EFFECTS OF INITIAL DISCRIMINATION TRAINING ON SUBSEQUENT SHIFT LEARNING IN ANIMALS AND HUMANS

John Sweller
B.A.(Hons.) (Adelaide)

Thesis submitted to The University of Adelaide in fulfilment of the conditions for the Degree of Doctor of Philosophy

Department of Psychology
University of Adelaide
South Australia

1972

TABLE OF CONTENTS

CHAPTER 5: (continued)

SECTION III.

Summary

A series of 6 experiments using animals and humans were carried out studying the effects of initial training on subsequent shift tasks.

Section I deals with animal discrimination shift learning, primarily reversal learning and the overtraining reversal effect (ORE). An empirical review of the rat literature on the ORE concludes (with Mackintosh, 1969) that a difficult discrimination and a large reward are necessary conditions for the effect. Theories designed to explain the ORE are evaluated in the light of the empirical findings.

Experiment 1 describes a pilot study designed to test a stimulus salience explanation of the ORE. The results indicated that change in stimulus salience was not a variable affecting the ORE. Further experimentation (Experiment 2) revealed that under the pertaining conditions, while the ORE was not obtained using the conventional criterion and overtrained groups despite the employment of a difficult discrimination and large reward, an analogue of the effect was obtained by using as the lesser trained group a group reversed just before criterion. The inclusion of another group given even fewer initial discrimination trials indicated that speed of reversal learning following various amounts of initial training could be described by a quadratic function.

Experiment 3 tested the hypothesis that there is a relationship between initial task criteria of learning and task difficulty such that lower criteria of learning on easier tasks are equivalent to higher criteria on more difficult tasks. It follows from this that the ORE should be just as readily obtained using an easy task as a difficult task providing that appropriate criteria of learning are employed. This was confirmed with rats trained to a low criterion on the initial discrimination of an easy spatial task. The inclusion of a group trained to an even lower criterion, again revealed a significant quadratic function as in Experiment 2.

Section II deals with human discrimination, verbal and concept shift learning. The empirical and theoretical review of the literature indicates that the relationship between task difficulty and criteria of learning suggested by the animal work, also applies to a substantial proportion of the human studies. Experiment 4 using adult humans was designed to directly test this hypothesis. The relationship was found where mediated shift learning occurred using a complex position discrimination with unrelated stimuli.

Experiment 5 used numerical stimuli and indicated one trial reversal learning by subjects trained to a conventional criterion. Slower reversal learning was demonstrated by subjects given a very low initial task criterion. Experiment 6 studied the effects of criterion levels on serial shift learning tasks rather than the single shifts employed in the previous experiments. Nonreversal shifts with similar mediators required for the solution of each task were used. The results indicated that while subjects given a higher criterion learned each subsequent task more rapidly than the previous task, subjects given a lower criterion eventually found the shift tasks insoluble.

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

John Sweller

Acknowledgements

The work for this thesis was carried out under the supervision of Dr. A.H. Winefield whom I wish to thank for advice, comment, encouragement, and countless hours of valuable discussion.

I would also like to thank Mrs. M. Blaber for typing this thesis, Mrs. K. Casey and Miss G. Comport for typing papers for publication, Mrs. H. Lomax for photographic work, and Mr. H. Littlejohns, Mr. G. Matthews and Mr. T. Sudomlak for assistance in apparatus construction.

SECTION I: ANIMAL DISCRIMINATION SHIFT LEARNING.

CHAPTER 1

A REVIEW OF THE ORE USING RATS.

1. An empirical history of the ORE

(a) 1953-1961

In 1953, Reid trained three groups of rats on a black-white discrimination in a Y maze before reversing them. The amount of training on the initial discrimination for the three groups was: to a criterion of 9/10 consecutive correct responses with the last 5 responses correct; to the same criterion plus an additional 50 trials; and to the same criterion plus an additional 150 trials, respectively. Reid found that the group given the most training on the original discrimination learned the reversal significantly more rapidly than either of the groups given less training. The phenomenon, known as the Overlearning Reversal Effect (ORE), engendered an enormous amount of interest which has continued to the present time. This interest has been due to two factors. Firstly the ORE is paradoxical in that it is not intuitively obvious that additional training on one task should facilitate the learning of the reverse task. Secondly, in 1953 the Hullian learning theory (Hull, 1943) was still at the height of its influence and the ORE could not be readily incorporated into it, while later interest in the phenomenon tended to centre on modern chaining theories. Theories concerning the ORE will be discussed in Part 2 of this chapter.

Two additional findings of Reid's were of interest. Firstly, the group given 150 additional trials beyond criterion tended to perseverate to the old positive stimulus for a longer period during reversal than the other two groups, and secondly, this group position responded (i.e. responded to the same position for a certain number of consecutive trials) less than the other two groups. Hence it did not appear probable that overtraining had the effect of reducing resistance to extinction of the old response during reversal.

Until the early 1960's the ORE was invariably obtained by all experimenters using the basic paradigm, which normally consisted of a criterion and an overtrained group rather than the three groups used by Reid. Pubols (1956), verified Reid's result using a visual discrimination, and, more importantly in the light of subsequent results, obtained the ORE in a second experiment using a position discrimination. A position ORE was also obtained by Bruner, Mandler, O'Dowd & Wallach (1958) although only when animals were under low deprivation. Subjects in this experiment had to learn to make single-alternations in a four-unit straight-alley T maze on each trial rather than the conventional single left or right 2 choice position discrimination. Other early attempts to obtain the effect were equally successful. Capaldi & Stevenson (1957), Brookshire, Warren & Ball (1961), D'Amato & Jagoda (1961), and Komaki (1961) all obtained the ORE using brightness discriminations while North & Clayton (1959) obtained it using a horizontal vs. vertical line discrimination. In addition, Brookshire et al obtained the effect using a spatial task and Komaki obtained a similar effect using non-reversal tasks (i.e. overtraining facilitated extra-dimensional shift tasks as well as the intra-dimensional reversal task).

There were two other experiments, which while not employing conventional ORE paradigms, nevertheless did use related designs and are consequently relevant. Birch, Ison & Sperling (1960) used a successive discrimination problem in a single runway. Since correct or incorrect responses are not involved in this situation, their measure of learning was latency of response on a black-white discrimination. Animals attained criterion when there was no overlap between latencies to the two cues during one day's run of ten trials. The group given post-criterial trials on the initial discrimination learned the reversal more rapidly than criterion trained animals.

Ison & Birch (1961) used differential end box placement as a substitute for the conventional initial discrimination. One group received 50 placements, half into a black end box containing no reward and the other half into a white rewarded end box. The other group received 200 such placements. Conventional reversal training was then given with the exception that the position of the black and white end boxes did not alter. The group given more initial placements learned the reversal more rapidly.

(b) 1962-1965

(1) Successful attempts to obtain the ORE

After 1961, while the ORE was still obtained by experimenters, there were also many, at the time, apparently inexplicable failures. Capaldi (1963) and Theios & Blosser (1965) both obtained the effect using a position discrimination. In the latter study, a large reward on each trial was found to be necessary - a small reward resulted in no difference between groups. Neither experiment used criteria of learning on the initial task but rather gave animals a fixed number of trials with one group (the overtrained group) being given more trials than the other group. These two were the only experiments to demonstrate the effect using spatial discriminations during this period.

Mackintosh (1962, 1963a, 1965b), was the only experimenter to obtain the phenomenon using a visual (brightness) discrimination during this time. In addition he found that overtraining retarded a nonreversal shift (1962), a result in direct contradiction to that obtained by Komaki (1961) who as mentioned previously found that overtraining facilitated shift learning whether it involved reversals or nonreversals. Mackintosh (1963a) only found the ORE when irrelevant cues other than position were present during reversal. The irrelevant cues appeared to retard reversal learning of the groups trained to criterion only on the initial discrimination.

(2) Failures to obtain the ORE

(a) The reverse ORE. There were no other successful attempts to obtain the ORE during this period and in fact, not only were there many experiments in which no difference was obtained between groups, but several spatial discrimination studies obtained reverse OREs, i.e. overtraining retarded reversal rather than facilitating it. Hill, Spear & Clayton (1962) in three experiments found either no effect due to overtraining or else a reverse ORE. They used a fixed number of trials for both acquisition and reversal. Hill & Spear (1963) in an attempt to see whether this result was due to the unconventional procedure, repeated the experiment using criteria of learning on both phases. They again found reversal retardation due to overtraining. Clayton (1963a) also obtained this result in two experiments and in addition found that the addition of irrelevant cues tended to accentuate the inferiority of overtrained subjects. Kendler & Kimm (1964) obtained a reverse ORE when using a small reward on each trial and no difference between groups when using a larger reward.

The only other experimenter to obtain a reverse ORE during this period was Mackintosh (1965c). The rats were trained on an unconventional spatial task. While the distance that the animals had to traverse to reach both left and right hand goal-boxes was identical, the turn-off point of the left hand alleyway occurred before that of the right hand alleyway. A reverse ORE was only obtained when initial training was given with the right hand alleyway positive. There was no difference between groups when initial training was to the left alleyway or when hurdles were placed at the decision point of the maze.

(b) Failure to obtain the ORE involving no difference between groups. Many studies found no effect due to overtraining on a spatial task. Clayton (1963b) modified his previous procedure (Clayton, 1963a) by using a larger reward and by giving animals 1 hour of free feeding each day rather than a constant daily ration. D'Amato & Jagoda

(1962) and D'Amato & Schiff (1964) in a series of six experiments, varied the number of trials given each day, varied the number of overtraining trials given, correlated brightness with position, and made the stimulus consequences of an incorrect response as distinct as possible by extinguishing the illumination after an incorrect response. Paul & Kesner (1963) used escape from aversive stimulation rather than the usual positive incentive. The T-shaped discrimination box was filled with water which the animals could escape from on choosing the correct side. Overtraining was not found to have a significant effect on reversal in any of these studies.

Four papers were published during this period in which the ORE was not obtained using visual discriminations. D'Amato & Schiff (1965) carried out 8 ORE paradigm experiments using a brightness (dimmer and brighter light) discrimination. The first attempted to replicate D'Amato & Jagoda's (1961) successful attempt to obtain the effect. Subsequent experiments varied the postchoice exposure time to the discriminanda during reversal, varied the postchoice exposure to the discriminanda during the initial discrimination, varied the prechoice exposure to the discriminanda for the entire experiment, increased the inter-trial interval from approximately 1 minute to 5 minutes, increased the amount of reward (water reward was used), and varied the strain of animals used. None of these manipulations resulted in any effect due to overtraining. Erlebacher (1963) obtained a reverse ORE using 50% reinforcement on the initial discrimination of a brightness task but obtained no effect using 100% reinforcement. Paul & Havlena (1965) varied spatial delay of reinforcement - whether animals are reinforced near or far from the positive stimulus door - and found that it did not affect the occurrence of the ORE which was not obtained using a brightness discrimination. Tighe, Brown & Youngs (1965) also found no effect due to overtraining using both horizontal vs. vertical stripes and flat vs. raised squares on both reversal and extradimensional shifts. The extra-dimensional shift result contrasts with that obtained by both Komaki (1961) and Mackintosh (1962) who respectively found that overtraining facilitated and retarded extra-dimensional shifts. The procedure used by Tighe et al differed from the other two studies primarily in that the relevant dimension during the extradimensional shift task was present and irrelevant during the initial task. Only the relevant dimension was present during the shift task. Both Mackintosh and Komaki on the other hand, had one dimension only present for both tasks, i.e. the dimension to be relevant on the shift task was not present during the original discrimination.

(c) 1966-1969

The experiments conducted during this period were heavily influenced by four reviews which were published during the mid 1960's (Lovejoy, 1966; Mackintosh, 1965a; Paul, 1965; and Sperling, 1965a, 1965b). These reviews dealt largely or solely with the ORE and had been primarily motivated by the enormous bulk of conflicting evidence concerning the phenomenon generated during the preceding years. While the reviewers disagreed on many points, on one point they were in complete accord. This concerned the relative frequency of occurrence of the ORE in spatial as opposed to visual studies. While the majority of visual studies succeeded in obtaining the effect, the majority of spatial studies did not, and indeed, it appeared to be only when using spatial studies that the reverse ORE occurred. Clearly, there was some factor in visual discriminations, either not present or only weakly present in spatial tasks, which predisposed most experiments employing visual discriminations to demonstrate the ORE. For this reason, while previously the majority of experiments involved spatial discriminations, during this period experimenters tended more frequently to employ visual tasks. The general aim of many experimenters was to attempt to find the conditions under which the ORE could reliably be found.

(1) <u>Spatial studies</u>

Five experimenters employed spatial tasks during this period and none of them unambiguously demonstrated the ORE in these particular experiments. Weyant (1966) found no difference in errors to criterion. Trials to criterion data ~~was~~ were not given. Eimas (1967) did three experiments. The first varied the number of irrelevant dimensions and found no effect due to overtraining irrespective of the number of irrelevant dimensions: the second used a Ross (1962) discrimination box rather than a Wisconsin General Test Apparatus and varied the size of reward. A reverse ORE was obtained: the third, using the same apparatus as the second, increased the number of overtraining trials from 100 to 200, giving a possible ORE - the effect was not quite significant at the .05 level.

Kendler & Kimm (1967) following on from their earlier study on the effect of reward size on the ORE, again found that a small, as opposed to a large, reward retards reversal learning more after overtraining than after criterion training. Their results indicated a reverse ORE when a small reward was used on the initial discrimination or on both the initial and reverse discriminations, but no effect due to overtraining when it was used during reversal only or not used at all, i.e. if a large reward was used on both tasks.

Fidell & Birch (1967) did a study in which reward was available on both sides of a T-maze with the positive side containing more food than the negative side. During reversal, the amount of food in the old positive side remained constant while that in the old negative was increased so that it contained more than the old positive. The results indicated no effect due to overtraining in terms of trials to criterion, but a reverse ORE in terms of errors to criterion. Mackintosh (1969) found no effect due to overtraining irrespective of reward size using a conventional ORE paradigm position reversal.

(2) <u>Visual studies</u>

(a) <u>Failures.</u> As was to be expected from previous results, a considerable proportion of visual discrimination studies succeeded in obtaining the ORE. Approximately half nevertheless, did not. Weyant (1966) as in his spatial discrimination, found no difference in errors to criterion on a brightness (lighted vs. unlighted) discrimination. Again, no data concerning trials to criterion ~~was~~ were given. Mandler (1966) found no effect of overtraining on either a brightness reversal or a non-reversal shift to a horizontal-vertical stripe discrimination.

Eimas (1967) obtained essentially the same results using brightness and form discriminations as he had obtained using position - no difference between groups. The only variation from his spatial studies was that he did not attempt to increase the number of overtraining trials from 100 to 200 using a visual discrimination. It was this manipulation that resulted in him possibly obtaining a position ORE (see above). Lukaszewska (1968) failed to obtain the ORE in four experiments in which the relevant dimension was either brightness or shape and there were either no irrelevant visual dimensions or the irrelevant dimension was the alternate one of the above two not used as relevant. In addition both correction and non-correction methods were used. None of these variables appeared to interact with overtraining resulting in the ORE not being obtained.

(b) Successes. Two papers were published in which all experiments reported succeeded in obtaining the ORE. Paul (1966a) used both an entry and a non-entry procedure on a brightness discrimination. An entry procedure involved animals entering an empty goal compartment on incorrect trials while a non-entry procedure involved locked negative stimulus doors which prevented animals from entering a goal compartment after an incorrect choice. The ORE was obtained using both procedures. Mandler (1968) used a brightness discrimination followed by one of the following: (a) conventional reversal; (b) conventional nonreversal to a dimension not present during the original discrimination; (c) reversal of S+ to S- with a new S+; (d) reversal of S- to S+ with a new S-; (e) a new S+ with the old S-; (f) the old S+ with a new S-. Overtraining facilitated shift learning under all conditions.

(c) Partial successes and suggested necessary conditions for the ORE. Several experiments found the ORE in visual discriminations under certain conditions only. Birnbaum (1967) using a light off-light on discrimination only found the effect when animals were trained with the bright alleyway as positive during the initial task and with 400 rather than 200 overtraining trials. Subjects took significantly longer to learn the original task when required to approach the lighter rather than the darker alleyway. Siegel (1967) used an apparatus in which animals had to push open left or right side swinging doors before they could observe the stimuli. There were two experiments, one of which involved a simultaneous discrimination on the shift task (as was used in all the experiments described above) while the other used a successive task. The ORE was obtained on the simultaneous discrimination but not on the successive. Extradimensional shifts to a dimension present during the initial discrimination were not affected by overtraining. Brightness and texture of the floor covering were the dimensions used. Hooper (1967), using a black-white discrimination, found that overlearning facilitated reversal when a large rather than a small reward was used, and under a correction rather than a noncorrection procedure.

Mackintosh (1969) in reviewing the literature claimed that two conditions were necessary for the ORE. These were firstly, a difficult rather than an easy discrimination, (a position discrimination is almost invariably easier than a visual discrimination), and secondly a large rather than a small reward on each trial. Mackintosh's review indicated that few experiments failed to obtain the effect when both these conditions were present and that fewer still obtained it when either or both conditions were absent. Thus, those visual studies that did not obtain the effect, failed due to either being easier than the usual visual discrimination; e.g. Eimas (1967, Experiment II): due to the use of a small reward; e.g. Eimas (1967, Experiment I); Hooper (1967, small reward groups); Mandler (1966); Paul & Havlena (1965); Tighe, Brown & Youngs (1965): or due to both; e.g. Erlebacher (1963). D'Amato & Schiff (1965) used water reward rather than food, making their studies difficult to compare with others.

Of the few studies that had obtained a position ORE, two probably had methodological deficiencies. Pubols (1956) had used an overtrained group which had learned the original discrimination in almost half the number of trials required by the criterion trained group (first pointed out by Lovejoy, 1966), while Theios & Blosser (1965) had employed such a substantial reward for their large-reward group that significant weight increases may have occurred with extended training. This was pointed out by Clayton (1965) and quoted by Mackintosh. Clayton found that when he repeated Theios & Blosser's experiment he found both substantial weight increases and obtained the ORE. Since there is evidence that reversals are learned more rapidly under low rather than high drive, (Bruner et al. 1958; Kendler & Lachman, 1958) Theios & Blosser may have obtained their ORE because overtrained animals were under a lower drive at the beginning of reversal training than criterion trained animals.

The hypothesis, nevertheless, could not account for the results of all experiments. Results inconsistent with it were obtained by Bruner et al. (1958) and Capaldi (1963) both of whom succeeded in demonstrating the ORE using position discriminations, and also Lukaszewska (1968) and Weyant (1966) who did not obtain any effect due to overtraining despite the use of a large reward and a difficult discrimination.

Mackintosh confirmed his hypothesis in a series of experiments. His failure to obtain the ORE using a position discrimination irrespective of reward size has been mentioned above. In a second experiment, using a fairly easy black-white discrimination and a reward size equal to the large reward in the first experiment, he succeeded in obtaining the effect. Experiment 3 employed two tasks - an even easier black-white discrimination and a difficult dark-grey, light-grey discrimination, and two levels of reward, large and small. As predicted the ORE was only obtained when both the large reward and difficult discrimination were used.

2. A theoretical history of the ORE

An enormous number of theories and explanations have been proposed to account for the ORE. These began as early as Reid's (1953) paper which contained two possible explanations. With the advantage of hindsight, it is now obvious that the majority of these hypotheses were highly premature and that their originators would probably not have proposed them had they known the restricted conditions under which the phenomenon was obtainable. Most of the theories and hypotheses were suggested during the era when the ORE was, justifiably in the light of experimental evidence, considered a reliable, readily obtainable phenomenon. It is for this reason that any mention of theories has been delayed until the present point, making it possible to evaluate each theory and hypothesis in the light of all the evidence available until 1969.

(a) Spence's equalisation of position habits explanation.

This explanation was cited by Reid (1953) as a personal communication from Spence. It follows directly from Spence's theory of discrimination learning (Spence, 1936). According to this theory, in a discrimination learning situation, stimulus components have approach-eliciting potentials or habit strengths which can increase or decrease according to whether they are reinforced or non-reinforced. In a simultaneous black-white discrimination using a conventional 2-choice maze, there are four obvious component habit strengths - approach to black, white, left, and right. An animal's choice on a particular trial can be predicted, according to the theory, by summing the total habit strength of a particular choice combination. Thus, if black is on the left and white on the right, for example, the animal will approach the black-left combination if the summed habit strength of approaching black and approaching left is greater than that of approaching white and approaching right. The outcome of this response - whether the animal is rewarded or not -

will in turn alter the strengths of all the components of the stimulus complex chosen. The rules according to which this occurs are as follows. A rewarded response will result in all the components of the complex being strengthened. A stimulus component of intermediate strength will be strengthened more by reward than a component which at the time of reward has either a high or low habit strength. Hence there should be a lesser increment in habit strength at the beginning and end of learning than during intermediate trials. If the response is nonrewarded, all the components of the approached stimulus complex will be weakened by an amount proportional to their strength - stronger habits are decreased more than weaker habits if nonrewarded.

Spence, in applying his theory to the ORE, assumed that at criterion animals still have differential habit strength to the two positions. Consequently, animals reversed after criterion training only, will still have a relatively strong position habit which must be expected to interfere with reversal learning. Subjects on the other hand given overtraining, should have their position habits equalised during this additional training. Reversal learning should as a consequence be more rapid since subjects will not be hindered by a tendency to approach one position to the exclusion of the other irrespective of the position of the correct stimulus.

Computer simulations of Spence's model

Spence at no time attempted to test the validity of his explanation by formally demonstrating that it could predict the ORE under certain conditions, i.e. with certain parameter values. This was done by Wolford & Bower (1969) using computer simulation. The parameter values set for increments and decrements were identical to those used by Spence (1936). The parameter values set for the four component habits (2 values of both a relevant and an irrelevant dimension) at the beginning of training were varied over the possible range beginning with a very low habit strength and progressing to a very high strength. They found that the model predicted an ORE under conditions of a difficult discrimination as measured by the number of correct responses to criterion on the initial task, and at the same time a large difference in initial habit strengths between the two cues of the irrelevant dimension (i.e. a strong tendency to approach one of the cues of this dimension).

While the results of Wolford & Bower's simulation are impressive in that they predict the occurrence of the ORE using a difficult but not an easy task, there must nevertheless be considerable doubt whether the conditions under which the model predicts the effect, pertain in the actual experimental situation. These doubts were expressed by Turner & Mackintosh (1970). They carried out similar computer simulations using identical parameter values and found that nonovertrained subjects reversed slowly because they reverted to their original position habit (i.e. one of the cues of the irrelevant dimension) during reversal, while overtrained subjects did not exhibit position responding during reversal. There were two primary objections, both concerned with position responding. Firstly, the model appears to only predict the ORE under conditions of a very strong initial position habit, as pointed out above, and under no other conditions. The experimental evidence does not support this restriction. Pubols (1956) in order to test whether this was in fact a necessary condition, gave his animals pretraining in order to eliminate any initial biases for a particular position and yet still obtained the ORE. It is hence pointless if the theory can predict the effect under these conditions only. The second objection concerns the nature of the position responding dictated by the model. Criterion trained animals according to the model, reverse more slowly because they revert to the position habit manifested on the initial task. This does not correspond to the mode of responding normally exhibited by groups of animals in an experimental situation. It is well known that while position habits tend to be strong during both the initial and reversal tasks, they are not necessarily correlated - the same animal may prefer one position during the initial discrimination and the other during reversal. Turner & Mackintosh gave evidence of this from their own data and from that of Lovejoy, and Sperling (personal communications, 1968).

It can be concluded that while Spence's theory can predict the ORE, it can only do so under conditions which are empirically untenable. For this reason it must be rejected.

(b) Orienting response theory

This theory (also known as the observing response theory) was suggested and favoured by Reid (1953) as an alternative to Spence's hypothesis. It has been further developed by Mandler (1966, 1968) and Siegel (1967). According to this explanation, subjects, as well as learning to approach the positive stimulus and avoid the negative, must learn overt orienting responses to the stimulus set. Reid assumed that this "response of discrimination" both develops and extinguishes more slowly than the choice response. It develops more slowly because firstly, it cannot be initiated until the habits of approaching the positive and avoiding the negative stimuli are reasonably strong, and secondly, because increases in its strength are likely to be small due to the delay between making this observing response and obtaining reward. Reid also suggested two possible reasons for its slow rate of extinction. Firstly, there is a greater opportunity for reactive inhibition to build up to the response to the old positive, and secondly, there is the same delay in nonreinforcement of the response of discriminating during early reversal trials as occurred for reinforcement of the response during the initial task.

Mandler's (1966, 1968) version of the observing response theory was based on the results she obtained using a Y maze. She used a correction procedure. Touching the incorrect door was counted as an error while entering the same arm on eight of the ten daily trials irrespective of whether the subject made an error or not was defined as a position habit. Mandler found that irrespective of whether or not the ORE was obtained (in 1966 it was not obtained using a small reward while in 1968 it was obtained using a large reward) overtraining affected the amount of position responding. At criterion, most animals still tended to enter the preferred side on virtually every trial and retrace on those occasions when the correct stimulus was on the non-preferred side. During overtraining, this position responding was gradually extinguished and replaced by scanning behaviour at the choice-point.

Mandler reasoned that this scanning strategy was more efficient than a retracing procedure since an animal could virtually register the two stimuli simultaneously rather than successively. If this more efficient orienting response carries over into reversal, it is to be predicted that overtrained animals should learn the reversal more rapidly.

Siegel's (1967) experiment also supported an observing response hypothesis as an explanation of the ORE. He used an unconventional apparatus, which despite the use of a simultaneous discrimination paradigm, did not allow animals to observe both stimuli simultaneously. The apparatus consisted of a T maze with two identical, opaque swing doors at the choice point. Before observing the stimuli beyond the doors, the subjects had to push them open. This meant that only one side of the T maze could be observed at a time. If the correct stimulus was on this side, animals were rewarded for passing through the door, while if it was the incorrect stimulus, they were required to execute a "conditional reorientation" - to turn around and go through the other door.

Siegel theorised that overtraining should strengthen this reorientation response which in turn should facilitate reversal learning since no learning was possible in the apparatus without the mediating response. He found that criterion trained subjects responded by choosing the side of initial orientation, rather than reorienting, for significantly more days than overtrained subjects, and also began this ill-adaptive mode of responding significantly earlier in the shift problem than over-trained subjects. Siegel suggested that the tendency for criterion trained subjects to abandon reorienting behaviour accounts for the ORE.

While observing responses probably do play a role in the occurrence of the ORE, it is doubtful whether they are sufficient to account for all successful demonstrations of the phenomenon. A Y- or T-maze, or Siegel's complex apparatus in which animals find it difficult or impossible to observe both stimuli simultaneously, may well compel them to learn to make observing or orienting responses which subsequently facilitate reversal learning. There has, nevertheless, been a successful demonstration of the ORE using an apparatus in which animals would have had considerable difficulty in not seeing the two stimuli simultaneously. Mackintosh (1969) obtained the effect in two experiments using a Grice box. This was designed to reduce the importance of observing responses by having the stimuli immediately adjacent to each other and covering as wide an area as possible.

Two further objections to this theory are its inability to explain the necessity of (a) a difficult discrimination before the ORE can be observed, and (b) the necessity for a large reward. (Since in the author's opinion, no single theory at the present time can successfully explain the latter fact, the second objection is not as strong). It does seem to follow from the theory that the effect will not be observed using a position discrimination. There is no obvious orienting response which an animal must learn during the initial discrimination which will be of benefit during the reversal of a spatial task. Nevertheless, the ORE has never been observed using an easy visual discrimination (learned in less than 30 trials) and there is no obvious way in which the theory can predict its occurrence with difficult tasks only.

(c) Reduction of inhibition

This explanation was first suggested by D'Amato and Jagoda (1960). It is well established that during overtraining animals make very few, if any, errors, and as a consequence obtain virtually no experience with the negative stimulus during this period. It follows that at the beginning of reversal, criterion trained animals have had considerably more recent experience with the negative stimulus than have overtrained animals. D'Amato

& Jagoda reasoned that during reversal, this should result in overtrained animals finding the old negative stimulus (which will be positive during reversal) less aversive. If one assumes, as is necessary, that nonreinforcement results in an increase in aversiveness of the nonrewarded stimulus, and that furthermore this aversiveness decreases if no responses, or very few responses, are made to the cue in question, it follows that the inhibition associated with the negative cue will decrease during overtraining resulting in overtrained animals approaching it more readily and hence learning more rapidly than criterion trained animals.

D'Amato & Jagoda (1961) tested their hypothesis by forcing animals to the negative stimulus on some trials during overtraining. They found that this eliminated the ORE observed using control groups. D'Amato & Jagoda (1962) found that forced trials to the negative stimulus during overtraining of a position discrimination resulted in a reverse ORE while control groups showed no effect due to overtraining. The authors concluded that these results supported their interpretation of the ORE. Sutherland & Mackintosh (1971) cast some doubt on this conclusion by pointing out that it is possible that the very fact of being forced to a stimulus may have the effect of making it more aversive irrespective of its value - i.e.

irrespective of whether it is positive or negative.

Experiments avoiding this possible objection have been done by Deutsch & Biederman (1965), and Biederman (1967), employing a modification of a design used by Coate & Gardner (1965) to study the ORE. Coate & Gardner gave their animals two tasks simultaneously. On each trial the subjects were required to discriminate between the pair of stimuli pertaining to one or other of the two tasks. One pair of stimuli was presented on 3/4 of the trials, while the other pair was presented on the remaining 1/4 of the trials. Hence over a given number of trials, subjects were given more training on one task than the other. For half of the animals, training continued until they reached criterion on the more frequently presented task, while for the other half it continued to criterion on the less frequently presented task. Half of the animals in both of these groups were then reversed on one problem only and the other half on the other problem. The results indicated that the more training a subject received on a given problem - i.e. those trained to criterion on the less frequently presented task - the more slowly it learned the reversal, which means animals reversed onto the more frequently presented problem, exhibited a reverse ORE.

