X}$: 0.7	$\bar{X}$: 2.9
Learning-to-learn control	$\bar{X}$: 2.8	-	$\bar{X}$: 0.4	$\bar{X}$: 2.9
Uncertainty	-	$\bar{X}$:2.1	$\bar{X}$: 2.4	$\bar{X}$: 5.0
Naive control	-	-	$\bar{X}$: 1.1	$\bar{X}$: 2.6

There was no significant difference between the frustration and learning-to-learn control groups as regards position responding during the initial black-white discrimination ($t(16) = 1.735$, $p > .05$, two-tailed). Since half the subjects scored zero days of position responding in the course of the transfer task, a nonparametric Kruskal-Wallis one-way analysis of variance (Siegel, 1956, p.184) was used to analyse the data. The difference between the groups was significant ($H = 9.611$, $df = 3$, $p < .05$). A one-way analysis of variance on position responding during reversal training was not significant ($F < 1$, $p > .05$).

In the 12-door groups, only 6 days of position responding were recorded throughout the entire experiment. The distribution of door preferences is summarised in Table 5.33. The overall pattern closely resembles that observed in Experiments 3.1 and 3.2.

TABLE 5.33

Door preferences in the 12-door subjects
Mean no. of trials per day on which most preferred door was chosen

Group:	Phase 1	Phase 2	Phase 3	Phase 4
Frustration	3.0	3.2	2.9	3.2
Learning-to-learn control	3.0	-	3.4	3.1
Uncertainty	-	3.0	3.2	3.6
Naive control	-	-	3.0	3.3

Perseverative responding

The amount of perseveration, in terms of both days on which subjects made more than 9/12 responses to the former S+ and the number of nonrewarded responses before the first correct response following the reversal of the horizontal-vertical discrimination, is indicated in Table 5.34.

TABLE 5.34

Perseverative responding during reversal training.

Group		Days of > 9/12 to former S+	No. of trials before a correct response
Frustration	2-door	$\bar{X}$: 1.9	$\bar{X}$: 9.0
	12-door	$\bar{X}$: 2.9	$\bar{X}$: 16.8
Learning-to-learn control	2-door	$\bar{X}$: 3.1	$\bar{X}$: 19.7
	12-door	$\bar{X}$: 2.7	$\bar{X}$: 16.4
Uncertainty	2-door	$\bar{X}$: 3.1	$\bar{X}$: 18.4
	12-door	$\bar{X}$: 4.3	$\bar{X}$: 20.4
Naive Control	2-door	$\bar{X}$: 3.1	$\bar{X}$: 18.3
	12-door	$\bar{X}$: 6.8	$\bar{X}$: 13.9

A 2 x 4 analysis of variance on the days of perseverative responding revealed no significant main effects on the 2- versus 12-door variable ($F(1,63) = 2.675$, $p > .05$) or pretransfer treatment variable ($F(3,63) = 1.822$, $p > .05$). The interaction effect was not significant ($F < 1$, $p > .05$). The only planned comparison which was significant was that between the groups with and without initial black-white training ($t(63) = 8.281$, $p < .005$ two-tailed).

The above results leave unanswered a number of questions and are subject to alternative explanations which can only be resolved by further experimentation. Consequently the detailed discussion of these results will be postponed until these experiments (Experiments 5.4, 5.5 and 5.6) have been described. However,some broad conclusions can be formulated.

(a) Random reinforcement did have an effect on the acquisition of the subsequent discrimination and this effect was more marked for the uncertainty groups than it was for the frustration groups.

(b) The presence or absence of spatial cues was not a critical factor except in reversal learning. Since this result merely replicated previous findings, and at great cost in time and energy, the reversal phase was not included in subsequent experiments. However, for relatively small groups, the differences between the 2- and 12-door uncertainty and naive control groups were promising. It seemed worthwhile to increase the number of subjects in these groups to determine whether the nonsignificance of the 2- versus 12-door effect was due to sample size. This was done in Experiment 5.4.

(c) Those groups which learned an initial black-white discrimination were greatly advantaged in learning the subsequent horizontal-vertical discrimination. This effect showed up in acquisition, perseveration and reversal scores.

One question which should be raised at this point concerns this weak effect of random reinforcement on the frustration groups and the apparent importance of the initial black-white discrimination. It is possible that the relatively fast acquisition of the horizontal-vertical discrimination by the frustration groups as compared with the uncertainty groups was due to the extent of the positive transfer from black-white to horizontal-vertical. Certainly, the learning-to-learn group provided a control condition, but only for positive transfer due to the experience of learning a discrimination before being shifted to the transfer task. It did not control for positive transfer due to the particular symbols used in the initial and transfer tasks, i.e. it did not exclude the possibility that a horizontal-vertical discrimination may be easier if subjects have already learned to distinguish between black and white. Indeed, Law (1954) showed that subjects trained with black as S+ prefer horizontal patterns and those trained with white as S+ prefer vertical patterns. To a certain extent, the question could only be answered by doing another experiment with different symbols. Such an investigation was incorporated in Experiments 5.5 and 5.6. Within experiment 5.3, however, it was possible to tell whether the particular values of the stimuli used, or particular combinations of these values used, had any effect on the learning of the transfer task, despite the counterbalanced design used to control this factor. When the data was broken down into subgroups on the basis of whether black or white was the S+ and whether the subject was transferred to horizontal or vertical, the number of subjects per group was too small to allow a meaningful analysis. However, there was some indication that subjects with white as their S+ were able to learn the transfer task faster if horizontal was S+ than if vertical was S+. This effect was more noticeable in the 2- and 12-door learning-to-learn groups than in the frustration groups. These sub-groups within the 2- and 12-door conditions were merged on the basis of which symbol was S+. The pattern which emerged is summarised in Table 5.35 The fact that the subgroups were not equal in terms of trials to criterion on the initial task was due to the overriding concern to allot subjects equitably to treatment groups.

Another possible explanation of the relatively weak effect of random reinforcement on the frustration groups is the possibility that the frustration subjects were not really frustrated by 60 trials of random reinforcement. This could be for two reasons: (a) the 50:50 reward:nonreward condition that constituted random reinforcement provided reward with sufficient frequency to offset the frustrative effect of nonreward;

TABLE 5.35

Transfer due to symbol preferences.

Direction of symbol transfer		Mean trials to criterion on Initial task	Transfer task
2 door Ss			
Black to	horizontal	33.8	27.2
	vertical	54.5	28.5
White to	horizontal	49.2	14.0
	vertical	83.8	26.8
12 door Ss			
Black to	horizontal	41.0	15.4
	vertical	64.3	26.8
White to	horizontal	64.2	11.2
	vertical	64.3	49.0

(b) the continuing presence of the stimulus which was S+ in the initial discrimination provided subjects with a consistent way of responding and one that, from the rat's point of view, was consistently rewarded according to a partial reinforcement schedule. In other words, it may not be the experience of being consistently rewarded on the initial task which helps subjects cope with later frustration, but the presence of a stimulus which has previously been associated with reward.

Subsequent experiments investigated these points by means of a more rigorous random reinforcement schedule (Experiment 5.5) and by random reinforcement of stimuli other than the stimuli used in the initial discrimination (Experiment 5.6).

EXPERIMENT 5.4. Replication of the uncertainty and naive control conditions from Experiment 5.3.

METHOD

The experimental design, apparatus and procedure used in this experiment were exactly the same as those used for the uncertainty and naive control groups of Experiment 5.3, except that Phase 4 (reversal of the horizontal-vertical discrimination) was not retained. A further 23 rats of the same type and condition as those used in Experiment 5.3 were distributed across the four experimental groups.

RESULTS

The results of both Experiment 5.4 and the uncertainty and naive control groups of Experiment 5.3 are combined in Table 5.4.

A 2 x 2 analysis of variance of the trials to criterion on the horizontal-vertical transfer task, revealed a significant main effect for the 2- vs. 12-condition ($F(1,54) = 4.746$, $p < .05$) and a nonsignificant pretransfer treatment effect ($F(1,54) = 1.323$, $p > .05$). The interaction effect was not significant ($F < 1$, $p > .05$). The same planned comparisons as had been made in Experiment 5.3 were made between the individual means. The difference between the 2- and 12- door uncertainty groups was significant ($t(54) = 1.773$, $p < .05$) whereas that between the 2- and 12-door naive control groups was not significant ($t(54) = 1.320$, $p > .05$). Although the pretraining main effect in the analysis of variance was not significant, the 2- and 12-door uncertainty groups were significantly different from the 2- and 12-door control groups ($t(54) = 2.302$, $p < .05$). These results do suggest that the failure to find a significant difference between the 2- and 12-door conditions in Experiment 5.3 may have been partly due to the fact

TABLE 5.4

Trials to criterion on the transfer task (H/V) of Experiment 5.4.

Group		Phase 3 (H/V)
Uncertainty	2-door	$\bar{X}$: 40.4
		S.D.: 20.7
		N : 15
	12-door	$\bar{X}$: 53.7
		S.D.: 23.2
		N : 15
Naive control	2-door	$\bar{X}$: 36.0
		S.D.: 14.1
		N : 14
	12-door	$\bar{X}$: 45.9
		S.D.: 18.5
		N : 14

that the number of subjects in the individual groups was not large. This should be borne in mind when the results of Experiment 5.3 are discussed.

EXPERIMENT 5.5. The effect of more severe frustration on subsequent discrimination learning.

Random reinforcement is usually taken to mean that, on any trial, the subject has a 50:50 chance of being rewarded. This was the schedule of random reinforcement used by Maier and it was the schedule of reinforcement that was used in the previous experiments reported in this thesis. However, it is possible that such a schedule of random reinforcement, providing as it does rewards on half the day's trials, is too generous to really frustrate the subjects. Consequently, a more severe schedule of reinforcement was used in this experiment.

METHOD

Experimental Design

The overall design of this experiment was essentially the same as that used in Experiment 5.1 and for the frustration and learning-to-learn control groups of Experiments 5.2 and 5.3, namely, an initial discrimination which was learned to criterion by all subjects followed by either a non-reversal shift to another solvable discrimination for half the subjects (the learning-to-learn control group) or a period of random reinforcement before the nonreversal shift for the remaining subjects (the frustration group). Two important changes made within this design were:

(a) the use of a more severe or more frustrating random reinforcement schedule for the frustration group. Instead of a 50:50 schedule a 25:75 reward:nonreward schedule was used. No matter what response was adopted during frustration training, only 25 per cent of the responses, or 3/12 per day, resulted in the subject being rewarded. Since the stimuli used in the initial discrimination remained present during frustration training, the nonfulfilment of the subject's expectancies was assumed to be more acute.

(b) a more difficult transfer task was used in the hope that an extended training period would differentiate between the frustration and the control group. The transfer task used was the light grey-dark grey discrimination used in Experiments 3.1 and 3.2.

Hence the stages of the experiment were as follows:

Phase 1: a horizontal-vertical discrimination learned to criterion by all subjects.

Phase 2: random reinforcement for 60 trials according to a 25:75 reward nonreward schedule for half the subjects (the frustration group) with the horizontal-vertical discriminanda present.

Phase 3: nonreversal shift of all subjects to the light grey-dark grey discrimination which was learned to criterion and used to assess the effect of frustration training.

Subjects

The subjects in this experiment were 40 experimentally naive, male, Wistar strain, hooded rats which were approximately 100 days old at the beginning of pretraining. They were maintained at 85 per cent of their ad lib. body weight throughout the experiment but had water available at all times.

Apparatus

The apparatus was the circular maze. The horizontal-vertical discriminanda were the same as those used in the previous experiments in this chapter. The light grey-dark grey discriminanda were the same as those used in Experiments 3.1 and 3.2.

Procedure

The procedure used in this experiment was the same as that used for the frustration and learning-to-learn control groups in the previous experiments described in this chapter. The reinforcement schedule used in Phase 2 was such that only 3 rewards were provided each day - one occurring randomly in each block of 4 trials.

RESULTS

The results of Experiment 5.5 are summarised in Table 5.5.

TABLE 5.5

Trials to criterion on the initial discrimination (H/V)and the transfer task (light-dark grey) of Experiment 5.5.

Group		N:	Phase 1 (H/V)	Phase 3 (light-dark grey)
Frustration	2-door	10	$\bar{X}$: 42.2 S.D.: 13.4	$\bar{X}$: 134.2 S.D.: 56.7
	12-door	10	$\bar{X}$: 57.7 S.D.: 27.8	$\bar{X}$: 131.4 S.D. 59.1
Learning-to-learn	2-door	10	$\bar{X}$: 42.3 S.D.: 8.7	$\bar{X}$: 125.3 S.D.: 41.6
	12-door	10	$\bar{X}$: 56.9 S.D.: 21.7	$\bar{X}$: 121.8 S.D.: 49.2
All subjects	2-door	20	$\bar{X}$: 42.3 S.D.: 11.3	
	12-door	20	$\bar{X}$: 57.2 S.D.: 24.9	

The 2-door subjects learned the initial horizontal-vertical discrimination faster than the 12-door subjects ($t(38) = 2.383$, $p < .05$). Consequently, the four experimental groups could not be equated in terms of trials to criterion on the initial task. However, within the 12-door subjects and within the 2-door subjects there was no difference between frustration and control subjects on the initial task.

A 2 x 2 analysis of variance of the trials to criterion on the light grey-dark grey transfer task revealed that neither of the main effects nor the interaction effect were significant ($F < 1$, $p > .05$ in all cases). It is possible that the use of the more difficult transfer task had the opposite effect from what was intended, i.e. it may have obscured any difference existing between the frustration and control groups at the beginning of the transfer task. Alternatively the 25:75 random reinforcement schedule may have had the same effect as a longer period on a 50:50 schedule (Cf. Experiment 5.1), i.e. by the time subjects are transferred to the test task they have become so used to inconsistent reinforcement that it is no longer frustrating. However, in the light of the results of the previous experiments, the more likely conclusion is that an initial solvable task preceding frustration, weakens the effect of the frustrating operation on a subsequent transfer task. Among the 12-door subjects there were no instances of position responding. The pattern of door preferences is summarised in Table 5.52.

TABLE 5.52

Door preferences in the 12-door subjects

Mean no. of trials per day on which most preferred door was chosen

Group:	Phase 1	Phase 2	Phase 3
Frustration	3.3	4.1	2.9
Learning-to-learn	3.0	-	3.4

EXPERIMENT 5.6. Random reinforcement in the presence of novel stimuli and its effect on a subsequent discrimination.

In the preceding experiments (Experiments 5.1, 5.2, 5.3 and 5.5) the frustration group was transferred from an initial, solvable discrimination to a random reinforcement situation in which the stimuli used in the initial discrimination were present, but randomly reinforced. The reason for this procedure was to ensure that the subjects came to the random reinforcement situation with definite expectations. The results of Experiments 5.3 and 5.5. indicated that the effect of random reinforcement on a subsequent discrimination task was itself affected by this initial discrimination. It is not clear whether the initial discrimination has its effect irrespective of the discriminanda present during random reinforcement, or whether it is necessary for the same stimuli to be present during random reinforcement as were present during the initial discrimination. As has been said, it may not be the experience of acquiring the initial discrimination which helps subjects cope with later frustration, but rather the presence of a stimulus to which the subject has learned to make a response.

METHOD

Experimental Design

The overall design of Experiment 5.6 was the same as that used for the frustration and learning-to-learn control groups in Experiments 5.1, 5.2 and 5.3, except that the discriminanda for the initial task (large and small checkerboard patterns) were not present during the random reinforcement. Instead they were replaced by the usual black-white discriminanda. Hence the stages of the experiment were:

Phase 1: an initial discrimination between large and small checkerboard patterns.

Phase 2: 60 trials of random reinforcement (50:50) for the frustration group with the black-white discriminanda present.

Phase 3: nonreversal shift of all subjects to a horizontal-vertical discrimination task.

Subjects

The subjects in this experiment were 30 experimentally naive, male, Wistar strain, hooded rats which were experimentally naive at the beginning of pretraining. They were maintained at 85 per cent of their ad lib body weight but had water available at all times.

Apparatus

The apparatus was the circular maze. The checkerboard discriminanda consisted of alternating black and white squares which were either 1.2 x 1.2 cms large (small pattern: 48 squares per door) or 4.5 x 3.5 cms large (large pattern: 4 squares per door). The black-white and horizontal-vertical discriminanda were the same as those used in previous experiments.

Procedure

The procedure used in this experiment was the same procedure as that used for the frustration and learning-to-learn control groups in the previous experiments.

RESULTS

The results of Experiment 5.6 are summarised in Table 5.61.

TABLE 5.61.

Trials to criterion on the initial discrimination (large-small checkerboard) and the transfer task (H/V) of Experiment 5.6.

Group			Phase 1 (large-small check)	Phase 3 (H/V)
Frustration	2-door	8	$\bar{X}$: 77.3 S.D. : 30.2	$\bar{X}$: 55.6 S.D. : 27.8
	12-door	8	$\bar{X}$: 71.0 S.D. : 25.2	$\bar{X}$: 32.8 S.D. : 18.5
Learning-to-learn control	2-door	7	$\bar{X}$: 79.1 S.D. : 32.4	$\bar{X}$: 36.1 S.D. : 32.7
	12-door	7	$\bar{X}$: 64.1 S.D. : 16.9	$\bar{X}$: 15.6 S.D. : 12.3

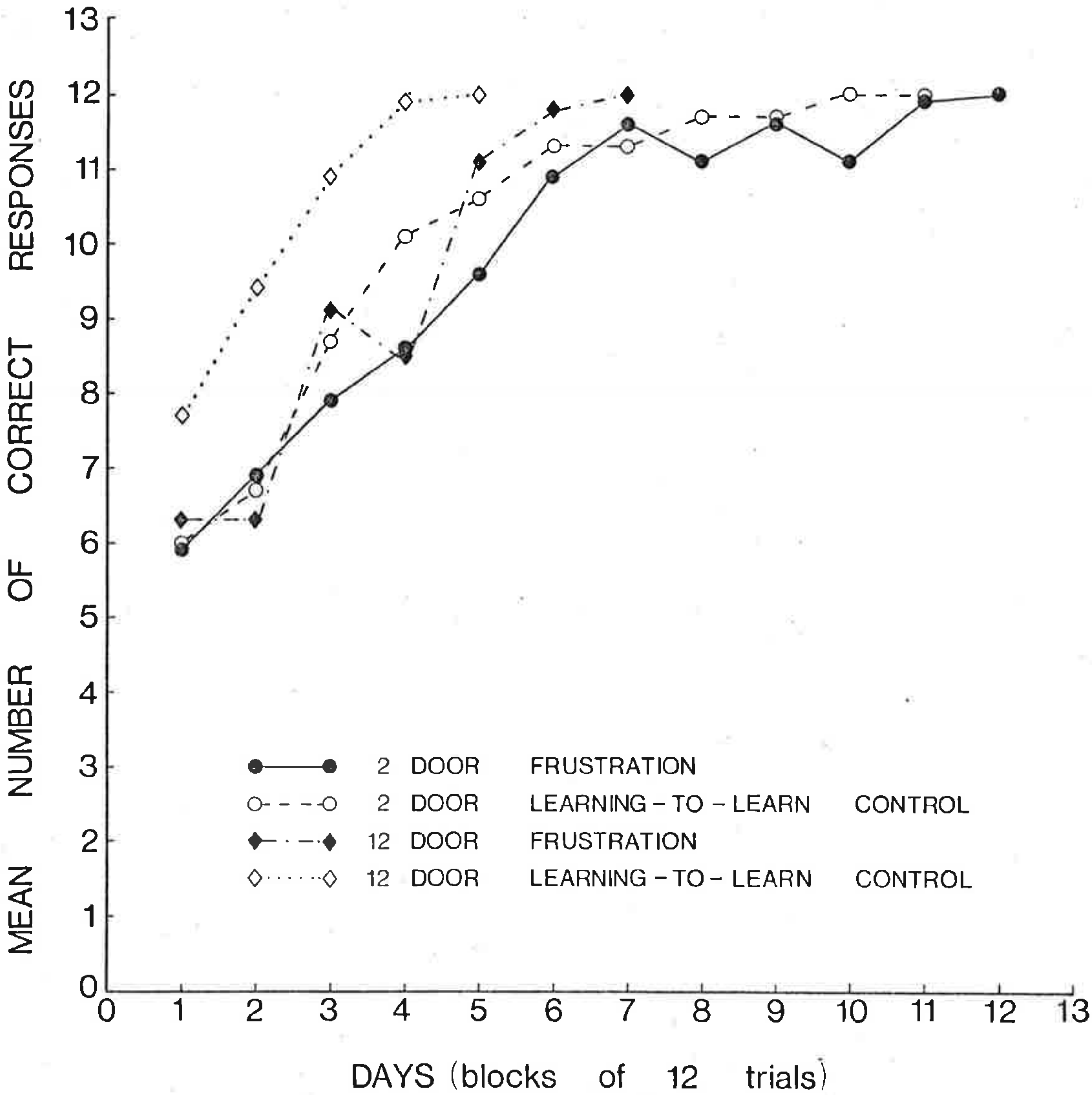
There was no significant difference between the 4 groups on the initial discrimination ($F < 1$, $p > .05$) although the 12-door subjects did learn this discrimination faster than the 2-door subjects (mean trials to criterion were 67.8 and 78.1 trials respectively).