Deutsch & Biederman (1965) did not use reversal in their experiment. They trained animals on two simultaneous tasks in the same manner as Coate & Gardner (1965), but for a fixed number of trials rather than to a criterion, and then gave them a test trial in which the two negative stimuli were opposed. The prediction was, that if increased training resulted in a decrease in aversiveness of the negative stimulus, then on the test trial animals should choose the more frequently presented negative stimulus. This prediction was verified for a group given 9 days training but another group of subjects chose both stimuli with equal frequency after being given 11 days training. Biederman (1967) confirmed this result and also found that subjects preferred the more frequently presented positive stimulus irrespective of the total number of pre-test trials given. (64 and 128 trial groups were used).

There are several objections to these two experiments as a test of the hypothesis. Firstly, subjects may have chosen one of the negative stimuli in preference to the other irrespective of the amount of training with either. Secondly, the amount of training given appears to have been insufficient to have included any overtraining. Deutsch & Biederman (1965) found that the group given the lengthier training period were obtaining only approximately

80% of their responses correct on the more frequently presented discrimination, while the equivalent figure for Biederman's (1967) study was 70%. It is probable that most animals had not learned the task, and had certainly not been overtrained. The last objection concerns Biederman's (1967) finding that animals preferred the most frequently presented positive stimulus as well as the most frequently presented negative. If the positive stimulus becomes more attractive at the same rate as the negative stimulus becomes less aversive, the ground for an explanation of the ORE disappears. Any increased tendency to approach the old negative stimulus after overtraining (on its own, resulting in an ORE) would presumably be neutralised by an equally increased tendency to approach the old positive stimulus.

Mandler (1968) suggested an interesting hypothesis which indicated that a decrease in avoidance tendencies towards the negative stimulus may follow from her orienting response interpretation. She suggested that while animals were position responding (which by her definition included turning around and going to the positive stimulus after first approaching but not necessarily touching the negative stimulus) they were learning more and being largely controlled by the negative stimulus. During overtraining, after they had adopted a choice-point strategy, performance should not be controlled as strongly by the negative stimulus, but rather it should either be equally controlled by both stimuli or largely by the positive stimulus. Her data only partly supported this hypothesis in that while she found that overtrained animals were more disrupted by changes in the positive than the negative stimulus, criterion trained subjects were only slightly more disrupted by changes in the negative stimulus as opposed to the positive stimulus.

Irrespective of the status of the experiments designed to test D'Amato & Jagoda's hypothesis, there must be some doubt as to its ability to fully explain the ORE. If the sole effect of overtraining is to decrease the aversiveness of the negative cue, animals will presumably approach this cue more readily (i.e. earlier) during reversal. In other words, the hypothesis assumes in effect that the ORE is caused by more rapid extinction of the old response. This is directly contradicted by the facts. Overtraining, rather than resulting in more rapid extinction, appears to have the opposite effect. As was pointed out at the beginning of this chapter, Reid (1953) found that overtraining not only resulted in more rapid reversal learning, but also increased initial perseveration to the old positive stimulus. This increase in perseveration appeared to have been offset by an even larger decrease in the position responding which followed the perseveration phase and preceded criterion trials. This result has been verified on many subsequent occasions (e.g. Komaki, 1961; Mackintosh, 1962; Mandler & Hooper, 1967). Hence a simple decrease in aversiveness of the negative cue is insufficient, and at the very least supplementary principles are required.

Since the aversiveness of the negative cue should decrease with overtraining irrespective of the nature of the task, the hypothesis would not appear capable of incorporating the finding that the ORE tended to occur using difficult tasks only. Furthermore, unlike the orienting response theory, the present hypothesis would make an identical prediction whether a spatial or visual task was used. The ORE should be obtained with equal facility using either task.

(d) The discriminable change hypothesis

This hypothesis was suggested by Capaldi & Stevenson (1957). It assumes, more directly than the preceding hypothesis, that overtraining will result in more rapid extinction of the old response during reversal. The rate of extinction is hypothesized to be directly related to the extent to which subjects are able to detect a change in the pattern of reinforcement. After a long series of overtraining trials, it should be readily apparent to the animals at the beginning of reversal that the reinforcement contingencies have changed. This should result in faster extinction of the old response permitting the new response to be learned in fewer trials. Criterion trained animals on the other hand, having more recently experienced non-reinforcement due to errors in initial learning, will not find the reversal change as discriminable and hence will continue responding in the old manner despite the initial errors.

The discriminable change hypothesis suffers from the same defect common to all explanation of the ORE which rely on more rapid extinction of the old response following overtraining as the basic mechanism underlying the phenomenon. As pointed out in the previous section, overtraining results in slower rather than faster extinction when measured in terms of perseveration. Nevertheless, while the hypothesis cannot explain the phenomenon in terms of the effect of overtraining on extinction, differences in discriminability of change may possibly contribute to the effect by other means. It is for instance possible that criterion trained animals, unable to detect the change very clearly and unable to obtain consistent reinforcement (since reversal is in effect instituted as soon as they show clear signs of responding correctly on the first problem), begin position responding as a natural response in this situation early during the reversal. Overtrained animals, having obtained consistent reinforcement for a lengthy period, firstly have a strong response and hence perseverate longer, and secondly, having readily detected the change, do not respond as though they are faced with a single seemingly insoluble problem. Hence once the old response has been extinguished, they proceed to learn the new task more rapidly which results, of course, in a decrease in the amount of position responding.

On an easy task, even criterion trained animals may detect the change since they will have had fewer nonreinforced trials during initial training and so the criterion trials themselves may be sufficient for the animals to detect the change as readily as overtrained subjects. It would follow that the ORE should not be obtained using an easy discrimination. Hence it is possible that the discriminable change hypothesis plays some part in the phenomenon although the mechanism is probably not that originally suggested by Capaldi & Stevenson.

(e) Frustration theory

A frustration theory explanation of the ORE was first suggested by Birch (1961) using the theory elaborated by Amsel (1958). Birch based his theorising primarily on the results of Birch, Ison & Sperling (1960) (described on p.3) who found the ORE in a go-no-go brightness discrimination situation using latency as the response measure. They found that overtraining resulted in more rapid extinction of the running response to the former positive stimulus. (Since a single stimulus was being used, it was possible to record running speeds to both stimuli separately). Birch reasoned that the ORE was caused by more rapid extinction of the old response after overtraining and that this in turn was caused by increased frustration which followed unrewarded trials at the beginning of reversal. The amount of frustration according to Amsel's theory is determined by the magnitude of fractional anticipatory goal responses which in turn is a function of the number of rewarded trials received. Hence overtrained animals, having had more rewarded trials, should be more frustrated by nonreward at the beginning of reversal and extinguish the old response more rapidly.

Birch made two other predictions of importance which follow from frustration theory. Firstly, the magnitude of fractional anticipatory goal responses and hence frustration, will depend on the magnitude of the goal object as well as the number of rewarded trials. It follows that the larger the reward the greater the frustration due to nonreward and hence the more probable that the ORE will be obtained. Secondly, a similar argument should apply to the degree of deprivation appropriate to the goal object. The more deprived the subjects, the greater the frustration and rate of extinction during reversal, increasing the probability of the effect being observed.

Theios & Brelsford (1964) were the first to point out that the occurrence of the ORE was in fact more probable under conditions of high reward as predicted by frustration theory. Theios & Blosser (1965) tested the hypothesis that a large reward was necessary for the effect and while they obtained a spatial ORE using a large reward only, as was pointed out previously (p. 15) their study was methodologically deficient and the results probably due to a failure to equate the total food intake between groups.

There has been no direct attempt to test the prediction that increased deprivation appropriate to the goal object increases frustration during extinction of the old response after overtraining thus leading to a greater probability of observing the ORE. The study by Bruner, Mandler, O'Dowd & Wallach (1958) may nevertheless bear on this problem, although it was not originally designed to do so. Using a complex position discrimination (see p. 2), they obtained the effect under conditions of low deprivation rather than high deprivation which is directly contrary to the predictions of frustration theory.

It can be seen that the main support for the frustration theory analysis comes from the experiment of Birch et al (1960) in which they found more rapid extinction of the old response after overtraining (although the two previous theories discussed - D'Amato & Jagoda's (1960) reduction of inhibition hypothesis and Capaldi & Stevenson's (1957) discriminable change hypothesis - would presumably also predict this result) and from the increased tendency for the ORE to occur in experiments employing a large reward. Doubts, nevertheless, have been expressed concerning the extent to which the former finding does support a frustration theory explanation of the phenomenon (e.g. Sutherland & Mackintosh, 1971).

As mentioned previously, most of the evidence from simultaneous discriminations indicates that the old choice response extinguishes more slowly during reversal for overtrained animals. There is hence a conflict between Birch et al's result and that of other experiments. This conflict would appear to be due to their use of latency as a response measure, forced upon them by their choice of experimental design. In a single stimulus runway situation, latency is the only response measure available since the animal is not required to make a choice. Experiments demonstrating an increase in perseveration after overtraining have, of course, used the animal's choice as a response measure. It appears to be the case that latency and choice measures are not correlated.

Mackintosh (1963b) shed further light on this problem. He gave animals conventional initial discrimination training either to criterion or else to criterion plus 150 overtraining trials. This was followed by extinction to a criterion of equal choice of the two stimuli over ten consecutive trials. The overtrained group took significantly more trials to reach this extinction criterion than the criterion trained group. (This finding was replicated by Mackintosh, 1965b). All subjects were then reversed with the results indicating that the overtrained subjects learned the reversal more rapidly than criterion trained subjects. Hence the results indicated that overtraining facilitated learning of the new response rather than, as suggested by frustration theory, extinction of the old response. Mackintosh (1963b) also recorded latencies during the extinction period. Using this as a response measure, his results were in accord with those of Birch et al (1960):- overtraining decreased resistance to extinction. He offered no explanation for this discrepancy between latency and choice response measures and at the present time there is no obvious solution available.

Recently, Furstenau & Schaeffer (1970) carried out an experiment similar in design to that of Mackintosh (1963b) with results indicating considerably more support for the frustration theory. They used a fixed amount of training on the initial task (40 or 100 trials) and three levels of reward magnitude. Initial training was followed by 60 extinction trials which in turn was followed by reversal to criterion. In terms of "errors" (i.e. choices to the previously nonrewarded stimulus), they found slower extinction after overtraining for the two groups given the smallest reward, no difference between the two groups given the medium reward, and faster extinction after overtraining for the large reward groups. Hence they only replicated Mackintosh's (1963a) result when using a small reward. When using a large reward they obtained exactly the result predicted by frustration theory. Their latency data replicated that obtained by Mackintosh in that overtraining increased latencies during extinction. In addition, they found that small reward decreased latency. Reversal results indicated that the small reward group given overtraining learned more slowly than all the other groups and that there were no other significant differences. Furstenau & Schaeffer also ran two ORE paradigm groups (i.e. without the extinction period) using a large reward and obtained the ORE. Hence the interpolation of an extinction period had the effect of reducing the ORE to a nonsignificant level. From this result, overtraining would appear to affect extinction rather than reacquisition as was found by Mackintosh (1963b) and hence supports the frustration theory account of the ORE. Some slight additional support for the theory came from Furstenau & Schaeffer's finding that for the ORE paradigm groups, overtraining resulted in more rapid extinction of the old response (although nonsignificantly) during reversal.

It must be concluded that at present the evidence is too contradictory to be able to clearly evaluate the influence, if any, of frustration on the occurrence of the ORE. The following points have emerged. It is clear that in accordance with frustration theory, overtraining will result in more rapid extinction of the old response when latency is used as a response measure. Its effect on choice responses appears to vary, with the relevant variables as yet unknown. Most experimenters, in direct opposition to frustration theory, have found an increase in resistance to extinction with overtraining while Furstenau & Schaeffer (1970) found a decrease (large reward groups). The strongest evidence for the theory comes from the apparent necessity for a large reward in order to obtain the effect. Unfortunately this evidence is considerably weakened by the fact that the mechanism through which, according to the theory, large reward should interact with overtraining, is either not operative or else operative under limited conditions, i.e. large rewards combined with overtraining should facilitate reversal as a consequence of more rapid extinction of the old response. The evidence concerning this point, as just mentioned, is unclear. Lastly, frustration theory would not seem to predict that a difficult discrimination is a necessary condition for the occurrence of the phenomenon, and indeed, frustration theorists such as Theios & Blosser (1965) have ~~attempted and~~ succeeded (under conditions described on p. 15) ~~to obtain~~ in obtaining the ORE employing a spatial discrimination.

(f) Attention theory

The attention theory has provided the most popular interpretation of the ORE, and with respect to this particular phenomenon, is the most detailed and thorough explanation available at the present time. It was originated by Sutherland (1959, 1964) and developed further by Mackintosh (1965a, 1969). Mathematical versions have been provided by Lovejoy (1966, 1968).

1. Rules of the attention theory. The theory assumes that as well as learning the choice response in a discrimination learning task, the animal must learn to attend to the relevant dimension, where a dimension refers to differences in for example, brightness, size, position, etc., between the stimuli (listed by Sutherland & Mackintosh, 1971, p.39). There are several rules which determine the performance of subjects.

Rule I: the strength of choice responses is increased by reward and decreased by nonreward and the size of the change is proportional to the strength of the relevant attending response. Consequently a strong attending response should result in rapid changes in the strength of the choice response and hence rapid changes in performance with respect to the dimension attended to and a weak attending response should result in slow changes in the strength of the choice response. This rule has certain limitations. A choice response near or at asymptote cannot be increased substantially by reward nor a very weak choice response be greatly affected by nonreward irrespective of the strength of the analysers. The rule does, on the other hand, apply to the two alternate situations. A strong choice response may be decreased more and a weak choice response may be increased more under conditions of a strong attending response to the relevant dimension than when the attending response is weak. Hence when predicting the change in response strengths due to reward and nonreward, the actual strength of the choice response in question as well as the strength of the relevant analyser needs to be considered.

Rule II: the strengths of the attending responses to all possible dimensions are postulated to sum to a constant amount. The base level of these strengths, i.e. their strength before the subject has been given any training, will vary for different dimensions. The more obvious a dimension the greater will be the base value of the attending response to it. Attending response strength is varied by correct and incorrect predictions concerning trial outcome. If an animal makes a correct choice response on the basis of attending to a particular dimension, the strength of the attending response to that dimension will be increased. If on the other hand it makes the alternate response (in a two choice situation) while attending to this dimension, the incorrect prediction will result in a decrease in the strength of the attending response. Since at any given time the strengths of all the attending responses must sum to a constant amount, a change in a particular direction by one attending response must be accompanied by a commensurate change in the opposite direction in the total strength of all the other attending responses. When attending to the available dimensions does not result in consistently correct responses (as in the case of a difficult or insoluble problem) the strengths of all the attending responses revert to their base level.

Rule III: if the base level of the attending response to the relevant dimension is low, as is the case when the discrimination is difficult, its strength will reach asymptote more slowly than will the strength of the choice response. An easy discrimination on the other hand may result in the base level of the attending response to the relevant dimension being sufficiently high to reach asymptote at the same rate or even more rapidly than the choice response.

Rule IV: the last rule concerns performance of subjects on each trial. Performance is determined by both the strength of the choice responses associated with the strongest attending response and with the choice responses associated with other attending responses whose strength is within a certain range of the strength of the highest attending response. If all other attending responses are so weak that none of them fall within this range, then performance will be determined by the choice responses associated with the strongest attending response only. Hence during the training trials of a reasonably difficult discrimination, performance may be determined by several dimensions (unless the animal enters the experimental situation with a strong attending response to a particular dimension such as position), but as learning progresses, the attending response to the relevant dimension should eventually become sufficiently strong to completely determine performance.

2. Application of the attention theory to the ORE. The theory has been applied to the ORE in the following manner. It predicts that reversal learning will be rapid under conditions which ensure that the subject will continue to attend to the relevant dimension, i.e. a strong attending response, while it will be slow under conditions where attention to the relevant dimension has largely extinguished. (In reversal learning, of course, the same dimension is relevant after the shift as was relevant during the initial discrimination). This follows from the first rule above. Reversal involves increasing the strength of the choice response to the formerly negative stimulus and decreasing the strength of the formerly positive stimulus, and by Rule I these changes should be more rapid under conditions of a strong attending response. It should be noted that the aforementioned limitations to this rule (see p. 41) do not apply since it is precisely the two situations under which

the rule can operate - decreasing a strong choice response and increasing a weak choice response - that are specific to reversals.

The strength of attending responses to various dimensions will also change during reversal. At the beginning of reversal, while the animal will presumably be attending to the correct dimension, it will not be making any correct predictions concerning outcomes since the choice response will be incorrect (due to perseveration). Hence, according to the second rule, the attending response to the relevant dimension will decrease towards its base level. This decrease will continue either to the base level or alternatively until the strengths of the two choice responses associated with the relevant dimension are equal, since until that point is reached, the subjects predictions will be consistently disconfirmed.

From the above it can be seen that the speed of reversal learning is dependent on the relative strengths of the attending response to the relevant dimension and its associated choice responses. If the attending response is extinguished (i.e. reaches the base level) before the choice responses are equalised, reversal learning will be slow since this attending response will have to again be strengthened before the strengths of the choice responses can be further changed. If on the other hand, the choice responses are equalised while the attending response is still reasonably high, reversal learning should be more rapid due to the more rapid change in the strengths of the choice responses (by the first rule).

It is the third rule that is crucial to the ORE since it is this rule which allows the attention theory to predict that during reversal of overtrained animals, the attending response to the relevant dimension will in fact remain relatively high, while in the case of non-overtrained animals it should extinguish and will require relearning before the reversal criterion can be attained. If, as the rule states, under conditions of a low base level attending response to the relevant dimension, the attending response reaches asymptote more slowly than its choice responses, then at criterion, animals will have relatively weak attending responses but stronger choice responses. Reversal should consequently take many trials due to the extinction of the attending response as explained previously. Overtraining should substantially strengthen the attending response, since it is relatively weak, but have a lesser effect on the choice response since it is either near or at asymptote. Hence overtrained animals should begin reversal with stronger attending responses to the relevant dimension relative to the attending responses of criterion trained animals, but have choice responses left largely unaffected by overtraining. As a result of this situation, overtrained subjects should learn the reversal more rapidly than criterion trained subjects, giving the ORE.

The attention theory can not only predict the occurrence of the ORE, it is also able to accurately predict the course of reversal learning for both criterion and overtrained groups. If, when using a reasonably difficult discrimination, attention to the relevant dimension is not very high, in particular if it is not much higher than attention to an irrelevant dimension with a high base level such as the spatial dimension, then the strength of the attending response to the relevant dimension should fall below that of the spatial dimension fairly early in reversal. Since overtraining results in an increase in the strength of the attending response to the relevant dimension, during reversal it should take longer for this attending response to be extinguished to the point where the subject is controlled by an irrelevant dimension such as position. It can hence be predicted that overtraining will increase perseveration to the old positive stimulus and decrease position responding during reversal. This, of course, is exactly what occurs.

3. The effect of overtraining on extinction.
Mackintosh (1963b, 1965b) has provided further evidence for an attentional explanation of the ORE using experimental designs other than those normally employed in conventional ORE paradigm experiments. These experiments were prompted by results obtained firstly by Lawrence & Mason (1955) and Goodwin & Lawrence (1955), and secondly by D'Amato & Jagoda (1960).

Lawrence & Mason's experiment involved three stages. During the first stage animals were trained to criterion with one dimension relevant and another irrelevant. For the second stage the roles of the two dimensions switched - the previously relevant dimension became irrelevant and the previously irrelevant dimension became relevant. After attaining criterion on this problem, the animals were shifted back to the original discrimination with half being required to relearn it and the other half learning the reversal. The results indicated that animals required to relearn the original problem reached criterion more rapidly than animals required to learn the reversal. According to a single stage view of discrimination learning, this difference between groups should not have been obtained. During the second stage of the experiment, since the originally relevant cue became irrelevant, responses to it should have extinguished, giving no difference between reversal and nonreversal during the third stage. Clearly, extinction had not occurred and Lawrence & Mason suggested that their results could be explained by assuming that during the second stage, extinction of attention to the previously relevant dimension occurred before extinction of the choice responses preventing any further equalization of these choice responses. This could have subsequently facilitated relearning and inhibited reversal when the dimension was reintroduced as relevant.

Since the incomplete equalisation of response strengths during extinction of the first stage learning in the second stage of Lawrence & Mason's experiment may have been due to insufficient second stage training (i.e. insufficient training to ensure complete extinction of first stage training), Goodwin & Lawrence (1955) partially replicated the experiment and included overtraining during the second stage. They found that overtraining had no effect with reversals still being learned more slowly than nonreversals during the third stage. Hence the attentional hypothesis could be left intact.

Mackintosh (1963b) hypothesised that if the attention theory explanation of the ORE was correct, then overtraining of Stage I of Lawrence & Mason's experiment should largely abolish the difference between reversal and nonreversal during the third stage. If the ORE is caused by the attending response which is readily extinguished, then overtraining on the first stage of Lawrence & Mason's experiment should strengthen the attending response allowing the choice responses to be equalised in the second stage. This should result in no difference between relearning and reversal in the third stage. Mackintosh (1963b) replicated Lawrence & Mason's experiment, with half the animals being overtrained during the first stage. The difference between the reversal and relearning groups during the third stage was considerably less marked for subjects overtrained in the first stage, confirming the hypothesis.

D'Amato & Jagoda's (1960) experiment involved training animals to a criterion followed by 60 extinction trials during which reward was eliminated following either choice. After extinction, animals were trained on the reversal of the original problem. The results indicated that immediately upon the reintroduction of reward, subjects significantly increased their choice of the former positive stimulus (which was a negative stimulus at this time). This response was eventually extinguished, followed by equal responding to both stimuli and then learning of the reversal. The phenomenon has been labelled the "dip effect" by Sutherland & Mackintosh (1971).

Mackintosh (1963b, 1965b) did further work on the dip effect using overtraining. He trained some of his subjects to criterion on the initial discrimination and overtrained the others. Extinction was then taken to a criterion of equal choice of both stimuli over 10 trials followed by reversal. Reversal results for criterion trained subjects replicated those obtained by D'Amato & Jagoda (1960) in that the dip effect was obtained. Over-trained subjects on the other hand did not show the effect but rather responded at chance level during the initial stages of reversal.

Again these results can be explained in attention theory terms employing the same postulated mechanisms used to explain the ORE, and Lawrence & Mason paradigm experiments. During the extinction period of criterion trained animals, the attending responses, being weak, extinguish before the choice response strengths have been equalised. During reversal, the attending response is reactivated and since the old choice response strengths are unequal, animals tend to respond in the manner learned during the original discrimination giving the dip effect. Overtrained subjects on the other hand, having a stronger attending response to the relevant dimension, are able to completely equalise their choice responses during extinction, and hence do not show the effect in reversal.

4. The effect of overtraining on nonreversal shifts. Extradimensional transfer shifts would potentially appear to be useful techniques for testing the specific effect of overtraining on attention as opposed to the more general effects which follow from the other theories described earlier. Unfortunately the situation is somewhat confused due to conflicting experimental results. There are two forms of extradimensional shift which will be considered in this section. The first involves training subjects with one dimension relevant and another constant (i.e. with both stimuli of the simultaneous discrimination having an equal value on this dimension) for the initial discrimination, followed by a shift to the previously constant dimension with the previously relevant dimension now being held constant. An example of this would involve training subjects on a black-white brightness discrimination using unpatterned stimuli and transferring them to a horizontal-vertical orientation of striations discrimination in which the two stimuli were of equal brightness.

An alternative paradigm involves the use of an irrelevant and relevant dimension for the initial discrimination (with the two stimuli of the irrelevant dimension having different values on each trial in this case). For the shift task the previously relevant dimension becomes irrelevant and the previously irrelevant dimension becomes relevant. An example of this is the use of stimuli containing rectangles which may vary in orientation (horizontal-vertical) or brightness (black-white).

Originally the attention theory did not distinguish between these two paradigms (Mackintosh, 1962). Increased attention to a particular dimension due to original learning was assumed to have the same effect irrespective of whether or not that dimension was held constant during shift learning. The prediction concerning overtraining was that since the total attending response to all possible dimensions was assumed to sum to a constant amount, the increase in the attending response to the relevant dimension due to overtraining would result in a corresponding decrease in the total of the attending response to the remaining dimensions. The consequences of this should be that after shifting to a new dimension, overtrained animals, having a lower attending response to this dimension should learn the task more slowly than criterion trained animals.

Mackintosh (1962) tested and confirmed this prediction using the irrelevant cue held constant paradigm. Unfortunately, his experiment has been the only one to yield this result using this particular paradigm. Komaki (1961), Mandler (1966, 1968), Sutherland & Andelman (1969) and Waller (1970, 1971) all found facilitation of extra-dimensional shift learning following overtraining, while Tighe et al. found no effect due to overtraining.

The conflicting results prompted Sutherland & Mackintosh (1971) to modify the attention theory. (It should be pointed out that the evidence was somewhat more conflicting at the time of their writing since they apparently did not have the results of Waller (1970, 1971) available. The inclusion of these results makes the evidence overwhelmingly favour the hypothesis that over-training normally facilitates extradimensional shift learning). They suggested that the absence of differences between the stimuli on a previously relevant dimension, results in an indeterminate but substantial drop in the strength of the attending response to that dimension which may obscure any differences brought about by overtraining. This, of course, makes it almost impossible to predict the effect of overtraining on extradimensional shifts. If the attending response to the previously relevant dimension becomes inoperative after the shift, then overtraining should facilitate extradimensional shift learning. This follows because overtraining should reduce attention to irrelevant cues such as position, increasing the base level of the attending response to the dimension relevant during the shift. If on the other hand, the attending response to the previously relevant dimension is still reasonably effective after the shift, it should impair learning. Sutherland & Mackintosh concluded that the occurrence of contradictory results is not surprising on their model.

The attention theory's prediction concerning the effect of overtraining on nonreversals when the alternative paradigm is used is more precise. Overtraining should both strengthen attention to the relevant dimension and weaken attention to the irrelevant dimension. Consequently, when the roles of the two dimensions are switched during the shift, learning should be retarded when compared to animals that have only been trained to criterion on the initial task.

The results partially support the attention theory. Goodwin & Lawrence (1955) and Mackintosh (1963b) both found retardation of nonreversal shift learning following overtraining, while Brookshire et al. (1961), Mandler (1966) and Siegel (1967) found no effect due to overtraining. It is not clear at present why these results are inconsistent.

5. <u>The necessity for a difficult discrimination and a large reward.</u> Mackintosh (1969), when suggesting that a difficult discrimination and a large reward are both necessary conditions for the ORE, also suggested that the attention theory could satisfactorily account for this situation. There can be no doubt that the theory can explain the necessity for a difficult discrimination. According to the third rule of the attention theory (see p. 43) the strength of the attending response to the relevant dimension will only reach asymptote more slowly than the strength of the choice response if the base level of the attending response is low. A low base level attending response means that the discrimination is difficult. Hence the ORE should only be obtained using a difficult discrimination. This is probably the strongest evidence for the attention theory explanation of the ORE.

Mackintosh (1969) used Lovejoy's (1966) mathematical model of the attention theory to show how the attention theory can accommodate the finding that the ORE is only obtained using a large reward. According to Lovejoy's model, on each trial the animal may or may not attend to the relevant stimulus dimension, with the probability of attending to this dimension being P(A) and the conditional probability of making a correct response given a correct attending response being P(C/A). (Because of the all or none nature of the attending response on each trial it differs from the attention theory as described above). The model further states that P(A) may increase or decrease from trial to trial while P(C/A) can only increase or stay the same, and hence P(C/A) should reach asymptote before P(A), allowing P(A) to increase further during overtraining. These conditions will, of course, only apply using a reasonably difficult task. An easy task may result in P(A) being close to asymptote at criterion or even earlier. (Lovejoy was the first to point out that the attention theory could predict the necessity of a difficult discrimination for the ORE).

The size of the changes in P(A) and P(C/A) on each trial are determined by the values of the four rate parameters:- reward and nonreward operators for changing P(A) and reward and nonreward operators for changing P(C/A). By varying these rate parameters and varying the starting values of P(A) and P(C/A), it is possible to ~~specify~~ produce virtually any desired outcome. Using computer simulation Mackintosh (1969) was able to show that the ORE was eliminated for a difficult discrimination by setting the nonreward parameters for both P(A) and P(C/A) at the same level but setting the reward parameter for P(C/A) at a higher level than that for P(A), to correspond to a small reward. (The higher the value of the rate parameters the slower is the change in P(A) and P(C/A).) This resulted in P(C/A) increasing more slowly than it would with both operators equal and as a consequence, at criterion, P(A) was relatively high and approximately equal to P(C/A). Since they both needed to increase only slightly in order to reach asymptote, overtraining had no appreciable effect and so no ORE was obtained. High reward groups on the other hand, had a relatively low value of P(A) and a near asymptotic value of P(C/A) at criterion due to the reward rate parameter value for P(C/A) being set at a value which ensured rapid change. Overtraining strengthened P(A) only, resulting in the ORE.

While the above post-hoc manipulation does give the desired end result, there does not appear to be any evidence, either experimental or intuitive, that changes in reward size affect the value of the reward parameter for choice responses but not for attending responses. Until this evidence is available it is necessary to withhold judgement concerning the attention theory's ability to explain the effects of reward size.