A 2 x 2 analysis of variance on the trials to criterion revealed a significant main effect on the 2- vs. 12-door variable ($F(1,26) = 5.245$, $p < .05$) and a nonsignificant pretransfer treatment effect ($F(1,26) = 3.736$, $p > .05$). The interaction effect was not significant ($F < 1$, $p > .05$). The planned comparisons which were made between the group means in previous experiments would have been meaningless in this case since both frustration and learning-to-learn 12-door groups acquired the transfer discrimination faster than the 2-door groups. The planned comparison for the 2- versus 12-door frustration and control groups yielded $t(26) = 1.759$ and $t(26) = 1.480$ respectively.) However, the learning-to-learn control groups combined did learn the transfer task faster than the frustration groups ($t(26) = 3.868$, $p < .005$).

These results create certain problems of interpretation, but they do indicate that the acquisition of an initial discrimination does modify the effect of frustration on a subsequent discrimination irrespective of whether or not the stimuli present during random reinforcement are those present during the initial discrimination. The difficulty of interpretation springs from the fact that when the discriminanda present during the random reinforcement are different from the discriminanda of the initial discrimination the presence or absence of spatial cues appears to become important. In order to throw some light on the pattern of responding, the course of transfer learning is illustrated in Figure 5.6 and the position responding of the 2-door subjects is summarised in Table 5.62. As far as the 2-door subjects are concerned, there was no significant difference between

FIGURE 5·6

ACQUISITION OF HORIZONTAL - VERTICAL TRANSFER TASK.
(Exp. 5·6 Phase 3)



the amount of position responding during the initial discrimination ($t < 1$, $p > .05$) or on the transfer task ($t(13) = 1.009$, $p > .05$). Seven days of position responding were recorded for the 12-door subjects. The distribution of door preferences is summarised in Table 5.63.

TABLE 5.62

Position responding by the 2-door groups in Experiment 5.6 (Days of more than 9/12 to one side).

Group	Phase 1 (large-small check)	Phase 2	Phase 3 (H/V)
Frustration	$\bar{X}$: 4.4 S.D. : 3.3	$\bar{X}$: 2.9 S.D.: 1.7	$\bar{X}$: 2.5 S.D. : 1.7
Learning-to-learn control	$\bar{X}$: 3.0 S.D. : 2.0	-	$\bar{X}$: 1.7 S.D. : 2.0

TABLE 5.63

Door preferences in 12-door subjects

Group	Phase 1	Phase 2	Phase 3
Frustration	3.9	4.6	4.2
Learning-to-learn control	2.9	-	3.8

The results of Experiments 5.1 - 5.6 will be discussed in the following chapter. An attempt will be made to outline the conclusions which can be drawn at this stage of the thesis.

CHAPTER 6

SOME CONCLUSIONS ABOUT THE EFFECT OF FRUSTRATION AND REDUCED SPATIAL CUES ON DISCRIMINATION LEARNING.

The preceding chapters have been concerned with two questions, which, although distinct issues, have implications one for the other. These questions are:

(a) What is the effect of reduced spatial cues on discrimination learning? What role does position responding play in the learning process?

(b) What is the effect of frustration on discrimination learning? What is the nature of the relationship between position responding and frustration?

The question of position responding will be discussed first since it is the less complex of the two and has already been discussed in some detail.

Quite a large amount of data has been gathered from experiments in the circular maze in which 2- and 12-door conditions were compared. Some of these comparisons were complicated by overtraining, frustration or transfer operations, but it is possible to compare those involving the learning of a simple discrimination by naive subjects, or the reversal of such a discrimination. Table 6.1 summarises the findings of a number of experiments involving a simple discrimination and Table 6.2 summarises those involving reversal learning. There was a strong trend in this data favouring a conclusion of no difference between the two conditions. Where there was a significant difference it was in favour of the 2-door groups. These were instances involving a large number of subjects (Experiment 5.5) a very difficult discrimination (Experiment 3.1), or reversal learning. Why there should have been a significant difference in Experiment 5.5 and not

TABLE 6.1

Comparison of 2- and 12-door conditions in various experiments: discrimination learning by naive subjects

Discriminanda:				
Black-white	$\bar{X}_2$ =	30.6	N=10	(Buxton, 1968)
	$\bar{X}_{12}$ =	32.8	N=10	
" "	$\bar{X}_2$ =	35.3	N=9	(Winefield & Jeeves, 1970b)
	$\bar{X}_{12}$ =	29.5	N=10	
" "	$\bar{X}_2$ =	48.8	N=6	(Experiment 5.1)
	$\bar{X}_{12}$ =	49.0	N=6	
" "	$\bar{X}_2$ =	39.2	N=4	(Experiment 5.2)
	$\bar{X}_{12}$ =	58.3	N=3	
" "	$\bar{X}_2$ =	53.7	N=18	(Experiment 5.3)
	$\bar{X}_{12}$ =	57.7	N=18	
Horizontal-Vertical	$\bar{X}_2$ =	31.8	N=12	(Mullins, 1969)
	$\bar{X}_{12}$ =	27.7	N=12	
" "	$\bar{X}_2$ =	50.2	N=20	(Experiment 3.2)
	$\bar{X}_{12}$ =	47.1	N=20	
" "	$\bar{X}_2$ =	36.0	N=14	(Experiment 5.4)
	$\bar{X}_{12}$ =	45.9	N=14	
" "	$\bar{X}_2$ =	42.3	N=20	(Experiment 5.5)
	$\bar{X}_{12}$ =	57.2	N=20	
Light-dark grey	$\bar{X}_2$ =	89.7	N=11	(Experiment 3.1)
	$\bar{X}_{12}$ =	117.7	N=11	
Large-small checkerboard	$\bar{X}_2$ =	78.1	N=15	(Experiment 5.6)
	$\bar{X}_{12}$ =	67.8	N=15	

TABLE 6.2

Comparison of 2- and 12-door conditions in various experiments: reversal learning.

Discriminanda:

Black-white	$\bar{X}_2$	= 42.4	N=10	(Buxton, 1968)
	$\bar{X}_{12}$	= 59.0	N=10	
" "	$\bar{X}_2$	= 52.7	N=9	(Winefield & Jeeves, 1970b)
	$Median_{12}$	= 74.0	N=10	
Horizontal-vertical	$\bar{X}_2$	= 97.4	N=12	(Mullins, 1969)
	$\bar{X}_{12}$	= 95.8	N=12	
" "	$\bar{X}_2$	= 100.0	N=8	(Experiment 5.3)
	$\bar{X}_{12}$	= 151.5	N=9	
Light-dark grey	$\bar{X}_2$	= 211.5	N=5	(Experiment 3.1)
	$\bar{X}_{12}$	= 334.2	N=5	

one in Experiment 3.2, with just as many subjects, or in Experiment 5.4, is particularly difficult to explain. It may have been due to differences in batches of rats, but such explanations lead to the same problems faced by Maier and Ellen (1959) when they attempted to list the variables which might explain why a specific response is fixated by any particular rat. Either the beneficial effects of spatial cues are rather unstable or the necessary and sufficient conditions for their occurrence remain to be specified.

The findings of Experiments 3.1 and 3.2 must be added to the evidence presented in Tables 6.1 and 6.2. These experiments were designed to test directly the widely held view that position responding is detrimental to discrimination learning in cases of overtraining and nonreversal shift. In neither experiment did the results support this view. Hence the conclusion suggested in Chapter 3 ought to be adopted: in most situations the presence or absence of spatial cues makes little difference to the rats' ability to master a simultaneous visual discrimination, and, in some situations, especially a difficult discrimination or reversal, the presence of spatial cues may facilitate performance.

A recent experiment carried out in the circular maze does provide support for the traditional view of position responding. Winefield (1973) studied the performance of rats over 12 reversals of a black-white discrimination under 2- and 12-door conditions. One aim of this study was to obtain a more sensitive measure of learning than simple discrimination and reversal performance for the comparison of 2- and 12-door conditions. Winefield found little difference between the two groups on the initial discrimination and the first reversal, as one would expect from previous work in the circular maze, but thereafter the performance of the 2-door subjects deteriorated whereas that of the 12-door group steadily improved. By the fifth reversal the 12-door subjects were performing better than they had on the initial discrimination. Deterioration in the 2-door subjects was associated with increased position responding whereas perseverative errors declined <u>for both groups</u> in a very similar fashion. Winefield argued that the superior performance of the 12-door subjects suggested the possibility of a mechanism which applies to the re-acquisition of previously learned habits but not to the acquisition of new habits (i.e. initial discrimination and first reversal). Clearly, further research with serial reversal is required, and is in hand, but the results of the Winefield study must be kept in mind when the data reported in this thesis is evaluated.

A second point which must also be considered concerns the experimental design used in the present series of experiments. The conclusion of no difference between 2- and 12-door conditions expressed above holds only if one accepts that the circular maze does what it was designed to do, i.e. significantly reduce position responding. The features of the apparatus, the details of procedure and the measures to be taken relevant to this point are outlined in Chapter 2. The degree of "position responding" recorded by the 12-door subjects in the experiments described in Chapters 3 and 5 was negligible. On this score at least, the maze proved effective. As regards door preferences among the 12-door subjects, the mean daily response to the most preferred door ranged between 2.7 and 4.6 over 33 groups. On the average, subjects chose the same door no more than 3 or 4 times on any one day. The problem of determining, mathematically, the expected frequency of response if the subjects' choice was indeed random is formidable (cf. Hays, 1963, pp. 154, 155). However a computer was used to generate 1000 sequences of numbers between 1 and 12 in which any number was equiprobable. Three samples of 1000 sequences were taken. The programme determined the frequency of the most common number from each sequence. The means of the three samples were 2.870, 2.894 and 2.882. The computer procedure was repeated but with 6 equiprobable numbers. The means of the three samples were 3.855, 3.889 and 3.876. These two sets of means represent the two extreme conditions of the 12-door subjects, i.e.

the situation before the subjects have learned anything about the discrimination and are randomly selecting any one of the 12 doors, and the situation after the subjects have learned to make a choice of one of the 6 correct doors. Reference to Tables 3.16, 3.23, 5.33, 5.52 and 5.62 shows that the rats behaved about as randomly in their choice of doors as one might expect. The circular maze does reduce position responding.

On the whole then, the conclusion stated above, has reasonable support. It is not a trivial conclusion in two senses. Firstly, the assumption that position responding is detrimental to discrimination learning is made by a number of theorists of very different persuasion, and it underlies, in quite a basic fashion, their theories of discrimination learning (Cf. Chapter 1). If it is not supported the theories are, to that extent weakened. Secondly, from a more practical point of view, there is evidence that position responding is not confined to rats but extends to children and even adults (Zeaman and House, 1963; Hill, 1965; Arnberg and Rydberg, 1972).

The second question to be considered in this chapter concerns the effect of frustration on discrimination learning. This involves the results of Experiments 5.1 to 5.6 Experiments 5.1 and 5.2 were pilot studies and merely indicated the usefulness of further research on:

(a) the effects of different frustrating operations on subsequent discrimination learning,

(b) the effect of such frustrating operations under conditions of reduced spatial cues.

The major study was Experiment 5.3 and the results of this experiment showed that frustration did have a detrimental effect on subsequent learning, and that this effect varied according to the type of frustration preceding the discrimination learning. That the random reinforcement treatment had an effect is shown by the comparison of the Amsel-type frustration groups with the learning-to-learn control groups and of the uncertainty groups with the naive control groups. Planned comparisons in both cases were significant. The implication of this finding is that, despite the frequent lack of clarity about what is meant by frustration, at least two different kinds of frustrating operation have detrimental effects on subsequent learning. Secondly, uncertainty seemed to have a more detrimental effect than Amsel-type frustration in that the difference between the frustration group and the appropriate control was more marked in the former case. The basis of this result seemed, at first sight,to be the presence or otherwise of a stimulus to which subjects had learned to respond. In the absence of such a stimulus, subjects, during random reinforcement, responded on the basis of spatial cues, or, if 12-door subjects, in the more or less haphazard manner described above. In the presence of such a stimulus, subjects responded consistently to that cue and were rewarded for doing so on 50 per cent of the trials. It might be considered, from the rat's point of view, that the situation involved a shift from continuous or 100 per cent reinforcement to 50 per cent reinforcement for the same response, rather than a shift from a learned discrimination to an insolvable problem. This finding was consistent with a variety of previously reported research. As far back as Maier and Klee (1943) it was found that when subjects were transferred from a solvable task to a random reinforcement schedule, they persisted in the response adopted in the initial stage. More recently, Tanner (1967), who continued Maier's line of research, found that random reinforcement had no effect on a subsequent task if the first stage was preceded by a solvable task. Using aversive stimulation, Seligman and Maier (1967) found that prior experience with escapable shock immunised subjects against the "learned helplessness" which usually resulted from such experience (Maier, Seligman and Solomon, 1969). The detrimental effect of random reinforcement on human learning reported by Levine (1962, 1963b) was not found by Trabasso and Staudenmayer (1968) when discrimination training preceded random reinforcement. Finally, Wagner et al (1968) found that the discrimination of subjects transferred from the TD to the PD condition (from true to pseudodiscrimination) deteriorated, but not as badly as subjects which were consistently, randomly reinforced. On the other hand, Eck et al (1969) found that pigeons which were differentially reinforced on a line-tilt discrimination (TD group) learned a wavelength and a brightness discrimination more rapidly than subjects whose initial experience was random reinforcement (PD group). Mandler (1966) using rats, found that a period of random reinforcement preceding a brightness discrimination resulted in deterioration in performance by comparison with naive subjects. These findings were replicated in the uncertainty and naive control groups.

However, in a more recent paper Mandler and Goldberg (1973) investigated the effect of partial or continuous reinforcement on the acquisition of a subsequent discrimination task. They found that, irrespective of whether the partial or continuous reinforcement was given in the presence of one or both of the stimuli which constituted the subsequent discrimination, in the presence of different stimuli or without distinctive stimuli being present at all, neither partial nor continuous reinforcement had much effect on subsequent choice learning. Partial reinforcement did affect the latency of choice responding. Mandler and Goldberg argued that the latency data, but not the choice data, was compatible with Amsel and Ward's (1965) application of frustration theory, i.e. that partial reinforcement should retard subsequent discrimination because approach responses become conditioned to frustration cues associated with nonreward. Conversely, the choice data, but not the latency data, were seen as compatible with Sutherland and Mackintosh's (1971) attention theory which predicted that neither continuous nor partial reward, delivered prior to discrimination learning, would affect attention to the relevant dimension and, consequently, subsequent learning.

However, in another recent paper, Waller (1973) made quite a different prediction on the basis of Sutherland and Mackintosh's (1971) theory and, in an experiment similar in many respects to that of Mandler and Goldberg, found quite different results. Waller assumed that random, partial reinforcement would diminish the strength of attention to prominent environmental cues and so affect discrimination learning. In his first experiment, Waller gave rats partial or continuous reinforcement either in a grey runway or in one with vertical stripes. On a subsequent stripe-orientation discrimination task (45° to the left of vertical versus 45° to the right), partial reinforcement training in the presence of stripes led to inferior performance, whereas subjects given partially and continuously reinforced training in the grey runway performed at a similar level. In a second experiment, Waller gave partial or continuous reinforcement in the presence of stripes randomly varying in orientation. This training did not affect the acquisition, by either group, of a compound-cue discrimination task in which both orientation and width of stripes were relevant. Nor did these groups differ from naive control subjects on this task. However, subsequent single-stimulus transfer tests revealed that the partially reinforced subjects learned less about orientation than the other groups. Waller concluded that his results supported Mackintosh and Sutherland's (1971) theory. Partial reinforcement suppressed attention to cues present in the runway and so affected subsequent learning. In the absence of such cues, partial reinforcement had little effect on subsequent learning.

The results of both Mandler and Goldberg (1973) and Waller (1973), although differing with each other, also differ with the findings reported in Chapter 5. Mandler and Goldberg found no difference between the effect of partial and continuous reinforcement on subsequent discrimination and Waller found a much more specific effect of partial reinforcement than was observed in the experiments reported above. The most likely explanation is that neither Mandler and Goldberg nor Waller allowed their subjects free choice during the initial training. Mandler and Goldberg did so to prevent the development of position habits and so to avoid the possibility of the retardation of subsequent learning being due to position responding, as in Mandler (1966). However, the results of the 2- versus 12-door comparisons discussed below, indicate that this issue is not all that critical. It would seem that a general detrimental effect of frustration is only demonstrated when the frustrating operation is imposed on a free-choice situation.

The presence or absence of spatial cues in Experiment 5.3 at least on the transfer task, did not appear to be a significant factor. It should be noted, however, that in every case, except the Amsel-type frustration, the 2-door group learned the transfer task faster than the 12-door group. The results of Experiment 5.6 complicated this straightforward interpretation, but, overall, there seemed to be little support either for the idea that position responding reflects an internal state of frustration (Mandler, 1966), or for the alternative suggestion, based on work in the circular maze, that the presence of spatial cues somehow allows subjects to cope with frustration. The results of Experiment 5.3 contributed more to an understanding of the effects of frustration as such than to an understanding of the role of position responding.

Experiments 5.4 and 5.5 were in the nature of follow-up studies which eliminated several possible explanations of the data of Experiment 5.3. Experiment 5.4 indicated that the rather small sample size had not had an undue effect on the results. Experiment 5.5 considered another possible explanation, i.e. that the difference between the frustration and uncertainty groups and the lack of difference between the 2- and 12-door conditions was due to the frustration group not being severely enough frustrated. Maier and Ellen (1955) had found that 80:20 or 20:80 schedules of random reinforcement induced more fixations than a 50:50 schedule. On the other hand, Coghlan (1970) found a stronger frustration effect, in the Amsel sense of the word, with a 50:50 schedule of partial reinforcement than with a 20:80 or 80:20 schedule. However, a 50:50 schedule of inconsistent reinforcement in Experiment 5.3 and a 25:75 schedule in Experiment 5.5 produced very much the same pattern of results. Indeed, the difference between the frustration and the learning-to-learn control groups was less marked in Experiment 5.5 than in 5.3.

Experiment 5.6 was designed to investigate the most important aspect of the Experiment 5.3 results: namely the possibility that the results of the frustration and learning-to-learn control groups were dependent on the presence, during random reinforcement, of a cue previously associated with reward. In some ways the results of Experiment 5.6 merely complicated the picture. However, it does appear that, not only did frustration still have an effect on subsequent discrimination learning when the S+ of the initial discrimination was no longer present, but, under this condition, the performance of the frustration groups deteriorated to a level comparable to that of the uncertainty groups in Experiment 5.3. This conclusion must be qualified in the light of three factors:

(a) It can be very misleading to make comparisons between groups from different experiments even when they are run under comparable conditions. A glance at Table 6.1 indicates the variability of the rate of learning displayed by groups in different experiments even when the discriminanda were identical.

(b) The effect of reduced spatial cues is quite significant in Experiment 5.6, whereas it had not been so in Experiment 5.3. Moreover, the effect was in favour of the 12-door subjects in Experiment 5.6, whereas it tended to be in favour of the 2-door subjects in Experiment 5.3.

(c) If the performance of both learning-to-learn control groups in Experiment 5.6 had shown similar deterioration, the results could have been explained in terms of some perceptual characteristics of the discriminanda, i.e. that there was more positive transfer when subjects shifted from black-white to horizontal-vertical than when they shifted from large-small checkerboard to horizontal-vertical. However, only the performance of the 2-door learning-to-learn control group suffered by comparison with the learning-to-learn control groups from Experiment 5.3. Indeed it ought to be noted that in all the experiments involving a non-reversal shift (Experiment 3.2, 2→2 and 12→12 groups, and the learning-to-learn control groups of Experiment 5.3, black-white to horizontal-vertical, Experiment 5.5, horizontal-vertical to light-dark grey, and Experiment 5.6, large-small checkerboard to horizontal-vertical) there was no marked difference between the 2- and 12-door groups, despite the fact that in at least two cases (Experiments 3.1 and 5.5) naive 2-door subjects could learn the discrimination faster than 12-door subjects. As Winefield (1973) suggested in relation to serial reversal, it may be that once 12-door subjects are switched in to the relevant modality or set of relevant cues, they are less prone to distraction than 2-door subjects which retain a tendency to revert to position responding.