CHAPTER 2

EXPERIMENT 1: OVERTRAINING AND THE DISCRIMINABILITY OF STIMULI.

1. INTRODUCTION

A possible alternative to the attention theory's explanation of the ORE is presented in this chapter.

The improvement of human perceptual abilities with practice is a well documented phenomenon (see Gibson, 1953, 1969 Chapter 9). Differentiation theory (Gibson & Gibson, 1955) accounts for this phenomenon by assuming that variables initially poorly detected become more obvious with practice although it does not closely specify what these variables might be. In some situations entire dimensions become more obvious in a manner similar to that postulated by the attention theorists. For example, Gibson & Gibson (1955) described an experiment in which subjects were presented with stimuli consisting of "scribble" which could vary on a critical item on one or more of three dimensions - number of coils, horizontal compression or stretching, and orientation. Practice results in fewer of the stimuli being mistaken for the critical item. Obviously the relevant dimensions had become more salient.

Improvement with practice may also occur in other situations where it is clear that no readily specifiable dimension could have increased in salience. If, for instance, a subject is informed that the stimuli will differ on a specific and familiar dimension beforehand, it is improbable that his attention to that dimension will vary during the experiment, i.e. dimensional salience should remain constant and asymptotic. Any improvement will presumably be due to the stimuli on that dimension becoming less easily confused, i.e. apparent stimulus salience will increase where changes in apparent stimulus salience are operationally defined here in terms of changes in the values of the stimuli on a particular dimension (changes in physical stimulus salience). There is a substantial body of evidence that apparent stimulus salience can increase with practice. (See, for studies employing pitch discrimination, Heimer & Tatz, 1966, and Wyatt, 1945; weight discrimination, Bevan & Saugstad, 1955, and Bjorkman & Ottander, 1959; size discrimination using circles, Englund & Lundberg, 1963).

These considerations suggest a distinction between changes in apparent dimensional salience and changes in apparent stimulus salience. (The term "changes in apparent dimensional salience" will be used as an exact equivalent of the term "changes in the strength of the attending response". It is introduced solely in order to increase the preciseness of the contrast between changes in the strength of the attending response and changes in apparent stimulus salience). When an organism learns to look for differences between stimuli on a particular dimension rather than other dimensions, then there has been an increase in the apparent salience of that particular dimension (an increase in apparent dimensional salience) and probably a decrease in the apparent salience of the other dimensions. In contrast, when an organism's ability to distinguish stimuli on a dimension is changed, there has been a change in apparent stimulus salience. The hypothesis to be pursued in the present chapter is that it is changes in the latter, rather than the former, that cause the ORE.

The following assumptions are necessary.

(1) The values of both physical dimensional salience and physical stimulus salience are directly proportional to the difference between the values of the stimuli on a particular dimension. Changes in apparent dimensional salience and apparent stimulus salience are due to learning.

(2) Training on a discrimination task will result in increases in apparent dimensional salience and the strength of the choice response. Overtraining will further strengthen these and in addition strengthen apparent stimulus salience. It is hence assumed that the latter will only change appreciably after considerable practice.

(3) At pre-asymptotic levels, increases in apparent stimulus salience are proportional to the strength of the attending response (apparent dimensional salience). In other words, if the animal is not attending to a given dimension, there can be no increase in apparent stimulus salience on that dimension. It also follows, that for most tasks, increases in apparent stimulus salience will tend to be greater during overtraining than during training since it is probably only then, that attention to the relevant dimension is sufficiently strong.

(4) Increases in apparent stimulus salience are either permanent, or if decreases do occur, are sufficiently small to be insignificant during the course of a normal discrimination experiment. This means that changes in apparent stimulus salience do not follow the normal rules of conditioning as do changes in apparent dimensional salience and choice response strength. "Extinction" of apparent dimensional salience, if it occurs at all, is probably not contingent on lack of reward, but one would guess, is more likely to occur if the subject is entirely removed from the learning situation for an extended period.

(5) Increases in apparent stimulus salience have an identical effect on subsequent learning as increases in physical stimulus salience brought about by changing the physical values of the stimuli so as to increase the

difference between them on the relevant dimension. Hence total stimulus salience is dependent both on the stimuli employed (which determine physical stimulus salience), and the amount of training using the stimuli (which determines apparent stimulus salience). If one assumes that the increase in apparent stimulus salience during overtraining is inversely proportional to the total stimulus salience, it follows that apparent stimulus salience has an asymptotic value because it will increase less rapidly with higher values of total stimulus salience. This means that the change in total stimulus salience due to overtraining will be greater in the case of a difficult discrimination because the total stimulus salience is low due to the low value of physical stimulus salience. Alternatively, if the physical stimulus salience is high (an easy discrimination), increases in apparent stimulus salience may be either insignificant or even non-existent due to the high level of the total stimulus salience.

The ORE is readily predicted by these assumptions. At the completion of overtraining, the stimuli should be more salient than at criterion. If increased stimulus saliency results in a more rapid change in the strength of the choice response (all else being equal), then reversal should be more rapid after overtraining than after criterion training.

Increased perseveration followed by the rapid attainment of the reversal criterion following overtraining is also explained. The increase in perseveration is to be predicted due to the increase of primarily, the choice response, and probably also to the increase in apparent saliency of the relevant dimension. There seems little reason to assume that once criterion has been reached, that the choice response cannot be strengthened any further. Subjects may be able to reach criterion well before their choice responses have reached asymptote. Despite the increased strength of the choice response after overtraining, it is proposed that the rate of extinction or weakening of the old choice response during reversal is more rapid for overtrained animals. This is due to the increased saliency of the stimuli. Hence it is assumed that despite the fact that the change in the strengths of the responses to the two stimuli during reversal is more rapid for overtrained animals, the choice response to the old positive stimulus for these animals is sufficiently stronger than that of criterion trained subjects, to ensure that the strengths of the responses to the two stimuli are equalised at a later stage of reversal. After the equalisation in strength of the responses to the two stimuli, the more rapid change in response strength for overtrained subjects continues, resulting in criterion being attained earlier.

The necessity of a difficult discrimination for the ORE follows directly from the fifth assumption. If the increase in total stimulus salience due to overtraining is greater for a difficult rather than an easy discrimination due to the initially high level of physical stimulus salience present in an easy task, then it follows that the ORE will not be obtained if the level of physical stimulus salience is above a certain level. For an easy discrimination there may either be no increase in apparent stimulus salience during overtraining due to the physical stimulus salience (and hence the total stimulus salience) being at a level sufficiently high to prevent increases, or alternatively, the increase will be very small both in absolute and relative terms. If the former occurs, the increased perseveration due to overtraining might be expected to retard reversal learning resulting in overtrained animals learning more slowly than criterion trained subjects. If on the other hand, the latter occurs, the slight increase in stimulus salience due to overtraining, may be sufficient to negate the increase in perseveration, resulting in no difference between groups. For a difficult discrimination, the relatively large increase in total stimulus salience due to overtraining, should result in more rapid reversal, as described previously.

The necessity of a large reward for the ORE does not automatically follow from any of the foregoing. It may be the case that a large reward increases the rate at which apparent stimulus salience increases, or perhaps it increases its asymptotic value. Alternatively reward size may have no effect at all on apparent stimulus salience and be necessary for the ORE for an entirely unconnected reason.

The purpose of the experiment to be described was to test between the effects of changes in apparent dimensional salience and apparent stimulus salience during initial training on reversal. It should be possible to separate the two effects by varying both the number of training trials and the difficulty of the discrimination on a given dimension during initial training. If a group of animals is trained to criterion on an easy discrimination and then reversed on a difficult discrimination on the same dimension, it should learn the reversal more rapidly than a group given the same number of training trials as the previous group, but using the difficult discrimination on both initial training and reversal. This should occur because of the stronger attending response of the easy discrimination group. This comparison is similar to one made by Lawrence (1952) with the exception that reversal is employed. All cues retained the same value throughout

Lawrence's experiment. He found that the easy discrimination group performed at a higher level when transferred to the difficult discrimination than the difficult discrimination group after an equal number of total training trials. This was explained by assuming that the easy discrimination group had a stronger attending response which subsequently assisted in the learning of the difficult discrimination. This explanation would presumably lead to the same prediction if reversal is used as suggested above.

While changes in apparent dimensional salience are important in the above comparison, increases in apparent stimulus salience are probably virtually non-existent because overtraining is not being employed. In addition since the difference between the cues is relatively large for the easy discrimination group, total stimulus salience should be sufficiently high to either prevent any increase in apparent stimulus salience or to restrict it to a very slight increase during initial training. Increasing the number of initial training trials should not affect the easy discrimination group as much as the difficult discrimination group. The high initial stimulus salience of the easy group should result in overtraining having only a marginal effect. This constraint does not apply to the difficult discrimination group and so additional training should result in increases in apparent stimulus salience. Hence by increasing the number of initial training trials, it should be possible to reach the point where: (1) both groups had equally strong attending responses (both at a maximum), due to the initially weaker attending responses of the subjects in the difficult group continuing to be strengthened after those of the easy group had reached asymptote; and (2) the difficult group had a higher level of apparent stimulus salience due to its having increased during overtraining while that of the easy group remained static or almost static because of the high initial level of physical stimulus salience. On transferring subjects to the reverse of the initial difficult discrimination, the only difference between groups should be that the total salience of the stimuli should be greater for the difficult group due to the increase in apparent stimulus salience during initial training. Hence, under these circumstances, the difficult group should learn the reversal more rapidly. (This contrasts with the previous situation in which far less training is given on the initial discrimination and it is predicted that the easy group will learn the reversal more rapidly). The attention theory predicts that since both groups have equally strong attending responses because of overtraining, there should be no significant differences between them on reversal.

In line with the above argument, three pairs of groups were used in a 3 x 2 factorial design with 3 levels of initial task training and 2 levels of initial task difficulty. The groups were:

(1) Low initial training trials groups in which the easy discrimination group was trained to criterion and the difficult discrimination group given the same number of trials as the easy discrimination group.

(2) Medium initial training trials groups in which the difficult discrimination group was trained to criterion and the easy discrimination group given the same number of trials as the difficult discrimination group.

(3) Overtrained groups in which the difficult discrimination group was given overtraining trials and the easy discrimination group given the same number of trials as the difficult discrimination group.

All groups were reversed to criterion on the difficult discrimination. It was predicted that for the first pair of groups the easy group would learn the reversal more rapidly; for the third pair that the difficult group would learn more rapidly; and for the second pair it was expected that there would (a) either be no difference between groups, or (b) if a difference was found, that it would be smaller than the difference between either the first pair if the easy group learned more rapidly, or the third pair if the difficult group learned more rapidly. It should also be noted that the difficult discrimination group trained to criterion and the overtrained difficult discrimination group constitute the normal ORE paradigm. The ORE should consequently be obtained by using a large reward.

2. METHOD

Subjects. Sixteen experimentally naive male hooded rats, approximately 120 days old at the beginning of the experiment were used. A further 6 animals were eliminated during pretraining for responding too slowly and two more during the experiment after being accidentally food satiated. (It was initially intended to replicate this experiment twice. These two replications were not carried out for reasons to be explained later . The experiment can hence be considered a pilot study.)

Apparatus. The apparatus was constructed of flat grey painted wood with clear perspex lids. It consisted of a 14.0 cm long, 6.5 cm wide, and 9.0 cm high starting box separated by a guillotine door from a 26.5 cm long, 20.5 cm wide, and 9.0 cm high runway ending at a 7.5 cm wide airgap. The runway then continued as two parallel alleyways 20.5 cm long and separated by a 1.5 cm wide partition. Two top hinged, removable stimulus doors 7.5 cm high and 9.0 cm wide could be placed 12.5 cm from the airgap in each alleyway.

The runway continued for 20.5 cm past the two alleyways before opening into the goalbox which was 23.0 cm long, 20.5 cm wide and 15.0 cm high. A 60-W globe was located 10.0 cm in front of the stimulus doors, immediately above the perspex lid. Dark grey and light grey painted aluminium doors were used. Their brightness readings using a spot photometer in the normal experimental lighting conditions were 1.2 and 1.7 log foot-lamberts respectively.

Procedure. Pretraining: During the 10 days of pretraining, animals were tamed, reduced to and maintained at 85% of their ad lib weight, and trained to run through black-white vertical striped doors for food. All animals experienced locked doors on some occasions. Manual guidance was given throughout pretraining in order to equalise experience with both positions.

Training: Animals were given 10 non-correction trials a day in groups of three giving an intertrial interval of approximately 3 minutes. The position of the stimuli were varied according to Gellermann series. The negative stimulus door was always locked. Correct responses were rewarded by 30 seconds access to wet mash. After incorrect responses animals were retained on the platform in front of the locked stimulus door for 10 seconds. The criterion of learning was 18/20 correct responses over 2 successive days for those groups trained to criterion on the original discrimination, and for all groups on the shift task.

Design: A 2 x 3 design was used with 2 levels of task difficulty on the initial discrimination - easy or difficult (E or D), and 3 levels of amount of training on the initial discrimination - low, medium or high (L, M or H). Table 2.1 gives the number of animals in each group.

The easy task involved a black-white discrimination while the difficult task involved a dark grey-light grey discrimination. Each LD subject was randomly paired with an LE subject and shifted to the reversal after the same number of trials as its LE partner. LE subjects were shifted after attaining criterion on the original task. Each ME subject was similarly paired with an MD subject. MD subjects were trained to criterion on the initial task. (One of the accidentally satiated subjects mentioned previously was in Group MD and paired with an ME subject after attaining criterion on the initial discrimination. Hence the results of the ME subject are included in the analysis). HE subjects were paired with HD subjects and HD subjects were given 150 overtraining trials after reaching criterion on the initial task. (The other accidentally satiated animal had been assigned to Group HE). Each group was balanced with respect to the positive stimulus on the initial discrimination as far as was possible given the odd number of subjects in most of the groups. All animals were reversed to criterion on the difficult discrimination.

Table 2.1. Experiment 1.

Design of Experiment 1 and days to reversal criterion.

Amount of training on the initial task	Low		Medium		High	
Task Difficulty	Easy	Difficult	Easy	Difficult	Easy	Difficult
Group	LE	LD	ME	MD	HE	HD
N	3	3	3	2	2	3
Days to criterion	14.0	22.7	16.0	15.5	14.0	22.7

3. RESULTS

Initial discrimination. Group LE took a mean of 4.7 days to reach the initial discrimination criterion (excluding the 2 criterion days). Hence both Group LE and Group LD were reversed after a mean of 6.7 days on the initial task. On the day preceding reversal, two of the animals in Group LD were still position responding (where position responding is defined as all of the responses to one position), while the other animal was responding in a random manner.

Group MD took a mean of 8.5 days to reach criterion which resulted in Group ME (yoked to Group MD) being given a mean of 4.0 days of overtraining. The latter group took 4.0 days to reach criterion. Hence Group MD was reversed after a mean of 10.5 days (8.5 days plus the 2 criterion days) on the initial task and Group ME after 10 days. (The slight difference is due to the animal eliminated from Group MD).

Group HE required a mean of 22 days of overtraining, after learning the task in 3.5 days, in order to be equated in terms of amount of initial training with Group HD. The latter group took 11.7 days to reach criterion. This resulted in Group HE being given 27.5 days and Group HD being given 28.7 days of training before reversal.

There was no significant difference in days to criterion between any of the groups given the easy task ($F < 1$), nor between the two groups (Groups MD and HD) trained to criterion on the difficult discrimination ($F < 1$). There was no overlap between any of the scores (days to criterion) of subjects given training on the easy discrimination, and those subjects trained to criterion on the difficult discrimination.

Reversal learning. Days to reversal criterion are given in Table 2.1. This data was analysed by analysis of variance using the method of unweighted means (Winer, 1970, p.222-224) designed for multi-way analysis of variance with unequal cell numbers. The results indicated a significant effect due to difficulty of initial training, $F = 4.71$, d.f. = 1/10, $p = .05$, no effect due to the amount of initial training, $F = .444$; and no interaction effect, $F = 1.40$, d.f. = 2/10, $p = .292$.

4. DISCUSSION

Despite the small number of subjects used, the results were fairly clear. The original hypotheses were not all supported and hence it was felt, the results did not warrant the continuation of the experiment. The crucial prediction, designed to test the hypothesis that over-training would result in an increase in apparent stimulus salience for the difficult but not the easy group, appears to have been quite incorrect - Group HE learned the reversal considerably more rapidly than Group HD rather than vice versa. While the number of subjects is too small to allow an individual test of significance on these two groups, it is ~~highly~~ probable that an increase in numbers would be ~~most~~ unlikely to both reverse the relationship between these 2 groups and in addition yield a significant difference.

The relationship between the 2 groups given a low amount of initial training, and the 2 groups given a medium amount of initial training, is on the other hand, exactly as predicted. Group LE learned the reversal more rapidly than Group LD, as is predicted by the attention theory[1], while Groups ME and MD learned the reversal in approximately the same number of trials. The slow reversal learning rate of Groups HD and LD was obviously the primary contributory factor in the significant effect of ease of initial discrimination. This was in part an unexpected result since it had been predicted that the relationship between Groups HE and HD would be the reverse of the relationship actually obtained (i.e. Group HD should have learned the reversal rapidly). Had the predicted relationship been obtained it would probably

---

[1]This has implications for the "easy-to-hard" effect and is discussed further in Appendix I.

have resulted in no significant main effects but a significant interaction effect. There is no indication in the data of an interaction effect.

As mentioned previously, the experimental design includes two ORE paradigm groups - Groups MD and HD. Since both groups were given a difficult discrimination and a large reward, one would expect some indication that the ORE would be obtained given the use of a sufficient number of subjects. In fact, there is no indication whatsoever that the ORE could be obtained under the conditions pertaining in the experiment. (This conclusion is substantiated in Experiment 2). The fairly substantial difference between the 2 groups is in the wrong direction with Group HD learning the reversal more slowly rather than more rapidly compared to Group MD. As will be shown in Experiment 2, an increase in numbers still does not yield the ORE.

The theory elaborated at the beginning of this chapter was based on the assumption that under conditions of a difficult discrimination and a large reward, the ORE would be readily obtained. No support was obtained for this assumption. There are three possibilities.

(1) The theory is incorrect and apparent stimulus salience does not increase with overtraining.

(2) The theory is partially correct and apparent stimulus salience does increase with overtraining under those conditions which allow the ORE to occur. Since those conditions did not seem to pertain in the experiment, no evidence for an increase in apparent stimulus salience was obtained. If all the conditions for the ORE were known, then the conditions for an increase in apparent stimulus salience would also be known. These conditions might necessitate a greater or lesser modification of the theory as it stands at present.

(3) The theory is correct as it stands but the experimental design and/or the small number of subjects used did not allow for an adequate test of the theory.

The results are probably sufficiently unambiguous (as pointed out previously) to warrant the rejection of the third possibility on the grounds of an insufficient number of subjects. As pointed out previously, this conclusion is further strengthened by Experiment 2. As for the experimental design, it depends on the assumption that overtraining will increase apparent stimulus salience for difficult groups, but not easy groups. This should have been reflected in more rapid reversal learning with overtraining for difficult groups, but no difference between easy groups. If overtraining had facilitated reversal learning for the easy groups as well as for the difficult groups, this might have indicated a deficiency in the experimental design, i.e. it would have indicated that the easy groups were inadequate as control groups. Since the easy groups all learned in approximately the same number of trials, this is implausible.

One is hence left with the possibilities that the theory is either incorrect, or at best, only partially correct. The results of the present experiment give some slight indication that it is the first of these alternatives which is the most probable. From the data of the difficult groups, it appears possible that the ORE (or an analogous effect) could be obtained using Group LD as the lesser trained group in an ORE paradigm experiment. There is a considerable drop in the days to reversal criterion scores from Group LD to Group MD. While there is a rise of identical magnitude from Group MD to Group HD, this rise is entirely caused by one animal that took approximately twice as long to learn the reversal as the other animals in Groups MD and HD. This animal also shared the highest initial discrimination score. Hence, from the data obtained, it appeared reasonable to hypothesise, that if the number of subjects per group was increased sufficiently, Group LD (or a similar group) would learn the reversal more slowly than groups given additional initial discrimination training.

If the above is correct, then the ORE (or analogue of the ORE) obtained, could obviously not be explained by the sort of theory proposed at the beginning of this chapter. The theory assumed that increases in apparent stimulus salience were slow and required considerable practice, as is the case with human subjects. If under some conditions, an ORE analogue can be obtained with virtually no overtraining, it cannot be caused by increases in apparent stimulus salience.

CHAPTER 3.

EXPERIMENT 2. UNDERTRAINING, OVERTRAINING, AND REVERSAL LEARNING.

1. INTRODUCTION.

The indication from Experiment 1 that animals reversed before criterion might learn the reversal more slowly than criterion and overtrained subjects, led to the present experiment which involved introducing two pre-criterion groups and increasing the number of subjects in the criterion and overtrained groups. The decision to follow this line of research was also strongly influenced by a paper by Sperling (1970) which became available at this particular time.

Sperling used a 2 x 3 x 2 factorial design with two initial training procedures, three amounts of initial training, and two reversal training procedures. The two training procedures involved either conventional simultaneous stimulus presentation or alternatively, differential stimulus presentation in which one stimulus only was presented on each trial. For simultaneous acquisition, the three levels of training were: to a criterion of 10/12 correct responses or more on a single day; to a criterion of 21/24 correct responses or more over two successive days with no more than two errors on the first day and no more than one error on the second day; to this latter criterion with an additional 180 overtraining trials. The two day criterion was used for reversal. Criteria were based on latency of response for differential acquisition and reversal. For acquisition, the three levels of training were: (a) to a criterion of either (1) two or less of the six latencies of response to the negative stimulus on a single day lower than the highest latency of the six responses to the positive stimulus or (2) one or less of the six latencies of response to the negative stimulus lower than the two highest latencies of the six responses to the positive stimulus; (b) a two consecutive days criterion on which the previous criterion was attained on the first day and not more than one of the latencies to the negative stimulus was lower than the highest latency to the positive stimulus on the second day; (c) to this latter criterion with an additional 180 overtraining trials. The 1-day criterion was used for reversal for the differential condition.

The exact criterion of learning on the initial discrimination for both procedures, and the exact reversal criterion for the simulatneous discrimination, were found to significantly affect the relationship between groups with respect to their speed of learning the reversal. (Since groups given the simultaneous discrimination on reversal were taken to the 2-day criterion, the number of trials to the 1-day criterion was also available. Groups given differential stimulus presentation were only taken to the 1-day criterion on reversal). Initial discrimination training to the 1-day criterion resulted in slower reversal learning than training to the 2-day criterion or overtraining for groups given the same stimulus presentation method for both the initial and reversal discrimination. For the simultaneous discrimination this only applied when the 1-day reversal criterion was used. Amount of initial discrimination training had no differential effect on reversal learning when the mode of stimulus presentation was changed for reversal or when the 2-day criterion was used for the simultaneous discrimination reversal.

Sperling's findings that a low criterion on the initial discrimination was a necessary condition for the ORE may have been analogous to the suggestion that a precriterion group took longer to learn the reversal than a group trained to a fairly strict criterion. The present experiment was designed to test this hypothesis.

2. METHOD.

Subjects. The subjects were 24 experimentally naive, male hooded rats (including the 5 animals in the 2 ORE paradigm groups of Experiment 1 - Groups MD and HD) approximately 120 days old at the beginning of the experiment. An additional 8 subjects were eliminated during pretraining for responding too slowly.

Apparatus and Procedure. As in Experiment 1.

Design. Animals were randomly assigned to four groups of six animals each. Groups 2D and 5D (pre-criterion groups) received two and five days discrimination training respectively before reversal (Experiment 1 had indicated that it was most unlikely that any overt sign of learning would occur on day 5): Group C was trained to a criterion of 18/20 correct responses over two successive days before being reversed (this group consisted of the two animals in Group MD of the previous experiment plus an additional four animals): Group OT was trained to the same criterion and then given an extra 150 trials before reversal (this group consisted of the three animals in Group HD of the previous experiment plus an additional three animals). Half of the subjects in each group were trained with light grey positive during the initial discrimination while the other half were trained with dark grey positive. Reversal training continued for each animal until it obtained 18/20 correct responses over two successive days.

3. RESULTS.

Initial training. No animals in Group 2D or 5D showed any overt sign of learning (in terms of choice responses) before reversal. On the last day of initial training animals in Group 2D had a total of 29 correct out of 60 responses while those in Group 5D had a total of 30 correct. Most of the animals were still position responding at this stage. For Group 2D, four subjects responded on all 10 trials of the last day of initial discrimination training to the same position, while another responded to the same position on 8 trials and the last on 7 trials. While there was less position responding for Group 5D on the last day of initial training, responding was still random with respect to the stimuli on the last day. The highest score obtained was 7/10 correct responses. Of the six animals, two responded on all trials, two responded on 7 trials, and two responded on 6 trials to the same position.

Group C and Group OT both took a mean of 8.83 days to reach criterion (excluding the two criterion days) on the initial discrimination.

<u>Reversal training</u>. <u>Days to Criterion 18/20</u>. Group means are given in Table 3.1. Trend analyses were carried out using orthogonal polynomials. The independent variable - mean number of days on the initial discrimination - was transformed using an $X^1 = \frac{X-1}{X}$ transformation in order to "compress" the large difference in number of

initial trials between the overtrained animals and the other groups.

The results indicated a significant quadratic component, $F = 5.17$, d.f. = 1/20, $p < .05$. No other trends were significant. Fig. 3.1 graphs the relationship.

In order to facilitate the comparison of the present results with those of previous studies, individual orthogonal comparisons between groups were also carried out. These indicated that (a) Group 2D learned more rapidly than a combination of Groups 5D, C, and OT, $F = 5.78$, d.f. = 1/20, $p < .05$: (b) Group 5D learned more slowly than a combination of Groups C and OT, $F = 4.12$, d.f. = 1/20, $p = .053$: (c) there was no significant difference between Groups C and OT, $F < 1$.

Days to Criterion 8/10. Since Sperling (1970) was only able to obtain the ORE when using a low reversal criterion, the data were analysed using individual orthogonal comparisons for a criterion of 8/10 correct responses on one day as well as the above analysis using 18/20 correct responses over two successive days. These indicated that (a) Group 2D learned more rapidly than a combination of Groups 5D, C, and OT, $F = 3.51$, d.f. = 1/20, $p < .10$: (b) Group 5D learned more slowly than a combination of Groups C and OT, $F = 4.20$, d.f. = 1/20, p = .051; (c) there was no significant difference between Groups C and OT, $F < 1$.

Days of position responding. Planned comparisons between groups, identical to those carried out for days to criterion results, indicated no significant differences in position responding (where position responding is defined as 10/10 responses to one position on any particular day), $F < 1$ for all three comparisons.

Perseveration to the old positive stimulus. There was no significant difference in perseveration scores (measured by the number of incorrect trials before the first correct trial) between Groups C and OT, $t = 1.43$, d.f. = 10, $p > .10$. Perseveration scores for Groups 2D and 5D are meaningless since no overt sign of learning had occurred during the initial discrimination for these groups and hence all animals were responding randomly with respect to the discriminative stimuli on the first day of reversal, i.e. perseveration scores for all animals must be considered 0.

4. DISCUSSION.

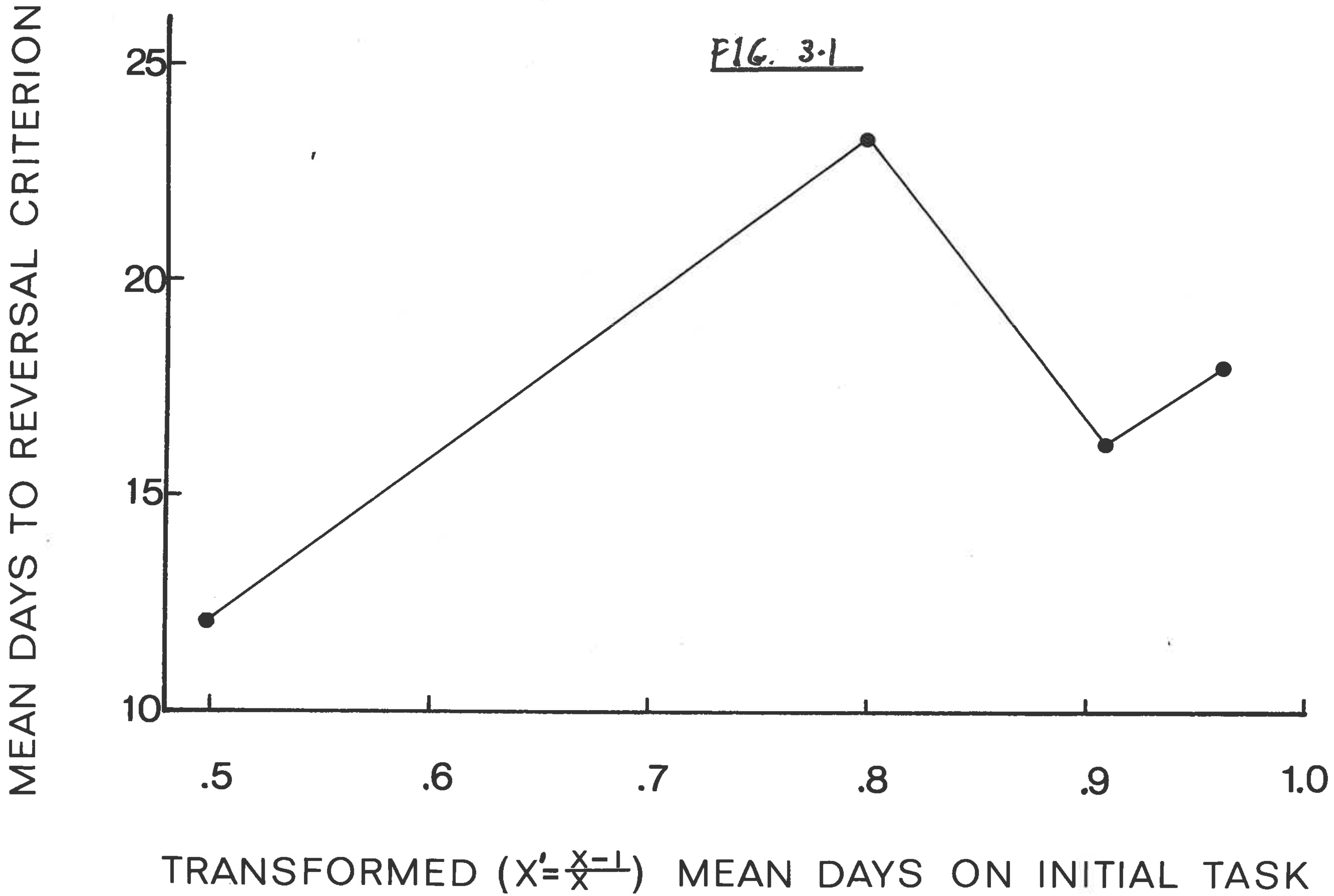
The days-to-reversal-criterion results indicate that as the degree of initial training increased, reversal initially required more trials but subsequently required less. This result was obtained irrespective of the

Table 3.1. Experiment 2.