With the above cautions in mind, it is still possible to conclude that frustration had a detrimental effect on subsequent learning irrespective of the discriminanda present during frustration training since, in both Experiments 5.3 and 5.6, the learning-to-learn control groups did acquire the subsequent discrimination faster than the frustration groups. This general deterioration in the quality of performance as a result of frustration, with the specific reaction depending on circumstances, is consistent with the ideas of Child and Waterhouse (1953) and Waterhouse and Child (1953) and, more recently, of Schmeck and his associates (Schmeck and Bruning, 1968, 1970; Schmeck, 1970; Bruning, Schmeck and Silver, 1971). Position responding is not so much a reaction to frustration as a readily available response which is adopted in the absence of an established response to some other cue. The failure to replicate this finding in Experiment 5.5 can be explained in terms of the altered conditions in that experiment, especially the use of a particularly difficult discrimination as the transfer task.

The discussion so far has made the conventional assumptions about the effect of random reinforcement, i.e. that it affects the motivational or emotional state of the organism and elicits what may be described as "frustration", "conflict" or "uncertainty". As has been noted in Chapter 4 there is a large body of research which describes the use of random reinforcement without any reference to frustration. The effect of random reinforcement is considered entirely in associative terms. The possibility of the present data being so described needs to be considered.

The effect of random reinforcement, according to an attentional model, such as that proposed by Sutherland and Mackintosh, would have been to decrease or to extinguish attention to the randomly reinforced discriminanda and to strengthen attention to irrelevant cues in the experimental environment. Mandler and Goldberg (1973) derived from Sutherland and Mackintosh (1971) the prediction that partial reinforcement would have no effect on subsequent learning. However, this could only apply to situations in which partial reinforcement was delivered in the presence of only one, or of none of the stimuli relevant to the subsequent test discrimination. Mandler and Goldberg's application of this prediction to the situation in which the same cues are present during partial reinforcement and discrimination learning is questionable. The interpretation offered by Waller (1973) seems to be a more reasonable reading of Sutherland and Mackintosh. When no analyzer accurately predicts the occurrence of reward and non-reward, the strength of attention to prominent environmental cues is weakened and many other analyzers are switched in. Presumably the subjects in the experiments described above learned that the cues present during random reinforcement did not reliably predict reinforcement. Since rats tend to respond to spatial rather than symbol cues, position responding was a more likely form of behaviour under such conditions - at least for the 2-door subjects. The 12-door subjects may have managed to detect some consistent, nonvisual cues inside or outside the maze, but these subjects also should have learned that the symbol cues did not predict reinforcement. In the frustration condition in Experiment 5.3, the subjects were attending to the brightness dimension and responding to one value within that dimension when they entered the random reinforcement stage. During random reinforcement this cue ceased to reliably predict reinforcement but no other stimulus predicted reinforcement more reliably and so most of the subjects continued to respond to that cue and their responses were rewarded on 50 per cent of the trials. When they were transferred to the horizontal-vertical discrimination these subjects were still responding to symbol cues and so they learned the horizontal-vertical discrimination faster than subjects in the uncertainty or naive control groups. To the extent that their attention to symbol cues had been extinguished by the 50 per cent reinforcement, they learned the subsequent discrimination slower than the learning-to-learn control subjects. The deterioration of performance of the frustration groups in Experiment 5.6 is explicable in the sense that when the stimuli from the initial discrimination were not present during random reinforcement, there were no cues which reliably predicted reinforcement and no cues to which the animals were predisposed to respond, except, once again, spatial cues. Consequently when transferred to the horizontal-vertical discrimination the performance of the frustration subjects, especially the 2-door subjects which could respond to spatial cues, approached that of the uncertainty groups of Experiment 5.3. The 12-door subjects were more likely to continue to attend to symbol cues during random reinforcement, for lack of other available cues. However, the deterioration of the 2-door learning-to-learn control group remains unexplained. Experiment 5.5 also poses difficulty for a non-frustration explanation. In Experiment 5.5 the more rigorous random reinforcement schedule should have increased the rate of extinction of attention to the symbol cues, and so slowed the rate of learning on the subsequent task. In fact, the learning-to-learn control groups and the frustration groups both found the task equally difficult.

Overall then, a non-frustration explanation of the results of these experiments does not add any more to our understanding of the data, than does a frustration explanation, but such an explanation is more parsimonious. If the postulation of a state of frustration does not clarify otherwise inexplicable aspects of the findings, it may be better done without.

CHAPTER 7

THE RELATIVE EFFECT OF REWARD AND NONREWARD IN DISCRIMINATION LEARNING.

Introduction

In a conventional 2-choice discrimination task, the subject is presented with two stimuli and responses to one (S+) are consistently rewarded and responses to the other (S-) are not rewarded. Allowing for the individual preferences for symbol or spatial cues which each subject brings to the task, the chances of the subject responding to S+ or S- on the early trials are about equal. As the discrimination is mastered, responses to S+ become more and more frequent and responses to S- become less frequent, presumably as a function of the consequences of earlier responses. The problem for any theory of discrimination learning is to show how responses to S+ and S- lead to this mastery of the discrimination, and, more specifically, to say whether subjects learn to approach S+, to avoid S-, or to do both. This is a very basic question which is related to, but is more fundamental than those considered in the first half of this thesis. The topics considered so far have been the role of a common error factor in discrimination learning, position responding, and the role of one of the important effects of making an error, frustration. The remainder of the thesis attempts to assess the role of responses to S-, or errors, in discrimination learning.

The reinforcement theories of discrimination learning include examples of the three possible relationships between S+ and S-. Thorndike (1932) studied the role of reward and what he defined as "punishment" in an experiment with chickens. Correct responses were rewarded by freedom, food and company, while incorrect responses were punished by 30 seconds confinement. As Postman (1947) remarked,

> One may question the appropriateness of the term "punishment" or "annoyer" for the description of an effect which is primarily informative in nature. (page 504)

Thorndike's revised Law of Effect (Thorndike, 1931, 1935) put all the emphasis on rewarding a connection in order to strengthen it. The role of punishment in weakening an inappropriate response or connection was almost denied.

Harlow (1949), on the other hand, viewed the process of learning as "a learning of response tendencies that counteract the error-producing factors" (page 58). Learning was considered to be an inhibitory process in the sense that a discrimination will be mastered when all error producing factors have been counteracted so that S- is consistently avoided. Indeed the name "Moss-Harlow effect" (after Moss and Harlow, 1947) is often used to describe results in which responses to S- are more important than responses to S+. Amsel's (1958, 1962, 1967) emphasis on the frustrative effect of nonreward puts him in the same category as Harlow.

Finally, Spence (1936) assumed that responses to S+ and S- were of equivalent importance. Although the magnitude of the incremental effect of reward was assumed to be a bell-shaped function of absolute response strength and the effect of nonreward was an increasing linear function of this absolute value, correct responses and errors, as such, were assumed to be of equal value. Sutherland and Mackintosh (1971), when describing the attention model of discrimination learning, stated,

> We have assumed that animals usually learn in a simultaneous discrimination situation both to approach the positive and to avoid the negative (page 71).

Clearly the assumptions made about the relative weight of responses to S+ and S- are very basic assumptions. The resolution of the issue has proved particularly difficult. Firstly there are problems of definition which carry over from Thorndike's era. The consequences of a response to S- range from information feedback ("wrong" to human subjects or a stimulus change for animals), through failure to obtain a reward, to some noxious event. At this latter end of the continuum one generally talks of punishment if the noxious event is a severe shock. One might also talk of punishment if an error results in the subject falling into a net several feet below the apparatus, as is the case in many versions of the Lashley jumping stand. To describe negative feedback as punishment seems to be an over extended use of the word. For practical purposes one must draw a somewhat arbitrary line, and for the purposes of this discussion the emphasis will be on the non-attainment of reward, which is the usual effect of a response to S- in animal studies. However, other response consequences will not be ignored. In fact, a great deal of research following Thorndike's work focussed on the comparison of motivational states, i.e. hunger versus pain or fear, rather than a comparison of the associative effects of responses to S+ and S-.

Secondly, there is the practical problem of developing an experimental design which will sort out the effects of responses to S+ from those of responses to S-. One cannot merely observe an animal in the act of acquiring the discrimination since there is no way of telling whether a response to S+ is an approach response to that stimulus or an avoidance of the alternative stimulus, S-. Attempts to resolve the problem have included manipulation of the ongoing discrimination situation to separate responses to S+ and S-, various pretraining or feedback procedures, multiple stimulus situations which allow S+ and/or S- to be differentially weighted; and cue substitution procedures after discrimination to assess the influence of S+ and S-. The remainder of this chapter will be a review of the research in this field. The circular maze offers the possibility of multiple stimulus presentation without some of the problems besetting multiple stimulus designs. A subsequent chapter describes experiments using this technique.

Responses to S+ and S- in the course of discrimination learning.

Thompson (1954) used what he described as an "ambiguous cue discrimination problem" to separate approach and avoidance trials. One stimulus, S+ or S-, was presented on each trial. Chimpanzees made fewer errors on approach trials than on avoidance trials. Thompson was undecided between the conclusion that rewarded responses to S+ contribute more to learning than non-rewarded responses to S-, a reinforcement interpretation, or the conclusion that S+ is more discriminable than S-, a perceptual explanation. Thompson, in fact, used a successive discrimination procedure familiar in operant conditioning studies, and failed to provide subjects with an alternative response, consequently inflating the response rate to S-. Ettlinger (1960) came to a similar conclusion to that of Thompson. Using Rhesus monkeys he observed that S- was chosen on 64 per cent of trials, whereas S+ was chosen on 36 per cent of trials without the subjects touching S-.

He concluded that responses to S+ lead to greater efficiency in learning than responses to S-. Moreover, the greater the separation of the positive cue from the reward container the greater was the decrease of efficiency in performance by comparison with the similar separation of the negative cue from the reward container. However, Ettlinger looked at the final 100 trials of the two tasks under observation, by which time the discrimination must have been well advanced and the effect of responses to S- no longer critical. Finally, Behar (1961) attempted to discriminate between the effects of response to S+ and S- by comparing the performances of naive and sophisticated monkeys. Since the latter learned to avoid S- more quickly than the naive subjects, Behar concluded that the S- did indeed have an inhibitory effect and that this effect was learned. King (1971) replicated Behar's finding.

Overall, the results of such direct approaches to the problem, as far as animals were concerned, were ambiguous or unimpressive. The study of human learning presents quite a different picture.

The Thorndike approach mentioned above has received considerable attention in the areas of discrimination learning and concept formation. The more recent work has been initiated by Buss and his associates (Buss, Braden, Orgel and Buss, 1956; Buss and Buss, 1956; Buss, Weiner and Buss, 1954; Ferguson and Buss, 1959; Jones, 1961), who combined positive and negative feedback ("Right" or "Wrong") with nonreward or a condition of no feedback. Buss constructed a "theoretical verbal reinforcement continuum" to show the relative effectiveness of different valences of feedback. He concluded that "Wrong" as a feedback condition was a stronger negative reinforcer than "Right" was a positive reinforcer - the opposite conclusion to that reached by Thorndike.

However, Buchwald (1959a and b) suggested that the initially neutral "nothing" or no feedback condition acquired a value opposite in sign to the type of feedback with which it was paired and that a greater value of "Nothing" accompanied the "Nothing-Wrong" condition than the "Right-Nothing" condition. In later studies Buchwald (1962, 1966, 1967) showed that task and procedural differences (e.g. alternative responses and delay of reinforcement) affect the varying values of "Right" and "Wrong". Finally, Buchwald (1969) presented a model designed to explain how "Right" and "Wrong" affect subsequent responding, based on the assumptions that a subject may recall a response without recalling its outcome and that the probability of repeating a response that is recalled is independent of the outcome of that response unless it is also recalled. He presented supporting evidence for this model. Estes (1969) has developed a model based on a similar distinction between the associative learning process and rewarding or punishing aftereffects. Controversy over the role of feedback continues. A similar debate focusses on verbal discrimination learning (Cf. Ekstrand, Wallace and Underwood, 1966; Tulving and Madigan, 1970).

Within a different context, the role of negative instances in concept formation tasks may be considered relevant. The early work in this area indicated that positive instances were more effective than negative instances (Cf. Bourne and Dominowski, 1972, for a review of the issue). However, the findings of Bourne and Guy (1968), Bourne Ekstrand and Montgomery (1969) and Schroth and Tamayo (1973) indicated a more complex view in which the nature of the instance interacted with the rule being learned (e.g. positive instances are more effective for conjunctives and negative instances are more effective for conditionals) and with the memory conditions.

The whole area of human learning, in so far as it concerns the above topics, is in a lively state of flux.

Pre-discrimination experience with S+ and S-

Moss and Harlow (1947) introduced the technique of providing information about either S+, S- or both on initial trials and assessing the use of this information on later trials. They trained monkeys on 90 discrimination problems in which, on initial trials of each problem, responses to a single stimulus were always or never rewarded. On subsequent two-choice trials this stimulus was S+ or S- respectively. Subjects given experience with S- were correct on 90 per cent of the first test trials, whereas subjects given experience with S+ were correct on less than 80 per cent of the first test trials. Moss and Harlow concluded that reward is not essential for discrimination learning and that learning what response not to make or what stimulus to avoid is more important than learning what response to make or what stimulus to approach. The Moss and Harlow study was replicated, with minor variations, by Harlow and Hicks, (1957), Blomquist, Deets and Harlow (1973) and Leary (1956). However, Leary (1956) found that positive transfer from the pre-discrimination phase to the discrimination task depended on S+ or S- being chosen. Otherwise subjects tended to respond to an unchosen S-.

Moss and Harlow's research cut across an issue raised by Lashley and Wade (1946) who argued that reinforcement of a single stimulus does not produce transfer effects in subsequent discrimination tasks which involve the previously rewarded stimulus and a new stimulus. A similar argument has been revived by Davenport and Hagquist (1968). In the course of an experiment to test Lashley and Wade's proposition, Lipsett (1962) found a reverse Moss-Harlow effect for first grade children. This finding both undermined Lashley and Wade's position and introduced a developmental aspect of the role of S- in discrimination learning.

There are few studies using the Moss-Harlow paradigm with rats as subjects. Fitzwater (1952) gave three groups of subjects single stimulus training to both S+ and S- in the ratios of 5:35, 10:30, 20:20 and 40:0. By comparison with control subjects which were given pre-discrimination experience with S+ and a neutral stimulus, the subjects receiving experience with both S+ and S- performed better on a subsequent discrimination, but the amount of preliminary training made little difference to performance. In a replication of the Fitzwater study using children (3 to 5 years old) as subjects, Evans and Endsley (1966) found that a low reward:nonreward ratio led to an increase in the number of correct responses, i.e. nonreward was a more important determinant of learning. Evans and Endsley suggested two explanations of their data: either Lachman's (1961) suggestion that the acquisition gradient of r_F-s_F resulting from nonreward is steeper than the gradient of r_G-s_G resulting from reward, or that nonrewarded trials elicit more attention or orienting responses than rewarded trials. More recently, Traupman and Wong (1971) found that if rats were given reinforced experience in a black alley which became either S+ or S- on a subsequent discrimination based on different magnitudes of reward, the discrimination was mastered more rapidly if the black alley became S-.

The classic Moss-Harlow design involves the introduction of a novel stimulus after the pre-discrimination training, i.e. the S+ or S- experienced in pretraining is paired with a novel S- or S+ for the test discrimination. Cross and Brown (1965) attempted to avoid this problem by inserting the information about S+ and S- between discrimination and reversal training. Squirrel monkeys had 6 or 8 discrimination trials followed by 4 pre-reversal trials which provided positive (experience with S+), negative (experience with S-), mixed or no information about the reward conditions holding during the subsequent reversal trials. Over the course of 64 problems they found:

(a) a reverse ORE in that reversal was faster after 6 rather than 8 initial trials,

(b) negative information led to faster reversal than positive information,

(c) the complete absence of pre-reversal information led to the slowest reversal learning.

This study and result was replicated by Cross, Fickling, Carpenter and Brown (1964). However, when this experimental design was used with children the Moss-Harlow effect appeared in children younger than 4½ years (Cross and Vaughter, 1965), a reverse Moss-Harlow effect appeared in children older than 4½ years (Vaughter and Cross, 1965; Cross and Vaughter, 1966), and there was no Moss-Harlow effect with either age group when children above and below 5 years of age were used (Vaughter, 1968). This further evidence of a developmental aspect of the effect, with less and less reliance on S- as age increases, suggested the possibility that there may be a phylogenetic progression. However, the Moss-Harlow effect was not observed in rats when the Cross and Brown design was used (Vaughter, Tyer and Halcomb, 1966). The rats in this study were given only two information feedback trials and were not run to criterion on the reversal task. It may well be that the failure to find a difference between positive and negative feedback groups was due to procedural details. Support for this criticism was provided by Stevens and Fechter (1967) and Sasaki (1969). In both studies rats were trained on a brightness discrimination, given 20 trials pre-reversal experience with responses to the former S+ being unrewarded and responses to the former S- being rewarded, and then reversed to criterion. The Moss-Harlow effect was observed in both cases, i.e. subjects given nonreward experience with the former S+ (the new S-) learned the reversal task faster than subjects given rewarded experience with the former S-.

Olton (1972) attempted a different solution to the problem of the novelty effect in the Moss-Harlow design. Rats were given information about reinforcement and nonreinforcement and were then placed in a 3-choice simultaneous discrimination situation consisting of both alternatives plus an additional one, so that avoidance of S- was not synonomous with approach to S+. In each experimental session subjects were given 2 forced trials to S+ and S- and then 3 choice trials. However, although a novel stimulus was not introduced, subjects were placed in a novel situation. The pattern of responding (fewer responses to S-, and an equal number of responses to S+ and the neutral stimulus) indicated that the nonreinforced trials contributed more to successful discrimination than the reinforced trials, especially at the beginning of training. This finding was confirmed in another experiment which introduced a 50 minute delay between information and discrimination, and in a third experiment in which, on some days, information was given about reinforcement or nonreinforcement while on other days it was not. The number of choice responses to the stimulus indicating reinforcement was approximately the same irrespective of whether information had been given. On the other hand, the numbers of responses to S- when information was given was less than half than when information was not given.

The overall conclusion concerning this line of research must be that with non-human subjects, and perhaps with very young human subjects, information about S- is more useful than information about S+ when a subject must learn to discriminate between them.

Multiple stimulus discrimination learning.

Quite a different approach to those already described is represented by multiple stimulus situations in which the relative importance of responses to S+ or S- are assessed by weighing one or the other stimulus and examining the effect on discrimination learning. This weighting is achieved by varying the number of S+'s and S-'s. The major advantages of this approach are:

(a) Ongoing discrimination is directly studied and the experimenter need not rely on pre- or post-discrimination treatments or tests,

(b) No novel stimulus need be introduced, although this feature is not always utilised.

The several stimuli used in such designs may be repetitions of the same stimulus or a set of different stimuli.

Multiple homogeneous stimuli Studies using different numbers of homogeneous S-'s could be considered to be concerned with oddity learning where the subject learns to select the odd stimulus, i.e. the unique S+ among an array of identical S-'s. As such, some of the earliest research on the role of S- in discrimination learning by chimpanzees was done by Klüver (1933) who found that subjects learned a discrimination faster when there were several rather than one S-. This work was extended by Nissen and McCulloch (1937) and McCulloch and Nissen (1937) who found discrimination facilitated with 9 S-:1 S+ and a correction procedure, and with 11 S-:1S+ and a noncorrection procedure. Similarly Smith (1936) found that cats required fewer trials to acquire a discrimination where there were 4 S-'s rather than 2 or 1. The same finding has been reported for canaries with 8 S-:1 S+ (Pastore, 1954), pigeons with 7S-:1 S+ (Williams, 1967) and rats with 3 S-:1 S+ (Weaver and Michels 1961). Williams (1968) followed up his earlier finding that pigeons with 7 S-:1 S+ learn a simple discrimination faster than subjects with 2 S-:1 S+. He hypothesised that since the subjects with 7 S-'s made more errors early in the task this led to S- becoming more aversive more quickly. Williams (1968) attempted to offset this aversiveness by subjecting the 2 S-:1 S+ group to a series of nonreinforced trials prior to the actual discrimination task (as in Moss and Harlow, 1967). The difference between the 7 S- group and the 2 S- group was no longer apparent.

The Weaver and Michels (1961) study consisted of 9 problems in a 4-choice apparatus with multiple S-'s (the stimuli were displayed on a rectangular panel) followed by 4 problems under single S- conditions or vice versa. The facilitation effect occurred only in the former case i.e. multiple S- presentation followed by single S- presentation, and then only on the second and subsequent problems.

The most recent study in this line of research is that of Schaeffer and Shandro (1969) who studied acquisition and reversal of a black-white discrimination as a function of the number of S-'s (1, 2 or 4). The apparatus in this study consisted of a semi-circular area with 5 goal boxes equi-distant from the choice point. False walls could be inserted to vary the number of choices available. Subjects were given 4 days of acquisition and 6 days of reversal training. The number of S-'s was not a critical factor in acquisition, but reversal performance improved as a function of the number of S-'s. Unfortunately, Schaeffer and Shandro did not train their subjects to criterion on either task. Had they done so they would have thrown more light on the role of responses to S- in conventional discrimination tasks. Also, they used a very easy discrimination which may account for the failure to differentiate between the groups on the initial task.

The finding is fairly consistent across several situations - discrimination learning is improved by increasing the number of homogeneous S-'s.

Multiple heterogeneous stimuli. The work described in the previous section varied the number of S-'s and kept S+ constant. This puts all the emphasis on the role of S- in the discrimination and, obviously, considers only one aspect of the situation. Just how misleading this can be is indicated by the varied results of work done on multiple heterogeneous stimuli which has tended to weigh both stimuli. This line of research was initiated in the early 1960's. Coate and Gardener (1964) compared the performance of groups with 3 S+:1 S- and 3 S-:1 S+ on a successive operant discrimination task. Increasing the number of S+'s led to comparatively poor performance. Gardener and Coate (1965) found similar results in a study of simultaneous discrimination learning. Training, in this study, was given in what was described as a "choice box", although the situation was more like an operant conditioning situation than a conventional simultaneous discrimination choice box. In terms of level of performance over 432 trials, and of the numbers of trials required to reach several criteria, performance of the subjects with multiple S+'s was poorer than that of subjects with multiple S-'s. In both studies Coate and Gardener argued that since variability of S+ was associated with greater deterioration in performance than variability of S-, reward for responses to a specific S+ was more critical than nonreward for the avoidance of a specific S-.

Meyer (1964) also studied multiple stimulus discrimination learning when he attempted to test Hull's (1952) 14th theorem, which predicted that discrimination between multiple stimuli in the pattern S-:S+:S- would be more difficult than the conventional array, S+:S- or S-:S+. Six groups of rats were trained in a Grice discrimination box to distinguish between circles of different sizes displayed in the conventional array or in various 3-stimulus arrays. The performance of subjects with 2 S-'s and 1 S+ or 2 S+'s and 1 S- did not differ significantly from conventional control groups.

The multiple stimulus technique has been used extensively by Jean Mandler (1970, 1971, 1973). Mandler (1970) used a 2-choice discrimination task in a Y- maze, such that 1 S+ and 1 S- was presented on each trial. However, for one group of rats S+ varied from trial to trial between three stimuli and with another group S- varied. The stimuli used in two experiments were horizontal, vertical and diagonal stripes, a black triangle and circle on a white ground and a checkerboard pattern. In both experiments the Constant S- group (3 S+:1 S-) learned the discrimination faster than the Constant S+ group. There was no obvious relationship between this result and position responding, and it was not explicable in terms of approach tendencies to novel stimuli. As far as a reinforcement explanation was concerned, the single S+ in the 1 S+:3 S- group received more than three times as many reinforcements as each S+ in the 3 S+:1 S- group, and yet subjects took longer to learn to respond to it. The explanation suggested by Mandler herself was either a motivational one - hitting a locked door in response to S- constituted punishment rather than merely non-reinforcement, or an associative one - for the 3 S+:1 S- group there were three times as many nonreinforcements per stimulus by comparison with the 1 S+:3 S- group. The difference between her results and those of Gardener and Coate were ascribed to apparatus differences. The Y- maze used by Mandler emphasised inhibitory control since a response to S- either involved turning around and going back (correction method) or it involved detention in the presence of S- (noncorrection method). Mandler (1971) replicated the above result, and also found that the difference between the two groups was no longer in evidence when subjects received prior training on a black-white discrimination. Weaver and Michels (1961) reported a similar finding. Overtraining on the black-white discrimination improved performance on the multiple stimulus task but without leading to a difference between the groups. However, Mandler (1973), in the course of a different experimental design, did not replicate the 1970 result. It is possible that this was due to her use of different stimuli. It is more likely that it was due to the bias in her method of selecting subjects: subjects failing to learn the 3 S-:1 S+ task were replaced by new subjects.

The importance of weighing both S+ and S- is indicated by a study by Douglas, Barrett, Pribram and Cerny (1969). These authors varied only the number of heterogeneous S-'s (1, 2 or 4) and found that the performance of hippocampal lesion subjects deteriorated as a function of the number of S-'s by comparison with sham or amygdeloid lesion subjects. Pribram (1971) quoted this study as evidence when he argued that the hippocamus is critical in an organism's error evaluation system. However, it may well be that performance would have deteriorated even more if the authors had considered the case of multiple S+'s.

The results of studies using heterogeneous multiple stimuli are more ambiguous than those using homogeneous multiple stimuli. However, the more recent, more carefully controlled, work indicates that the S- is relatively, but not absolutely, more important, at least as far as rats are concerned. This conclusion is not supported by the work done with human subjects. House, Orlando and Zeaman (1957), working with a sample including a variety of mental retardates (I.Q. mean = 44) found that performance under a constant S+ and S- condition was better than that under a variable S+ condition (5 S+:1 S-). Performance under a variable S- condition (5 S-:1 S+) began at the same low level as the variable S+ condition, but improved over repetitions to the level of the constant condition. The authors opted for the conclusion that S- was not used by subjects, and that the performance of the 5 S+:1 S- group was due to approach tendencies towards the changing aspect of S+. Walk and Saltz (1965), using normal children of two age groups (5-6 years and 8-9 years), reached a less extreme conclusion. The performance of the younger children was unaffected by multiple (2 or 3) S+ or S- conditions. However, the older children were only able to solve the 2-choice discrimination task under the multiple S+ condition. Walk and Saltz suggested an explanation in terms of the subject's past experience with reward and punishment. Clearly, the developmental aspect of the role of S- is again in evidence.

Cue substitution techniques

The techniques so far reviewed have involved pre-discrimination manipulation or direct intervention in the discrimination process. The next area to be reviewed involves techniques which assess the stimulus control exercised by S+ and S- after the discrimination has been acquired. By substituting a new stimulus for S+, S- or both, choice behaviour on the next few trials or the amount of disruption in learning the new task are taken as an index of stimulus control. The technique of cue substitution followed by choice discrimination was first used by Chang (1937, as in Wu, 1938) with rats in a Lashley type apparatus. He found ambiguous or inconsistent results and concluded that discrimination was not wholly either avoidance or approach learning. A similar result was observed in the second stage of Fitzwater's (1952) experiment which involved replacing S+ or S- with a new stimulus for 16 trials. Subjects were as proficient at approaching S+ as they were at avoiding S-. Stevens and Fechter (1968), however, reported more definite results. Subjects learned a horizontal-vertical discrimination in a runway either for food or to avoid shock. For the next 10 trials either S+ or S- was replaced by a new stimulus with alternate black and white quadrants. The rats trained with positive reinforcement made more errors when S- was replaced. However, the opposite held for subjects trained with negative reinforcement.

With monkeys as subjects the results were also ambiguous. Behar (1962a), using a cue substitution technique, found that subjects responded to S+ on 95.6 per cent of the test trials and avoided S- on 57.2 per cent of those trials. Avoidance of S- seemed to depend on the extent to which the nonreinforced stimulus had been responded to in the course of discrimination learning. With another species (Mangabeys rather than Rhesus monkeys) Behar (1962b) found similar results. However, Rees and Shrier (1971) used a "discriminative switching procedure" in which subjects could switch back and forth between S+ and S- before making a choice. S+ and S- were never presented simultaneously. Hence subjects continued to make responses with reference to S- even when the discrimination was almost mastered. Stimulus substitution tests after this form of discrimination learning indicated that S- control was much stronger than S+ control and was sufficient to maintain performance.

Work with monkeys using a re-training test rather than a choice test has not been much more fruitful. Leary (1956) replicated the Moss-Harlow effect in one part of his study, but when S+ or S- was paired with a new stimulus after the acquisition task there was only slightly better retention of S+ rather than S-. Riopelle (1955) also found little difference in performance following substitution of S+ or S-. However, Warren and Kimball (1959), using kittens as subjects, found strong positive transfer when the new S+ was substituted and the old S- was retained, and little positive transfer if a new S- was substituted and S+ was retained.

Once again Mandler (1968, 1973) has done the most informative work in the area. Mandler (1968) gave rats training to criterion or overtraining on a black-white discrimination followed by one of the following:

(a) reversal of S+ and S-,

(b) reversal of S+ to S- and new S+,

(c) reversal of S- to S+ and a new S-,

(d) new S+ and new S-,

(e) retention of S- and a new S+,

(f) retention of S+ and a new S-.

Mandler found:

(i) an ORE for all conditions,

(ii) a decrease in the number of errors from (a) to (f) for the overtrained groups, but the criterion groups made slightly more errors in (c) than in (b) and in (f) than in (e), i.e. overtrained subjects were more disrupted by changes in S+ and groups trained to criterion were more disrupted by changes in S-.

Mandler (1973) followed up this result and her previous finding with multiple cues (Mandler, 1970, 1971) by examining two questions:

> First, given that a multiple stimulus task has been mastered, how much has been learned about the multiple stimuli compared to the constant stimulus? Second, if the constant stimulus is the only stimulus that has been used in the formation of the discrimination, is that stimulus more effective in controlling choice behaviour when it has been learned on the basis of approach or avoidance responses? (page 113-114).

Following training on either a 3 S+:1 S- or a 3S-:1 S+ discrimination task, rats were transferred to a 2-choice stimulus discrimination task which:

(a) retained the single stimulus (S+ or S-) paired with a new stimulus, or

(b) retained one of the multiple stimuli (S+ or S-) paired with a new stimulus, or

(c) introduced two new stimuli (control group).

Only the latency data indicated that some response had been learned with reference to the multiple stimuli, and this was taken by Mandler to indicate that subjects had learned to attend to the multiple stimuli without learning a consistent response to them. The choice data indicated that the discrimination had taken place on the basis of the constant stimulus alone. Neither choice nor latency data differentiated between the constant S+ and the constant S- conditions. Mandler concluded that the greater number of trials taken to learn a multiple stimulus task is a function of the time required to isolate the constant stimulus in this situation. Indeed, Nash (1970), using squirrel monkeys, also suggested that subjects do not learn to respond to all stimuli of a set with equal facility.

A variation of the post discrimination test is that whereby response tendencies to an individual S+ or S- are determined without substitution of a new stimulus. For example, Sutherland (1961) found that after initial training on a 2 choice discrimination, rats presented with S+ alone or S- alone responded to S+ on 76 per cent of the 12 test trials and to S- on 26 per cent of the trials, i.e. subjects had learned to select S+ and to avoid S- with almost equal accuracy. Sutherland, Carr and Mackintosh (1962) carried out a similar experiment, except that after discrimination training S+ or S- was presented alone for 120 trials (10 days) and subjects were reinforced for responding to S+ or, when S- was presented, for responding to the opposite side of the maze which consisted of a feeding tube but no stimulus. Over the first 50 trials all subjects responded to S- on more than 50 per cent of the trials, i.e. S- seemed to resemble S+ more than the blank side of the maze. These results were seen as consistent with Sutherland (1961) and formed the basis of Sutherland and Mackintosh's (1971) assumption, mentioned above, that in a simultaneous discrimination situation subjects learn a discrimination on the basis of both approach and avoidance.

Deutsch and Biderman (1965) developed this type of experimental design in their investigation of the possibility that the ORE was due to changes in the aversiveness of S- as a function of overtraining. Rats were trained concurrently on two discriminations (large-small square and horizontal-vertical. One discrimination was presented on 9 trials per day and the other on 3 trials per day until subjects were responding correctly 80 per cent of the time in the case of the more trained discrimination and 64 per cent of the time in the case of the less trained discrimination. When the two S-'s were presented together 10/12 rats chose the S- from the more trained discrimination. Moreover, when one group's training was continued until response rate on both discriminations was almost equally accurate (81 per cent and 71 per cent) 7/12 subjects chose the S- from the more trained discrimination. Deutsch and Biderman concluded that the negativity of S- was not monotonic throughout acquisition. Biderman (1967) replicated and extended Deutsch and Biderman (1965), using a 2 bar operant chamber. In one experiment rats were given four times as much training on one discrimination as on another. When the S-'s were paired 18/22 subjects chose the more trained S- and when the S+'s were paired 15/17 chose the more trained S+. In another experiment all subjects received 128 trials on two discriminations. When the S-'s were paired 7/17 subjects chose the more trained S- and when the S+'s were paired 10/12 subjects chose the more trained S+. Biderman argued that initially the negative value of S- is high, but as training proceeds this function changes so that S- no longer serves as an effective cue.

These ideas may serve as an introduction to the study of stimulus control data in operant situations which are relevant to this discussion.

The most interesting lines of research are concerned with the "feature positive effect", with the inhibitory control of behaviour and with errorless discrimination learning.

Jenkins and Sainsbury (1969, 1970) and Sainsbury (1971a), working with pigeons, found that if two displays are differentiated by a single distinctive feature located on only one of the displays, e.g. 3 stars versus 2 stars and one circle, the acquisition of a discrimination is faster if the distinctive feature, the circle, is on S+ rather than S-. They called this the "feature-positive effect". Jenkins and Sainsbury (1970) found that when the distinctive feature was on S+, the subjects' responses converged on it in preference to the common features. When the distinctive feature was on S-, the responses moved away from it towards the common features. They proposed a simultaneous discrimination theory as the best explanation of their results: subjects learn to respond to the distinctive feature since a response to it is rewarded on 100 per cent of trials, whereas a response to the common features is rewarded on only 50 per cent of the trials, i.e. on those trials on which the common and distinctive features are presented together. The failure to acquire the discrimination in the feature-negative condition was ascribed to the inability of the pigeon to form a conditional discrimination - the bird is required to learn that responses to the common feature must be made conditional upon the presence (S-) or absence (S+) of the distinctive feature. However, in a situation involving successive, rapid alternation of the different features on the response key, Farthing (1971) did find that birds could learn the discrimination in the feature-negative condition. They were slower, although not significantly so, than the subjects in the feature-positive condition. Post-discrimination gradients indicated that the distinctive feature in the feature-positive condition became an excitatory stimulus and the distinctive feature in the feature-negative display became an inhibitory stimulus. The common features acquired an inhibitatory or excitatory function opposite to that of the distinctive feature. Furthermore, Hearst (1969) presented data which was the opposite to that of Jenkins and Sainsbury (1969, 1970), i.e. a "feature-negative effect". However, he argued that the difference was due to procedural variations (continuous versus discrete trials and different inter-trial conditions) and that Jenkins and Sainsbury's (1970) theory could be reconciled with the data.

Sainsbury (1971b, 1973) investigated the feature-positive effect in children, especially to determine why the feature-negative effect was so slow to develop. He found the feature-positive effect with 4 year olds, only minimally with 7 year olds and not at all with 9 year olds. Subjects which solved the feature-negative display seemed to use the distinctive feature more than the common features. They used the distinctive feature as a cue in a conditional decision, i.e. "if the distinctive feature then respond to the opposite display", in the way predicted by Jenkins and Sainsbury's simultaneous discrimination theory.

Jenkins and Sainsbury (1970) denied that their research had any bearing on the question of whether S+ is more or less important than S- in controlling discriminative performance.

> The distinctive feature is converged upon when it is on the positive display and diverged from when it is on the negative display. It therefore controls performance in both arrangements even though the end result is the development of a successive discrimination in one case and the failure of a successive discrimination in another case. In general, our interpretation of the displays as consisting of common and distinctive features, rather than as a single undifferentiated amalgam, prevents us from relating the results to traditional questions about the role of positive and negative stimuli in discriminative conditioning. It is possible, however, that some experiments directed towards these issues might be interpreted in the terms we have thought appropriate to the feature-positive effect. (p.268)

The methods and problems associated with the study of inhibitory stimulus control are reviewed and evaluated by Hearst, Besley and Farthing

(1970). The application of Hearst's approach of obtaining excitatory, inhibitory and intra-dimensional gradients to discrimination learning was presented in Hearst (1969). Hearst showed that it was possible to obtain separate, empirical gradients which provided strong support for the Spence-Hull approach based on assumed or hypothetical gradients. He also raised the question of whether excitatory pre-training was more valuable than inhibitory pre-training when both are required in the eventual discrimination, i.e. the same question asked by Moss and Harlow (1947). Using pigeons in an operant situation, Hearst (1969) found a reverse Moss-Harlow effect, due, it seemed, to a higher absolute difference in the rate of responding to S+ and S- on the part of subjects which received excitatory pre-training. Hearst (1971) studied the same problem with a more sophisticated design. Pigeons were given excitatory, inhibitory, single-stimulus or extradimensional pre-training on a line length discrimination before transfer to a successive discrimination. Generalization tests on line length variations were made at the end of the experiment. Once again Hearst found a reverse Moss-Harlow effect: the subjects receiving inhibitory pre-training were not consistently superior to the single-stimulus or extradimensional control groups. No large or consistent differences in the shape or slope of the generalization gradients were found among the four groups. Hearst (1969, 1971) argued that the results were due to the fact that the group which received excitatory pre-training entered the test discrimination responding rapidly to S+, due to the pre-training, and responding at a low rate to S-, since there was a steep absolute gradient about S+, and S- was far from S+ along the line length dimension. Subjects which received inhibitory pre-training entered the test discrimination with a low rate of response to S-, due to pre-training. The introduction of reinforcement for responding to S+ led to an increase in responding to that stimulus and, by generalization, to an increase in S- responding as well. Therefore, responding to S- had to be reextinguished and this impeded the acquisition of the test discrimination.

However, Hearst's explanation relied heavily on the effect of introducing a novel stimulus into the situation. As has been noted above, this is generally considered to be a problem with the Moss-Harlow approach to the assessment of the role of responses to S+ and S-. Hearst has shown that, for efficient successive discrimination learning, excitatory pre-training may be more useful than inhibitory pre-training. He has not proved that this is due to the properties of S+ and S- independent of one particular experimental design.

Finally, the research on errorless discrimination learning is of interest in that this form of learning represents the antithesis of the work discussed in this thesis. (Cf. Terrace 1966, 1972 for reviews of this line of research). Errorless discrimination learning begins with a situation in which some discriminative control already exists, usually a very easy discrimination, and the S- of a much more exacting discrimination is gradually "faded in". Eventually the subject is responding differentially, but without having made many responses to S-. Terrace (1966) lists several observations which suggest that two different sorts of discriminative control arise from conventional and errorless discrimination training. Neither behavioural contrast nor the peak shift were observed following errorless training (Terrace, 1963a, 1964); subjects do not display the emotional behaviour and bursts of pecking characteristic of subjects trained with errors (Terrace, 1966); and performance was not susceptible to disruption by drugs which usually have a marked effect on error rates (Terrace, 1963b).

The theoretical implications of errorless discrimination learning are not clear at this stage. What the phenomena does indicate is that responses to S+ and responses to S- may influence quite different mechanisms of learning. In a rather indirect way this does support the conclusions derived from earlier research.

Conclusion.

The conclusions which can be drawn from the literature on the relative effect of reward and nonreward in discrimination learning must be tentative. The main problem is that of designing an experimental situation which allows the effects of the two stimuli to be distinguished. Certainly, the results of the more carefully controlled experiments performed and the more successful experimental designs, i.e. the later developments of the Moss-Harlow approach and homogeneous and heterogeneous multiple stimulus situations, favour the conclusion that S- is more important than S+. In the following chapter a series of experiments is described in which the circular maze was used to study multiple stimulus discrimination with S+ and S- differentially weighted.

CHAPTER 8

EXPERIMENTS ON VISUAL DISCRIMINATION LEARNING WITH S+ AND S- DIFFERENTIALLY WEIGHTED

Introduction

The experiments described so far in this thesis have focussed on a particular property of the circular maze, i.e. its reduction of spatial cues. Hence an integral part of the experimental designs used in Chapters 3 and 5 has been a comparison of the 2- and 12-door conditions. In fact it was for this purpose that the apparatus was designed.