Reversal means

Group	N	Days to Criterion 8/10	Days to Criterion 18/20	Days of position responding	Perseverative trials
2D	6	12.17	12.33	9.67	-
5D	6	22.00	23.33	12.33	-
C	6	14.83	16.33	8.83	11.00
OT	6	16.33	18.00	7.83	16.33

FIG. 3.1


MEAN DAYS TO REVERSAL CRITERION
25
20
15
10
.5
.6
.7
.8
.9
1.0
TRANSFORMED (X'= (X−1)/X) MEAN DAYS ON INITIAL TASK

reversal criterion used although the initial increase in the number of reversal trials to criterion with increased training on the first task was more obvious when Criterion 18/20 was used rather than Criterion 8/10.

These results confirm the suspicion raised by the results of Experiment 1, specifically, that despite the use of a difficult discrimination and a large reward suggested by Mackintosh (1969) to be the optimal conditions for its occurrence, the conventional ORE normally obtained by the use of criterion and overtrained groups (Groups C and OT in the present instance) is not in evidence. Clearly, while a difficult discrimination and a large reward may be necessary conditions for the ORE, they are not sufficient and the specification of supplementary conditions is required.

The finding that a similar phenomenon to the ORE was obtained when criterion and overtrained groups were compared to a group reversed a short period before criterion (Group 5D), tends to indicate that one of the supplementary conditions required is that the nonovertrained group be given a sufficiently low level of training on the initial discrimination. This result is almost certainly analogous to Sperling's (1970) finding that the ORE was only obtained using a low criterion on the initial discrimination for the nonovertrained groups. At present it would appear reasonable to suggest that under some (at present unspecifiable) conditions, the ORE can only be obtained providing that the amount of training given the lesser trained group falls within a fairly strict range. This range possibly falls between a point preceding the initial breaking of position habits and the point at which the subjects have attained low criteria of learning. (This applies to visual discriminations only. Spatial discriminations will be discussed in the following chapter).

Treating Group 5D as the lesser trained group of an ORE paradigm yields further similarities between the present results and those frequently obtained using the conventional design. Since no perseveration was or could have been obtained for Group 5D, there is obviously an increase in perseveration for the two groups given additional initial discrimination training (Groups C and OT). (There is also decreased position responding for Groups C and OT as compared to Group 5D, although in this case it does not approach significance). Hence one of the paradoxical aspects of the ORE - more rapid learning of the reversal despite apparently slower extinction of the old response - is also exemplified in the present ORE analogue.

Only two studies have completely failed to obtain the ORE despite the use of a difficult discrimination and a large reward. It is possible that Lukaszewska (1968) may have failed to obtain the effect because of the criterion of learning she chose for her initial discrimination. She did four experiments. A brightness discrimination with a criterion of 18/20 correct trials on two consecutive days for both the initial and reversal discriminations was used for the first two experiments. (The only difference between the two experiments was that a self-correction method was used for the first experiment while non-correction was used in the second). Since this criterion is identical to the one used in the present experiment, it would appear reasonable to hypothesize that Lukaszewska failed to obtain the ORE because of excessive training on the initial discrimination for criterion trained groups. While this possibility also applied to her third and fourth experiments, the argument is not as strong. These two experiments vary from the first two in that irrelevant visual dimensions were also employed - shape and brightness with one relevant and the other irrelevant in each experiment, and a rerun correction procedure used due to the increased difficulty of the tasks. The most important variation for present purposes was the use of a criterion of 11/12 correct responses on any single day. This criterion is reasonably low (as compared to a criterion based on 20 consecutive correct responses) and compares with the criterion of 10/12 correct on a single day used by Sperling (1970) as a low criterion. Hence in order to explain these results in terms of excessive training on the initial discrimination for the nonovertrained groups, it is necessary to assume that in the conditions pertaining in Lukaszewska's experiment, either an exceedingly low criterion, or alternatively, precriterion training was necessary before the ORE could have been obtained.

The other failure to obtain the ORE was that of Weyant (1966). He did a serial reversal experiment in which animals were given ten successive reversals on a brightness (light on - light off) discrimination. He used three groups of subjects with three criteria of learning. These were 8/10 correct including the last 5: 12 consecutive correct; 30 consecutive correct. It can be seen that the initial discrimination and the first reversal constitute an ORE paradigm with three levels of initial training. Furthermore, there can be no doubt that a criterion of 8/10 with the last 5 correct is a very low criterion. Since a large reward was used, and from the number of errors to criterion a difficult discrimination as well, all the conditions for the ORE appear to be present. Nevertheless, in terms of the number of errors to criterion (the only measure of learning used), there were no significant differences between groups. The most obvious explanation of this result (suggested by Sperling) is that the wrong measure of learning was employed. As pointed out previously, reversal learning after overtraining is characterised by increased perseveration (relative to criterion trained groups) to the old positive stimulus followed by more rapid attaining of criterion. It is hence possible for the overtrained group to attain criterion before the criterion trained group in terms of number of trials to criterion but not in terms of number of errors e.g. Capaldi & Stevenson (1957). The uneven distribution of errors between groups during reversal training in ORE paradigm experiments makes the number of errors to criterion an unsuitable measure of learning.

On the basis of her own results, Sperling (1970) suggested that the ORE is dependent on criterion trained animals not having reached asymptotic performance on the initial discrimination, a condition more likely to hold if a low criterion is used. For the simultaneous discrimination, her results showed a significant increase in the frequency of correctly choosing the nonpreferred side over incorrectly choosing the preferred side from the day on which the 1-day criterion was attained to the last day of the 2-day criterion. A similar analysis indicated that these response category frequencies did not undergo a further change during overtraining. It was hence reasonable to suggest that the ORE was not obtained using the 2-day criterion because asymptotic performance had been attained at this point resulting in overtraining having no effect. The pre-asymptotic performance of the 1-day criterion animals on the other hand, allowed additional training to have an effect, giving the ORE.

In further support of this hypothesis, Sperling discussed three other experiments that had also used multiple acquisition criteria as well as overtraining before reversal. Weyant's (1966) experiment was considered uninterpretable on the previously mentioned grounds. Capaldi & Stevenson (1957) also used three successively more stringent acquisition criteria. These were: Criterion 1 - 7/8 consecutive correct responses; Criterion 2 - Criterion 1 plus 8 additional consecutive correct responses; Criterion 3 - Criterion 2 plus 35 subsequent correct responses. The analysis of reversal learning indicated that the group trained to Criterion 3 learned the reversal more rapidly than the groups trained to Criteria 1 and 2. The latter two groups did not differ from each other.

According to Sperling's hypothesis, it should follow that the groups trained to Criteria 1 and 2 had not attained an asymptotic level of performance on the initial discrimination. Capaldi & Stevenson state that "Criterion 1 did not provide a sufficient number of trials for the animals to reach a stable level of performance.", and imply by omission that animals trained to Criterion 2 had reached a stable level of performance. (They merely state that few errors were made once Criterion 2 had been met). Sperling suggested that there was in fact some evidence that subjects trained to the second criterion had not ~~in fact~~ reached asymptote. Using the data provided in Capaldi & Stevenson's paper, she converted the mean errors to proportions of mean trials to each of the three criteria. The proportion of errors to the first criterion was .29, from the first to the second .27, and from the second to the third .07. For her own study, these proportions were .38, .07, and .08. Sperling took the large difference between the two intermediate proportions as indicating that in her own study asymptotic performance had been attained by Criterion 2 but had not been attained by this criterion in Capaldi & Stevenson's experiment.

The third study to use multiple acquisition criteria was that of Reid (1953). As described at the beginning of this thesis, Reid found that reversal learning was more rapid after 150 overtraining trials than after either 50 overtraining trials or after criterion training (to a criterion of 9/10 with the last 5 correct). Since it is probable that asymptotic performance had been attained after 50 overtraining trials, Sperling suggested that this was the only result not supporting her hypothesis.

Despite the fact that the present results accord entirely with Sperling's hypothesis (a precriterion group obviously cannot have reached asymptote), there must nevertheless be considerable doubt concerning its validity other than that raised by Reid's results. Firstly, when using the proportion of mean errors to mean trials to each criterion as a means of comparing her own results with those of Capaldi & Stevenson, Sperling assumed that the proportion of errors up to a certain criterion indicates whether or not the subjects have reached asymptote at that criterion. In fact, the proportion of errors made after, rather than before the criterion of interest would be a better indicator of whether or not a stable level of performance has been attained. While a low proportion of errors before the criterion would certainly indicate the attainment of asymptotic performance, a high proportion would be equivocal. It may be the case, as Sperling implicitly assumes, that the errors were fairly evenly distributed throughout the pre-criterion period, but alternatively, it may also be the case that the majority of errors were made early in the period in question, resulting in a high proportion of errors for the entire period despite the fact that asymptotic performance could have been reached at criterion. A high proportion of errors after a given criterion, would on the other hand, clearly indicate that a stable level of performance had not been reached at that criterion, while a low level would again indicate that it had been reached.

Sperling's comparison of the proportion of errors made between the attaining of the first and second criteria of her own and Capaldi & Stevenson's experiment illustrate the problems associated with her mode of analysis. It will be recalled that a low proportion of errors was obtained for her own experiment (.07) and a high proportion for Capaldi & Stevenson's experiment (.27). She concluded that in her own experiment, subjects had reached a stable level of performance by the intermediate criterion, but had not done so in Capaldi & Stevenson's experiment. In fact, as suggested above, the respective proportions probably give more information concerning the first criterion of both experiments rather than the second. Capaldi & Stevenson's first criterion was exceptionally low - seven correct responses out of any eight consecutive trials. One might expect a substantial number of errors after this criterion, indicating that animals had not reached asymptote and hence yielding a high error proportion. Sperling's first criterion was considerably higher - ten correct responses out of the twelve trials on any given day. The low proportion of errors made after this criterion probably indicates that animals had reached asymptote at or immediately after this criterion. Since the proportion of errors made after the second criterion was equally low for both experiments, it is probable that asymptotic performance had been attained at this point in both studies. It is hence doubtful whether Capaldi & Stevenson's experiment indicates that pre-asymptotic performance by criterion trained groups is necessary for the ORE.

While as mentioned previously, the present results accord with Sperling's hypothesis, they also provide a strong argument against using her method of detecting asymptotic performance. The proportion of mean errors over mean trials between the fifth day of training (the point at which Group 5D was reversed) and criterion (the point at which Group C was reversed) for Groups C and OT was .41. Clearly, if this proportion is considered as a measure of whether or not a stable level of performance has been reached at criterion one can only conclude that it has not. Nevertheless, the conventional ORE was not obtained. Despite this, the results do support Sperling's hypothesis, since during overtraining the proportion of errors to trials is .03, indicating asymptotic performance at criterion.

When discussing her hypothesis, Sperling only considered experiments involving multiple acquisition criteria. There appears to be no good reason for this. Considering standard ORE paradigm experiments, it is doubtful whether all successful demonstrations of the effect have involved pre-asymptotic performance by criterion trained animals. The vast majority of experimenters have used 18/20 correct responses as the criterion of learning. This in itself should ensure asymptotic performance. Nevertheless, the ORE has been obtained with the use of even stricter criteria. Mackintosh (1962, 1963a) using a criterion of 18/20 correct with the last 10 trials all correct, North & Clayton (1959) using 19/20 with the last 10 correct, and Siegel (1967) using 16/16 correct over two days, all obtained the effect. It must be considered highly probable that all of these criteria represent a level of responding that is asymptotic. Further evidence on this point may be obtained from those of the above experiments which reported the number of errors made during overtraining. Mackintosh (1962) reported that no subject made more than 3 errors during overtraining, and the mean number of errors was 0.9, while Siegel (1967) reported that subjects chose the correct stimulus on 98.7% of the trials. This may be contrasted with the present experiment in which subjects had a mean of 4.83 errors during overtraining (hence choosing the correct stimulus on 97% of the trials) and yet the conventional ORE was not obtained.

It should at this stage be pointed out that while strict criteria may ensure asymptotic performance in the case of discriminations which tend to be learned in approximately 100 trials or less such as the experiments discussed to the present point, this may not hold for extremely difficult tasks requiring several items as many trials to criterion. Winefield & Jeeves (1968) overtrained animals on a successive discrimination which took animals a mean of 290 trials to reach a criterion of 18/20 correct responses over two days. During overtraining the mean percentage of correct responses underwent a substantial and continuous reduction. Nevertheless, as indicated above, a high criterion does usually indicate asymptotic performance and is not incompatible with the occurrence of the ORE.

Hence in total, the evidence is very strongly against the hypothesis that pre-asymptotic performance on the part of nonovertrained subjects is necessary for the ORE. The only conclusion that can be offered, is that the exact degree of initial training of the nonovertrained group is vital to the occurrence of the ORE under some conditions at least, and that the relationship between (1) this degree of initial training, (2) performance during initial training, and (3) subsequent reversal learning, is a complex one. One of the variables which it is considered governs this relationship is discussed in the following chapter.

CHAPTER 4.

EXPERIMENT 3: THE RELATIONSHIP BETWEEN CRITERIA OF LEARNING AND TASK DIFFICULTY: EFFECTS ON REVERSAL LEARNING.

1. INTRODUCTION.

Sperling's (1970) results and the results of Experiment 2 (Chapter 3) suggest a reason for the rarity of the ORE when experimenters use spatial discriminations. If the exact degree of initial training of the nonovertrained group is vital to the occurrence of the ORE, it may well be the case that in an easy discrimination such as position, animals trained to conventional criteria are normally reversed at a point which will not allow the effect to occur when the discrimination is a rapidly learned one; i.e. there may be a relationship between criteria of learning and task difficulty. Since experimenters tend to use the same criteria of learning irrespective of task difficulty, it is to be expected that the results of experiments involving easy tasks should vary in a consistent manner from difficult tasks.

A direct relationship between task difficulty and criteria of learning is proposed, such that all else being equal, a lower criterion of learning will have the same effect on an easy discrimination as a higher criterion on a difficult one. It may hence be predicted that if a criterion of 18/20 correct responses frequently gives the ORE using a difficult discrimination, a far lower criterion will be required using an easy task such as position.

The evidence strongly supports this hypothesis. Excluding the experiment of Pubols (1956) on the grounds of inadequate matching of groups, and that of Theios & Blosser (1965) on the grounds of failing to equate the total food intake between groups (these two experiments were discussed in Chapter 1), there have been only two experiments to show the ORE using a spatial discrimination; Bruner, Mandler, O'Dowd & Wallach (1958), and Capaldi (1963). Both of these experiments used variations of the conventional design.

Bruner et al's experiment was concerned with the effects of both overtraining and motivation on reversal learning. They used a complex position reversal. Animals had to learn to traverse a four-unit linear T maze which involved learning whether to turn left or right at each of four consecutive choice points on each trial. The authors hypothesised that there were two methods by which animals could learn a single alternation task (e.g. following a LRLR pattern on each trial) using this apparatus. Either they could learn the specific response required at each choice point independently of that required at the other choice points, or alternatively, they could learn "the principle of single alternation". By this they meant a recoding of information giving a reduction in the number of decisions the organism must make in the task situation, e.g. "Choice Point 1, turn left; then keep reversing sides". Reversal learning can be used to determine which of these possibilities does in fact occur. Reversal would require animals to learn RLRL rather than LRLR. It was hypothesised that if there were substantial savings in reversal learning, this might indicate that the principle of single alternation had been learnt rather than a series of specific turning responses.

Two further factors were suggested as probably influencing the likelihood of the attainment of "principle" learning. Firstly, increased overtraining was hypothesised as increasing the probability of principle learning, and secondly, motivation was thought to interact with over-training such that overtraining under conditions of mild drive increased the tendency to learn by principle, while overtraining under conditions of high drive led to "rigidification" - the inability to go beyond the learning of specific responses. The influence of motivation follows from the assumption that high drive reduces the operation of "any processes not essential to attaining the immediately present goal as rapidly as possible". If this includes processes more complex than simple response learning, then under high drive, animals should not learn the principle of single alternation.

To test their hypotheses, Bruner et al. used a 2 x 3 experimental design consisting of two levels of hours of food deprivation - 12 or 36 hours, and three levels of initial training on the single alternation. These levels were: to a criterion of 80% correct consisting of no more than four wrong turns in the five trials given in a single day; to the same criterion plus four days (20 trials) of overtraining; to the same criterion plus 16 days (80 trials) of overtraining. All animals were then trained to criterion on the reverse pattern under the same level of deprivation as had been used for the initial discrimination.

Bruner et al's results supported their hypotheses in that the ORE was obtained for animals under moderate motivational conditions (12 hours deprivation), but was not obtained under conditions of high motivation (36 hours deprivation). The relationship between the ORE and conditions of motivation will be further discussed subsequently. For the present, the mere fact that the ORE was obtained using a position discrimination is of interest.

It was suggested at the beginning of this chapter that the ORE would not be obtained using an easy discrimination (such as position) unless a sufficiently low criterion was used on the initial task. One must hence look for evidence either that Bruner et al's position task was more difficult than usual, or that the criterion of learning was lower than usual, or a combination of the two. Since the task was more complex than the conventional spatial discrimination, one would expect it to be more difficult, which in turn should be indicated by an increase in the number of trials to the initial discrimination criterion. It took approximately ten trials for the subjects to reach this criterion. The number of trials to reach the initial discrimination criterion for most spatial tasks falls between 10 and 30. Clearly, on these figures Bruner et al's task was not difficult. Nevertheless, due to the nature of the discrimination, the average of ten trials to criterion may not adequately represent task difficulty. A trial in this case represents four decisions at four choice-points which gives an average of approximately 40 choices to reach criterion. In a conventional position discrimination a trial represents one decision at one choice-point. Consequently, in terms of choices to criterion, animals took longer to learn the task than is normally the case.

Bruner et al. also used a criterion somewhat lower than that normally employed - 16/20 correct choices. This contrasts with the most frequently used criterion - 90% rather than 80% correct based on 18/20 correct trials. It may hence be concluded that Bruner et al's experiment does not contradict the hypothesis that a lower criterion of learning is required in order to obtain the ORE using an easy discrimination such as position.

The other experiment to unambiguously demonstrate the ORE using a spatial discrimination was that of Capaldi (1963). He used the conventional position discrimination task with the exception of one detail. Rather than training his subjects to criterion on the initial discrimination, he gave all the animals a fixed number of training trials before reversal. Eight trials per day were given. One group was reversed after two days of initial discrimination training while the other group was reversed after 15 days. The group given greater initial training learned the reversal significantly more rapidly, giving a position ORE.

Capaldi also gave the number of correct responses for each of the five animals in both groups on the second day (and last day for the lesser trained group) of the initial discrimination. For the lesser trained animals, four obtained scores of 7/8 correct responses on this day of training, while the fifth obtained 8/8. These are the sort of scores one would expect to obtain had a criterion of 7/8 correct responses on a given day been used as a criterion of learning for the initial discrimination, rather than the fixed number of trials actually used. A criterion of 7/8 correct would be considerably lower than that used by any other experimenter attempting to obtain the ORE using a position discrimination. Since, from the above scores, the task was obviously an easy one, this result lends further credence to the hypothesis that a lower criterion of learning on the initial discrimination is required for the ORE when employing an easy task.

The purpose of the present experiment was to attempt to confirm the relationship found between groups in Experiment 2 (Chapter 3) using a position rather than a brightness discrimination. In line with the general hypothesis of a relationship between task difficulty and criteria of learning, it was hoped that this could be accomplished by including groups reversed after only attaining very low criteria of learning on the initial discrimination as well as the more conventional groups.

2. METHOD.

Subjects. The subjects were 29 experimentally naive male hooded rats approximately 120 days old at the beginning of the experiment. An additional 15 animals were eliminated during pretraining for responding too slowly and 4 were eliminated after not obtaining any correct responses during the first three days of initial discrimination training.

Apparatus. As in Experiments 1 and 2.

Procedure. The pretraining procedure was identical to that used in the two preceding experiments. The same vertical striped doors were used during training as were used during pretraining. Both doors were locked on the first trial of the first day for all subjects and the side chosen was subsequently designated the negative stimulus. In all other respects the procedure for each individual trial was identical to that employed in the preceding experiments.

Design. There were five groups. Groups 2, 4, 6 and 10 were reversed immediately after any 2, 4, 6 and 10 consecutive correct trials respectively. Group OT was reversed after 10 consecutive correct trials plus an additional 50 trials. Reversal training continued for each animal until it obtained 10 consecutive correct responses.

The use of statistically unreliable criteria (the lower range of the above criteria) requires comment. While a low criterion is statistically unreliable, it was assumed that due to the nature of the task, most of the criteria used were psychologically valid in the sense that they did largely represent learning rather than chance events. This assumption appeared reasonable due to the response characteristic of position responding by rats in a 2-choice maze. Position responding has previously been mentioned primarily with respect to reversal learning. It is normally exhibited equally strongly during the initial discrimination. While most experimenters equalise each animal's experience with both positions during pretraining, this may have the effect of reducing position preferences but rarely eliminates them. Consequently, at the beginning of initial discrimination training, or soon after, all or most animals beging position responding. The occasional breaking of this position habit in order to approach the positive stimulus on the non-preferred side is normally one of the first signs of learning.

In a spatial discrimination with animals being trained with their non-preferred side as the positive stimulus, any switch to the correct side probably indicates learning since random position switching is rare. In other words, since animals generally do not respond randomly with respect to the relevant dimensions at any stage during training, chance factors in the attainment of criteria of learning are reduced, presumably allowing a commensurate reduction in the stringency of the criterion employed.

This argument does not generalise directly to a visual discrimination, because in this case the number of consecutive correct responses an animal can obtain before actually learning, is in large part determined by the number of times the positive stimulus appears consecutively on the preferred side. An analogous situation for a visual discrimination would perhaps involve the counting of correct responses on the non-preferred side while ignoring correct responses on the preferred side.

3. RESULTS.

Group means are given in Table 4.1. Trials to a reversal criterion of four consecutive correct responses (Criterion 4) as well as ten (Criterion 10) are included.

Initial training. Using Criterion 2 proved to be an unreliable method of detecting learning. Evidence for this comes from the fact that, (a) a total of 10 animals in Groups 4, 6, 10, and OT made a total of 27 errors after reaching Criterion 2 and before reaching Criterion 4, and (b) two animals in Group 2 reversed in 0 trials. It is hence probable that chance factors played an important role in the attaining of this criterion. This may be contrasted with Criterion 4. (a) A total of only 2 animals in Groups 6, 10, and OT made a total of five errors after

TABLE 4.1. EXPERIMENT 3.

Group	N	Initial discrimination: Trials to Criterion 4	Initial discrimination: Trials to own criterion	Reversal: Trials to Criterion 4	Reversal: Trials to Criterion 10	Reversal: Perseverative trials
2	9	-	6.22	6.56	8.22	3.67
4	11	9.18	9.18	22.91	25.45	9.00
6	9	9.33	10.33	12.78	13.22	4.00
10	10	11.10	11.10	17.70	18.90	7.40
OT	10	9.20	10.00	15.30	16.90	9.20

reaching Criterion 4 and before reaching Criterion 6.
(b) The lowest number of perseverative errors before the first correct responses in reversal for Group 4 was three. Hence this particular animal made a total of 7 consecutive responses to one side. One may conclude that it is improbable that chance factors played a significant role in the attaining of Criterion 4. For this reason, for comparative purposes, mean trials to Criterion 4 are included in Table 4.1 for Groups 6, 10, and OT as well as mean trials to each group's own criterion. A similar number of trials was required by Groups 4, 6, 10 and OT to reach Criterion 4, $F < 1$.

Reversal training. Trials to Criterion 10. Orthogonal comparisons indicated that (a) Group 2 learned more rapidly than a combination of Groups 4, 6, 10, and OT, $F = 9.64$, d.f. = 1/44, $p < .005$. (b) Group 4 learned more slowly than a combination of Groups 6, 10, and OT, $F = 8.58$, d.f. = 1/44, $p < .01$. (c) There was no significant difference between Group 6 and a combination of Groups 10 and OT, $F = 1.69$, d.f. = 1/44, $p > .1$. (d) There was no significant difference between Groups 10 and OT, $F < 1$.

Trials to Criterion 4. Orthogonal comparisons indicated that (a) Group 2 learned more rapidly than a combination of Groups 4, 6, 10, and OT, $F = 13.99$, d.f. = 1/44, $p < .005$.

(b) Group 4 learned more slowly than a combination of Groups 6, 10, and OT, $\underline{F}$ = 8.39, d.f. = 1/44, $p < .01$. (c) There was no significant difference between Group 6 and a combination of Groups 10 and OT, $\underline{F}$ = 1.55, d.f. = 1/44, $p > .1$. (d) There was no significant difference between Groups 10 and OT, $\underline{F} < 1$.

Perseveration. Orthogonal comparisons indicated that (a) Group 2 perseverated less than a combination of Groups 4, 6, 10, and OT, $\underline{F}$ = 5.01, d.f. = 1/44, $p < .05$; (b) there was no significant difference between Group 4 and a combination of Groups 6, 10, and OT, $\underline{F}$ = 1.91, d.f. = 1/44, $p > .1$; (c) Group 6 perseverated less than a combination of Groups 10 and OT, $\underline{F}$ = 5.83, d.f. = 1/44, $p < .05$; (d) there was no significant difference between Groups 10 and OT, $\underline{F} < 1$.

Due to the surprisingly rapid reversal learning of Group 6, the data were reanalysed with this group excluded. This was in order to ensure that the significantly slower learning of Group 4 when compared to groups given additional training on the initial discrimination was not solely caused by the results of Group 6.

Trials to Criterion 10 (Group 6 excluded). Orthogonal comparisons indicated that (a) Group 2 learned more rapidly than a combination of Groups 4, 10, and OT, $\underline{F}$ = 12.07, d.f. = 1/36, $p < .005$; (b) Group 4 learned more slowly than a combination of Groups 10 and OT, F = 4.79, d.f. = 1/36, $p < .05$; (d) there was no significant difference between Groups 10 and OT, $F < 1$.

This particular set of data was also subjected to a trend analysis using orthogonal polynomials. While this analysis is somewhat redundant since it will not reveal more than the previous three orthogonal comparisons, it should conveniently summarise them with one F ratio. The independent variable - mean number of trials on the initial task - was transformed using an $X^1 = \frac{X-1}{X}$ transformation in order to "compress" the large difference in number of initial trials between the overtrained animals and the other groups. A significant quadratic component was indicated, F = 10.42, d.f. = 1/36, $p < .005$. No other trends were significant. Fig.4.1 graphs the relationship.

Trials to Criterion 4 (Group 6 excluded). Orthogonal comparisons indicated that (a) Group 2 learned more rapidly than a combination of Groups 4, 10, and OT, F = 17.27, d.f. = 1/36, $p < .005$; (b) Group 4 learned more slowly than a combination of Groups 10 and OT, F = 4.86, d.f. = 1/36, $p < .05$; (c) there was no significant difference between Groups 10 and OT, $F < 1$.