However, the circular maze can be put to a wider use. The 12-door condition is a situation in which several different stimuli can be presented simultaneously. As the review of the literature in Chapter 7 indicated, multiple stimulus presentation is a very useful technique for the study of the role of responses to S+ and S- in discrimination learning. Indeed apparatuses which allow the simultaneous presentation of multiple stimuli have already been used in several studies. Nissen and McCulloch (1937) and McCulloch and Nissen (1937), using monkeys, and Smith (1936), using cats, presented subjects with a display of several stimuli. Weaver and Michels (1961) used a 4-choice apparatus with rats in which the 4 stimuli were presented on a rectangular panel. The closest approximations to the circular maze are the semi-circular apparatus with 5 goal boxes equi-distant from the starting box used by Schaeffer and Shandro (1969), and the circular apparatus with 6 goal boxes used by Barns et al (1970). There were a number of advantages to be gained by these multiple stimulus presentations. The discrimination was studied as an ongoing process. There was no novelty effect due to the sudden introduction of new stimuli or a sudden change of the experimental situation. Moreover, any order effects due to the sequence in which the variable stimuli were presented was avoided. However, all these experiments studied the effect of varying the number of homogeneous S-'s. There has been no research done on the simultaneous presentation of several heterogeneous stimuli. Hence the use of the circular maze as a means of multiple stimulus presentation is an obvious extension of Schaeffer and Shandro's work in the semi-circular apparatus, and its use with heterogeneous multiple stimuli is an extension of Mandler's (1968, 1970, 1971, 1973) studies of such stimuli in a Y-maze. The study of heterogeneous stimuli was chosen because, despite Mandler's work, or perhaps because of it, the picture in this area is less clear and a number of very interesting questions have been raised.

There is the danger that the 12-door situation is so different from the conventional 2-choice experimental situation that the results of learning in such a situation are difficult to interpret. However, in the experiments described in Chapters 3 and 5 there was no evidence that the rats in the 12-door groups behaved in an atypical fashion, and comparisons between 2- and 12-door conditions were usually not significant. Hence the advantages of the circular maze for the simultaneous presentation of multiple stimuli do seem to outweigh any fears on this score.

EXPERIMENT 8.1. Discrimination learning as a function of the ratio of S+ to S- in terms of stimulus variability.

Very few experiments in the area of multiple stimulus discrimination learning have considered a range of variable stimuli. Williams (1968), using homogeneous stimuli, compared 7 S-:1 S+ with 2 S-:1 S+. Schaeffer and Shandro (1969) found that with 1, 2 or 4 homogeneous S-'s to 1 S+ performance in reversal learning improved as a function of the number of S-'s. Douglas et al (1969) found the contrary with 1, 2 and 4 heterogeneous S+'s to 1 S-. The present experiment compared 2, 3 and 6 heterogeneous S+'s to 1 S- and vice versa. Thus there were six experimental groups, i.e. 2 S+:1 S-, 2 S-:1 S+, 3 S+:1 S-, 3 S-:1 S+, 6 S+:1 S-, and 6 S-:1 S+.

If, as the literature review in Chapter 7 indicated, responses to S- are relatively more effective in discrimination learning than responses to S+, groups with a constant S- should learn a discrimination faster than groups with a constant S+, since variability in S+ will be less detrimental to speed of learning than variability in S-. There was very little evidence on which to base a prediction about whether speed of learning would be a function of the number of variable stimuli. What one can say is that if subjects have to learn the appropriate response to each variable stimulus, the speed of learning should be a function - direct or inverse - of the number of multiple stimuli. But if, as Mandler (1973) suggested, discrimination takes place on the basis of the constant stimulus alone, the range of variable or multiple stimuli presented should not affect the speed of learning.

There were two problems with the proposed experimental design. Firstly, there was the question of appropriate control groups for the experiment. In one sense this was a nonissue in that the Multiple S+: Constant S- versus Multiple S-: Constant S+ design is a balanced one, and the important comparison was between these two conditions. Further controls were not absolutely necessary, and are seldom used in experiments in this area. In another sense, a control condition which used multiple or variable stimuli without weighting S+ or S- would be useful. Moreover, Mandler's suggestion that the constant stimulus is a critical factor adds force to this argument. Since the main experimental groups involved 3, 4 and 7 stimuli, control groups of 2 S+:2S-, 3 S+:3 S- and 6 S+:6 S- were included in the experiment. These groups involved 4, 6 and 12 stimuli. The particular combinations of S+ and S- were determined by the nature of the maze, since an even number of S+'s and S-'s was required. Consequently the number of stimuli in the experimental groups were not matched exactly by the control groups, but at least some indication of the importance of the constant stimulus could be provided by these control groups. Finally, an idea of the rate of learning a 1 S+:1 S- task, i.e. the conventional two stimulus task, was determined from the results of previous experiments together with the results of a small group of subjects in this experiment.

The second problem in the experimental design concerned the equivalence of the stimuli in terms of their discriminability or the subjects' preference for one rather than another. With up to 12 different stimuli involved in the experiment, it is possible that some patterns may have been more discriminable than others, or that it may have been easier for subjects to learn to discriminate between one pair of patterns rather than another. For example, a pattern of diagonal stripes may be easier to perceive or remember than a pattern consisting of a white circle on a black background. Or it may be easier to learn to discriminate between horizontal and vertical striped patterns than between circles and squares.

This issue could be settled by testing each stimulus against every other stimulus in a series of 1 S+:1 S- tasks - a long and uneconomic process. An acceptable alternative is to look at the distribution of responses to the different stimuli and to make a post hoc assessment of stimulus equivalence on this basis.

METHOD

Experimental Design

Basically the design of the experiment involved:

(a) A 3 x 2 design with 2, 3 or 6 heterogeneous stimuli and S+ or S- constant.

(b) Four control groups with S+:S- ratios of 1:1, 2:2, 3:3 and 6:6.

(c) The groups in all the conditions except the 3:1 condition learned a discrimination to a criterion of 22/24 correct responses over two consecutive days. On attainment of this criterion the two groups in the 3:1 condition learned the reversal of the original discrimination to a criterion of 22/24 correct over two consecutive days. This was in the nature of a pilot study to determine the usefulness of continuing this line of research.

Subjects

The subjects were 114 experimentally naive male, Wistar strain, hooded rats, which were approximately 100 days old at the beginning of pretraining. The subjects were maintained at 85 per cent of their ad lib. body weight throughout the experiment, but had water available at all times.

Apparatus

The apparatus was the circular maze described in Chapter 2. The stimuli used in the experiment are illustrated in Figure 8.1. These black and white patterns were such that in each case 50 per cent of the 9 x 7 cm plate attached to the goal box door was black and 50 per cent of the plate was white. The groups in the 2:1, 3:1 and 2:2 conditions used the horizontal, vertical, chequerboard and one circle stimuli. The groups in the 6:1 condition used these stimuli plus the quadrants, square and diagonal stimuli. The 3:3 group used all the 12 stimuli except the cross, the four circles and the "random" stimuli. Finally, the 6:6 group used all the stimuli shown in Figure 8.1. The stimuli were arranged on the doors of the maze such that, for the groups in the 2:1, 3:1 and 6:1 conditions every second door displayed the constant S+ or S-. Every other door displayed one of the variable stimuli such that each was represented equally often. For the 2:2, 3:3 and 6:6 conditions the stimuli were juxtaposed such that as wide a range of the 12 possible pairings of the different stimuli as was practical was presented. This was done in order to control for possible preference for particular pairings of stimuli. For example, in the 2:2 condition, when horizontal and vertical were the S+'s and chequerboard and one circle were the S-'s or vice versa, the sequence of stimuli from door 1 to door 12 was: horizontal, chequerboard, vertical, one circle, vertical, chequerboard, horizontal, one circle, horizontal, chequerboard, vertical and one circle. If this arrangement had not been made subjects would have been presented with, for example, horizontal always on the left of chequerboard.

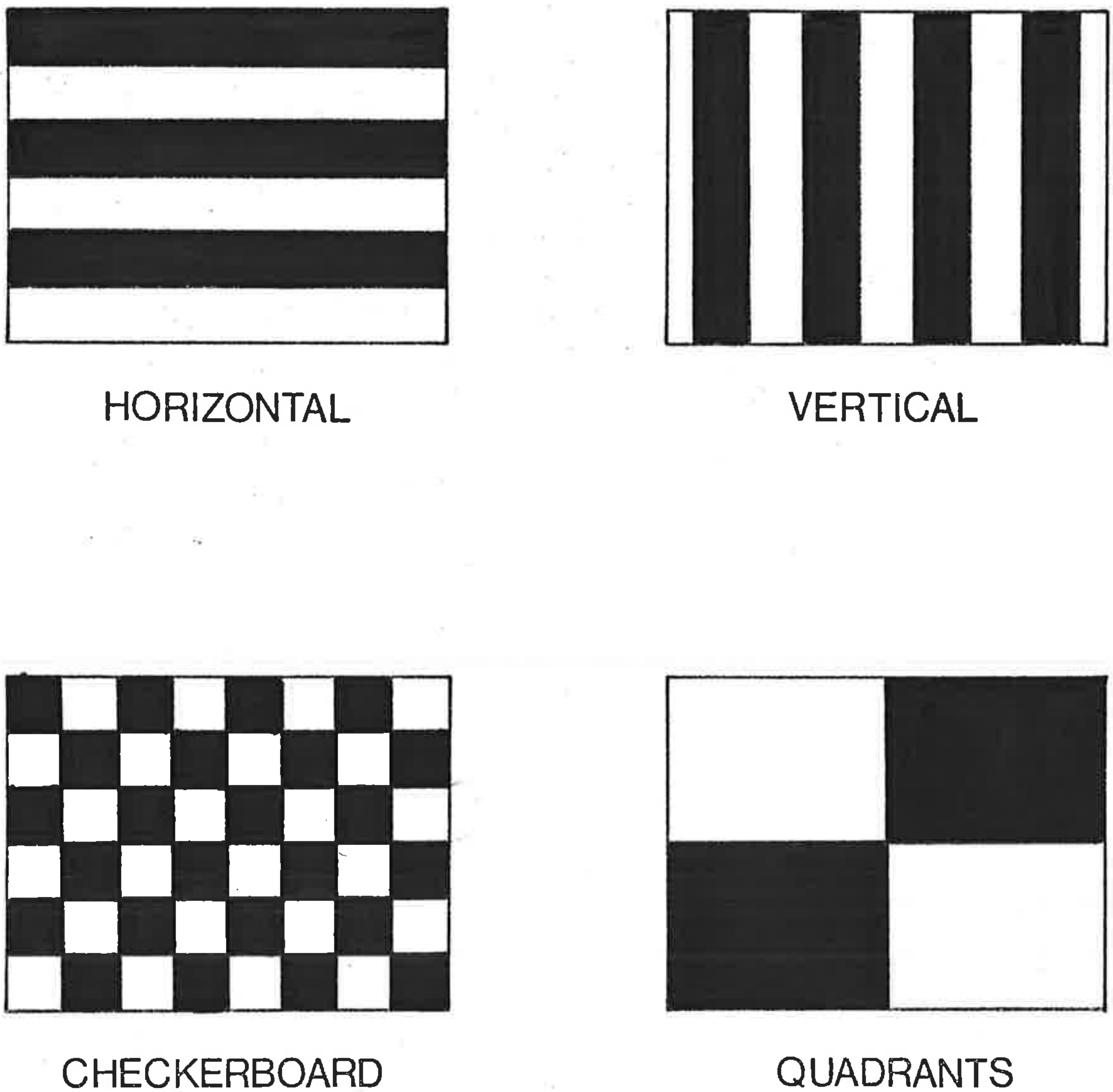
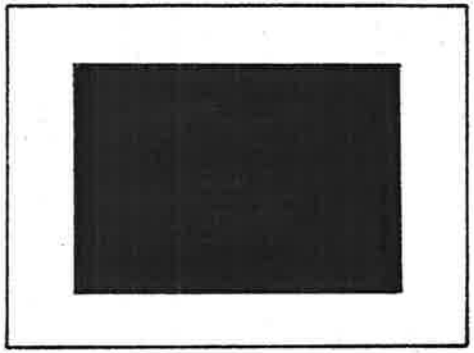
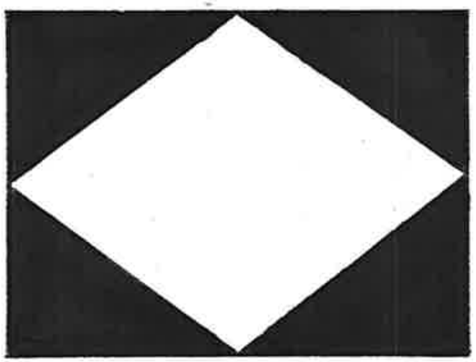


FIG. 8·1 STIMULI FOR MULTIPLE DISCRIMINATION EXPERIMENTS.

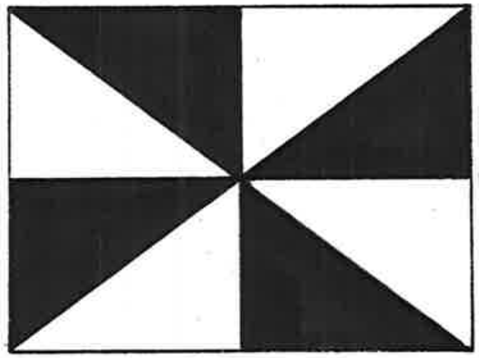
DIAGONAL



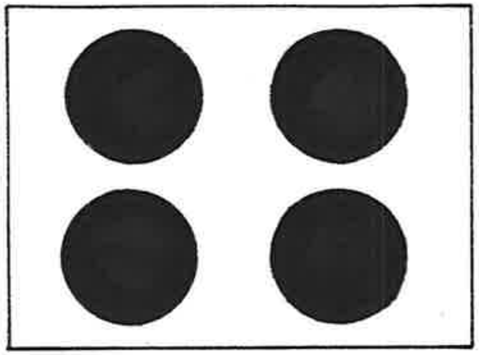
SQUARE



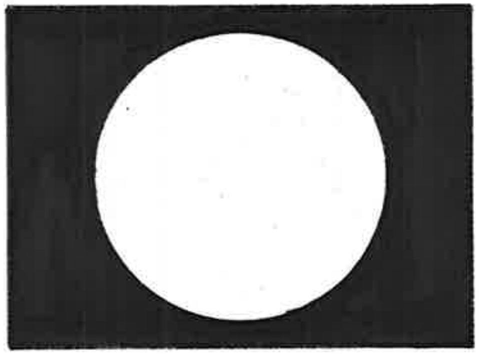
DIAMOND



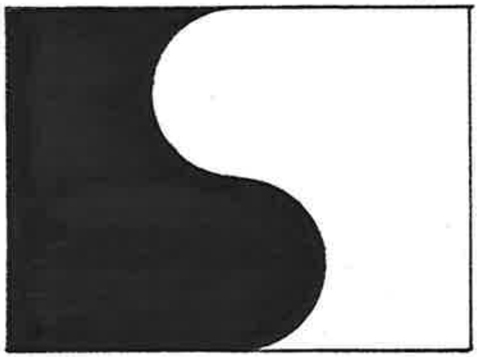
CROSS



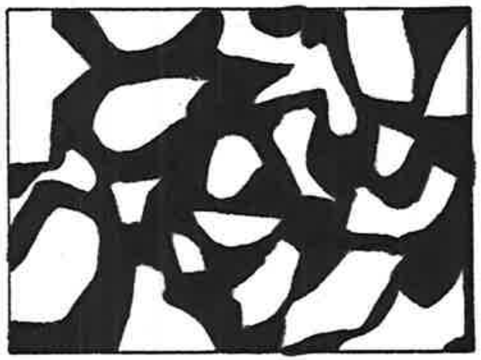
FOUR CIRCLES



ONE CIRCLE



CURVE



RANDOM

Procedure

Because of the very large number of subjects involved all conditions in the experiment could not be run at the same time. The 3:1 groups were run first to determine whether this line of research in the circular maze was worth further investigation. The results were encouraging. Hence the 2:2 group and then the 2:1 and 6:1 group were run followed by the 1:1 subjects, the 3:3 group and the 6:6 group. This procedure raised problems in the interpretation of the results. It is possible that over the course of the experiment, which took 6 months, variations in the conditions of the subjects could affect the results. This point must be borne in mind when the results of this experiment, especially the comparison of the 2:1, 3:1 and 6:1 conditions, are discussed.

Pretraining. The pretraining procedure used in this experiment was the same as that used for the 12-door subjects in the previous experiments described in this thesis. On the day following the end of pretraining subjects were transferred to the initial discrimination task.

Discrimination training. The details of the procedure used in this experiment were the same as those described for the 12-door subjects in earlier experiments in this thesis. Subjects were run in batches of 2, 3 or 4 depending on the arrangements which had to be made to balance stimulus combinations. These arrangements are described below. In all cases the intertrial interval was 2 to 2½ minutes. Subjects were run to a learning criterion of 22/24 correct responses over two successive days.

Sub-groups of subjects were presented with different stimulus arrays. With so many stimuli it was not possible to arrange a perfectly counterbalanced design, but there were three or four sub-groups in each major group and so a reasonable control for stimulus preferences could be organised. The assignment of subjects to sub-groups within the main groups is shown in Table 8.11.

TABLE 8.11

The distribution of subjects across conditions and sub-groups in Experiment 8.1.

Condition	Sub-group	N	S+	S-
2S+:1S-	1	3	One circle, checkerboard	Horizontal
	2	3	Horizontal, checkerboard	Vertical
	3	3	Horizontal, vertical	One circle
	4	3	Vertical, one circle	Checkerboard
2S-:1S+	1	3	Horizontal	One circle, checkerboard
	2	3	Vertical	Horizontal, checkerboard
	3	3	One circle	Horizontal, vertical
	4	3	Checkerboard	Vertical, one circle
3S+:1S-	1	3	Vertical, checkerboard, one circle	Horizontal
	2	3	Horizontal, checkerboard, one circle	Vertical
	3	3	Horizontal, vertical, one circle	Checkerboard
	4	3	Horizontal, vertical, checkerboard	One circle
3S-:1S+	1	3	Horizontal	Vertical, checkerboard, one circle
	2	3	Vertical	Horizontal, checkerboard, one circle

Condition	Sub-group	N	S+	S-
3S-:1S+	3	3	Checkerboard	Horizontal, vertical, one circle
	4	1*	One circle	Horizontal, vertical, checkerboard
6S+:1S-	1	3	Vertical, checkerboard, one circle, quadrants, square,diagonal	Horizontal
	2	3	Horizontal, checkerboard, one circle,quadrants, square, diagonal	Vertical
	3	3	Horizontal, vertical, one circle,quadrants, square, diagonal	Checkerboard
	4	3	Horizontal, vertical, checkerboard, quadrants,square, diagonal	One circle
6S-:1S+	1	3	Horizontal	Vert., check., one circle, quadrants,square, diagonal
	2	3	Vertical	Horiz., check., one circle, quadrants, square, diagonal
	3	3	Checkerboard	Horiz., vert., one circle, quadrants, square, diagonal
	4	3	One circle	Horiz., vert., check.,quadrants, square, diagonal
1S+:1S-	1	3	Checkerboard	One circle
	2	2	One circle	Vertical
	3	2	Horizontal	Checkerboard
2S+:2S-	1	4	Horizontal, checkerboard	Vertical, one circle
	2	4	Horizontal, vertical	Checkerboard, one circle

Condition	Sub-group	N	S+	S-
2S+:2S-	3	4	Horizontal, one circle	Vertical, checkerboard
3S+:3S-	1	3	Horizontal, one circle, square	Check., vert., quadrants
	2	3	Check., vert., quadrants	Horiz., one circle, square
	3	3	Horiz., quadrants, diamond	Check., square, curve
	4	3	Check., square, curve	Horiz., quadrants, diamond
6S+:6S-	1	3	Horiz., one circle, check., diagonal, cross, square	Vert., quadrants, curve, diamond, four circles, random
	2	3	Vert., quadrants, curve, diamond, four circles, random	Horiz., one circle, check., diagonal, cross, square
	3	3	Horiz., square, cross, quadrants, curve, four circles	Vert., one circle, check., diamond, diagonal, random
	4	2	Vert., one circle, check., diamond, diagonal, random	Horiz., square, cross, quadrants, curve, four circles

(* 2 Ss were discarded, one due to an eye infection and the other due to failure to learn after 360 trials with 172/360 correct.)