Perseveration (Group 6 excluded). Orthogonal comparisons indicated that Group 2 perseverated less than a combination

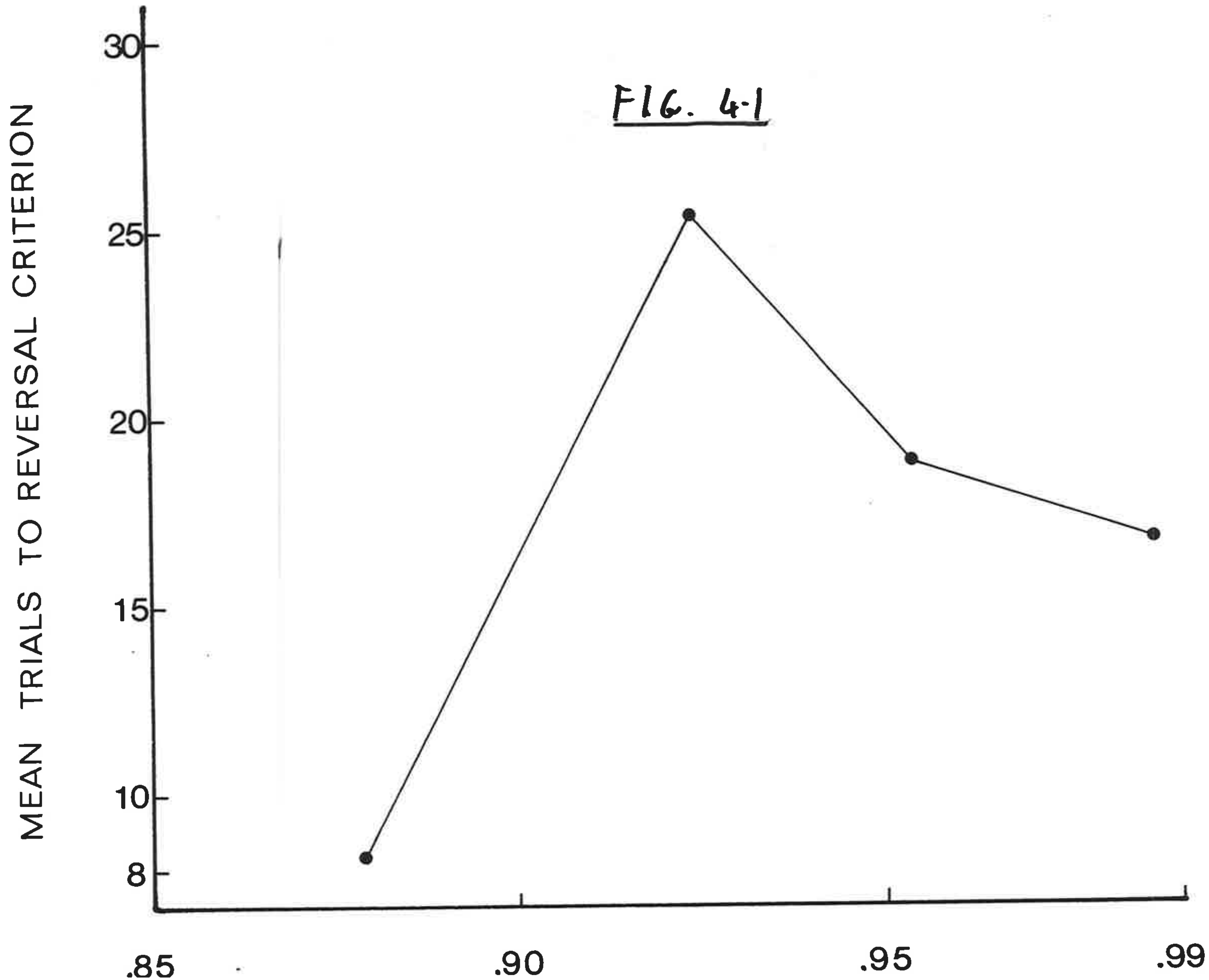


FIG. 4·1
MEAN TRIALS TO REVERSAL CRITERION
30
25
20
15
10
8
.85
.90
.95
.99

of Groups 4, 10, and OT, $F = 7.24$, d.f. = 1/36, $p < .01$. There were no other significant differences, $F < 1$ in all cases.

4. DISCUSSION.

The trials to reversal criterion results again indicate an increase in the number of trials with increases in the degree of initial training up to a point, followed by a decrease. This was not affected by the reversal criterion used. Nor was it merely due to Group 6 possibly being unrepresentative since the same effect was observed after the exclusion of this group from the analysis.

Interpretation of the perseveration results with the inclusion of Group 6 is difficult. It was expected that perseveration would increase with increases in amount of initial training and then become asymptotic. The former result was obtained (Comparison a), and Comparisons (b) and (d) support the latter assumption. Comparison (c) on the other hand, indicated that Group 6 perseverated significantly less than those groups receiving more training on the initial discrimination. In the light of Comparison (b), this is unexpected and is at present difficult to interpret. As is to be expected, the exclusion of Group 6 eliminates this difficulty. The only significant effect was the initial increase in perseveration with an increase in amount of initial training. Further increases in initial training had no effect on perseveration.

Unlike the previous experiment (Experiment 2, Chapter 3), the present experiment does not support Sperling's (1970) hypothesis concerning the cause of the ORE - non-asymptotic performance on the part of nonovertrained groups. Taking Group 4 as the lesser trained group, it is quite clear that the amount of perseveration shown by this group, and the few errors made after attaining Criterion 4 by those subjects given additional initial discrimination training, precludes the assumption of non-asymptotic performance at Criterion 4.

Since both the increase and decrease in case of reversal learning occurred using initial discrimination criteria well below those normally employed, it is reasonable to assume that the rarity of the ORE in easy discriminations is due to training for seemingly non-overtrained groups being in fact extended for too long a period. This in turn supports the hypothesis of a relationship between criteria of learning and ease of task such that lower criteria for easy tasks are equivalent to higher criteria for difficult tasks.

Richman & Coussens (1970) arrived at the same conclusion based on similar results. Using a position discrimination, they trained four groups of rats to criteria of 4/8 correct trials, 6/8 correct, 8/8 correct, and 8/8 correct plus an additional 96 overtraining trials. They found that the two groups given the most training on the initial discrimination learned the reversal more rapidly than the two groups given the least training.

The proposed relationship between criteria of learning and ease of task is of particular importance in the case of easy tasks. An easy task can be defined as one in which the learning process is "compressed" relative to a difficult task. As a consequence it may be very sensitive to slight changes in the criterion of learning as was the case in the present experiment. The more difficult the task, the more leeway should be available in choice of criterion. Hence the greater number of experiments successfully demonstrating the ORE using a visual rather than a spatial discrimination.

While the relationship between task difficulty and criteria of learning may play an important role in reversal learning, other factors, play an equally important role. Irrespective of the ease of the discrimination, whether a spatial or a visual task is used will have an effect on the above relationship and hence on the ORE. Possibly, overt signs of learning (i.e. onset of criterial trials) occur relatively earlier in the case of a spatial discrimination because strong position responding during a visual discrimination may prevent an animal from responding correctly until the learning process has continued for some time. In the case of a position discrimination, correct responding may occur at a lower level of learning. In other words, the difference in response strengths to the positive and negative stimulus may not need to be as great in order for animals to attain criterion in the case of a position discrimination, as compared to a visual task.

It is in part probably this that allowed all groups in the present experiment to be trained to a criterion on the initial discrimination, while groups given a low level of training in the previous experiment (Experiment 2 - Chpater 3) were precriterion groups. Strength of position responding (which is certainly apparatus-dependent) will hence affect the relationship.

The results obtained have certain implications for the attention theory, since the theory states that the ORE will not be obtained using easy tasks such as position discriminations. As pointed out in Chapter 1, the basis for this statement is the assumption that the main effect of overtraining is to increase attention to the relevant dimension. If the relevant dimension is an obvious one as in the case of an easy discrimination, attention to this dimension will be so high at criterion, that overtraining should have no effect.

The attention theory can be modified to allow it to handle the present data. It need merely be assumed that since attention to the correct dimension builds up more rapidly using an easy task, lower criteria of learning on the initial task, or, depending on the nature of the task, pre-criterion levels of learning, are necessary in order to ensure that attention has not reached an asymptotic level for all groups. In other words, even on an easy task, it must be assumed that the choice response reaches asymptote before the attending response. This assumption necessitates the further assumption that differences in task difficulty are primarily (though not necessarily entirely) due to differences in rate of change of the relevant attending response, rather than differences in its base level. As mentioned previously, at present the theory assumes that for easy tasks, attention to the relevant dimension is relatively high even before training commences, and hence reaches asymptote either simultaneously with, or even before the choice response. This would not allow the ORE to occur in easy spatial tasks no matter what criterion was used.

At the beginning of this chapter, considerable emphasis was given to Bruner et al's (1958) finding that overtraining only facilitated reversal learning under conditions of relatively low motivation, as determined by the degree of deprivation. High deprivation resulted in overtraining having no effect on reversal. This finding provides a possible explanation for the necessity of a large reward for the ORE. It may well be the case that a large reward results in the level of deprivation being lowered during each day's trials to an extent which in effect has animals running under low drive for the latter part of the day. Paradoxically, this would mean that a large reward decreases rather than increases motivation, as a consequence of substantially decreasing the level of deprivation during the day's trials.

SECTION II. HUMAN SHIFT LEARNING.

CHAPTER 5.

THE EFFECT OF OVERTRAINING ON SHIFT LEARNING IN HUMANS.

I. AN EMPIRICAL (NONTHEORETICAL) REVIEW.

The relationship between criteria of learning and task difficulty found to hold for rats and described in Section I, is quite possibly highly general, and consequently extends to other species as well. For this reason, the experiments to be described in later chapters of Section II were primarily designed to find those combinations of task difficulty and criteria of learning that would yield the ORE in human subjects. This chapter reviews experiments using human subjects in which overtraining on the initial task was used in order to observe its effect on a shift task - involving either reversal or nonreversal. Relevant theories primarily applying to human rather than animal learning are also discussed.

Experimental designs - The manipulation of dimensions.

The basic design used by the majority of experimenters in the area (whether or not overtraining was employed) was introduced by Buss (1953). Using this paradigm, a subject is presented with a series of stimuli and must respond on each trial with one of two responses. He is informed after each trial whether his response was correct or incorrect. Either a successive discrimination (one stimulus presented at a time) or a simultaneous discrimination (two stimuli presented simultaneously) is employed. In the latter case subjects in effect must choose one of two stimuli rather than one of two responses on each trial. The stimuli vary on several dimensions (e.g. colour, number, size, etc.) with two or more values being employed on each dimension. (Non-dimensional designs will be discussed later). On the initial discrimination, one dimension is designated relevant and the other dimension irrelevant. In order to learn the task, one of the responses must be associated with one value of the relevant dimension, and the other response with the other value. After initial discrimination training, shift training is introduced, normally with no warning being given to the subjects. The shift may involve either reversal or nonreversal training. For reversal the same dimension remains relevant but the alternate response is required for both stimulus values (or the alternate stimulus must be chosen in the case of a simultaneous discrimination), while for nonreversal, one of the previously irrelevant dimensions becomes relevant and the two responses must be associated with two of its values. In order to facilitate post-shift comparisons, reversal and nonreversal groups are usually given different relevant dimensions on the initial discrimination, allowing an identical task to be given to both groups for the shift.

Buss (1953) found that reversals were accomplished more rapidly than nonreversals. This finding gave rise to a large number of subsequent experiments and to a considerable amount of theorising. Many of the experiments used overtraining as well as criterion training on the initial task and it is these experiments that will be of primary interest in this review. (Buss, 1953, used a fixed number of trials rather than criterion training).

While the above pattern of dimension and response manipulations has been the most commonly used, the reversal and nonreversal shifts described are in fact, respectively, specific examples of a more general set of intradimensional and extradimensional shifts. They may be distinguished from the alternative designs by the fact that the stimulus set does not change after the shift, which consequently is defined solely by the change in reinforcement contingencies. All other shifts which have been used involve changes in the stimuli presented on one or more dimensions. Hence for intradimensional shifts other than reversal, the originally relevant dimension remains relevant but the stimulus values presented on this dimension change, e.g. if the shape dimension was initially relevant, new shapes are used during the shift with this dimension again relevant. For extradimensional shifts, the situation is more complex in that several shifts other than the one described above (Paradigm 1) are possible. These are: Paradigm II - a previously irrelevant dimension may become relevant without changes in cue values, but the previously relevant dimension may take new values (and perhaps become constant by taking one value only): Paradigm III - a previously irrelevant or constant dimension may take new values and become relevant while the previously relevant dimension becomes irrelevant with no other change: Paradigm IV - the values of all dimensions may change resulting in totally new stimuli. In this case, subjects may be prevented from responding differentially on any of the originally present dimensions by making them all constant and varying previously constant dimensions. In addition, the use of simultaneous discriminations allows dimensions to vary within trials as well as between trials. (Successive discriminations can only vary between trials). While the relevant dimension for each task must vary within trials in order to present subjects with a positive and negative stimulus, irrelevant dimensions may vary within or between trials (or both) and may be changed for the shift task.

1. Intradimensional (primarily reversal) shifts.

(a) Normal adult subjects.

For present purposes adults will be defined as being 15 years old or more. One of the first studies on the effect of the degree of initial training on reversal was that of Iwahara & Sugimura (1960). They trained males aged 15 to 19 years on a simultaneous size discrimination and reversal problem with colour as an irrelevant dimension. Seven groups with seven degrees of initial discrimination training were used. These degrees of training were to criteria of 1, 2, 3, 5, 7, and 10, consecutive correct responses and to a criterion of 10 consecutive correct responses plus an additional 20 trials. The results indicated that reversal became more difficult with increases in the initial discrimination criterion level up to the criterion of three consecutive correct responses, and then became easier with subsequent increases in criterion level. This inverted U shaped function is identical to that obtained in Experiment 2 and 3 (Chapters 3 and 4) using rats. While only an overall analysis of the mean trials to reversal criterion is given, it is clear from the means that the ORE could have been obtained using any of the first four groups (up to the group with a criterion of five consecutive correct responses on the initial discrimination) as the lesser trained group, against any of the remaining three groups as the greater trained group. Obviously, had a large range of criteria, including low criteria, not been used, the ORE would not have been obtained. The ease of the discrimination may be gauged from the fact that it took subjects approximately 8 trials to attain a criterion of 10 successive responses on the initial task.

Ludvigson & Caul (1964) using college students, compared the effect of criterion training and overtraining for both a two and a four category sorting task on concept reversal. Their task was identical to one used by Kendler & Mayzner (1956) and was designed to allow reversals when more than two categories of stimuli and responses are used. In a four category sorting task involving either the line-angularity or the radii-position concept, subjects had to learn to sort each of 16 response cards under one of four stimulus cards. The radii-position concept will be used as an example. The stimulus cards had arrows pointing in four different directions and each response card had a circle with a radius line in a position in the circle pointed to by one of the stimulus card arrows. A correct response involved matching these two cards. During reversal, subjects were required to match a radius position with an arrow pointing in the opposite direction. For the two category sorting task, only the horizontal-vertical aspect of the arrows and radii was used (necessitating the use of only two stimulus cards). A conventional (response switch) reversal was possible in this case. Ludvigson & Caul found that overtraining facilitated reversal using both 2 and 4 sorting categories. On the original discrimination the 4 sorting category task with approximately 5 trials to a criterion of 10 successive correct responses was learned more rapidly than the 2 sorting category task with approximately 8 trials to criterion, although the difference was not significant. This may have been reflected in reversal learning since the difference between groups for two sorting categories was significant at the .002 level, while that for four sorting categories was only significant at the .02 level. It is possible that the relationship between criteria of learning and task difficulty influenced these results.

Sugimura (1965, summary only) trained 15-19 year old boys on a simultaneous size or colour discrimination task to a criterion of 3, 5 or 10 plus 20 consecutive correct responses. This was followed either by an immediate reversal, or alternatively, a reversal after a 30 minute rest interval. The ORE was obtained for the conventional no rest condition, with large differences being obtained between all three groups, but was not obtained for the rest condition, with all three groups learning the reversal exceedingly rapidly. It took a median of 5 trials to attain the criterion of 10 successive responses on the initial discrimination.

Uhl (1966) used intradimensional shifts involving both reversals and nonreversals. He gave undergraduate students a simultaneous discrimination with the stimuli varying on the dimensions of shape, size, colour, and position. The subjects were given a fixed number of trials (16 or 48) on the initial discrimination rather than being trained to a criterion. The last 4 of every 16 trials were nonoutcome trials in which subjects were not given any feedback concerning their responses. Subjects who did not respond correctly on the 4 trials just before the shift period were eliminated from the experiment on the grounds that they had not learned the initial task. The relevant dimension was form. For half of the subjects given an intradimensional shift, the stimuli did not change and reversal training was initiated while for the other half, new stimuli with new forms were used, with form again being the relevant dimension.

Mean trials to criterion on the shift task indicated that overtraining facilitated intradimensional shift learning whether this consisted of a reversal or nonreversal shift. (Individual statistical tests were not carried out. Only an overall analysis of variance was done, including extradimensional shifts discussed in a subsequent section. The results of this test indicated that additional training facilitated shift learning). It took approximately 7.5 trials to attain a criterion of 4 consecutive correct responses on the initial discrimination.

Sitterley & Capehart (1966) trained undergraduate subjects on a successive discrimination task using odd or even digit pairs as the two relevant cues. They used three different criteria on the initial discrimination:- 8/10, 13/15, and 18/20 correct responses. In addition, each of these three groups was divided into two reinforcement groups such that one group was presented with a green light following a correct response and a noxious buzzer following an incorrect response, while the other group was presented with the green light after a correct response only. The results indicated that the groups trained to the criterion of 8/10 correct responses learned the reversal more slowly (with the group given the buzzer learning most slowly) than the other groups which did not differ from each other. The number of trials to the initial discrimination criterion were not given.

McAllister, Capehart, & Rogers (1970) specifically tested whether a difficult discrimination was necessary for the ORE using undergraduates as subjects. They did this on the basis of Lovejoy's (1966) mathematical interpretation of the attention theory. A successive discrimination with geometric figures on cards was used. The easy task involved an obvious shape discrimination while the difficult task involved the conjunction of three dimensions. Two criteria of learning were used:- 8/10 and 18/20 correct responses. As hypothesised, the ORE was obtained for the difficult discrimination but not for the easy discrimination. On the initial task, it took subjects a mean of 0.17 trials to solve the easy problem, and 6.54 trials to solve the hard problem.

Lowenkron (1969) used a "nonoutcome" trials technique for studying the ORE. This involved the interspersion of nonoutcome trials amongst the conventional outcome trials. On nonoutcome trials subjects were required to respond but were not given any feedback concerning the response. Lowenkron used a successive discrimination task with 12 different stimuli, 4 of which only appeared on nonoutcome trials. These stimuli varied on four dimensions - size, colour, shape, and number, with shape or number providing the relevant dimension. Initial training continued to a criterion of 8 consecutive correct responses, one to each of the reinforced stimuli, or, in the case of overtraining, to the same criterion plus an additional 48 trials. The reversal results yielded the ORE.

Further analysis employing the nonoutcome trials indicated that only certain subjects contributed to the difference between criterion and overtrained groups. On the basis of the responses on nonoutcome trials, subjects could be classified as being either consistent or inconsistent. A consistent subject responded correctly on the nonoutcome trials despite never having been reinforced for making either response to those particular stimuli. Inconsistent subjects did not respond correctly on all the nonoutcome trials.

These results indicated that consistent subjects had extracted the relevant dimension and were responding correctly on the basis of this dimension, while inconsistent subjects had presumably merely learned the correct response to the 8 outcome stimuli by rote.

Whether a subject responded in a consistent or inconsistent manner had important effects on both the acquisition and reversal learning phases. Firstly, inconsistent subjects took far longer to learn the initial discrimination. They took a mean of approximately 23 errors to learn the initial task, while consistent subjects took a mean of approximately 6.5 errors. (Trials to criterion were not given). Secondly, the overall ORE that was obtained, was entirely due to the inconsistent subjects. Separate analyses of the reversal data for both consistent and inconsistent subjects indicated that while the ORE was obtained for the latter, it was not obtained for the former. The suggested relationship between task difficulty and criteria of learning on the initial discrimination is clearly applicable in this case. Subjects who extracted the relevant dimension (consistent subjects), in effect had an easy task and hence were overtrained at criterion giving no difference between groups. Rote learning subjects (inconsistent), had a more difficult task and were not overtrained at criterion, giving the ORE.

Lowenkron & Driessen (1971) repeated the above experiment, studying in addition the effect of varying the difficulty of the task and the number of irrelevant dimensions. The same dimensions (size, colour, shape and number) as in the previous experiment were used to give a three-irrelevant-dimensions task, while the number dimension became constant to give a two-irrelevant-dimensions task. Using colour as the relevant dimension resulted in a more difficult task than using shape. (11.80 vs. 7.42 errors to criterion on the initial task).

Lowenkron & Driessen found similar differences between consistent and inconsistent subjects as had been found in the previous experiment (Lowenkron, 1969). Inconsistent subjects took longer to learn the initial discrimination and demonstrated the ORE, while consistent subjects learned more rapidly and did not demonstrate the effect. Combining the results of both types of subject resulted in an overall ORE. These results may again be explained in terms of a relationship between task difficulty and initial discrimination criterion level. Two additional findings were that the number of inconsistent subjects increased with an increase in the number of dimensions from two to three, and also increased with the use of a more difficult task (i.e. colour rather than shape relevant). As stated above, increases in the number of inconsistent subjects resulted in increases in ORE magnitude.

The following conclusions may be suggested on the basis of the above review. Firstly, using normal adult human subjects, the ORE can be very readily obtained. No experimenter (of those who have published) has failed to find the effect under some conditions. Secondly, from the few failures it appears probable that as with rats, the ORE is less likely to occur using an easy discrimination and this in turn may be caused by the use of inappropriate criteria of learning on the initial task.

(b) Normal child subjects.

(1) Three-choice experiments.

The majority of experiments studying the effect of overtraining on intradimensional shifts have used normal children as subjects. Many of the early experiments used three-choice rather than two-choice-tasks. While these tasks allow a shift in which the same dimension is relevant with no change in stimulus values - which can define a reversal shift in a two-choice task - it is probably more accurate to refer to them as nonreversal intradimensional shifts since there is no clear reversal of either stimulus values or responses. (Authors have frequently referred to them as reversal shifts, presumably on the basis of the above definition of a two-choice reversal).

Stevenson & Zigler (1957) trained 4-5 year old children on a simultaneous three-choice size discrimination problem. Subjects had to respond to one of three blocks varying in size for the first task and respond to a different block on the second task. The criterion group was shifted after 5 consecutive correct responses on the first task while the overtrained group was given an additional 30 trials. A fixed number of trials (30) was given on the shift task. There was no significant difference between the two groups in number of correct responses on the shift task. It took subjects approximately 15 trials to learn the initial discrimination.

Stevenson & Weir (1959) trained 6-8 year old children on a successive three-choice colour discrimination problem. The criterion was 6 consecutive correct responses with one group being shifted immediately after attaining this criterion and two other groups being shifted after an additional 36 and 72 overtraining trials respectively. The shift task involved reassignment of the three spatial responses. There was no transfer effect due to overtraining. The number of trials to criterion on the initial discrimination was not given. In both this study and the previous one, (Stevenson & Zigler, 1957), approximately twice as many subjects attained criterion during reversal after overtraining than after criterion training.

Youniss & Furth (1964a, 1964b), and Furth & Youniss (1964) were the only others to use three-choice tasks. Youniss & Furth (1964a) used 7-9 year old subjects in a partial replication of Stevenson & Weir's (1959) experiment. The primary difference was the use of three digits as responses, rather than three spatial responses. In addition to a successive three-choice colour discrimination and shift of the previously discussed kind, they also employed a shift in which the three original colours were replaced by three different colours. This more closely resembles the conventional nonreversal intradimensional shift. Overtrained subjects were given 18 additional trials to the 6 consecutive correct criterion trials. Overtraining only facilitated shift learning in the case of subjects given the same stimuli for both tasks. The number of trials to criterion on the initial discrimination was not given. The experiment of Furth & Youniss (1964) included the same shift paradigms as that of Youniss & Furth (1964a) and from inspection of the data, probably yielded the same pattern of results. (No statistical analysis of the effect of overtraining was given). Youniss & Furth (1964b) used the constant stimulus design and found overtraining facilitated shift learning in the case of both a nonspatial task and a spatial task with irrelevant dimensions, but found no facilitation in the case of a spatial task with no irrelevant dimensions. (Their "spatial tasks" were in fact colour discriminations in which the response to each colour varied spatially). As pointed out by Wolff (1967), since overtraining resulted in far more rapid learning of the spatial shift task with the presence of irrelevant dimensions than without their presence, this result must for the time being be considered a chance event. Overtraining with irrelevant dimensions may negate the expected retardation due to these dimensions, but it is implausible that it should in addition facilitate shift learning when compared to a situation in which there are no irrelevant dimensions.

One may tentatively conclude that overtraining facilitates 3 stimulus intradieensional shift learning, although the effect may sometimes be weak. This facilitation does not seem to apply in the case of a stimulus change from the first to the second task.

(2) Two-choice experiments.

Most experimenters have used the conventional two-choice design and most of these found overtraining facilitated shift learning under some conditions at least.

Studies in which overtraining facilitated shift learning under all conditions.

Three experiments with similar designs all yielded the ORE. Marsh (1964) trained 3-4 year old children on a simultaneous size or brightness discrimination to a criterion of 8/10 correct responses. Overtraining consisted of 10 additional trials and facilitated reversal learning. The original task was learned in approximately 10 trials. Youniss & Furth (1965) gave 69-96 month old children a simultaneous colour or form discrimination. Training continued to a criterion of 9/10 correct responses or to the same criterion plus 15 or 25 overtraining trials. The ORE was probably obtained. (No statistical test of this comparison was reported). Mean trials to criterion on the original task were only given after a square root transformation and hence task difficulty cannot be gauged from this data. Tighe & Tighe (1965) used children with an average age of 6 years 8 months. They were trained on a simultaneous height or brightness discrimination to a criterion of 9/10 correct responses or to the same criterion plus 30 overtraining trials. This task took approximately 30 trials. Overtraining possibly facilitated reversal, $p < .10$.

Other experiments which have found a facilitatory effect due to overtraining have departed from the above basic design. Eimas (1966a) used a nonreversal intradimensional shift. A simultaneous colour or form discrimination was given to two age groups of children - 5-6 and 7-8 year olds. The criterion of learning was 20/25 correct responses and overtraining consisted of 50 additional trials. The trials to criterion score was not reported. Overtraining facilitated intradimensional shift learning for both age groups.

Heal (1966) used a part reversal, part nonreversal intradimensional shift design. During the shift, the positive or negative cue from the initial task was replaced by a new cue from the same dimension and the value of the retained cue was reversed. A simultaneous colour or form discrimination was given to 64-76 month old children. The criterion was 6 consecutive correct responses and overtraining consisted of 40 additional trials. The number of trials to criterion on the initial task was not reported. Overtraining facilitated the intradimensional shift irrespective of the cue replaced.

Steinmetz & Turnage (1966) tested a reversal index designed to predict speed of reversal learning. They predicted that on the initial task, the closer the ratio of number of rewarded trials to total number of trials was to unity, the easier the reversal learning. (This predicts the ORE). The hypothesis was tested by training 5-6 year olds on a simultaneous colour discrimination to 50%, 75% or 100% correct responding. The first level simply involved the termination of initial training after 12 trials, the second was based on a criterion of 9/12 and the third 10/10 correct trials. The ORE was obtained with the largest decrease occurring between the 50% and 75% criterion groups. It took a mean of 31 trials to reach the 100% criterion on the initial discrimination.

Turnage & Steinmetz (1968) further tested their reversal index by comparing an easy and a difficult task. They suggested that the faster the subject learns the task, the faster will he approximate a continuous reinforcement schedule. This should facilitate reversal learning (presumably reducing any effect due to over-training). Six to nine year old children were given an easy or a difficult simultaneous discrimination using stimulus materials described by Gibson (1963). The initial task criterion levels were identical to those used by Steinmetz & Turnage (above). A similar pattern of results, including the ORE, was obtained irrespective of task difficulty. Since on acquisition, it took many more trials to attain the 100% criterion level for the difficult task than the easy task (a mean of approximately 30 vs. 12 trials), one would expect the pattern of results to indicate that the ORE was only obtained for the easy task using a lower criterion of learning. The failure to obtain this result is possibly due to the subjects trained to the 75% criterion of the easy group being exceedingly slow learners. It took these subjects more trials to reach their low criterion than it took subjects given the same task to reach the 100% criterion level. Furthermore, it took them longer to reach their criterion than subjects given the same criterion on the difficult task. It is therefore possible that the large difference on reversal between these subjects and those given the maximum initial discrimination training is due to a failure to equate groups in terms of learning ability.

Studies in which overtraining facilitated shift learning under some conditions only.

Five studies using children have found facilitation after overtraining under specific conditions only. Gollin (1964) trained two age groups of children, $3\frac{1}{2}$-4 and $4\frac{1}{2}$-5 year olds on a simultaneous shape discrimination to a criterion of 10 successive correct responses or alternatively, an additional 10 or 20 overtraining trials, before reversal. The initial task proved exceedingly easy, with the group means ranging from .83 to 2.01 trials to criterion. For the younger children a reverse ORE was obtained. This result parallels that sometimes obtained when rats are given an easy task such as position. (See Chapter 1.). The older children learned the reversal so rapidly that a trials to criterion analysis was precluded. (2/3 of the subjects exhibited 1 trial reversal). There was nevertheless, a significant increase in 1 trial reversal with overtraining.

Cross & Tyer (1966) did an experiment superficially similar to that of Gollin (1964). Two age groups of children (with means of 46 and 67 months) were trained on a simultaneous discrimination using multidimensional or "junk" objects. Half of the subjects were trained to a criterion of 17/20 correct responses plus 6 overlearning trials, while the other half were given 86 overtraining trials, before reversal. The ORE was obtained for the younger but not the older children. The authors concluded that ontogenetic level is important in predicting the ORE. A more probable explanation is that younger subjects found the task more difficult than the older subjects. On the initial task, younger subjects made an average of 44 errors to criterion while older subjects made an average of 24. (Trials to criterion were not reported). This difference was significant. It is hence possible that all older subjects were overtrained, even those nominally only trained to criterion, resulting in no difference between groups. Younger subjects, finding the task more difficult, may not have been overtrained at criterion.

The different pattern of results found by Gollin (1964) was probably due to the very easy task used. This task did not differentiate between age groups on the initial discrimination, so that any relationship between task difficulty and criterion level would have been obscured.