Reversal learning. On the day following attainment of the learning criterion the subjects in the 3:1 condition were transferred to the reversal task and run to a learning criterion of 22/24 correct responses over two successive days.

RESULTS

The results of Experiment 8.1 are summarised in Table 8.12.

TABLE 8.12

Trials to criterion on the initial multiple stimulus discrimination, Experiment 8.1.

Group :	N:	$\bar{X}$	S.D.
2S+:1S-	11	87.2	23.9
2S-:1S+	11	118.1	47.1
3S+:1S-	12	74.6	26.0
3S-:1S+	10	103.4	53.6
6S+:1S-	12	86.2	24.7
6S-:1S+	12	102.7	41.5
1S+:1S-	69	49.7	49.5*
2S+:2S-	12	143.1	49.8
3S+:3S-	12	167.5	85.6
6S+:6S-	11	Median:358.5	-

(* Pooled estimate of S.D.)

The figure for the 1:1 condition on this table was determined on the basis of the results of 12-door subjects in Experiments 3.2, 5.4, 5.5 and 5.6 reported in earlier chapters of this thesis (Cf. Table 6.11)plus the data from the 7 subjects run under the 1:1 condition in this experiment. Only 7 subjects in the 6S+:6S- group learned the task after 360 trials, hence only a median score is reported. The experiment was discontinued at this point because there was no evidence that any more useful information could be gathered.

The main point of interest in this data is the comparison of the Multiple S+:Constant S- and Multiple S-:Constant S+ conditions, i.e. the 2:1, 3:1 and 6:1 conditions. For this purpose a 2 x 3 analysis of variance (by the method of unweighted means for unequal cell frequencies, Winer, 1971) was performed on the trials to criterion for these 6 groups. Inspection of the means and standard deviations in Table 8.12 suggested that these two statistics increased in proportion to each other and so were not independent. To correct for the possibility that the underlying distribution was not normal the analysis was done on log transformations of the data. The results of the analysis of variance indicated a significant effect for the Constant S- versus Constant S+ variable ($F(1,62) = 5.839$, $p < .05$), a nonsignificant effect for the number of stimuli variable ($F(2,62) = 1.097$, $p > .05$) and a nonsignificant interaction effect ($F < 1$, $p > .05$).

The indications are that responses to S- were more effective in the acquisition of the visual discrimination than responses to S+. This result confirmed previous findings in this area of research. Moreover, it confirmed those findings in a situation unconfounded by the order effects inherent in the conventional methods of presenting multiple stimuli. However, the fact that the number of heterogeneous variable stimuli involved was not critical confirmed the suggestion made by Mandler (1973) that the discrimination is made on the basis of the constant stimulus. If the constant stimulus is S- then learning is faster than if the constant stimulus is S+. Overall, however, it is the constant stimulus which matters rather than the number of variable stimuli involved. This conclusion received further support from the data of the control groups. The 1:1 group may be regarded as a reference point. When more than two stimuli were involved the speed of learning deteriorated severely. However, the difference between the means of the

2:2 and 3:3 groups was not significant ($t < 1$, $p > .05$). The 2:2 and 3:3 groups, which involved 4 and 6 stimuli respectively, took longer to acquire the discrimination than groups in the 3:1 and 6:1 conditions which involve 4 and 7 stimuli respectively. The difference between the combined means of the 3:1 groups and the mean of the 2:2 group was significant ($t(32) = 3.274$, $p < .05$). The difference between the combined means of the 6:1 groups and the 3:3 group was also significant ($t(34) = 3.516$, $p < .05$). However, the problem of interpretation which arises from the procedure of running the different conditions sequentially rather than concurrently is particularly relevant to this part of the data. The next experiment, Experiment 8.2, examined the role of the constant stimulus by keeping the ratio of S+:S- at 2:1 but without a constant stimulus being present in the situation.

However, an issue which must be examined before proceeding is that of stimulus preference. It is not possible to determine whether one stimulus is more discriminable than another. Nor is it possible to say, in the Multiple S-:Constant S+

situation, whether the subject is learning to avoid all the S-'s equally well, since the subjects' behaviour consists in making responses only to the constant S+. Finally it is not possible in the Multiple S+:Constant S- condition to say whether the subject has learned an equivalent approach tendency to all the S+'s. However, it is possible to determine whether one stimulus is responded to on a disproportionate number of trials. The 3:1 groups were chosen for such an analysis. The fact that this group was reversed meant that more data was available for such an analysis. In the 3 S-:1 S+ group, for none of the 10 subjects did a Chi squared test indicate a disproportionate amount of responding to the 3 S-'s in the course of the initial discrimination. In the 3 S+:1 S- group, however, for 4 subjects out of 12 the Chi squared test was significant at the .05

level. Furthermore, over the two criterion days (the final 24 trials for each subject) 5 subjects, including these 4 subjects, responded to the same stimulus on more than 11 of the 24 trials. The probability of such a response distribution is less than .05. Hence there is evidence, in the Multiple S+:Constant S- condition that subjects learn to respond to one particular S+ more than the others. On the other hand, when the discrimination was reversed the perseverative responding of these subjects was not confined to their preferred stimulus. On the average, 50 per cent of the responses of these 5 subjects were to non-preferred stimuli. It can be argued that perseverative behaviour is a good index of what a subject has learned. Overall, stimulus preference must be considered a complicating factor in this experimental design, but the evidence is not such as to invalidate the main findings.

When groups 3 S+:1 S- and 3 S-:1 S+ were reversed the mean trials to criterion were 178.3 and 198.9 respectively and the standard deviations were 44.2 and 105.3 respectively. The difference between the two groups was not significant (Mann Whitney U = 57, $p > .05$), consequently the study of reversal learning of multiple stimuli was not pursued.

EXPERIMENT 8.2. The effect of the constant stimulus in multiple stimulus discrimination learning.

In Experiment 8.1 various ratios of S+:S- and vice versa were studied. When the constant stimulus was S- learning was facilitated relative to the condition under which the constant stimulus was S+. It was concluded that, since variability in S- was more detrimental to learning than variability in S+, responses to S-, or errors, were relatively more important than correct responses. However, the fact that the difference between the constant S- and the constant S+ condition was unaffected by the number of variable stimuli, and also the progressive deterioration of the control groups as the number of stimuli increased, suggested the possibility that the results of Experiment 8.1 depended, to some extent, on one stimulus in the situation being constant. If this was so, the results of previous studies of multiple stimulus discrimination learning require some reinterpretation. In the studies reviewed in Chapter 7 various S+:S- ratios were used, but in every case multiple stimuli were paired with a constant stimulus. It is not that the conclusion concerning the relative importance of errors is in doubt, but rather that the conditions under which the effect occurs may be more restricted than had been thought.

The presentation of several S-'s and one S+ or several S+'s and 1 S- is not the only way in which a particular S-:S+ or S+:S- ratio can be achieved. The 2:1 condition can be used to illustrate this point. In Experiment 8.1 the 2:1 condition consisted of one group with 2 S+'s and 1 S- and another group with 2 S-'s and 1 S+. The same ratio is achieved by having 6 S+'s and 3 S-'s or 6 S-'s and 3 S+'s. This was done in Experiment 8.2. If it is the ratio of S+:S- or vice versa which is critical for a demonstration of the relative importance of responses to S-, then one would expect the 6 S+:3 S- group to learn the discrimination faster than the 6 S-:3 S+ group.

METHOD

Experimental design

The design of the experiment consisted of two groups: one with 6 different S+'s and 3 different S-'s and the other group with 6 S-'s and 3 S+'s. The subjects were trained to criterion on a simple discrimination.

Subjects

The subjects were 24 male, Wistar strain, hooded rats. They were approximately 100 days old at the beginning of pretraining and were experimentally naive. The subjects were maintained at 85 per cent of their ad lib. body weight throughout the experiment, but had water available at all times.

Apparatus

The apparatus was the circular maze described in Chapter 2. All the stimuli displayed in Figure 8.1 except the cross, four circles and random stimuli were used in this experiment. As in Experiment 8.1 the stimuli were arranged such that S+'s and S-'s were on alternate doors. There were four different arrangements of the stimuli so that four sub-groups within each experimental group could be presented with a different stimulus array to allow for stimulus preferences.

Procedure

Pretraining. The pretraining procedure used in this experiment was the same as that which had been used for 12-door subjects in previous experiments. On the day following the end of pretraining subjects were transferred to the discrimination task.

Discrimination training. The procedure used for discrimination training was the same as that used in Experiment 8.1. Subjects were run in batches of 3 with an inter-trial interval of 2 to 2½ minutes. The assignment of subjects to sub-groups within the two experimental groups is displayed in Table 8.21.

TABLE 8.21

The distribution of subjects across conditions and sub-groups in Experiment 8.2.

Condition	Sub-group	N	S+	S-
6S+:3S-	1	3	Horizontal, checkerboard square, diagonal curve, quadrants	Vertical, one circle, diamond
	2	3	Vert., square, one circle, diagonal, quadrants, diamond	Horiz., check., curve
	3	3	Horiz., vert., diagonal, curve, quadrants, diamond	Check., one circle, square
	4	3	Check., one circle, square, diagonal, curve, diamond	Horiz., vert., quadrants.
6S-:3S+	1	3	Vert., one circle, diamond	Horiz., check., square, diagonal, curve, quadrants
	2	3	Horiz., check., curve	Vert., square, one circle, diagonal quadrants, diamond.
	3	3	Check., one circle, square	Horiz., vert., diagonal, curve, quadrants, diamond
	4	3	Horiz., vert., quadrants	Check., one circle, square, diagonal, curve, diamond.

The subjects were trained to a learning criterion of 22/24 correct responses over two consecutive days.

RESULTS

The results of Experiment 8.2 are summarised in Table 8.22. One subject in the 6 S-:3 S+ group had not mastered the discrimination after 600 trials. The experiment was discontinued at this point since

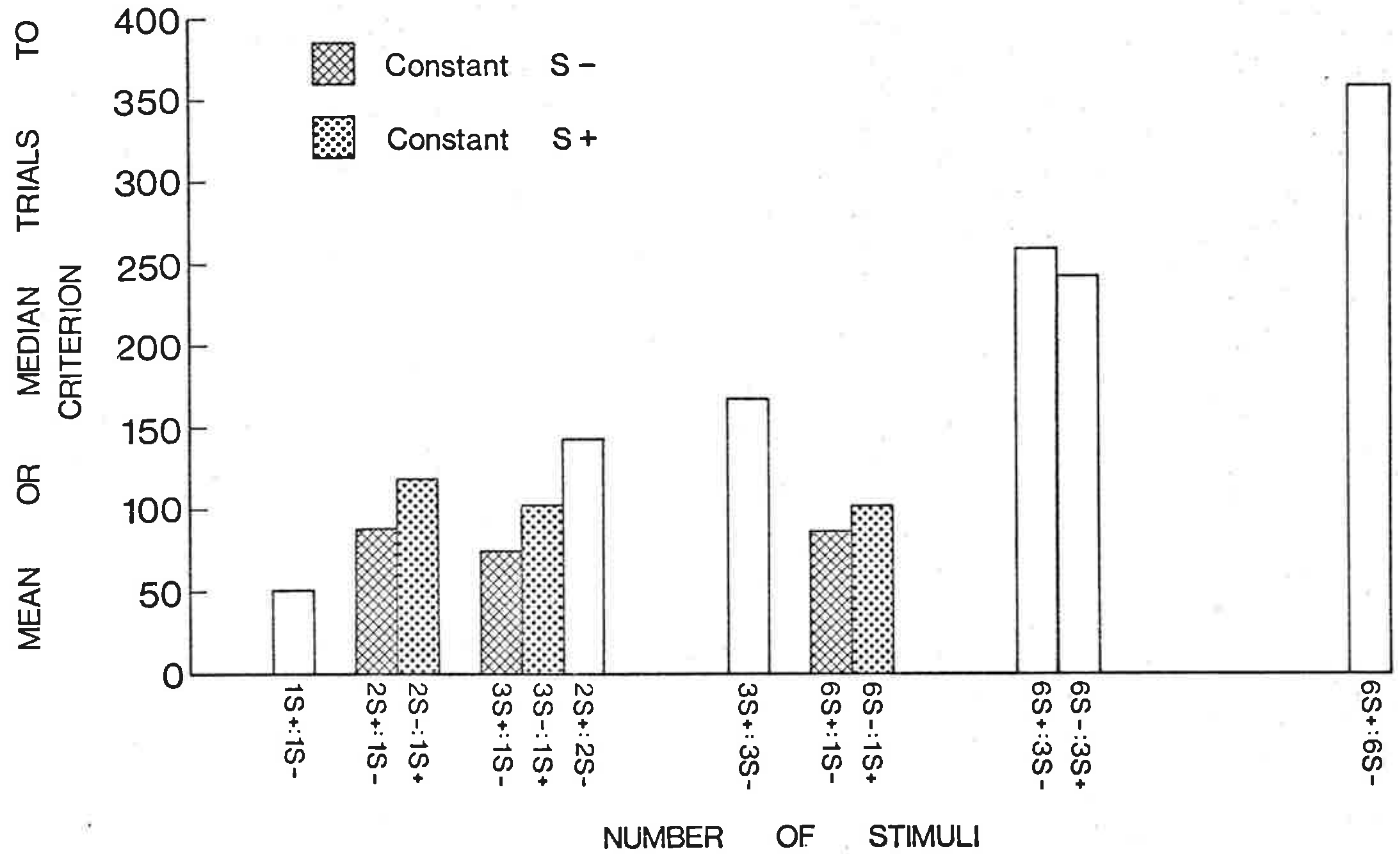
TABLE 8.22

Trials to criterion on the multiple stimulus discrimination. Experiment 8.2.

Group :			
6S+:3S-	Median	=	259.5
	$\bar{X}$	=	280.4
	S.D.	=	104.6
	N	=	12
6S-:3S+	Median	=	242.5
	N	=	12

the overall result was quite clear. There was not a significant difference between the two groups (Mann Whitney U = 53, $p > .05$). Indeed, apart from the subject which did not learn the discrimination, the difference between the groups favoured the 6 S-:3 S+ group. Hence, the results of this experiment are not in accord with predictions made above on the basis of the results of Experiment 8.1. In that experiment, in the 2:1 condition, the 2 S+:1 S- group mastered the task in fewer trials than the 2 S-:1 S+ group. Since the 2:1 ratio was maintained in both experiments, the conclusion must be that other factors besides the ratio of S+ to S- were involved. Figure 8.2 is a graphic representation of the results of both experiments in terms of the number of stimuli involved. This figure indicates the difference between the Multiple S+: Constant S- and Multiple S-:Constant S+ groups in Experiment 8.1, which was not affected by the number of multiple stimuli involved, but it also indicates how the rate of learning deteriorated as a function of the number of stimuli involved when a

FIG. 8·2 ACQUISITION OF MULTIPLE STIMULUS DISCRIMINATIONS AS A FUNCTION OF THE NUMBER OF STIMULI.



constant stimulus is not present in the situation. The point is made graphically rather than statistically due to the nature of the data: in two groups only median scores were available, the various conditions were not run simultaneously and in one group, the 1:1 group, the mean was based on several experiments. However, this issue will be taken up again in Experiment 8.5.

The next experiment in this series investigated another implication of Experiment 8.1.

EXPERIMENT 8.3. The effect of unequal numbers of S+ and S- on discrimination learning.

On the basis of the results of Experiment 8.1 it was concluded that responses to S-, or errors, had a greater effect on the speed of acquisition of a discrimination than correct responses, or responses to S+. If this is the case then rats presented with a situation in which most of the stimuli are S-'s would be less disadvantaged than subjects in a conventional situation, in which there are equal numbers of S+ and S-, or even by comparison with a situation in which most of the stimuli are S+'s. In all previous experiments in the circular maze the 12-door condition was such that half the doors were locked and half the doors were unlocked and that S- and S+ alternated from door to door. In Experiments 8.1 and 8.2, S+ and S- were differentially weighted, but only by varying the number of S+'s, S-'s or both in the sense that the 6 unlocked or locked doors displayed more or less varied stimuli. Another way of weighting S+ and S- is to provide more of one than the other in terms of the number of unlocked or locked doors. In this experiment subjects were required to learn a simple horizontal-vertical discrimination. However, instead of 6 horizontal and 6 vertical stimuli the subjects were presented with 8 S+'s and 4 S-'s in one case and 8 S-'s and 4 S+'s in the other.

For subjects in the 8 S+:4 S- group the task was "easy" in the sense that the initial probability of their making a correct response was .67, since 8 of the 12 doors displayed S+. Conversely, the task of the 8 S-:4 S+ group was made "difficult" by the fact that only 4 doors displayed S+. The initial chance of a correct response in this situation was .33. However, in the light of the finding in Experiment 8.1, this disadvantage may be considered more apparent than real.

From the results of Experiments 8.1 and 8.2 it was clear that the presence or absence of a constant stimulus may be an important factor which complicates the assessment of the role of responses to S+ and S-. In this experiment, however, one stimulus, S+ or S-, was more prevalent or more numerous than another, but there was no manipulation of the constancy or variability of the stimuli. In other words, S+ and S- were differentially weighted in a situation in which the constancy or variability of the stimulus was not an issue. Hence the assessment of the relative importance of responses to S+ and S- was uncomplicated by this factor. Similarly the question raised in Experiment 8.1 about the problem of stimulus preference or discriminability did not arise in this experiment. Horizontal and vertical were the only stimuli involved and a counter-balanced design was arranged to control for stimulus preference.

METHOD

Experimental design

The experimental design consisted of two groups: one group had 8 S+'s and 4 S-'s and the other group had 4 S+'s and 8 S-'s. Subjects learned a horizontal-vertical discrimination under these conditions to a criterion of 22/24 correct responses over two successive days.

Subjects

The subjects were 24 experimentally naive male, Wistar strain, hooded rats which were approximately 100 days old at the beginning of pretraining. They were maintained at 85 per cent of their ad lib weight throughout the experiment but had water available at all times.

Apparatus

The apparatus was the circular maze described in Chapter 2. The discriminanda used were the horizontal-vertical discriminanda used in previous experiments. The stimuli were arranged on the doors of the maze such that the horizontal stimulus was on every third door and the vertical stimulus was on the two intervening doors or vice versa.

Procedure

Pretraining. The pretraining procedure used in this experiment was the same as that used in previous experiments. On the day following the end of pretraining subjects were transferred to the discrimination task.

Discrimination training. The subjects were run in batches of 3 with an inter-trial interval of 2 to 2½ minutes. Half the subjects had horizontal as their S+ and half the subjects had vertical as their S+. The details of the procedure for discrimination training were the same as those used in previous experiments. The subjects were trained to a learning criterion of 22/24 correct responses over 2 consecutive days.

RESULTS

The performance of the subjects was scored in terms of their attainment of increasingly strict criterion levels: 12/24, 15/24, 20/24 and 22/24 over two successive days. However, since the 8 S+:4 S- groups had a chance level of performance of 16/24, the first two levels are meaningless for these subjects. Table 8.3 summarises the performance of the two groups. This table also indicates the likelihood

TABLE 8.3.

Acquisition of the horizontal-vertical discrimination, Experiment 8.3.

	Trials to criterion			
Group:	12/24	15/24	20/24	22/24
8S-:4S+ (N = 12)	$\bar{X}$: 15.6 S.D.: 13.9 p : .063	$\bar{X}$: 24.7 S.D.: 12.9 p : .003	$\bar{X}$: 37.2 S.D.: 14.7 p < .00001	$\bar{X}$: 42.0 S.D.: 11.4 p < .00001
8S+:4S- (N = 12)	-	-	$\bar{X}$: 27.9 S.D.: 21.7 p : .063	$\bar{X}$: 45.1 S.D.: 26.1 p : .005

of attainment, by chance, of the particular criterion given that the probability of a correct response was .33 or .67.

There was not a significant difference between the groups on the attainment of the conventional criterion of 22/24 ($t < 1$, $p > .05$). Nor was there a significant difference between the groups on their attainment of the less strict criterion of 20/24 ($t(22) = 1.177$, $p > .05$).

Figure 8.3 illustrates quite well what occurred in the course of the experiment. The starting points in the learning curves differ in the way in which one would expect on the basis of the two groups' initial probability of responding correctly. Thereafter the 8 S-:4 S+ group showed rapid improvement over the first 5 days, whereas the 8 S+:4 S- subjects were slow to improve their performance.

The fact that the disadvantaged 8 S-:4 S+ group mastered the discrimination as fast as the 8 S+:4 S- group, plus the fact that this group's rate of improvement was most marked over the first few days of the experiment when errors were most common, leads to the conclusion that making errors is a more effective way of learning than in making a high proportion of correct responses. Moreover, this demonstration of the greater improtance of errors as against correct responses took place in a situation uncomplicated by variable stimuli.

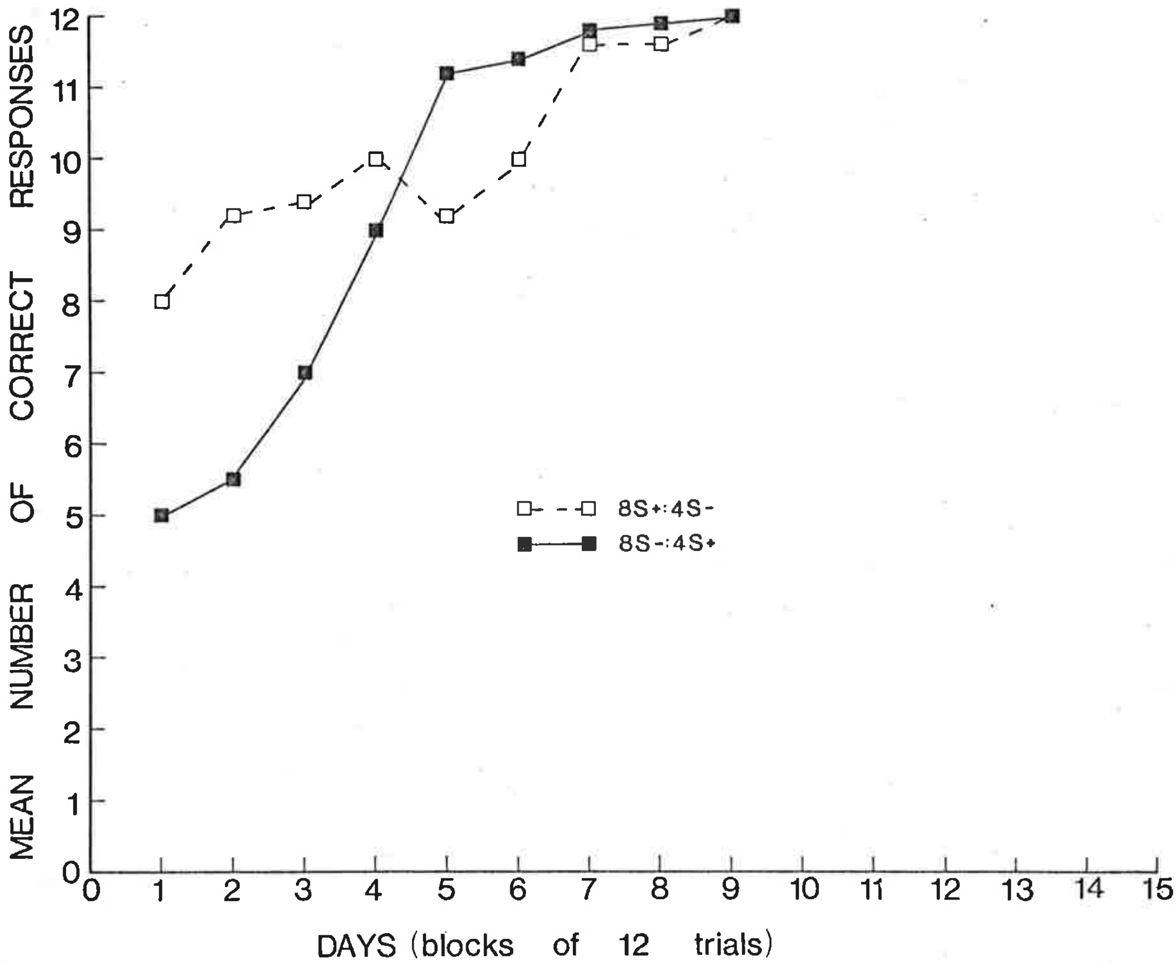
However, some reservations ought to be kept in mind about these results. There was not a difference in favour of the 8 S-:4 S+ group. The above conclusion is based on the failure to find a difference in favour of the 8 S+: 4 S- group. It would be more impressive to show that not only does the group with more S-'s catch up with the group with fewer S-'s, but that a group with more S-'s can master a discrimination task more rapidly than a group with few S-'s. Experiment 8.4 attempted to demonstrate this by increasing the ratio of S+:S-.

EXPERIMENT 8.4. The effect of unequal numbers of S+ and S- on discrimination learning: a replication.

The aim of this experiment was to replicate Experiment 8.3 with a different S+:S- ratio. The ratio in Experiment 8.3 was 2:1, resulting in groups with 8 S+'s and 4 S-'s or 8 S-'s and 4 S+'s. In

FIG. 8·3

ACQUISITION OF HORIZONTAL - VERTICAL DISCRIMINATION. Exp. 8·3



this experiment a ratio of 5:1 was investigated. Thus there were two groups with 10 S+'s and 2 S-'s or 10 S-'s and 2 S+'s. On the basis of the result of Experiment 8.3 it was predicted that the 10 S-:2 S+ group would master the discrimination faster than the 10 S+:2 S- group.

METHOD

Experimental design

The design of this experiment was the same as that of Experiment 8.3, except for the fact that there were now two groups one with 10 S+'s and 2 S-'s and the other with 10 S-'s and 2 S+'s.

Subjects

The subjects were 22 experimentally naive male, Wistar strain, hooded rats which were approximately 100 days old at the beginning of pretraining. They were maintained at 85 per cent of their ad lib weight throughout the experiment but had water available at all times.

Apparatus

The apparatus was the circular maze described in Chapter 2. The discriminanda used in this experiment were the horizontal-vertical discriminanda used in Experiment 8.3, but in this case the horizontal stimulus occurred on only two doors and the vertical stimulus occurred on the intervening five doors or vice versa.

Procedure

Pretraining and discrimination training. The same procedure for pretraining and discrimination training was followed in this experiment as had been followed in Experiment 8.4, except that the subjects in this experiment were run to a criterion of 24/24 correct responses over two successive days in order to provide further information for comparison between the groups.

RESULTS

The results of Experiment 8.4 are summarised in Table 8.4.

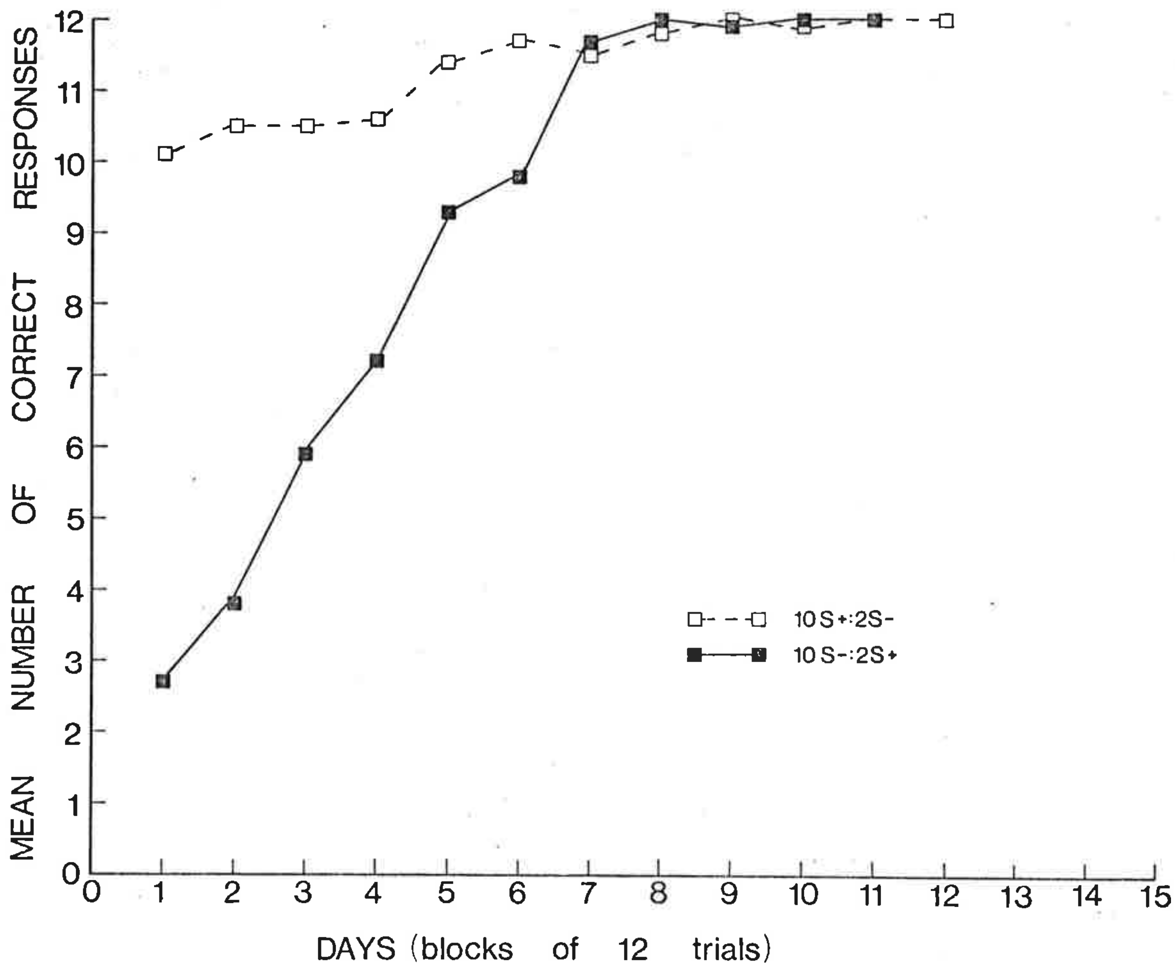
TABLE 8.4

Acquisition of the horizontal-vertical discrimination, Experiment 8.4.

Group:	Trials to criterion: 12/24	15/24	20/24	22/24	24/24
10S-:2S+ (N = 11)	$\bar{X}$: 28.3 S.D.: 16.3 p = .0002	$\bar{X}$: 31.6 S.D.: 17.6 p < .000001	$\bar{X}$: 44.3 S.D.: 15.4 p < .0000001	$\bar{X}$: 46.8 S.D.: 13.6 p < .0000001	$\bar{X}$: 64.3 S.D.: 18.6 p < .0000001
10S+:2S- (N = 11)	-	-	-	$\bar{X}$: 25.8 S.D.: 17.6 p = .200	$\bar{X}$: 62.6 S.D.: 21.8 p = .011

As in Table 8.3, the value of p given is the probability of a subject attaining a particular criterion by chance. The same phenomena as occurred in Experiment 8.3 was replicated. The contrast between the two groups is shown most clearly by the learning curves in Figure 8.4. Again the starting point of the two curves accurately indicates the initial probability of a correct response. This was followed by a dramatic improvement by one group, 10 S-:2 S+, but by a very gradual improvement by the other group. The improvement in the 10 S-:2 S+ group was such that this group mastered the discrimination as fast as the 10 S+:2 S- group ($t < 1$, $p > .05$). However, the difference between the groups in terms of attainment of the conventional criterion of 22/24 correct responses was significant ($t(20) = 2.990$, $p < .01$).

FIG. 8·4
ACQUISITION OF HORIZONTAL - VERTICAL DISCRIMINATION.
Exp. 8·4.



The prediction that a shift from a 2:1 ratio in Experiment 8.2 to a 5:1 ratio in Experiment 8.4 would lead to the 10 S-:2 S+ group mastering the discrimination faster than the 10 S+:2 S- group was not fulfilled. The striking similarity in performance of the 8 S+:4 S-, the 8 S-:4 S+ and the 10 S-:2 S+ groups on the horizontal-vertical discrimination is a point which will be further discussed later in this chapter.

There remains one further aspect of the problem to be investigated. This final experiment in this series combined the two methods of weighting S+ and S- which were studied in the above experiments. Experiment 8.1 and 8.2 involved 6 S+'s and 6 S-'s, but the variability of these stimuli was manipulated. Experiment 8.3 and 8.4 involved only two stimuli, horizontal and vertical, but the number of times each occurred in the 12-door situation varied. In the results of all four experiments there was evidence that responses to S- were more effective than responses to S+ as far as learning was concerned. In the first two experiments, however, this finding was complicated by the possibility that the effect occurred only when one stimulus in the situation was constant. In the last two experiments the effect was quite strong but not so strong as to lead to a significant difference between the two groups. It remains to vary both the number of locked and unlocked doors and the number of stimuli on those doors.

EXPERIMENT 8.5. The effect on discrimination learning of different numbers of S+ and S- when stimulus variability is held constant.

In this experiment the 8 S+:4 S- and 8 S-:4 S+ conditions were retained. However, the 8 S+'s and the 8 S-'s were composed, not of a constant stimulus but of four instances of two stimuli. The 4 S-'s and 4 S+'s consisted of repetitions of the same stimulus. Thus no stimulus was any more prevalent than any other stimulus. Each stimulus in the situation was displayed on only 4 doors, irrespective of whether it was S+ or S-.

The aim of the experiment was to replicate the effect obtained in Experiments 8.3 and 8.4, i.e. the rapid improvement of the 8 S-:4 S+ group by comparison with the 8 S+:4 S- group. To do so would demonstrate that the relative importance of errors in discrimination learning is not dependent upon the presence of a constant stimulus, or on one stimulus being more prevalent than another. There was also the possibility that the result predicted in Experiment 8.4 would be achieved in this situation, i.e. that the 8 S-:4 S+ group would master the discrimination faster than the 8 S+:4 S- group when the stimuli occurred equally often.

METHOD

Experimental design

The experiment consisted of 2 groups: Group 8 S-:4 S+ was presented with 8 locked doors and 4 open doors. The 8 locked doors consisted of 4 instances of each of 2 stimuli. The 4 open doors consisted of 4 instances of a single stimulus. Group 8 S+:4 S- was presented with 8 open doors and 4 locked doors. The 8 open doors consisted of 4 instances of 2 stimuli and the 4 locked doors consisted of 4 instances of a single stimulus.

Subjects

The subjects were 24 experimentally naive, male, Wistar strain, hooded rats, which were approximately 100 days old at the beginning of pretraining. They were maintained at 85 per cent of their ad lib bodyweight throughout the experiment but had water available at all times. One subject from the 8 S+:4 S- group became too savage to handle after three days of discrimination training and could not be retained in the experiment.

Apparatus

The apparatus was the circular maze described in Chapter 2. The discriminanda were the horizontal, vertical, checkerboard and quadrants displayed in Figure 8.1. The stimuli were arranged on the doors of the maze such that S+ was on every third door and S- was on the two intervening doors, or vice versa. The stimuli which served as S+ and S- varied from one sub-group to another in order to balance stimulus preferences, and the stimuli were juxtaposed such that as wide a range of the 12 possible pairings of the different stimuli as was practical was presented.

Procedure

Pretraining. The pretraining procedure used in this experiment was the same as that used in the previous experiments. On the day following the end of pretraining subjects were transferred to the discrimination task.

Discrimination training. The details of the procedure used in this experiment were the same as those used in previous experiments. Subjects were run in batches of 3 with an inter-trial interval of 2 to 2½ minutes. The assignment of subjects to sub-groups within the two experimental groups is displayed in Table 8.51. The subjects were trained to a learning criterion of 24/24 correct responses over two successive days.

TABLE 8.51

The distribution of subjects across conditions and sub-groups in Experiment 8.5.

Condition	Sub-group	N	S+	S-
8S+:4S-	1	3	Vertical, checkerboard	Horizontal
	2	3	Horizontal, quadrants	Vertical
	3	3	Vertical quadrants	Checkerboard
	4	3	Horizontal, checkerboard	Quadrants
8S-:4S+	1	3	Horizontal	Vertical, checkerboard
	2	3	Vertical	Horizontal, quadrants
	3	3	Checkerboard	Vertical, quadrants
	4	3	Quadrants	Horizontal, checkerboard

RESULTS

The performance of subjects in Experiment 8.5 was scored in the same way as that of subjects in Experiments 8.3 and 8.4, i.e. in terms of their attainment of criterion levels of 12/24, 15/24, 20/24, 22/24 and 24/24 correct responses over two consecutive days. The results of Experiment 8.5 are summarised in Table 8.52. Since the 8S+:4S- group had an initial probability of a correct response of .67, the first two criterion levels are meaningless for this group.

TABLE 8.52

Trials to criterion on the multiple stimulus discrimination, Experiment 8.5.

Group	Trials to Criterion: 12/24	15/24	20/24	22/24	24/24
8S-:4S+	$\bar{X}$: 28.5	$\bar{X}$: 49.3	$\bar{X}$: 60.5	$\bar{X}$: 67.6	$\bar{X}$: 85.7
	S.D.: 28.5	S.D.: 30.9	S.D.: 29.0	S.D.: 29.8	S.D.: 34.9
(N = 12)	p = .063	p = .003	p < .00001	p < .00001	p < .000001
8S+:4S-			$\bar{X}$: 60.4	$\bar{X}$: 79.5	$\bar{X}$: 98.6
	-	-	S.D.: 27.9	S.D.: 25.4	S.D.: 23.3
(N=11)			p = .063	p = .005	p < .0001

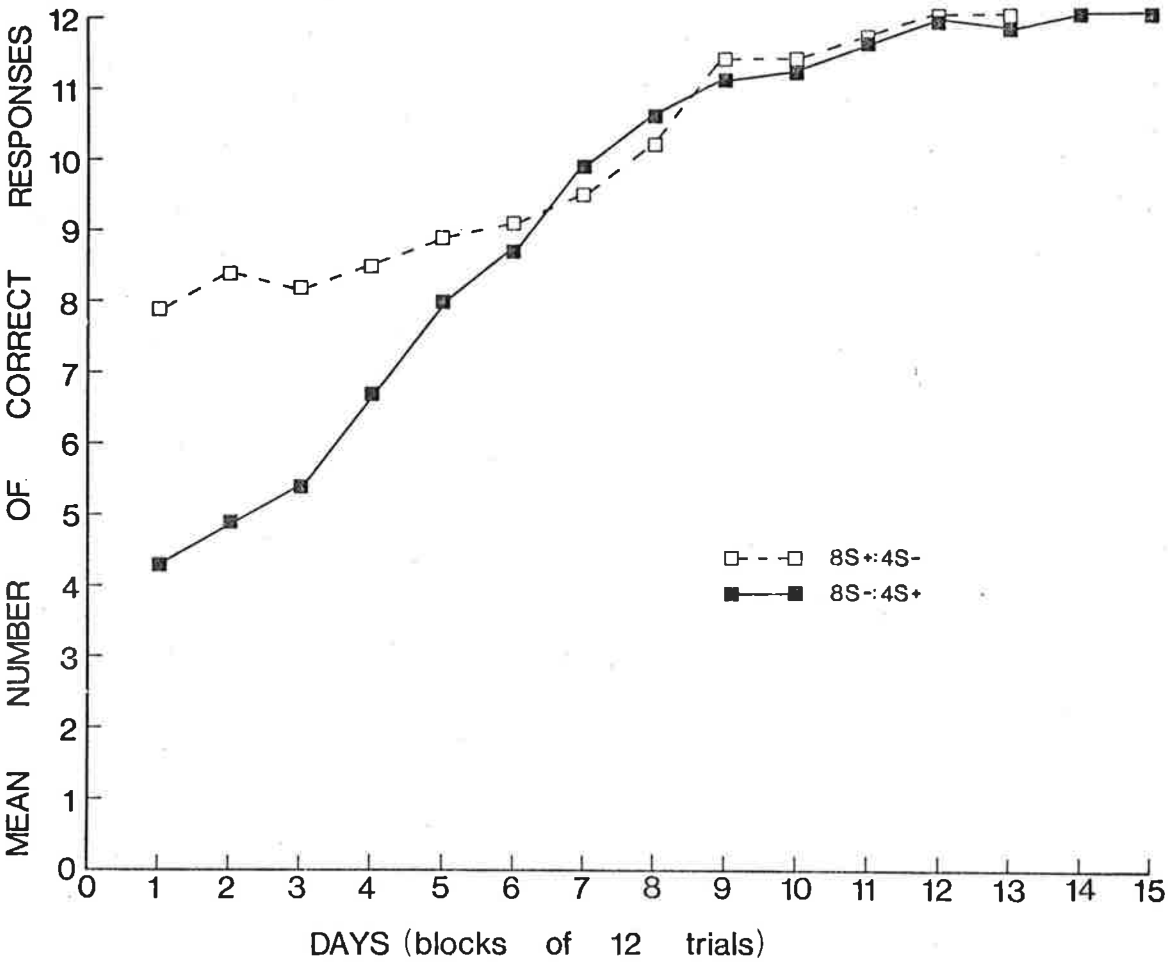
The differences between the two groups in the attainment of the criterion levels of 20/24, 22/24 and 24/24 were not significant ($t < 1$, $p > .05$ in each case). This finding and the pattern of the learning curves, illustrated in Figure 8.5, indicate that the same effect occurred in this experiment as had occurred in Experiments 8.3 and 8.4. Consequently, it seems that the effect is due to some property of responses to S-, or errors, rather than to experimental conditions, such as the prevalence of a particular stimulus.