Eimas (1966b) trained 86-110 month old children on a spatial or nonspatial simultaneous discrimination with one or two irrelevant dimensions. The criterion of learning was 20/25 correct responses. Trials to criterion on the initial task were not reported, but errors to criterion indicated that spatial tasks were learned more rapidly than nonspatial tasks, and in the case of non-spatial tasks only, two irrelevant dimensions retarded learning when compared to one irrelevant dimension. The ORE was not obtained for spatial tasks, but was obtained for nonspatial tasks, with the effect being stronger (although nonsignificantly) in the case of the more difficult two irrelevant dimension task. Eimas repeated the above spatial experiment using 58-80 month old children. A reverse ORE was obtained.

Tempone, Capehart, Atwood & Golding (1966) tested for the effect of task difficulty on the ORE by comparing simultaneous and successive discriminations. More rapid learning is normally found using simultaneous rather than successive tasks. Six to seven year old children were given a size discrimination to a criterion of 9/10 correct responses, or in the case of overtraining, 18/20 correct responses. The ORE was obtained for the successive but not the simultaneous task.

Studies which failed to obtain shift facilitation due to overtraining.

Only two studies using children have failed to find any shift facilitatory effect due to increases in the number of acquisition trials. Vaughter & Cross (1965) trained 4-6 year old children on a simultaneous multidimensional discrimination for 6 or 18 trials. Overtraining retarded reversal learning. Subjects given 6 trials on the initial task averaged 81% correct responses on trials 2-6, indicating a very easy task.

Hochman (1966) used 12-13 year old children. This is a rarely used age group, far older than that commonly employed. A simultaneous colour discrimination was given to a criterion of 5 consecutive correct responses, or to the same criterion plus 10 or 20 overtraining trials. Subjects took an average of less than 4 trials to reach criterion. There was no difference between groups on reversal.

Overall, the results of two-choice experiments using children are quite unambiguous. Overtraining facilitated intradimensional shift learning in the majority of cases. Those experiments that obtained this effect under some conditions only, uniformly found that tasks that were solved more rapidly tended not to indicate a facilitatory effect due to overtraining, this result only being obtained for more difficult tasks (including identical tasks that became more difficult as a consequence of using younger subjects). The two experiments that totally failed to obtain any facilitatory effect due to overtraining, probably involved very easy tasks. (It is quite impossible to rank all experiments in terms of task difficulty, due to either variations in the method used to report subjects' level of performance on the initial task, or in many cases, failure to report this variable at all). The few experiments that found retardation due to overtraining, also appear to have involved very easy tasks. From these results it is hence plausible to hypothesise that a relationship between task difficulty and criteria of learning prevented facilitation due to overtraining in the case of easy discriminations.

(c) Retardates.

Only a few studies have been done using retardates, but the results are more difficult to summarise than those using normals. Stevenson & Zigler (1957) gave feeble-minded children and adults a three-choice discrimination shift task identical in all respects to that given 4-5 year old children, described previously (see p.135). All categories of subjects were matched on initial discrimination performance. The results again indicated no effect due to overtraining. Furthermore, there was not even a suggestion of an effect (see p.136) unlike the case of normal children.

Bensberg (1958) trained 15-29 year old retardates on a three-choice successive form discrimination to a criterion of 9 successive correct responses or to the same criterion plus 27 additional responses. The task was learned in approximately 93 trials. There was no difference between the two groups on the subsequent intradimensional shift involving new stimuli.

Heal (1966) gave 16-28 year old retardates identical treatment to that given normal children. (Described previously - see p.139). Both categories of subjects were matched on initial discrimination performance. Unlike normal children, the retardates showed no effect due to overtraining. The criterion was again 6 consecutive correct responses and number of trials to this criterion were not reported.

Ohlrich & Ross (1966) trained retarded children on a simultaneous colour or form discrimination to a criterion of 10 consecutive correct responses or to the same criterion plus 125 overtraining trials. Errors to criterion on the initial task indicated that the colour discrimination was more difficult than the form discrimination. While the reversal results were not analysed in terms of the effect of overtraining, the mean errors during reversal indicated that the ORE was not obtained with form relevant - the slight difference between groups was in the wrong direction,- but probably was obtained when the more difficult colour-relevant task was used. A very large difference between groups was obtained in the latter case.

Shepp & Turrisi (1969a) gave retarded children a simultaneous colour or form discrimination to a criterion of 9/10 correct responses. Overtrained groups were given either two or three times the number of trials required to reach the above criterion. The number of trials to criterion on the initial discrimination was not reported. The nonreversal intradimensional shift results indicated that the group given the maximum overtraining learned more rapidly than the other two groups which did not differ. Shepp & Turrisi (1969b) used a virtually identical procedure to test for the effect of overtraining on a series of successive reversals. The initial discrimination and the first reversal constitute the conventional ORE paradigm. The results of this first reversal indicated increased perseveration followed by fewer trials to criterion for the overtrained group. Subjects took a mean of 35 errors to criterion on the initial task.

These results cannot be readily summarised at present, probably due to an insufficient number of studies having been carried out. There is no evidence that overtraining facilitates retardate 3-choice intradimensional learning. The conditions under which it facilitates 2-choice learning are not clear. The Ohlrich & Ross (1966) results provide some evidence that the ORE is less likely to be obtained using an easy task with the same criterion levels as a difficult task.

2. Extradimensional shifts.

(a) Normal adult subjects.

Most experimenters have used normal adult subjects and most of these have found facilitation due to overtraining under some conditions at least.

Studies in which overtraining facilitated shift learning under all conditions.

Stevenson & Moushegian (1956) gave subjects a 3-choice simultaneous size discrimination followed by a position discrimination. The stimulus set was identical for the 2 tasks (Paradigm I - see p.125). Training on the initial discrimination continued to criteria of 4, 16, or 40 consecutive correct responses. It took approximately 10 trials to learn this task and the two groups given more training learned the shift more rapidly.

Uhl (1966) used a form to colour shift with half the subjects being given the same forms on the shift task as on the original discrimination (Paradigm I) and the other half experiencing new forms on the shift task (Paradigm II). The general procedure was described previously (p.129). From the mean trials to criterion additional training facilitated both shifts. (Only an overall analysis of variance, including intradimensional shifts, was done).

Grant & Berg (1948) used 6 consecutive 4-choice tasks employing criteria of 3, 4, 5, 6, 7, 8 and 10 consecutive correct responses on each task for different groups. Subjects were required to match response cards with one of 4 permanently present stimulus cards. For the 6 tasks the matching was to be done on the basis of the dimensions of colour, number, form, number, colour, and form respectively. The stimulus set did not change in any way from shift to shift (Paradigm I). Approximately 2.7 errors were made on the first task. There was no effect due to criterion level except on Tasks 5 and 6. A combination of the groups given the 4 highest criteria learned these tasks more rapidly than a combination of the groups given the 3 lowest criteria.

Grant & Cost (1954) extended the results of Grant & Berg (1948) by using criteria of 5, 10, 20 and 40 consecutive correct responses with a similar experimental paradigm. Higher criteria appear to have facilitated shift learning at all stages but the effect was stronger for stages 4-6 than 1-3. Tests on the combined total errors for stages 1-3 indicated that only the "extreme differences" (presumably between Criteria 5 and 40) were significant. For stages 4-5, the group given Criterion 5 made significantly more errors than all of the other groups.

<u>Studies in which overtraining facilitated shift learning under some conditions only.</u>

Sugimura (1960) used a 3 x 4 design with 3 different shift tasks and 4 criterion levels. Simultaneous discriminations with a size to colour dimension shift were used in all three shifts. Under Condition I the previously irrelevant dimension (colour) became relevant with new cues while there was no change on the size dimension (Paradigm III). Under Condition II the previously relevant size dimension became constant while colour became relevant using the same cues (Paradigm II). Condition III was identical to Condition II except that new colour cues were used on the shift task (Paradigm IV). In addition, for Conditions II and III an irrelevant shape dimension was introduced for the shift. The four criteria were 3, 5, 10 and 10 + 20 consecutive correct responses and it took subjects approximately 6 trials to reach Criterion 10. For Condition I, Group 5 learned the shift task more rapidly than Group 10 + 20. The experiment yielded no other significant effects due to initial criterion level.

Iwahara & Sugimura (1962) gave both a low I.Q. and a high I.Q. group of subjects a simultaneous size followed by a colour discrimination with no change in stimuli between shifts (Paradigm I). The initial criteria of learning were 3, 7 and 10+20 consecutive correct trials. Both I.Q. groups attained the latter criterion in approximately 6 trials. Additional training facilitated shift learning in the case of high I.Q. subjects but had no effect on lower I.Q. subjects.

Ludvigson & Caul (1964) gave subjects either a 2 or a 4 category conceptual sorting task with the original and shift tasks being either radii-position or line-angularity concepts, or vice-versa. (General experimental details are given on p.127). There was no change in the stimuli between shifts (Paradigm I). While overtraining facilitated shift learning for both the 2 and 4 category sorting tasks, the effect was only significant in the latter case. Caul & Ludvigson (1964) replicated the 2 category paradigm and in this case found facilitation due to overtraining.

Guy, Van Fleet & Bourne (1966) gave subjects a successive form or size problem to criteria of 10, 10 + 20, or 10 + 20 consecutive correct trials and introduced a previously constant dimension - background (stippled cross hatched) as the relevant shift dimension (Paradigm III). The number of trials to criterion on the initial task was not reported. Overtraining possibly facilitated shift learning but the effect was not tested statistically. Two other paradigms were used in addition to the above. In the first, background was introduced as an irrelevant dimension during the overtraining trials. In this case overtraining possibly retarded shift learning (not tested statistically). In the second, background was introduced as a redundant dimension during overtraining almost certainly giving no effect due to number of initial trials on the shift task.

Studies in which overtraining did not facilitate shift learning under any conditions.

Only 2 studies failed to find any effect due to overtraining. Lowenkron (1969) used a shape to number' dimension (or vice-versa) shift with no change in stimulus values between shifts (Paradigm I). (See p.131 for the experimental details). LeBow (1971) gave subjects a simultaneous form discrimination followed by a colour relevant task. For half of the subjects the stimuli did not change between shifts (Paradigm I), while for the other half, new forms were used during the shift task (Paradigm II). Criteria of 5, 10, and 10 + 40 consecutive correct responses were used on the first task. Number of trials to criterion was not reported. There was no effect due to overtraining on the shift task.

It cannot be concluded from these experiments using normal adult subjects that a relation between task difficulty and criterion of learning influences non-reversal shift learning speed. This may of course be due to insufficient evidence having as yet accumulated. Slight evidence for a possible relationship comes from a statement by LeBow (1971) to the effect that his task was solved very rapidly. Since the task was also given to

5-6 year old children (see below) it clearly would have been solved rapidly by adults.

(b) Normal child subjects.[1]

In contrast to the adult studies, the majority of child studies have failed to obtain a shift effect due to overtraining. Only 2 studies have obtained an effect. Eimas (1966a, p. 139) gave his kindergarten or second grade subjects a colour or form discrimination, switching to the alternative dimension for the shift task. The values of the cues on both dimensions changed for the shift (Paradigm IV). Overtraining facilitated shift learning for both age-groups. LeBow (1971, p.153) gave 5-6 and 7-8 year old children identical treatment to that given adults. For subjects given Paradigm II, overtraining had no effect on the shift task. For younger children given Paradigm I, overtraining retarded shift learning, while for older children it facilitated second task learning.

[1]All of the experiments reviewed in this and the subsequent section also included either reversal shifts or used normal adult subjects. For this reason, general experimental procedures will not be given, having been described previously. Page numbers after dates of publication refer to the pages on which this description occurs.

The remaining studies failed to find an effect due to overtraining. Marsh (1964, p.138) used a size to brightness or vice-versa (size← →brightness) shift, with changes in the cue values of both dimensions (Paradigm IV). Furth & Youniss (1964, p.137) gave subjects a colour← →form shift, with no stimuli changes (Paradigm I) except that those stimuli combinations that would have contributed to partial reinforcement of the initial discrimination were eliminated, resulting in a decrease in the stimulus universe used. Youniss & Furth (1965, p.138) again used colour and form with the cues of the previously relevant dimension being replaced by new ones for the shift (Paradigm II) in order to eliminate partial reinforcement. (Statistical analyses of the effects of overtraining were not given in the last two experiments but inspection of the means strongly suggest that no effects would have been obtained). Tighe & Tighe (1965, p.139) used a size← → brightness discrimination with the originally relevant dimension becoming constant within trials but remaining variable between trials (Paradigm II). Hochman (1966, p.145) shifted subjects from the number to the colour dimension with new values on the number dimension for the shift task (Paradigm II). Heal (1966, p.139) used a colour← →form shift. For the shift task, the positive or negative cue from the initial task was replaced by a new cue from the same dimension (a combination of Paradigms I and II). As stated above, none of these studies found any effect due to overtraining.

Since neither of the two experimenters who found facilitation due to overtraining reported the number of trials to criterion on the initial task, it is impossible to know whether a relation between task difficulty and criteria affected these studies.

(c) Retardates.

The results of this particular class of studies are largely at variance to those obtained under previous classifications. Not only did no study obtain shift facilitation due to overtraining, all except one study obtained the opposite result - shift retardation due to overtraining. Bensberg (1958, p.146) used a colour to form shift with new cues on both dimensions (Paradigm III): Iwahara & Sugimura (1962, p.151) used a size to colour shift (Paradigm I): Heal (1966, p.139) gave adult retardates identical treatment to that given normal children (p.155): Shepp & Turrisi (1969a, p.148) gave subjects a form← →colour shift with new stimuli on both dimensions for the shift task (Paradigm IV). All of these studies obtained shift retardation due to overtraining.

The only experiment not to demonstrate this effect was that of Ohlrich & Ross (1966, p.147) who used a colour← → form shift with changes in the cue values of the previously relevant dimension (Paradigm II).

3. Studies using nondimensional (unrelated) stimuli.

All of the experiments discussed previously used related stimuli. This meant that each stimulus had a cue value on one or more dimensions, giving the relationship between them. Recently, several experiments have been done using unrelated stimuli.

(1) Successive discriminations.

Bogartz (1965) required subjects to learn to make one of two responses to 8 CVC stimuli presented successively. The criterion consisted of correct responses to a block of the 8 CVCs. Reversal involved switching to the alternate response for each stimulus. For nonreversal, responses were switched for only half of the stimuli. This is also a characteristic of Paradigm I nonreversals using dimensional stimuli. Bogartz found reversal facilitation due to overtraining, but no difference between nonreversal groups. Danks & Glucksberg (1968) and Richman & Trinder (1968) obtained similar results. Kendler, Kendler & Sanders (1967) found no effect due to overtraining for either reversals or nonreversals, although in their second experiment there were fairly substantial decreases in the number of trials to shift criterion with increases in the amount of overtraining on the initial task.

The above four studies used adults as subjects and either CVCs, CCCs or nonsense figures as stimuli. Schaeffer & Ellis (1970) used 8½ year old children as subjects and pictures of familiar but unrelated objects as stimuli. While the effect of overtraining was not directly tested, it probably facilitated reversal shifts and retarded nonreversal shifts.

(2) Simultaneous discriminations

Using this design, subjects must choose one of two unrelated stimuli rather than one of two responses. All experimenters have used normal adult subjects. While Paul and his associates have done considerable work recently using non-dimensional verbal stimuli, McClelland (1943) appears to have been the first to use this particular design, and indeed, the first to obtain the ORE using any design. The only major difference between McClelland's study and those done subsequently was that after the completion of initial training, subjects were instructed to reverse their responses on the next trial. Subjects trained to a criterion of 11/15 learned the reversal more slowly than those trained to a criterion of 15/15, the stimuli being unrelated two syllable adjectives.

Paul (1966b) required subjects to learn to respond to one of a simultaneously presented pair of antonyms. There was no relationship between the various pairs used. After 0 or 50% overtraining, reversed reinforcement contingencies were introduced for 25, 50, 75, or 100% of the stimulus pair items. (The 50 and 100% reversal are equivalent to the previously discussed nonreversal and reversal conditions respectively). An overall statistical analysis indicated facilitation due to overtraining. An identical result was obtained by Paul (1968) using completely unrelated stimuli rather than antonyms.

Paul, Callahan, Mereness & Wilhelm (1968) gave subjects a 3-choice rather than a 2-choice verbal discrimination shift using CVC words. For the reversal shift they had to learn to respond to one of the previously non-reinforced stimuli. In all other respects the design was identical to Paul (1966b, 1968). The results again indicated facilitation due to overtraining. Paul, Hoffman & Dick (1970) on the other hand, found no effect due to overtraining using 50% reversal shifts only.

Paul & Callahan (1972) did four verbal discrimination shift experiments in which the effect of overtraining was studied. Experiment I studied the effect of adding an exteroceptive discriminative cue to the shift task. This took the form of underlining the previously correct adjective of the 3-choice shift task. Overtraining had no effect due to the criterion group learning the shift more rapidly than usual. In the no-cue condition, slow learning by the criterion group resulted in the usual relative shift facilitation due to overtraining. A control group given a new list of adjectives for the shift task showed no effect due to either overtraining or the presence or absence of exteroceptive cues. Experiment II used a 5-choice task and found no effect due to overtraining. Experiment III involved a shift from a 3-choice to a 2-choice task. To accomplish this, either the originally positive stimuli, or alternatively, one of the two negative stimuli were eliminated from the lists. Overtraining had no effect on groups for which the initially positive stimuli were removed but facilitated shift learning when this stimulus remained. Experiment IV tested for the effect of overtraining using a "within-group" design rather than the conventional "between-subjects" design. Subjects were given a 3-choice task in which the responses to half of the triads were not reinforced in any way. Once criterion had been attained for the reinforced triads, all triads were reinforced in the normal manner until criterion was attained again. A normal shift task then followed. The subjects learned the correct shift response more rapidly for the triads reinforced from the beginning of the initial discrimination (over-trained) than for triads reinforced during the latter part of this task only (criterion trained).

4. <u>Conclusions</u>.

In summary, the following conclusions may be arrived at on the basis of this empirical review. For normal adults and children, intradimensional shift learning is normally facilitated by overtraining with the use of a 2-choice (either stimuli or responses) paradigm. Failures to obtain this effect uniformly occurred on the more rapidly learned tasks in those experiments which obtained mixed results under various conditions. This can be taken as evidence for the hypothesis that task difficulty and criteria of learning both contribute to shift learning results. Evidence for this hypothesis is almost impossible to obtain by comparing the results of experiments employing difficult or easy tasks under different conditions i.e. "between experiments/experimenters" rather than "within experiments/experimenters" comparisons. There are two basic reasons for this. Firstly, a large number of experimenters do not indicate the number of trials to criterion on the initial task, making it impossible to gauge its difficulty. (This problem did not arise for animal learning since it is known that there is very little overlap in trials to criterion between spatial and visual tasks. A similar division cannot be readily found for the human studies). Secondly, and more importantly, a variety of criteria of learning were employed. At present, it is impossible to simultaneously rank experiments according to both task difficulty and criteria of learning since the relative effects of both on shift learning are not known. This problem is eliminated by using the results of studies including both difficult and easy tasks, since in these cases the experimenters tend to use identical criteria of learning. Unfortunately, this in turn means no information is obtained concerning the effect of criteria of learning. Descriptions of the manipulation of this variable are given in subsequent chapters.

Overtraining also has fairly frequently facilitated 3-choice intradimensional learning in normal children and 2-choice learning in retardates although the conditions under which it is most likely to do so are not clear. There is no evidence at present that overtraining has any effect on 3-choice retardate learning.

For extradimensional shifts; (a) most studies using normal adults obtained shift facilitation due to overtraining; (b) most studies using normal children obtained no effect due to overtraining; (c) most studies using retardates obtained shift retardation following overtraining.

(This conclusion was also arrived at by Wolff, 1967).

For nondimensional successive discrimination shift paradigms, overtraining facilitated reversal learning in all but one case but had no effect on nonreversals except in one experiment using children, in which retardation due to overtraining was obtained. Paul's experimental results using simultaneous discriminations are difficult to summarise outside his theoretical context, although it is clear that overtraining of a 2-choice task will facilitate reversal learning. The results of Paul's other paradigms will be discussed in the theoretical section below.

II. Theoretical explanations of the effect of overtraining on shift learning.

Two of the theories used to explain the effects of overtraining on animals have also been used to explain similar effects on humans. These are the discriminable change hypothesis and the attention theory.

(1) The discriminable change hypothesis.

This hypothesis, applied by Capaldi & Stevenson (1957) to rat reversal learning, was initially suggested by Stevenson & Moushegian (1956) as an explanation of the effect of overtraining on nonreversal human shift learning. It assumes that overtraining facilitates shift learning by increasing the discriminability of the change in reinforcement. This hypothesis correctly predicts a sufficient number of the general empirical findings reviewed above to allow us to assume that variations in the discriminability of the shift ~~has~~ have some influence on experimental results. Some of its probable predictions (they were not specifically stated by its originators) are: (1) Overtraining should facilitate both reversals and nonreversals involving no change in stimulus values (Paradigm 1). This should apply irrespective of whether dimensional or nondimensional paradigms are employed. It could possibly be argued that it should have a greater effect on nonreversals since shift detection may be more difficult due to 50% reinforcement being obtained during perseveration. (2) Overtraining should either not facilitate, or have a lesser facilitatory effect with the use of paradigms involving a change in stimuli for the shift task. A change in stimuli should make it clearer to subjects that a shift of some sort has occurred irrespective of whether or not overtraining was given. (3) The effect of overtraining should be most apparent in the case of a difficult discrimination and a low initial task criterion and least apparent when an easy task and a high criterion are used. For nonovertrained groups, the change in reinforcement contingencies may be more discriminable if the string of criterion responses is relatively long in comparison to the overall number of responses. This will increasingly occur as the task used becomes easier and/or the criterion becomes higher resulting in a lesser effect due to overtraining. The other end of the continuum - a relatively short string of criterion responses in comparison to the overall length of the task - will occur with a more difficult task and/or lower criterion. The shift in this case should be less discriminable for nonovertrained groups resulting in greater shift facilitation due to overtraining.

Support for the first prediction comes from the fact that overtraining normally facilitated dimensional non-reversal shifts using normal adults, as well as reversal shifts using normal children and adults. The fact that overtraining generally had no effect on extradimensional shifts using normal child subjects may be explained using the second prediction. While most of the adult studies used Paradigm I, most of the child studies used one of the alternative paradigms. The third prediction would explain the suggested relation between task difficulty and criteria of learning for 2-choice intradimensional shift learning using normal adults and children as subjects.

There are also several respects in which the predictions are clearly not fulfilled. (1) There is no evidence that overtraining facilitates retardate extradimensional shift learning and one might guess that retardates would have greater difficulty in discriminating the change in reinforcement contingencies without the help of overtraining, than normal subjects. (2) In contradiction to the second prediction that overtraining will have a lesser facilitatory effect on extradimensional shifts involving a change in stimuli, the two experiments that totally failed to find an effect using normal adult subjects both used Paradigm 1. Similarly, one of the two extradimensional studies using normal children that _did_ find facilitation due to overtraining, used Paradigm IV (Eimas, 1966a). Facilitation should not have been obtained using this paradigm. (3) From the third prediction, the relationship between task difficulty and criteria of learning should occur using all experimental designs and all subject categories, not just intradimensional shifts using normal adults or children. (4) Overtraining clearly did not facilitate nonreversal successive discrimination learning using nondimensional stimuli. Since nonreversals in this case involve the reversal of only half of the stimuli, the shift should be more difficult to detect without the aid of overtraining than a complete reversal. One would hence expect overtraining to be particularly beneficial in this case.

It may be concluded that while the discriminable change hypothesis may be partially correct, on its own it can by no means explain all of the findings of the literature.

(2) The attention theory.

The attention theory has also been discussed previously with respect to animals. It is a mediational theory in that it postulates a specific mediating mechanism between the stimulus and the response, a feature which it shares with all of the theories to be discussed subsequently. The discriminable change hypothesis is the only clearly nonmediational hypothesis discussed in this section.

The attention theory of Zeaman & House (1963) has been applied to human subjects. In essentials, it is similar to the theories of Lovejoy (1966), Mackintosh (1965) and Sutherland (1959) which were primarily designed to explain animal behaviour. From the perspective of overtraining, it follows from the theory that additional training beyond criterion strengthens attention to the relevant dimension more than it strengthens the choice response. This should result in overtraining facilitating intradimensional learning and retarding extradimensional learning. (No distinction between extradimensional shift paradigms involving a change in stimulus values for the shift or alternatively no change, of the sort suggested by Sutherland & Mackintosh, 1971, has been proposed for human subjects).

The theory predicts the facilitatory effect of overtraining on intradimensional shifts found for normal adults and children by a mechanism identical to that used to explain the ORE using rats. In addition, if one assumes that the effects of overtraining occur more rapidly in the case of an easy discrimination, i.e. that the attending response is strengthened more rapidly than in the case of a difficult discrimination, this would explain the absence of a facilitatory effect using easy tasks.

The retardation of extradimensional shift learning following overtraining found for retardates, is clearly in accordance with the attention theory. The lack of any reliable effect on extradimensional shifts using normal children and facilitation after overtraining using normal adults, cannot on the other hand be readily explained. One must hence appeal to other theories to explain these results. Similarly, since the attention theory was specifically designed to explain the results of experiments using dimensional stimuli, it is not able (nor presumably intended) to explain the results of experiments employing nondimensional stimuli.

(3) The S-R mediational theory of the Kendlers.

The second mediational theory to be discussed is that of Kendler & Kendler (1962, 1968, 1970). The mediators in this case are assumed to be implicit responses which obey the same laws as overt responses. In the common experimental situation involving dimensional stimuli, the implicit responses are assumed to normally take the form of verbal labels applied to stimulus dimensions. While the emphasis is on verbal responses, these do not necessarily have to consist of labels to specific dimensions. The theory is intended to be highly general. Kendler & Kendler (1968, p.206), when discussing their 1962 paper state "... the exact nature of the (mediational) response, whether it was a verbal response naming a dimension (e.g. brightness), or a specific verbal label (e.g. black or white), or a perceptual attending response, or something else, was left unspecified." Despite this statement, the Kendlers do distinguish between their own theory and that of Zeaman and House (1963). Referring to the two theories, they state (Kendler & Kendler, 1970), "Both posit selective mediational mechanisms but assign different conceptual properties to them." For present purposes, it will be assumed that the Kendlers' primary emphasis is on the use of verbal processes as mediating mechanisms.

The emphasis on verbal processes results in the theory having comparative and developmental implications. Since animals and very young children cannot speak, it can be assumed that their learning processes do not involve mediation and hence are to be explained in the simple S-R terms of Hull and Spence.

The primary experimental technique used to test for the effects of mediation has been the reversal-nonreversal shift comparison. Since reversals involve the same verbal mediators, they should be learned more rapidly than non-reversals in the case of subjects capable of mediating. In the case of subjects who do not use mediators, non-reversals should be learned more rapidly than reversals because in the latter case, all of the previous connections need to be extinguished and relearned, while in the former case, this applies to only half of the connections. It follows, that animals and nonverbal young children should learn nonreversals more rapidly, while older children and adults should learn reversals more rapidly.

Evidence that adults learn reversal shifts more rapidly than nonreversal shifts has been obtained on many occasions (e.g. Buss, 1953, 1956; Harrow & Friedman, 1958; Kendler & D'Amato, 1955). There is also some evidence that animals execute extradimensional shifts more rapidly than reversal shifts, although this evidence ~~tends to~~ mostly occurs in situations involving no overtraining (e.g.

Brookshire, Warren & Ball, 1961; Kelleher, 1956; Mackintosh, 1962; Schade & Bitterman, 1966; Tighe, 1964). Evidence for a developmental trend comes from optional shift studies in which subjects, after the initial discrimination, are given a shift task which can be solved either as an extradimensional shift or as a reversal. Test trials indicate which method the subject has used. Experimental evidence has indicated that the proportion of optional reversers increases with age (Kendler, Kendler & Learnard, 1962; Kendler & Kendler, 1970).

Of more immediate interest are the predictions concerning overtraining. Unfortunately, the Kendlers have placed considerably less emphasis on the role of overtraining on shift learning. Kendler, Kendler & Sanders (1967) stated that overtraining should strengthen mediating responses (a prediction shared by the attention theorists) and that this in turn should facilitate reversal learning and retard nonreversal learning. Assuming that this is so, their theory would make identical predictions concerning the effect of overtraining using dimensional stimuli as the attention theory. In its general form, the theory can also be applied to experiments involving nondimensional stimuli. While it is able to successfully predict the reversal results of this class of experiments, the only evidence that overtraining retards nonreversal learning, comes from the experiment of Schaeffer & Ellis (1970).

(4) The discrimination set theory.

English statements of this theory may be found in Iwahara & Sugimura (1960); Iwahara & Sugimura (1962); Sugimura (1960) and Sugimura (1970). Like the two previous theories, it is a two factor mediational theory of discrimination learning. It assumes, as does the attention theory, that early stages of discrimination learning primarily consist of the strengthening of simple S-R connections. During later, overtraining stages, "discrimination sets" are built up but these differ from the previously discussed mediators in that they are completely general and nonspecific in nature. This means that they do not refer to specific dimensions. They have been compared (Sugimura, 1970) to Harlow's learning sets.

Discrimination sets, being nonspecific in nature, should facilitate all subsequent shift learning, irrespective of the relation between the relevant dimensions of the initial and shift tasks. The theory hence predicts that overtraining will facilitate shift learning whether intradimensional or extradimensional shifts are employed. From the perspective of experimental prediction, this is the primary difference between the discrimination set theory and the two previously discussed mediational theories.

It follows that this theory is equally able to explain the results of intradimensional studies as the attention theory and the S-R mediational theory. In addition, it can readily handle the results of extra-dimensional studies. The facilitation of extradimensional shift learning after overtraining, found for adult subjects, is clearly predicted. In addition, Iwahara & Sugimura (1962) suggested that as subjects' level of intelligence fell, so did their ability to form discrimination sets. For subjects who do not mediate (e.g. retardates), over-training should result in retardation of shift learning due to the strengthening of S-R bonds, at least some of which must be extinguished before the shift task can be learned. Iwahara & Sugimura (1962) confirmed that as I.Q. level fell, facilitation due to overtraining changed to retardation. This result may well mirror the overall results which indicated that while overtraining facilitated normal adult extradimensional learning, it had no effect on normal children and retarded shift learning of feebleminded subjects.

Discrimination set theory should presumably be just as applicable in situations involving nondimensional stimuli as related stimuli. It must hence predict that overtraining will have an identical (and generally facilitatory) effect on both reversals and part-reversals.

The clearest evidence that this is not the case, comes from the successive discrimination studies using normal adults. These normally indicated reversal facilitation due to overtraining, but no effect on half-reversals. It is at present not clear why general discrimination sets should have an effect on related stimuli but no effect on unrelated stimuli. One might guess that while they could have an effect on most discrimination shift experiments, they cannot be considered as a complete substitute for the specific mediators discussed previously.

(5) Mediational explanations of nondimensional shift results.

(1) Bogartz (1965) provided two possible explanations for his finding that overtraining facilitated reversal learning but had no effect on nonreversal learning. His explanations were in fact primarily intended to account for reversal facilitation when compared to nonreversal learning. They can nevertheless, also be used to explain the effect of overtraining.

He entitled his first explanation "Mediated Association". This assumes that stimuli which are associated with a common response become associated with each other. During reversal, once the response to one of the stimuli is learned, it should generalise to the other associated stimuli and so facilitate learning. Overtraining according to this hypothesis, facilitates reversal learning by strengthening associations between stimuli which have a common response. Since associations between stimuli with a common response will be of no benefit in shift tasks where a new combination of stimuli have a common response, overtraining should not facilitate half-reversals.

The second possible explanation suggested by Bogartz (1965) was called "Extraexperimental Transfer". This simply assumes that a reversal or "doing the opposite" rule is a preesperimentally acquired habit which is quite familiar to the subject and hence facilitates reversal learning. Clearly, the better the first task is learned, the more efficient will be the operation of this rule, resulting in reversal facilitation due to overtraining. Half-reversals on the other hand, should not be facilitated in this manner.

(2) Paul and his co-workers have provided the most extensive mediational theory to specifically explain the effect of overtraining on shift learning in humans. They introduced the concept of Transfer-Activated Response Sets or TARS (Paul & Paul, 1968). While the theory is intended to apply to verbal rote-learning tasks in general, only its implications for reversal and part-reversal shifts will be discussed.

The theory assumes that unrelated items can become associated during Task 1 learning. In the simultaneous discrimination situation used by Paul and his associates where the subject responds by articulating one of the stimulus words, this association is considered to be between "correct Task 1 responses" (Paul, 1970). These responses become instances of a functional concept. While the attaining of this concept by the subjects is incidental to first task learning, it is assumed to be activated during the second task. When this task is instituted, if an old response is no longer reinforced (e.g. a reversal), the subject activates an implicit self instruction to suppress this response. If several more initial discrimination responses are nonreinforced, this "suppression generalises ...to all instances of the functional concept" (Paul & Callahan, 1972).

The greater the discrimination of correct initial task responses, the more effective can be the subsequent suppression of these responses during the shift task. It follows, that if overtraining enhances this discrimination, reversal learning in particular will be facilitated, as will any shift task in which all or most of the previously rewarded responses are no longer reinforced.

This theory has been applied to the several varieties of simultaneous discrimination shifts carried out by Paul and his co-workers (see p.159). In a 2-choice situation (Paul, 1966b, 1968), overtraining should have its major effect on the 75% and 100% reversal groups. Greater differentiation between correct and incorrect responses should allow more effective operation of the suppression response set which would be more beneficial as the percentage of reversed items increased. A transfer-activated response set should not occur in a situation where only 25% or 50% of the items are reversed. The results of Paul (1968) support these predictions as do those of Paul, Hoffman & Dick (1970) who found no effect due to overtraining on a 50% reversal shift. The results of Paul (1966b) on the other hand are not as clear-cut since the greatest difference between the control and overlearning groups appears to occur at the 50% reversal level. (Tests between individual groups were not reported). Presumably other factors contribute to this result.

Strong evidence for a transfer-activated response set comes from the 75% reversal groups of Paul (1966b, 1968). Separate analyses of reversed and nonreversed items indicated that these groups responded as though a 100% reversal shift had been instituted since more errors were made on non-reversed rather than on reversed items. Hence one has the paradoxical finding that items for which the response was not changed caused greater difficulty than those for which it was changed. Paul, Callahan, Mereness & Wilhelm (1968) used a 3-choice rather than a 2-choice design and obtained similar results (see p.159). Again, substantial facilitation appears to have occurred due to overtraining for the 50% shift. An important additional finding from the point of view of the theory, is concerned with the class of errors made during shift learning. In a multi-choice rather than a 2-choice situation, errors may consist either of the initially correct responses, or alternatively, of responses not reinforced in either task. If overtraining increases the discriminability of previously correct responses and so allows more effective suppression of them during the shift, one would expect that overtrained subjects would make relatively fewer errors consisting of Task 1 correct responses than criterion trained subjects. The drop in the percentage of initially correct responses given by the subjects was in fact steeper after overtraining which confirms the theoretical prediction.

Paul & Callahan (1972) tested the differentiation-suppression hypothesis under a variety of conditions (see p.159). The first experiment tested the hypothesis that if the initially correct items are differentiated in the shift task by being associated with an exteroceptive discriminative cue, then further differentiation due to overtraining will not occur. This hypothesis was confirmed.

Groups shown the previously correct item underlined during the 3-choice shift task, learned the discrimination rapidly, irrespective of whether overtraining was used. The usual facilitation was found when underlining was not employed using two additional groups. Hence the no-cue, criterion group learned the shift more slowly than the other three groups which did not differ amongst themselves. Further support for the differentiation-suppression hypothesis comes from the fact that this group also elicited a higher percentage of correct first-task responses during the shift than the other three groups.

A 5-choice rather than a 3-choice task was used in the second experiment. The beneficial effect of suppressing previously correct responses should decrease as the number of choice alternatives increases. The results indicated that overtraining did not significantly affect Task 2 trials to criterion despite a decrease in the percentage of previously correct responses elicited (as in Experiment I).

It follows from the differentiation-suppression hypothesis that if the previously correct item in a 3-choice task is eliminated (making the shift a 2-choice task), overtraining should have no effect since the concept of variations in the degree of suppression of the previously correct alternative is inapplicable. Paul &

Callahan's third experiment confirmed this. Facilitation due to overtraining was obtained on the other hand when one of the previously negative items was eliminated for the shift task rather than the positive alternative.

The fourth experiment tested whether an effect due to overtraining could be obtained as a "within-group" effect by giving subjects different amounts of training on different items within the list (see p.160). This experiment was not performed in order to test the theory and need not be discussed further here other than to note that the pattern of results was identical with respect to the effect of overtraining to that obtained using the more conventional designs.

CHAPTER 6.

EXPERIMENT 4: A TEST OF THE HYPOTHESISED RELATION BETWEEN TASK DIFFICULTY AND CRITERIA OF LEARNING USING NONDIMENSIONAL STIMULI.

1. INTRODUCTION.

If lower criteria of learning on an easy task are equivalent to higher criteria on a more difficult task as was suggested on the basis of the animal experiments and the review of intradimensional shift learning experiments using humans, then this effect might well be obtainable using a nondimensional shift learning task using adult humans. There is little evidence concerning this in the literature, possibly due to an insufficient number of experiments using a nondimensional design having as yet been carried out. Hence the primary purpose of Experiment 4 was to test the hypothesised relation between task difficulty and criteria of learning using nondimensional stimuli.

There were two subsidiary aims of the experiment. Firstly, it was intended to indicate that there is probably a large variety of mediators available to normal adult subjects and that the mediator used is partly dependent on the subject and more importantly in the present context, dependent on the task. It was hoped to provide some evidence for this assertion by demonstrating that subjects had used a mediator other than those which were discussed in Chapter 5.

The second, subsidiary aim of the experiment was to introduce an experimental design which eliminates the five potential sources of bias which Slamecka (1968) suggested hinder the interpretation in mediational terms of experiments comparing reversal with nonreversal shifts. These are as follows:

(1) Differential presence of intermittent reinforcement.

In the common design involving no change in the stimulus set from the initial to the shift task, subjects who are reversed obtain no reinforcement for responding in the initially correct manner, while subjects who are given a nonreversal will obtain 50% reinforcement by continuing to respond as they had in Task 1. This may hinder nonreversal shift learning.

(2) Differential opportunity for detection of shifts.

It is normal in shift learning experiments not to inform the subjects when the shift is going to occur or even that a shift will be instituted. This may favour more rapid learning on the part of reversal subjects due to detection of the change in reinforcement contingencies being easier. Every response made on the basis of preshift habits is wrong for a reversal but only half of the responses are wrong for a nonreversal. It may hence take nonreversal subjects some time to realise that a shift has occurred. (This source of bias clearly stems from (1) above).

(3) Differential obviousness of postshift solutions.

In a 2-choice design, the perseverative responses made immediately after a reversal should tell the subject what the solution must be. The nonreversal tells subjects nothing concerning the correct solution during the period immediately following the shift. Hence this factor should benefit subjects given a reversal shift task. (This source of bias also clearly stems from (1) above).

(4) Differential consequences of partial stimulus novelty.

There is evidence that subjects are attracted by and are likely to attend to novel stimuli (Berlyne, 1960; House & Zeaman, 1962). This could clearly be a confounding variable in the case of experiments employing new stimulus values for the shift task. The direction of the effect would depend on the relation of the novel cues to reinforcement.

(5) Differential transfer of sorting responses.

This factor simply assumes that by their very nature, reversals involve negative-transfer situations, i.e. "the overt response reversal aspect of the reversal shift actually tends to inhibit postshift performance". Hence it should retard reversal learning in comparison to nonreversal learning.

In order to attain these aims (p. 181-182), a 4-stimulus 8 response spatial discrimination was employed rather than the conventional 2-response design. The advantages of this were: (1) task difficulty could be readily manipulated by making the spatial relationships between responses follow a pattern that could either be easily learned or learned with some difficulty; (2) the pattern of responses could possibly act as a mediator and hence facilitate shift learning if the shift involved a similar pattern; (3) the relatively large number of potential responses available, reduces to some extent the influence of chance factors in the attaining of low criteria of learning; (4) Slamecka's (1968) five potential sources of bias could be eliminated. By having a large number of potential responses available, it is possible to introduce many shift tasks with partial reinforcement eliminated in all cases and with no new stimuli needed to prevent partial reinforcement. This in turn means that in simple S-R terms, since all subjects are nonreinforced for all correct Task 1 responses on all trials after the shift, and reinforced for all correct Task 2 responses irrespective of the nature of the shift, differential transfer of responses should not occur irrespective of whether the shift has the properties of a reversal or not.

2. METHOD.

Subjects. The subjects were 160 students who were fulfilling an introductory psychology course requirement.

Stimulus materials and apparatus. The stimuli consisted of four CVCs (XOM, JIH, CEJ and QUC) from Noble's (1961) list ranging in m' from 0.99 to 1.02. They were presented to the subjects, one at a time, in a random order with two restrictions: (a) the four stimuli were presented in blocks of four with each appearing once only in each block; (b) no stimulus could follow itself.

A Kodak Carousel slide projector projected each item onto a screen 120 cm away giving a 20cm by 7cm image. The subject sat immediately to the right of the projector. A key-board in front of the subject contained a line of four normally vertical wire switches, each of which could be depressed backwards and forwards. Rubber bands ensured the return of each switch to its vertical position. A green and a red light hung immediately to the right of the screen with the red light 5 cm above the green. Each light could be switched on for 1 second by the experimenter.

Procedure. Subjects were instructed to respond to each word as it was screened by choosing a switch and choosing a direction in which to press it. A correct response was followed by the green light which in turn was followed by the next stimulus, giving an R-S interval of 1 sec. An incorrect response was followed by the red light indicating to subjects that another response was to be chosen. This procedure continued until a correct choice was made resulting in an equal amount of information being obtained on each trial irrespective of the number of incorrect responses. Subjects were allowed to respond at their own rate. After attaining a pre-assigned criterion, subjects without interruption, were shifted to a new task on which they continued until they obtained two consecutive blocks entirely correct. (Designated Criterion 2, in contrast to one block entirely correct - Criterion 1).

Experimental design. A 4 x 2 design with 4 levels of initial training and 2 shifts was used for both an easy (Groups E) and a difficult (Groups D) task. There were 10 subjects per group. The criteria of learning used for the 4 levels of initial training were 2/4 or more correct on any block (Criterion ½ - Groups ½), 1 block entirely correct (Criterion 1 - Groups 1), 2 consecutive blocks entirely correct (Criterion 2 - Groups 2), or 5 consecutive blocks entirely correct (Criterion 5 - Groups 5).

The responses to each stimulus for the easy tasks are given in Figure 6.1.

Each stimulus was assigned one switch with all switches to be pressed in the same direction for a correct response. A double position or pattern reversal (Groups R) was used which consisted of reversing the direction in

Figure 6.1.

Easy task response positions.

Reversal groups

Initial task

CEJ	JIH	QUC	XOM
-	-	-	-

Shift task

-	-	-	-
XOM	QUC	JIH	CEJ

Nonreversal groups

Initial task

QUC	CEJ	XOM	JIH
-	-	-	-

Shift task

-	-	-	-
XOM	QUC	JIH	CEJ

which a switch had to be pressed for each stimuli and reversing the spatial order of the responses to the stimuli along the key-board, i.e. subjects were required to press switches 1, 2, 3, and 4 (numbered from left to right) in response to stimuli CEJ, JIH, QUC, and XOM, respectively on the initial task, and were required to press 4, 3, 2, and 1 to the same stimuli on the reversal task. In addition the new switch now had to be pressed backwards instead of forwards or vice-versa.

The non-reversal (Groups NR) for the easy task consisted of reversing the direction in which the switches had to be pressed and changing the order of the stimuli along the key-board such that switches 2, 4, 1, and 3 had to be pressed in response to stimuli CEJ, JIH, QUC, and XOM, respectively on the initial task, and switches 4, 3, 2, and 1 on the shift. Reversing the direction of all the switches in the shift task rather than a different pattern was necessary in order to have original and shift tasks of equal difficulty. This also allowed all subjects to have an identical task during the shift. Whether the shift was a reversal or non-reversal varied according to the original task.

The responses to each stimulus for the difficult task are given in Figure 6.2.

Figure 6.2.

Difficult task response positions.

Reversal groups

Initial task

CEJ	-	-	XOM
-	JIH	QUC	-

Shift task

-	QUC	JIH	-
XOM	-	-	CEJ

Nonreversal groups

Initial task

-	CEJ	-	JIH
QUC	-	XOM	-

Shift task

-	QUC	JIH	-
XOM	-	-	CEJ

← Each stimulus was again assigned one switch but two of the switches were to be pressed in the opposite direction to the other two for a correct response. For the initial task for reversal groups, the two middle switches were to be pressed in the opposite direction to the two outer switches. As for the easy task, reversal involved both reversing the direction in which a switch had to be pressed and reversing the order of the stimuli along the key-board. Using this configuration, the four responses not used for any of the stimuli on the initial task, were used for the reversal, again mirroring the easy task.

For the difficult initial task for non-reversal groups, the direction in which the switches had to be pressed, alternated along the key-board. The shift involved a task identical to the second task of the reversal groups. Hence again, whether the shift was a reversal or non-reversal, varied according to the original task. Since a new response to each stimulus was required after both shifts, partial reinforcement was eliminated.

3. RESULTS.

All analyses for this experiment were done on square root transformed data.

Original task. Mean trials to criterion for both the easy and difficult tasks are given in Table 6.1. Trials to Criterion 1 for groups other than those shifted after attaining Criterion ½ (leaving 6 groups at each of the 2 levels of task difficulty), are included for comparative purposes. A 6 x 2 analysis of variance on this data, indicated a significant difference due to task difficulty, $F = 33.80$, d.f. = 1/108, $p < .005$, but neither a significant difference between groups within a given level of task difficulty, $F < 1$, nor an interaction effect, $F < 1$.

Easy task shift. Table 6.2 gives mean trials to Criterion 1, with mean trials to Criterion 2 in parentheses. Analysis of variance of trials to Criterion 1 yielded a significant shift effect, $F = 10.91$, d.f. = 1/72, $p < .005$, and a significant effect due to initial task criterion, $F = 9.08$, d.f. = 3/72, $p < .005$. For the interaction, $F = 2.36$, d.f. = 3/72, $.05 < p < .10$. The results of Duncan range tests are given in Table 6.4a. The means of any two groups not underlined by a common line are significantly different at the .05 level or beyond.

Analysis of variance of trials to Criterion 2, yielded the following results. Shift effect, $F = 3.30$, d.f. = 1/72, $.05 < p < .10$. Initial task criterion effect, $F = 5.84$, d.f. = 3/72, $p < .01$. Interaction effect, $F = 2.31$, d.f. = 3/72, $.05 < p < .10$. The results of Duncan range tests are given in Table 6.4b.

Difficult task shift. Table 6.3 gives mean trials to Criterion 1, with mean trials to Criterion 2 in parentheses. Analysis of variance of trials to Criterion 1, indicated a possible shift effect, $F = 2.79$, d.f. = 1/72, $.05 < p < .10$, a significant effect due to initial task criterion, $F = 5.25$, d.f. = 3/72, $p < .01$, and a significant interaction effect, $F = 4.03$, d.f. = 3/72, $p < .025$. The results of Duncan range tests are given in Table 4c.

Analysis of variance of trials to Criterion 2 only yielded a significant effect of initial task criterion, $F = 3.35$, d.f. = 3/72, $p < .05$. Neither the shift nor the interaction effect was significant with $F < 1$ and $F = 1.18$, respectively. The results of Duncan range tests are given in Table 6.4d.

4. DISCUSSION.

The results indicated that any effects of the initial task on the shift task were reduced by the use of a higher criterion of learning on the second task. All values of F were reduced by the use of Criterion 2 and this reduction was reflected in the fewer significant comparisons obtained using the Duncan range tests. As mentioned previously, Sperling (1970) found a similar effect for rats given a

Table 6.1.

Mean trials to criterion on original task.

Shift	Criterion	Own Criterion Easy Task	Own Criterion Difficult Task	Criterion 1 Easy Task	Criterion 1 Difficult Task
R	½	1.4	2.4	-	-
	1	3.3	7.6	3.3	7.6
	2	3.7	9.3	3.5	7.8
	5	5.1	10.9	4.0	8.3
NR	½	2.3	1.9	-	-
	1	4.5	7.6	4.5	7.6
	2	4.9	9.4	4.7	8.2
	5	5.1	14.0	4.6	8.9

Table 6.2.

Easy Task. Mean trials to Criterion 1 on shift
(Criterion 2 in parentheses)

Task 1 criterion

		½	1	2	5
Shift	R	4.6 (6.0)	2.5 (4.3)	2.4 (4.0)	1.9 (3.0)
	NR	6.1 (6.5)	6.3 (8.8)	2.2 (3.0)	3.3 (3.8)

Table 6.3.

Difficult Task. Mean trials to Criterion 1 on shift
(Criterion 2 in parentheses)

Task 1 criterion

		½	1	2	5
Shift	R	6.9 (7.8)	5.5 (8.7)	3.8 (5.4)	1.9 (4.8)
	NR	5.8 (7.4)	4.9 (5.0)	4.9 (5.6)	5.3 (5.7)

Table 6.4.

Duncan range tests of shift means. (Groups not underlined by a common line are significantly different from each other at the 0.05 level. Group means increase from left to right)

(a) Easy task, Shift Criterion 1

Group	5ER	2ENR	2ER	1ER	5ENR	½ER	½ENR	1ENR
	———	———	———	———	———			
					———	———		
						———	———	———

(b) Easy task, Shift Criterion 2

Group	5ER	2ENR	5ENR	2ER	1ER	½ER	½ENR	1ENR
	———	———	———	———	———			
		———	———	———	———	———		
				———	———	———	———	
						———	———	———

(c) Difficult task, Shift Criterion 1

Group	5DR	2DR	1DNR	½DNR	5DNR	2DNR	1DR	½DR
		———	———	———	———	———	———	
			———	———	———	———	———	———

(d) Difficult task, Shift Criterion 2

Group	5DR	2DR	5DNR	2DNR	1DNR	½DNR	½DR	1DR
	———	———	———	———	———			
		———	———	———	———	———	———	———

reversal task. It is probable that as training on the shift task continues, there is both a gradual reduction in the influence of the original task on the shift task and an increased opportunity for random variables to intervene. For this reason this discussion will be restricted to the results obtained using Criterion 1 on the shift task.

The reversal results clearly demonstrated the hypothesised relationship between initial task criterion level and initial task difficulty. For the difficult task, the range tests showed Group 5DR to have learned the reversal significantly more rapidly than any of the other three groups, indicating that the full facilitatory effect of overlearning was not apparent even after two consecutive blocks correct (Group 2DR). For the easy task on the other hand, the full effect of overlearning appears to occur two criterion levels earlier. While Groups 5ER, 2ER and 1ER learned the reversal significantly more rapidly than Group ½ER, they do not differ amongst themselves. Clearly, lower criteria using an easy task, are equivalent to higher criteria using a more difficult task.

The non-reversal results (range tests) for the difficult task indicated no effect due to amount of initial learning. This agrees with the findings of Bogartz (1965), Danks & Glucksberg (1968), Kendler, Kendler & Sanders (1967) and Paul, Hoffman & Dick (1970) using half-reversal shifts on a two choice task. There were no differences between reversal and non-reversal groups with the exception of Group 5DR, which learned significantly more rapidly than any of the non-reversal groups. This result is similar to that obtained by Bogartz, and Danks & Glucksberg.

The non-reversal results for the easy task indicated that both Group 2ENR and Group 5ENR learned significantly more rapidly than either Group ½ENR or Group 1ENR. This result is clearly at variance with that obtained using the difficult task, and with the results of the experiments mentioned in the preceding paragraph. It appears to be largely due to the exceedingly slow shift learning of Groups ½ENR and 1 ENR (although Group 2ENR also learned slightly more rapidly than expected). This result will be discussed in mediational terms below.

Assuming that shift facilitation after overtraining is due to the increased use of mediation, in the present experiment this must have been of a type not previously discussed in the literature. The mediating mechanism can neither be due to the use of verbal labels of the type postulated by Kendler & Kendler (1962, 1968) in their comparative and developmental theory, nor to attention to particular dimensions (Sutherland & Mackintosh, 1971, Zeaman & House, 1963), since the stimuli have nothing in common that can be labelled or attended to. The suggestion of Bogartz (1965), of a pre-experimentally acquired "doing the opposite" rule, is inapplicable as a mediating mechanism because of the complexity of the reversal employed. Similarly, since the four stimuli had four different responses, the suggestion of Bogartz and also Marquette & Goulet (1968) that stimuli associated with a common response become associated with each other, is also inapplicable. Differentiation followed by suppression of the old correct response should have had a negligible influence due to the large number of possible responses to each stimulus (see Paul, 1972, Experiment II).

The most probable mediator was the response configuration to stimuli on the key-board. The greater simplicity of the mediator used by subjects given the easy task presumably accounts for the relative rapidity with which this task was initially learned. Since reversal subjects had to reverse the pattern on the key-board, overlearning may have enabled them to remember and manipulate it more readily.

The relation between task difficulty and criteria of learning found for the reversal results can be readily explained within a mediational framework. The sole feature differentiating the easy from the difficult task was the complexity of the response pattern on the key-board. Subjects given the difficult task had a relatively complex pattern which involved learning the direction in which each key had to be pressed. The easy task involved a simpler pattern with a common directional response to each stimulus. Over a given number of trials, the preasymptotic rate at which this mediator is learned or strengthened, is presumably more rapid in the case of a simpler configuration. It follows, that during criterial trials there is greater mediator strengthening in the case of an easy task as opposed to a difficult task, making it less probable that an effect due to overtraining will be found. Lower criteria involving fewer trials on the easy task, may on the other hand, allow an effect to occur, resulting in the relation between criteria and task difficulty.

The effect of criterion level on the easy task non-reversal groups can also be explained using response configuration as a mediator. Both the original and shift tasks will only be "easy" if subjects learn the simple response pattern reasonably early. A low criterion on the initial task may prevent subjects from both fully learning that the initial task requires them to press all the keys in the same direction, and from realising that a shift has occurred. Under these circumstances, having experienced positive reinforcement for pressing the keys in both directions, the shift task would be equivalent to a difficult task (a similar mechanism could clearly not apply using the difficult task). One would also expect the effect due to mediation to be weaker and of less benefit in this case than for the reversal, since reversal involves reversing both the direction in which the keys had to be pressed, and reversing the spatial order of the responses. The easy non-reversal on the other hand, involved the former only, there being no spatial order relation between initial and shift task. It is probably this fact that resulted in the effect due to mediation not being manifested at such low criterion levels in the non-reversal case - Group 1ER learned the shift more rapidly than Group 1ENR.

CHAPTER 7.

EXPERIMENT 5: THE EFFECT OF OVERTRAINING ON A CONCEPT REVERSAL PROBLEM.

1. INTRODUCTION.

The use of low criteria of learning may be necessary in order to obtain the ORE using certain concept learning tasks. As was mentioned previously (p.131-134), Lowenkron (1969) and Lowenkron & Driessen (1971) gave subjects a discrimination learning task that could be solved either by identifying the relevant concept or by rote learning. In the case of the ORE paradigm experimental design, they found that the data of subjects who used a rote learning method of solving the task yielded the ORE, while the data of subjects who used a concept learning method did not. They suggested that the ORE is a function of the likelihood that the subjects will not identify the relevant concept and that this in turn casts doubt on the validity of theories which account for the ORE in terms of increases due to overtraining in the strength of dimensional mediating responses, such as attention.

This experiment, like most of the preceding ones, is concerned with the effects of using learning criteria on the initial task which are lower than those conventionally used. It is intended to test the hypothesis that the ORE can be obtained using a concept learning task provided that the initial discrimination criterion is appropriate. The criterion used by Lowenkron (1969) and Lowenkron & Driessen (1971) - 8 consecutive correct responses to a block of all 8 stimuli - in conjunction with a simple conceptual task, may be far too high and hence represent a considerable degree of overtraining. Subjects who have identified the correct concept, have presumably learned to use it on the first of their string of correct trials. (This would probably be before the first criterion trial since the criterion was based on a specific block of 8 trials rather than any 8 trials). The subsequent trials in any two-response concept identification situation are merely necessary to indicate to the experimenter that the first response was correct due to learning rather than to chance factors. Effects due to overtraining may occur during subsequent criterion trials, resulting in further training having no shift task consequences.

A stimulus universe sufficiently large to allow non-repetititon of any stimulus on the initial task was used in order to ensure that all subjects who learned the task did so by identifying the concept rather than by simple rote learning. A multiple rather than a dual response universe was again employed in order to allow the use of an extremely low criterion of learning while retaining statistical reliability.

2. METHOD.

Subjects. The subjects were 16 students who were fulfilling an introductory psychology course requirement. Four additional subjects were eliminated after failing to solve the initial task within 64 trials.

Stimulus material and apparatus. The stimuli consisted of all the numbers between 11 and 88 (inclusive) with the exception of those numbers containing a 0 or a 9. There are 64 such numbers.

A Kodak Carousel slide projector projected each item onto a screen 120 cm away giving a 10 cm by 5 cm image. The subject sat immediately to the right of the projector.

The slides were ordered randomly in the projector with the exception that each stimulus occurred once and once only in the first 64, and that the 25th.-40th. stimuli were then repeated in the same order. This made a total of 80 slides, in a sequence which could be repeated indefinitely.

Procedure. The stimuli were presented to the subjects, one at a time. Subjects were told that they were to respond to each stimulus by calling out any number between 0 and 110 and that the experimenter would then tell them the correct number that should have been said. They were instructed to learn the relation between the stimulus and the correct response. The initial task, consisted of adding the sum of the two digits of which each number was composed, to the number itself, e.g. the correct response to the stimulus "23" was "28". Subjects who had not learned this task within 64 trials were eliminated from the experiment. The reversal task consisted of subtracting the sum of the two digits from the number itself.

There were 2 groups. The first group was trained to a criterion of at least 1 correct response plus 1 perseverative trial before being reversed (Group 1). This meant that while subjects had to respond on the basis of the first task for at least two consecutive trials before being reversed, for the second trial they did not obtain feedback on the basis of the first task, but on the basis of the reversal. Initial task feedback continued in the case of subjects who made a single correct response followed by an error. Hence while the experimenter's criterion was two consecutive correct responses - a criterion most unlikely to be attained purely by chance - the subject was in effect reversed after one correct response.

The second group was trained to a criterion of 10 consecutive correct responses before being reversed (Group 10). In terms of total number of correct responses this is unlikely to be any higher than Lowenkron's (1969) and Lowenkron & Driessen's (1971) criterion of 8 consecutive correct responses since it is not based on any particular block of trials. The reversal criterion was 10 consecutive correct responses for both groups.

3. RESULTS.

Trials to criterion analyses were done on logarithmic transformed data. Group 1 took a mean of 14.75 trials to reach the initial task criterion (excluding the criterion trial) while Group 10 took 22.12 trials. There was no significant difference between groups on this measure, $t < 1$. No subject in Group 10 made any errors after two consecutive correct responses indicating that the criterion used for Group 1 represented learning rather than chance factors.