DISCUSSION

The main point of the experiments described in this chapter was not to initiate a new line of research, but rather to examine a long-standing issue under more refined experimental conditions. The conclusion, simply stated, was that even under the more carefully controlled conditions the earlier findings that responses to S- are more effective

FIG. 8·5

ACQUISITION OF THE MULTIPLE STIMULUS DISCRIMINATION. Exp. 8·5



in discrimination learning than responses to S+ were supported. However, in another sense the conclusion was not so simple. In Experiments 8.1 and 8.2 the relative importance of responses to S- was complicated by the problem of the role of the constant stimulus in the Multiple S+:Constant S- versus Multiple S-:Constant S+ design. In Experiments 8.3 and 8.4 the weighting of S+ and S- involved one stimulus being more prevalent than another.

As the literature review in Chapter 7 revealed, there has been little work done in the field of multiple stimulus discrimination learning with a range of heterogeneous S-'s. One aim of Experiment 8.1 was to fill this gap. Moreover, this experiment not only looked at the effect of several heterogeneous S-'s, but the design was counterbalanced to investigate the effect of varying both S+ and S-. Experiment 8.1 was also unique in that it involved control groups in which the number of stimuli was varied without S+ or S- being weighted. The results of Experiments 8.1 and 8.2 justified this more complex experimental design. although one should not overlook the procedural problems in Experiment 8.1. Not only did the number of stimuli involved in the Multiple S+:Constant S- or Multiple S-:Constant S+ conditions prove not to be a significant variable, but the deterioration in the performance of the control groups as the number of stimuli increased contrasted with the absence of any deterioration in the experimental groups as the number of stimuli increased.

Experiment 8.2 further demonstrated the flexibility of the circular maze. The same ratio of S+:S- could be studied under quite different experimental conditions. Whereas in Experiment 8.1 three stimuli constituted the S+:S- ratio of 2:1, in Experiment 8.2 nine stimuli constituted the ratio of 2:1, and the ratio was such that there was no constant stimulus in the situation. This allowed a test of Mandler's (1973) suggestion that the constant stimulus was a critical variable - an interpretation also suggested by the results of Experiment 8.1. Were it not for the fact that the Moss-Harlow effect has been demonstrated in quite a range of experimental designs besides multiple stimulus discrimination situations, one would have suspected, on the basis of the results of Mandler (1973) and Experiment 8.1 and 8.2, that the phenomenon was an artefact of the multiple stimulus experimental design, and that its demonstration depended on there being a constant stimulus present in the situation. It would be worthwhile replicating the design of Experiment 8.2 with a ratio of 3:1, i.e. a comparison of a 6 S+:2 S- group with a 6 S-:2 S+ group. However, the fact remains that, even when there was a constant stimulus present in the situation, a constant S- facilitated performance relative to a constant S+.

Experiments 8.3 and 8.4 represented an attempt to avoid the problems posed by the findings of Experiments 8.1 and 8.2. In Experiments 8.3 and 8.4 an attempt was made to differentially weight S+ and S- in a situation in which no one stimulus was more constant or more varied than any other stimulus. The two experiments demonstrated that the "dis-advantaged" group with more S-'s than S+'s could master the discrimination as easily as a group with more S+'s than S-'s. Once again, however, the change in the ratio of S+:S- or vice versa from 2:1 to 5:1 made little difference to the speed of learning. Table 9.1 demonstrates this point. The scores for the 1:1 ratio are derived from three earlier experiments in which naive 12-door subjects learned a horizontal-vertical discrimination. Admittedly, the results would have been easier to interpret if a 1:1 control group had been included in Experiments 8.3 and 8.4, since comparisons

TABLE 9.1

Trials to criterion for various S+:S- ratios

Ratio of S+:S-	Mean trials to criterion	Experiment
5:1	25.8	8.4 (Group 10S+:2S-)
2:1	45.1	8.3 (Group 8S+:4S-)
1:1	50.5	3.2, 5.4 and 5.5
1:2	42.0	8.3 (Group 8S-:4S+)
1:5	46.8	8.4 (Group 10S-:2S+)

across different experiments, using different batches of rats, can be misleading. Apart from the case of the S+:S- ratio of 5:1, where the initial level of chance performance was already 20/24, the mean trials to criterion of the groups are remarkably similar. It ought to be noted that the situation studied in Experiments 8.3 and 8.4 approximates to that used to study oddity learning. The task in these experiments for half the subjects was to select a few S+'s from among several S-'s. The research relevant to this experimental situation is reviewed in Chapter 7 under the heading of "Multiple heterogeneous stimuli". The overall conclusion from that research was that discrimination learning improves as a function of the number of S-'s. In Experiment 8.3 and 8.4 the reverse condition was also under investigation - half the subjects were required to avoid a few S-'s present among several S+'s. From this point of view the results summarised in Table 9.1 are particularly interesting. The speed of learning a simple discrimination was little affected by whether there were few S+'s and many S-'s or many S+'s and few S-'s.

Experiment 8.5 was a final attempt to define the role of responses to S-. Experiments 8.1 and 8.2 were complicated by the problem of the effect of the constant stimulus upon multiple stimulus discrimination. Experiments 8.3 and 8.4 involved one stimulus, S+ or S-, occurring more often than the other. In Experiment 8.5 there were more S+'s than S-'s or vice versa, hence S+ or S- was differentially weighted, but no one stimulus was more prevalent than another - each stimulus occurred equally often. The result was a re-occurrence of the phenomena observed in Experiments 8.3 and 8.4 - the group with fewer S+'s mastered the discrimination as easily as the group with more S+'s than S-'s.

The overall conclusion, therefore, confirms the position adopted by earlier workers in this field, i.e. responses to S-, errors, are more important in the acquisition of a simultaneous visual discrimination in rats than are responses to S+, correct responses. Increased variability in S-, or an increase in the number of S-'s results in deterioration or facilitation of learning respectively.

Historically, research into the role of errors in discrimination learning has been persistent over a number of years without being concentrated at any one time. This is not to deny the value of the substantial contributions made recently by Cross and his associates and by Mandler, but in general it is fair to say that the problem has been with us for a long time without being solved to general satisfaction. The history of the question reveals a series of experimental designs each one intended to sort out the effect of a response to S+ or S- from all the confounding variables, and each experimental design was beset by its own particular problems. The present thesis contributed to this body of research by further refining an experimental design, namely, multiple stimulus discrimination.

It is possible to suggest further research along these lines using rats as subjects. In the light of the suggestion by Deutsch and Biederman (1965) that the negativity of a stimulus changes as a function of overtraining, a reversal or shift task might be used to assess such changes. However, the more interesting extensions of the work described in this thesis would be with other species besides the rat. Research in this area has been characterised by the use of a wide range of species, at least by comparison with many other areas of discrimination learning. Also, the developmental aspect of the research in this area has been remarked on in Chapter 7. The refinements to the experimental design discussed in this thesis ought to be applied both to other species and to developmental studies of the problem.

One can only speculate as to _why_ responses to S- are more effective than responses to S+ in the course of discrimination learning. An explanation in terms of frustration is a plausible one. Responses to S- may result in an aversive condition, frustration, which is more conducive to avoidance learning than the satisfaction gained by responding to S+ is conducive to approach learning. An evolutionary explanation is another approach which focusses on the developmental aspects of the Moss-Harlow effect. The survival of the more primitive species depends more on avoiding mistakes, which tend to be fatal, than on getting things right. A more developed organism can afford the luxury of a few mistakes as it concentrates on acquiring the correct response. However, these are speculations.

This thesis has not attempted to explain *why* responses to S- are more important than responses to S+, and the results of the experiments described in this chapter do not indicate any particular explanation. The problem so far has been one of demonstrating convincingly that responses to S- are more important than responses to S+.

CHAPTER 9

SUMMARY AND FINAL CONCLUSIONS

The overall concern of this thesis has been to study the role of errors in visual discrimination learning in rats. To this end the effect of frustrative nonreward on a discrimination task, the role of simple, nonrewarded responses within a discrimination task and the role of a major source of errors, position responding, have all been considered. The results of the experimentation were often contrary to what one might expect on the basis of previous research, commonly held theoretical positions and "common sense". Detailed statements of the conclusions based on these results have been formulated in earlier chapters. What will be presented in this chapter is a review of the whole thesis: its aims, methods and results and the more important conclusions and implications of those experiments.

The line of research pursued in these experiments was initiated in the Adelaide laboratories by Winefield and Jeeves who designed the circular maze and supervised the early experiments performed in this apparatus. The circular maze was intended to provide a situation which allowed the simultaneous presentation of visual or symbol stimuli in the absence of visual spatial cues to position. This made possible a comparison between the performance of subjects which displayed the position responding characteristic of the "pre-solution" phase of visual discrimination learning and that of subjects which did not have available the spatial cues on which position responding could be based. A number of other intra- and extra-maze cues were also eliminated by the structure and use of the maze.

Since the circular maze allowed the simultaneous presentation of twelve stimuli, it could be used to study multiple stimulus discrimination learning, especially the effect of different weightings of S+ and S- on discrimination learning. The advantage of this adaptation of the maze was that one of the most fruitful methods for studying the relative effect of responses to S+ and S- could be used. Moreover, since the maze avoided various methodological problems, the multiple stimulus procedure could be improved.

However, interest, early in the research program, lay in the role of position responding in discrimination learning. The early experiments performed in the circular maze suggested that the assumption commonly made about that role, i.e. that position responding was detrimental to learning, was not valid. The reduction of spatial cues to position did not facilitate learning, and indeed it seemed possible that the very opposite might be the case.

The assumption that position responding was detrimental to discrimination learning is a particularly widespread one. It has been incorporated in most of the major theories of discrimination learning, from the time of Krechevsky and Spence to that of Harlow and Sutherland and Mackintosh. The assumption is not an unreasonable one. Position responding is a very strong phenomenon in the sense that it occurs very frequently, even in simple discrimination tasks, and it can be remarkably persistent. When a subject responds consistently to a set of irrelevant cues, at worst, it appears to prevent the animal learning about the relevant cues in the situation and at best, it delays the adoption of the response appropriate to the task. Hence the first two experiments described in the thesis concentrated on the issue of position responding in discrimination learning.

These two experiments studied the role of position responding in two experimental situations in interpretations of which the assumption about the detrimental effect of position responding has been most notable. These situations were the effect of overtraining on reversal learning and the study of nonreversal shifts. On the one hand the relatively small amount of position responding during reversal after overtraining and on the other the increased speed of reversal learning after overtraining have been seen as support for the proposition that overtraining facilitates reversal learning by minimising position responding.

Experiment 3.1, however, provided no support for this theory. The experiment was not a successful one in that the ORE was not observed in the 2-door subjects. Consequently speculation on the effect of reduced spatial cues on reversal training was made difficult. However, on the initial, difficult discrimination in this experiment the presence of spatial cues to position actually facilitated discrimination learning. This finding suggested that, far from interfering with learning, position responding constituted a transitional response strategy while the rat mastered the relevant discrimination task. The fact that this form of behaviour provides a reasonable rate of reinforcement (50 per cent of responses are rewarded) or the possibility that it relieves the tension or uncertainty inherent in any difficult task may be the reason why position responding is a useful strategy.

In Experiment 3.2, rats which had learned to ignore spatial cues to position in the course of acquiring a discrimination, were compared on a nonreversal shift, with rats which learned the initial discrimination in the 12-door condition and so did not learn to ignore spatial cues. If position responding is detrimental to learning, one would expect that subjects which had learned to ignore spatial cues on one task would transfer this learning to the subsequent shift task, and so learn that discrimination faster than subjects which had not learned to ignore spatial cues. In fact, no such difference in the rate of learning on the transfer task was observed.

The conclusion drawn from Experiments 3.1 and 3.2 was that the commonly held view of the detrimental effects of position responding was not justified. If an assumption made about a phenomenon as strong as position responding cannot be supported, assumptions made about other forms of systematic behaviour in rats ought to be questioned. Moreover the issue is not confined to rats. Position responding and other systematic behaviour patterns have been observed in other species, in children, both normal and retarded, and even in adults. The mere fact that these behaviour patterns do not contribute directly to the solution of the task under observation should not lead to the assumption that they are detrimental to the learning of that task. As a result of the influence of Maier, the next phase of the research program focussed on the role of frustration in discrimination learning and on the interaction of frustration and position responding. Just what aspect of frustration ought to be researched was a problem in itself since the whole concept of frustration involves a complex and often confusing argument. From the early work of Maier to the current theories of Amsel, "frustration" has been used to describe unobserved emotional states, to characterise experimental operations which are assumed to produce frustration and to explain particular patterns of behaviour which are said to result from frustration. Moreover, there has been a good deal of theoretical and empirical work which has never been discussed under the heading of frustration but which involved similar experimental designs and similar behaviour.

However, the approach adopted in this thesis has been to concentrate on the frustrating effect of placing rats under a schedule of random reinforcement so that no matter what pattern of behaviour was displayed, no more than 50 per cent of the responses were rewarded. The effect of this frustrative nonreward was assessed in terms of performance on a subsequent visual discrimination task. A situation analogous to Maier's concept of frustration was studied by confronting naive subjects with the insoluble task, and one analogous to Amsel's was achieved by first teaching the subjects an initial discrimination and then disconfirming their expectations of systematic reward and nonreward by transferring them to the insoluble task.

Position responding and frustration have been inescapably linked since Maier's work on frustration. In Maier's research stereotyped position responding was regarded as a reaction to a frustrating, insoluble task. It was relatively easy for Maier, and subsequent workers in this field, to assume that position responding was a reaction to or an expression of frustration. A rat in a very difficult or insoluble task, or after a reversal or nonreversal shift from an already mastered discrimination readily adopts a position habit. Early experiments in the circular maze and two pilot studies (Experiments 5.1 and 5.2) indicated the usefulness of using the circular maze to study the effect of frustration on learning and to investigate the relationship between position responding and frustration. Thus, rats subjected to the frustrating operations were studied under conditions of reduced spatial cues and their performance was compared with that of subjects in the more conventional 2-door condition.

Experiment 5.3 was the major study in this series of experiments. The experiment was designed to compare, on the basis of a horizontal-vertical transfer task, the effect of the two different frustrating operations described above with performance under appropriate control conditions, i.e. the transfer task learned by naive subjects or by subjects transferred immediately from the initial task. The results were that both frustrating operations had a deleterious effect on the acquisition of the subsequent transfer task, but this effect was not as marked in those groups which came to the insoluble problem after mastering an initial discrimination. Secondly, the 2-door groups, for the most part acquired the test discrimination faster than the 12-door groups, but not significantly so. On the reversal of the test discrimination, however, the superiority of the 2-door subjects was significant.

Subsequent experiments in this series concentrated on various aspects of the above results. Experiment 5.4 reduced the possibility that the results were due to the groups being too small. Experiments 5.5 and 5.6 were concerned with the effect of an initial discrimination task on frustration training. It became apparent that the advantage experienced by subjects which had mastered a discrimination task before confronting an insoluble problem depended on the presence, during random reinforcement, of a cue to which the subjects had learned a particular response. If such a cue was present these subjects were able to cope with a very testing random reinforcement schedule without deleterious effects on subsequent discrimination learning (Experiment 5.5). If such a cue was not present, position responding was a readily available form of behaviour for 2-door subjects, and in this case position responding did seem to delay their acquisition of the test discrimination by comparison with 12-door subjects.

What did these experiments contribute to a better understanding of the role of frustration in discrimination learning? Firstly they clearly show that the effect of frustration on a subsequent task is detrimental. Frustration might facilitate the performance of an ongoing task by increasing drive, incentive or persistence; or it might have a quite different effect on response latency rather than choice. But it is as an explanation of subsequent performance - the effect of overtraining on a subsequent reversal or the effect of some characteristic of an initial discrimination on a subsequent transfer task - that frustration is most freely used. In this situation, one which has received relatively little investigation, frustration appears to have a detrimental effect.

Secondly, it is not enough to talk of "frustration" as if this is a univocal concept. The effect of frustration on learning varies according to how frustration is defined. A host of experimental operations could be considered frustrating - punishment, extinction, time-out from positive reinforcement, reversal of an established discrimination, conflict etc. The experiments described in Chapter 5 looked at only two frustrating operations and found a marked difference between them.

A third point concerns the relationship between frustration and position responding. If the evidence gathered in this series of experiments is added to that of Experiments 3.1 and 3.2, the conclusion must be that the presence of spatial cues to position is seldom detrimental to discrimination learning and that in a demanding situation, such as a very difficult or insoluble problem or a reversal task, the availability of cues to position responding may be an advantage.

Finally, the importance of early and successful experience in a learning situation ought to be stressed. The underlying mechanism may be more complex than it seemed at first, but its effectiveness in offsetting frustration makes it worth emphasising.

The question of the role of simple errors, or responses to S-, in a discrimination task occupied the remainder of the thesis. To some extent interest in this question sprang from the usefulness of the circular maze for such a study. A less pragmatic reason was that, while an immense amount of research has gone into the role of responses to S- in more complex situations, e.g. extinction, reversal, etc., we know very little about the effect of responses to S- in the course of a simple discrimination. The history of research on this topic had shown that, for infraprimates and very young children, learning was more a matter of learning to avoid S- than of learning to approach S+. This relative importance of responses to S-, or errors, was called the Moss-Harlow effect. However, this conclusion was based on a variety of experimental designs each of which had methodological problems, usually involving novelty or order effects. One of the most successful of these experimental designs involved the study of multiple stimulus discrimination learning. This method allowed the role of errors to be studied without interruption of the ongoing discrimination task. It achieved its effect by differentially weighting S+ or S-, usually the latter, and then assessing the effect of the variability of the stimulus on performance. The use of the circular maze for the study of multiple stimulus discrimination learning allowed for S+ and S- to be differentially weighted and the whole stimulus array to be simultaneously presented to the subject on each trial.

In Experiment 8.1 both S+ and S- were differentially weighted to various degrees. In addition control groups in which both S+ and S-were varied without being differentially weighted were provided. This design was considerably more comprehensive than any which had been used in previous studies. The results of this experiment confirmed the finding of previous research: for rats errors are more important or more influential in discrimination learning than are correct responses. Variability in S- had a detrimental effect on learning by comparison with the effect of variability in S+. However, the Moss-Harlow effect observed in this experiment was not affected by the degree of variability of S+ or S-. Moreover, the performance of the control groups, for which no one stimulus was constant, deteriorated to an extraordinary degree as the number of stimuli involved increased. Clearly, it was not the effect of variability of S+ or S- which needed closer examination, but whether the constant stimulus played a more important role than had been suspected. Experiment 8.2 added weight to this suspicion since the Moss-Harlow effect was not observed in a situation in which the variability of S+ and S- was differentially manipulated but in such a way that there was some degree of variability in all stimuli.

Experiments 8.3 and 8.4 were designed to differentially weigh S+ and S-, but without stimulus variability being a factor in the situation. This was achieved by varying the number of S+'s and S-'s, or the ratio of S+:S-. The result provided further support for the idea that errors are more important than correct responses: subjects with the odds weighted heavily against them learned the horizontal-vertical discrimination as easily as subjects with more S+'s than S-'s. Experiment 8.5 completed this series of experiments. S+ and S- were differentially weighted by varying the number of S+'s and S-'s, but no stimulus occurred more often than any other. The result confirmed the earlier findings and demonstrated that they were not an artefact of stimulus frequency.

The overall conclusion of this phase of the research program was one of support for the ideas of previous workers in this field. This support can be given with a great deal more confidence as a result of improvements in the experimental design which were introduced in the above experiments. However, this research needs to be extended well beyond the study of discrimination learning in rats. The Moss-Harlow effect seems to be affected by phylogenetic differences and, with human subjects at least, by developmental differences. The more complex experimental designs used in this thesis need to be applied to the study of these phylogenetic and developmental changes. Finally, it ought to be recognised that the Moss-Harlow effect is, in a sense, contrary to what one might expect on the grounds of common sense or experience. We tend to think of learning as essentially a process of "getting it right". The assumption is apparently valid when applied to adults but not to young children. Since this assumption is often incorporated in instructional methods, the above finding has implications for educational psychology. Learning situations for very young children should, where possible, emphasise S- and the consequences of responses to this cue.

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