Group 1 took a mean of 14.25 trials to reach the reversal criterion while Group 10 took 1.12 trials. There was a significant difference between groups on this measure, $t = 3.42$, d.f. = 14, $p < .005$.

Additional information concerning the problem solving process in this type of task may be obtained from the responses made during the presolution period of Task 1. On the last trial before criterion, while the subjects had not discovered the correct solution to the task, they were nevertheless not responding in a completely random manner. On this particular trial, all sixteen of the subjects responded with a number that was higher than the stimulus number. This may be contrasted with the responses on the first trial of Task 1. On this trial, ten of the subjects simply read out the stimulus number, four responded with a lower and two with a higher number. Clearly, before actually discovering the relevant rule, subjects realised that the correct response was always higher than the stimulus number.

There is no evidence that subjects were able to further restrict the range of possible correct responses prior to solution. It was hypothesised that just before criterion, they may have noticed that the larger the two stimulus digits, the greater the difference between the stimulus number and the correct response number. Using the last trial before criterion, three Pearson r correlations were carried out with the difference between the stimulus number and the subject's response as one variable in each case, and the first digit, the second digit, or the sum of the two digits as the other variable. Values of $r(14) = -.17$, $-.32$, and $-.31$ were obtained respectively. These are all in the wrong direction and are not significant, $p > .10$.

4. DISCUSSION.

The results confirm the hypothesis that the ORE can be readily obtained using a conceptual task provided a sufficiently low criterion of learning is used on the initial discrimination for the lesser trained group. In addition, they indicate that the ORE would not have been obtained using a conventional criterion such as that given Group 10. Since seven of the eight subjects in this group learned the reversal in 1 trial, and the eighth in 2 trials, further initial discrimination training could not have resulted in the ORE using Group 10 as a criterion (lesser trained) group.

The primary implication for mediating theories is that once a simple, high information concept is discovered by normal adult human subjects, it can attain its asymptotic strength as a mediating response within a very few trials. Consequently, a failure to obtain the ORE in a task involving the extraction of a dimension or concept may simply be due to both groups having an equal and asymptotic facility in the use of the relevant concept. This may indicate the necessity for changes in experimental procedure - specifically the use of appropriate criteria - rather than flaws in theories. A mediating response which, before it can be used, must be preceded by rote learning, may on the other hand strengthen more slowly, allowing the use of conventional criteria.

Lowenkron's (1969) and Lowenkron & Driessen's (1971) results are hence not necessarily in conflict with attention theories. Instead, they may indicate that experimental parameters suitable for studying the effect of mediational changes due to overtraining in the case of subjects who learn partly by rote, are not suitable in the case of subjects attending to a dimension.

The results may also be considered in a somewhat different context. Levine (1969) found that in a concept learning task, the effect of negative feedback following a response almost invariably resulted in subjects abandoning the hypothesis held on that particular trial. Since negative feedback was obtained on the first shift trial of the present experiment, the Task 1 hypothesis was disconfirmed. The manner in which it was abandoned apparently differed for the two groups. Most of the Group 1 subjects not only abandoned their previously held hypothesis, but also failed to use it in the solution of the reversal. This may be contrasted with the behaviour of the Group 10 subjects whose exceedingly rapid reversal learning implies that while they abandoned their Task 1 hypothesis, they nevertheless used it to help solve Task 2.

CHAPTER 8.

EXPERIMENT 6: THE EFFECT OF OVERTRAINING ON SERIAL SHIFT TASKS WITH SIMILAR CONCEPTUAL MEDIATORS.

1. INTRODUCTION.

The vast majority of human experiments studying the effects of criterion levels and overtraining on shift learning have employed single shifts rather than serial shifts. Grant & Berg (1948) and Grant & Cost (1954) gave serial extradimensional shift tasks to normal adults and found increasing differences between criterion groups as the number of learned shifts increased. As there was no readily isolated mediator common to all tasks, the effect was probably due to nonspecific mediation such as differential development of learning sets.

A serial nonreversal shift learning task with specific and similar conceptual mediating responses required for the solution of each shift, may greatly magnify the difference between a low and a high criterion group, as compared to a situation in which there is either only one shift task (as in the previous experiment), or in which there is no readily isolated mediator (as in Grant & Berg, 1948, and Grant & Cost, 1954). Subjects trained to a high criterion on each task may become increasingly adept at correctly manipulating the mediating concept required to solve the problem and hence learn each succeeding task more rapidly than the preceding one. Subjects trained to a low criterion on the other hand, may tend to reject the relevant concept and hence learn each succeeding task more slowly than the preceding one.

The technique chosen was based on that used in Experiment 5. This allows the use of nonreversal shifts in which: (1) a similar mediating response is required for the solution of each shift; (2) partial reinforcement of previous task responses is completely eliminated; (3) no changes in the stimulus set are required from one task to the next.

2. METHOD.

The subjects were 20 students who were fulfilling an introductory psychology course requirement. Seven additional subjects were eliminated after failing to solve the initial task within 64 trials.

The stimulus materials, apparatus, and general procedure were the same as in Experiment 5. There were five tasks with half of the subjects (Group 1) being trained to Criterion 1 (as in Experiment 5) and the other half (Group 10) to Criterion 10 on each task. Training was terminated for those subjects who did not reach criterion within 40 trials on any of the shift tasks. The first task required subjects to add the sum of the two digits of which each number was composed, to the number itself (as in Experiment 5); the second task required the first task manipulation followed by the subtraction of 2; the third task required the first task manipulation followed by the addition of 5; The fourth task required the first task manipulation, followed by the addition of 2; the fifth task required the first task manipulation, followed by the subtraction of 1. Hence the correct response to stimulus "23" would have been "28", "26", "33", "30", and "27", respectively for each of the 5 tasks.

3. RESULTS.

The data are summarised in Table 8.1. The letter N refers to the number of subjects attaining criterion on each task. Since training was terminated for subjects who did not reach criterion on any particular task, the number of subjects given each shift task (Tasks 2, 3, 4 and 5) is equal to the N for the preceding task. Mean trials to criterion for Group 10 only includes subjects who learned the task in question. The criterion used for this measure was Criterion 1 - two consecutive correct responses.

All trials to criterion analyses were done on logarithmic transformed data. There was no significant difference in trials to criterion between the two groups on Task 1, $t < 1$. The enormous differences between the groups on all subsequent problems (caused by almost all

Group 1 subjects being unable to learn these problems), obviously precluded the use of a similar analysis for the shifts. A Fisher exact probability test indicated a significantly decreased number of Group 1 as compared to Group 10 subjects, who learned Task 2, $p < .05$. The same effect was also found for tasks 3, 4, and 5, $p < .01$.

Excluding the one subject in Group 10 who failed to learn Task 3 (see Table 1), a significant decrease in trials to criterion across tasks was found, $F = 9.58$, d.f. = 4/32, $p < .005$. A similar analysis for Group 1 was not possible since only one subject reached Task 5.

Presolution behaviour on Task 1 largely replicated the Experiment 5 data. On the last precriterion trial, eighteen of the twenty subjects responded with a number that was higher and two with one that was lower than the stimulus number. In contrast, on the first trial, ten of the subjects read out the stimulus number, five responded with a lower and five with a higher number.

For the last precriterion trial, again no relation was found using the difference between the stimulus number and the response as one variable, and the first digit, the second digit, or the sum of the two digits as the other variable. Values of $r(14) = -.05$, $+.25$, and $+.15$ were obtained respectively. None of these are significant, $p > .10$.

Table 8.1.

		Task				
		1	2	3	4	5
Group 1	N	10	5	1	1	1
	Mean trials to criterion	15.4	-	-	-	-
Group 10	N	10	10	9	9	9
	Mean trials to criterion	14.8	5.3	3.33	2.67	1.55

4. DISCUSSION.

The data indicate that under appropriate conditions a simple change in criterion level can have the consequence of a totally reversed pattern of results in serial shift learning. With the exception of the one subject who failed to reach Task 5, Group 10 subjects demonstrated a rapidly decreasing trend of trials to criterion across tasks. Group 1 subjects on the other hand, not only found successive shift tasks more difficult, but in most cases, within the limitation imposed by the maximum number of trials allowed before the discontinuation of training, found the latter shift tasks insoluble. Half of the subjects could not solve Task 2, and of the remainder, only one was able to solve the subsequent tasks.

These results would appear to be explicable only in terms of the presence and absence of the relevant mediating concept (i.e. adding the sum of the two digits to the number itself, plus or minus a constant) necessary for the solution of the task. Group 10 subjects, having fully learned to use the mediator, found the shift tasks relatively simple. Group 1 subjects, despite having presumably all used the mediator to reach criterion on the first, and half of them on the second task, were unable to continue to use it correctly on the subsequent tasks, and hence found them insoluble.

Levine (1971) and Ress & Levine (1966) also demonstrated nonlearning under certain conditions. In a 2-choice, simultaneous discrimination situation, they found that most subjects who were given a series of complex position alternation problems with circle size as an irrelevant dimension, were subsequently unable to learn the simple large circle-small circle discrimination. Subjects initially given size as the relevant dimension learned the task within a few trials.

Levine (1971) theorised that as a consequence of the position discriminations, subjects were testing hypotheses from a set which did not include the new relevant hypothesis. This either retarded or prevented discovery of the solution.

The present experiment may indicate that under Group 1 conditions, subjects not only failed to use earlier successful hypotheses to help formulate new ones as in Experiment 5, but in addition eventually rejected the entire relevant hypothesis set (where the hypotheses in the set consisted of adding the sum of the two digits to the number itself plus or minus a constant) resulting in nonlearning. Unlike Levine's tasks, they did this despite having previously tested a correct hypothesis (or hypotheses) from the set and subsequently receiving feedback consistent with another hypothesis from the same set. Group 10 subjects on the other hand presumably used previously correct hypotheses or rules to help formulate subsequently correct rules. They were consequently testing hypotheses from within the set, allowing them to find the shift task solutions rapidly.

SECTION III

CHAPTER 9.

CONCLUSIONS.

The series of experiments described were primarily designed to test mediational theories of learning and to describe further the mediational mechanisms involved. A secondary aim was to examine the experimental methods which are commonly used to test these theories.

The primary experimental findings for the studies using rats were firstly, that if sufficiently low levels of initial training are employed, the number of trials to reversal criterion varies as a quadratic function with increases in initial training level, and secondly that this function appears to hold irrespective of task difficulty providing that suitable levels of initial training are used. The initial increase can be explained in terms of increases in habit strengths to the stimuli which must be reversed during the reversal task. The subsequent decrease can be explained by assuming a mediating response (such as attention to a relevant dimension) which increases in strength with additional training and hence facilitates reversal.

In the studies using human subjects and nondimensional stimuli, increases in initial training resulted in decreases in number of trials to shift task criterion where the initial task was related to the shift task in such a way that information gained by the subjects during Task 1 could be used to help solve Task 2, hence acting as a mediating response. The rate of the decrease in number of trials to shift task criterion was more rapid in the case of an easy task which can be explained by assuming a more rapid increase in strength of the mediating response for an easy task. The fact that a quadratic function was not obtained as for the animal studies can be explained by assuming that changes in habit strength to the stimuli play a relatively minor role in adult human learning compared to changes in the strength of mediating responses. This may explain why the initial increase in trials to shift criterion did not occur.

The human studies using concept learning tasks indicated that very low criteria are necessary on the initial task if the ORE is to be obtained. In addition, differences in shift learning speed between groups trained to various criteria of learning were vastly increased by using a series of related shift tasks rather than a single shift. Further work would be necessary to establish whether the relation between task difficulty and criteria of learning found in the previous experiments holds for a hypothesis testing task.

The following general conclusions are suggested.

(1) When testing for the effect of overtraining on mediating responses, the degree of training given lesser trained groups is more critical than the amount given more highly trained subjects. In many situations, substantial changes in the amount of training given over-trained groups appear to have no noticeable effects on speed of shift learning. On the other hand, relatively small changes in the amount of training given lesser trained groups can radically alter speed of shift learning. This may be attributed to the strength of both mediating and choice responses reaching asymptote in many tasks somewhat more rapidly than was previously thought.

(2) The easier a task, the more sensitive it appears to be to changes in the degree of training given to lesser trained subjects. Easier tasks not only require lower criteria of learning on the original task in order to obtain the same effect using more difficult problems, but in addition the range of criteria of learning appears to be reduced. These facts can be accounted for by assuming that the strength of mediating responses builds up more rapidly and hence reaches asymptote more rapidly in the case of easy problems. In other words, for an easy task, the fact that the mediating response reaches asymptote more rapidly not only means that lower criteria (or lesser

amounts of training if criteria of learning are not used) are necessary to obtain the same effects as for a difficult task, but in addition means that it is more difficult to find the critical range of criteria (because it is smaller) necessary to obtain a shift effect.

(3) When studying the effects of criterion levels on mediating mechanisms, serial shift tasks may considerably magnify differences obtained using a single shift. While this possibility has been largely ignored in the past, it may be of considerable benefit in situations where experimental effects under single shift conditions are slight. For this reason it deserves further consideration and suitable tasks using this paradigm for various subjects under various conditions require development.

APPENDIX I: A TEST BETWEEN THE SELECTIVE ATTENTION AND STIMULUS GENERALISATION INTERPRETATIONS OF THE EASY-TO-HARD EFFECT.

1. INTRODUCTION.

Group LE and LD of Experiment 1 (Chapter 2) provide a direct test of two interpretations of the easy-to-hard effect. The basic experimental paradigm normally used to demonstrate this effect involves two groups of subjects. One group is given initial training on an easy task and then transferred to a more difficult task on the same dimension, while the other group is given all its training on the difficult task. The difficult task is normally learned in less trials (including trials given on the easy task) by the group given part of its training on the easy task.

The effect was first demonstrated by Gubergritz (in Pavlov, 1927) using classical conditioning of the salivary reflex of a dog. The dog was trained to salivate to a grey stimulus and after the response was well established an attempt was made to train the animal to discriminate between this stimulus and a slightly darker one. Despite many trials, no sign of learning could be detected. A much darker stimulus was then introduced instead of the slightly darker one resulting in rapid learning. When the slightly darker stimulus was then reintroduced as a substitute for the much darker one, discrimination occurred within a few trials.

Lawrence (1952) obtained the effect using instrumental conditioning of rats. He used four groups. One group was given a difficult brightness discrimination for 80 trials; a second group was given 30 trials on a very easy brightness discrimination before being given 50 trials on the difficult task; a third group was given 50 initial trials on a fairly easy brightness task (although not as easy as that initially given the preceding group) before being given 30 trials on the difficult task; the fourth group was given a total of 30 trials on three progressively more difficult brightness discriminations, with 10 trials being given at each level, and a further 50 trials on the difficult task. All three groups given initial training on easy tasks performed with a lower percentage of errors than the group given all its training on the difficult task, at all stages of the experiment, including the latter stages when identical (difficult) stimuli were used for all groups.

Lawrence suggested that selective attention could account for his results. If as well as learning the choice response, animals must learn to attend to the relevant dimension, then learning should be more rapid if the conditions are such that the relevant dimension is isolated early in training. This should be the case if an easy discrimination is used initially.

Lawrence forwarded this account on the assumption that excitatory and inhibitory stimulus generalisation gradients of the type postulated by Spence (1936) could not account for the effect. (See Lawrence, 1955). He pointed out nevertheless, that if the gradients became steeper with increased training (rather than being parabolic in shape as proposed by Spence) then the effect could be explained without recourse to attention. This explanation was accepted by Logan (1966) who showed that a modified Spence model could not only predict the easy-to-hard effect but could also predict the conditions under which it would be larger or smaller. He assumed that bell shaped excitatory (E) and inhibitory (I) stimulus generalisation gradients steepen while building up about the positive and negative stimuli respectively. The net E or I at any point on a stimulus continuum is calculated by obtaining the difference between E and I at that point. If two stimuli are far apart on the continuum (an easy discrimination - Figure 1a), then after training on these stimuli, the net E and/or I will be greater at two points closer together on the continuum that if all training had been carried out using these latter stimuli only (a difficult discrimination - Figure 1b). The easy-to-hard effect is hence predicted.

Singer, Zentall & Riley (1969) provided a direct test between the selective attention and stimulus generalisation gradient interpretations. They reasoned that if easy discrimination training using 3 stimuli such as black, grey, and white presented in pairs with the middle value present on all trials is substituted for easy discrimination training using 2 stimuli (e.g. black-white) then equal amounts of generalised E and I should occur at the 2 stimuli used for the hard discrimination (e.g. light-grey and dark-grey), eliminating the usual facilitatory transfer effect. (See Figure 1c). Two control groups were required. Firstly a group trained on the difficult discrimination only and compared from its first trial with the hard discrimination only of the easy-to-hard group rather than from the point where it had an equal number of training trials as the easy-to-hard group had on the easy task. The use of the latter procedure would have resulted in the control group having differential E and I at the time that the experimental group was switched to the difficult task. This necessitated the inclusion of a third, learning-to-learn control group initially trained on another dimension before switching to the hard discrimination.

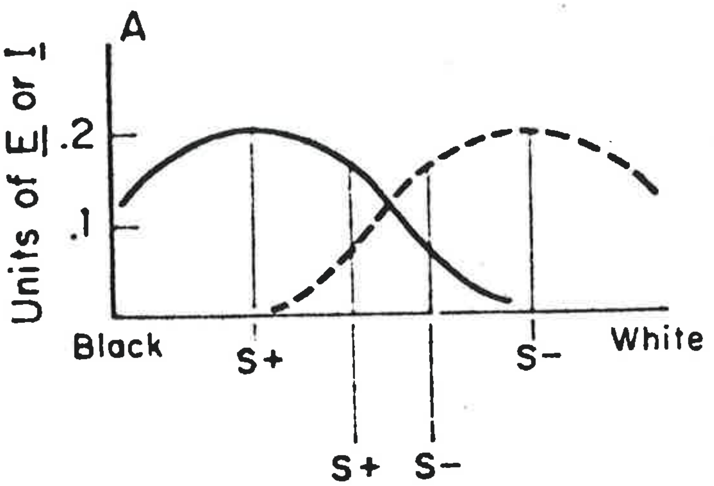


FIG. 1a

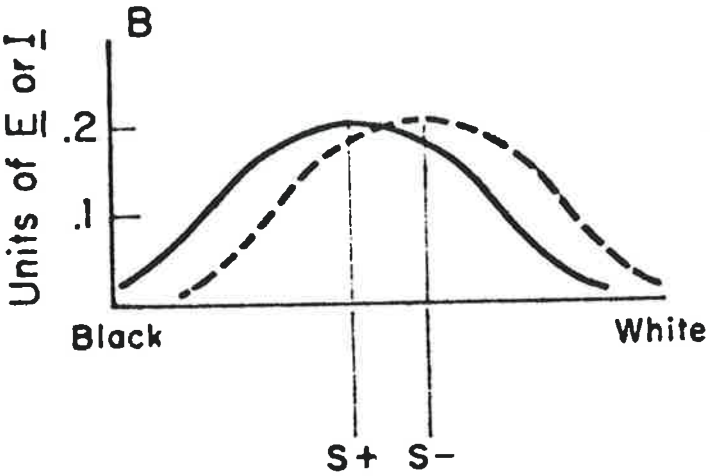


FIG. 1b

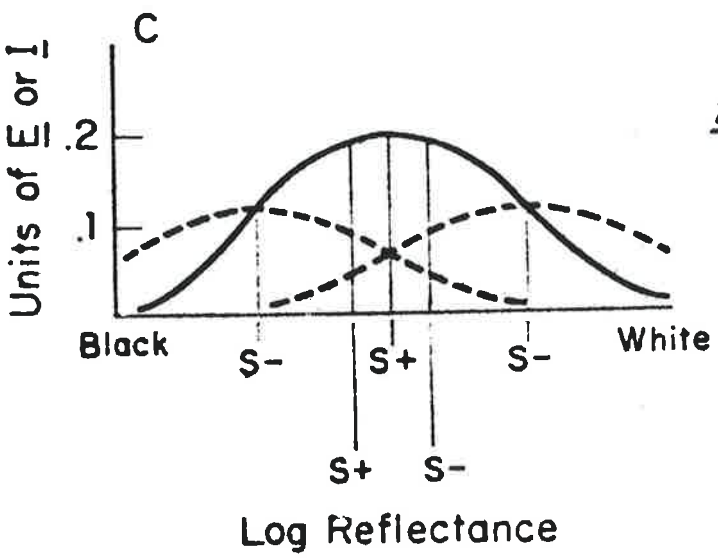


FIG. 1c

Singer et al's results supported the stimulus generalisation interpretation. The easy-to-hard effect was not obtained using a 3-stimulus easy discrimination group (i.e. there was no difference between this group and the difficult discrimination only group other than that seemingly caused by a learning-to-learn effect) but was obtained using the conventional 2-stimulus easy discrimination group. The attentional interpretation predicts that 3 stimulus easy discrimination training should have the same effect on dimensional salience as 2 stimulus training and hence was not supported by the results.

In order to increase the generality of Singer et al's conclusions, a further test of the 2 theories is possible which has the advantages that it is considerably simpler and also that its essential logic does not involve acceptance of the null hypothesis at any point as is the case with Singer et al's experimental design. This test simply involves the use of Groups LE and LD of Experiment 1 (Chapter 2). For the normal 2-stimulus paradigm, if net E and I are relatively large at the hard stimuli for the easy group, then by making the usual easy-to-hard shift a "reversal" shift as well (Group LE), and by simultaneously reversing the subjects in the "difficult" group (Group LD), a reverse easy-to-hard effect is predicted: i.e. the easy group should learn more slowly according to the stimulus generalisation interpretation because it has a larger net E and I to reverse. The opposite result would constitute strong evidence against the stimulus generalisation account. It might on the other hand, be explained by the attentional interpretation given the assumption that increased attention to the relevant dimension is beneficial irrespective of whether or not the cues are reversed (as was pointed out in Chapter 2). The apparatus and training procedure for this experiment were given in Chapter 2. The number of subjects per group was increased from three to six.

2. RESULTS.

Mean results are given in Table 1. Days to criterion include the two criterion days. Statistical tests yielded the following results:

(1) The easy group had significantly fewer correct trials on the first shift day than the difficult group, $t = 5.43$, d.f. = 10, $p < 0.001$;

(2) The easy group took significantly fewer days to reach the shift criterion than the difficult group, $t = 4.31$, d.f. = 10, $p < 0.005$.

3. DISCUSSION.

These results indicate that the performance of the easy group was significantly worse than that of the

Table 1.

	Days on initial task	Correct trials on 1st shift day	Days to shift criterion
Easy Group	6.33	1.67	16.17
Difficult Group	6.33	4.33	22.00

difficult group on the first shift day, but despite this the easy group took significantly fewer days to reach criterion. Since according to the stimulus generalisation interpretation, the performance of the easy group should have been inferior at all stages of learning, the former result is predicted but the latter is not. The most obvious explanation of both results is that the shift learning of the easy group was mediated by a higher level of attention to the correct dimension resulting in an initially greater difference in the response strengths to the 2 cues and subsequently followed by a more rapid rate of change.

That the conditions were similar to those normally pertaining in successful easy-to-hard effect experiments, can be seen from the first shift day results. Had there not been a reversal shift, an identical result would have indicated that the easy group had performed significantly better rather than significantly worse than the difficult group, giving the normal easy-to-hard effect.

The present results are probably analogous to those obtained by Mackintosh & Little (1970) using pigeons. They found that subjects "reversed" to a difficult task from an easy task (as was the easy group of the present experiment) eventually performed more accurately than control subjects given all their training on the difficult task with no reversal.

The contradiction between the theoretical position supported by the results of Singer et al and the present results requires an explanation. Three stimulus learning may have forced animals to respond to the absolute properties of the stimuli rather than to relationships. Singer et al provide evidence that this may have occurred. If subjects respond to the absolute properties of the stimuli, then learning one half of the three stimulus problem (with one of the extreme stimuli present) should facilitate learning of the other half (with the other extreme stimulus present). If on the other hand, subjects respond to relationships, then learning one half of the problem should interfere with learning the second half, since the relation of the middle stimulus to one of the extreme stimuli is the opposite of its relation to the other extreme stimulus. A comparison of errors on the more slowly learned half, immediately before and after the last error on the more rapidly learned half, indicated fewer errors after the last error on the more rapidly learned half. Since there should have been more errors if subjects were responding in a relational manner, (responding to the same relationship on the more slowly learned half as on the more rapidly learned half would result in no correct responses on the former after the latter had been learned) it is probable that they were responding to the absolute properties of the stimuli.

This mode of responding may generalise to all stimuli on the same dimension. If one assumes that absolute responding is more difficult for some or all animals than either relational responding or a combination of relational and absolute responding (as will be the case if some animals must adopt a mode of responding not naturally adopted), then this may negate any advantage accruing to the easy-to-hard 3 stimulus group due to a higher level of attention to the relevant dimension.

APPENDIX II: PAPERS BASED ON THIS THESIS ACCEPTED FOR PUBLICATION.

1. Sweller, J. A test between the selective attention and stimulus generalisation interpretations of the easy-to-hard effect. Quarterly Journal of Experimental Psychology, 1972, 24, 352-355.

2. Sweller, J. The effect of task difficulty and criteria of learning on a subsequent reversal. Quarterly Journal of Experimental Psychology, 1972, 24, in press.

3. Sweller, J. The effect of amount of initial training on concept shift problems. Journal of Experimental Psychology, 1973, in press.

Experimental Psychology——30407——1
Chapman——FC1——
SWELLER——1——

Quarterly Journal of Experimental Psychology (1972) **24**, 000–000

A TEST BETWEEN THE SELECTIVE ATTENTION AND STIMULUS GENERALIZATION INTERPRETATIONS OF THE EASY-TO-HARD EFFECT

J. SWELLER
University of Adelaide

The selective attention and stimulus generalization interpretations of the easy-to-hard effect were tested by training one group of rats on an easy brightness discrimination and "reversing" them on a more difficult brightness discrimination. A control group, initially trained on the difficult discrimination, was reversed at the same time as the experimental group. The experimental group learned the reversal more rapidly and this was interpreted as supporting the selective attention interpretation.

Introduction

If an animal is trained on an initial discrimination and then transferred to a more difficult discrimination on the same dimension, learning this second task is characteristically more rapid than if all training is given on the difficult discrimination only. This is known as the easy-to-hard effect. It was first demonstrated by Gubergritz (in Pavlov, 1927) using classical conditioning of the salivary reflex of a dog. Lawrence (1952) obtained the effect using instrumental conditioning of rats and suggested that selective attention could account for it. If as well as learning the choice response, animals must learn to attend to the relevant dimension, then learning should be more rapid if the conditions are such that the relevant dimension is isolated early in training, as will be the case if an easy discrimination is used.

Lawrence put forward this account on the assumption that excitatory and inhibitory stimulus generalization gradients of the type postulated by Spence (1936) could not account for the effect (see Lawrence, 1955). He pointed out nevertheless, that if the gradients became steeper with increased training (rather than being parabolic in shape as proposed by Spence) then the effect could be explained without recourse to attention. This explanation was accepted by Logan (1966) who showed that a modified Spence model could not only predict the easy-to-hard effect but could also predict the conditions under which it would be larger or smaller. He assumed that bell-shaped excitatory (E) and inhibitory (I) stimulus generalization gradients steepen while building up about the positive and negative stimuli respectively. The net E or I at any point on a stimulus continuum is calculated by obtaining the difference between E and I at that point. If two stimuli are far apart on the continuum (an easy discrimination), then after training on these stimuli, the net E and/or I will be greater at two points closer together on the continuum (a difficult discrimination) than if all training had been carried out using these latter stimuli only. The easy-to-hard effect is hence predicted.

Singer, Zentall and Riley (1969) have provided a direct test between the selective attention and stimulus generalization gradient interpretations. They reasoned that if easy discrimination training using three stimuli such as black, grey and white presented in pairs with the middle value present on all trials is substituted for easy discrimination training using two stimuli (e.g. black-white) then equal amounts of generalized E and I should occur at the two stimuli used for the hard discrimination (e.g. light-grey and dark-grey), eliminating the usual facilitatory transfer effect. In order to avoid differential E and I for the group trained on the hard discrimination only, the comparison was made from the first trial of the difficult discrimination for both groups. This necessitated the inclusion of a third, learning-to-learn control group initially trained on another dimension before switching to the hard discrimination.

Singer *et al.'s* (1969) results supported the stimulus generalization interpretation in that the easy-to-hard effect was not obtained using a three-stimulus easy discrimination group (i.e. there was no difference between this group and the difficult discrimination only group other than that seemingly caused by a learning-to-learn effect) but was obtained using the conventional two-stimulus easy discrimination groups. The attentional interpretation predicts that three-stimulus easy discrimination training should have the same effect on dimensional salience as two-stimulus training and hence was not supported.

In order to increase the generality of Singer *et al.'s* conclusions, a further test of the two theories is proposed. Advantages of the proposed test are that it is considerably simpler and also that its essential logic does not involve acceptance of the null hypothesis at any point as is the case with Singer *et al.'s* experimental design. For the normal two-stimulus paradigm, if net E and I are relatively large at the hard stimuli for the "easy" group, then by making the usual easy-to-hard shift a "reversal" shift as well, and by simultaneously reversing the subjects in the "difficult" group a reverse easy-to-hard effect is predicted: i.e. the easy group should learn more slowly because it has a larger net E and I to reverse. The opposite result would constitute strong evidence against the stimulus generalization account. It might on the other hand, be explained by the attentional interpretation given the assumption that increased attention to the relevant dimension is beneficial irrespective of whether or not the cues are reversed.

Method

Subjects

12 Experimentally naive male hooded rats, approximately 120 days old at the beginning of the experiment were used.

Apparatus

The apparatus was constructed of flat grey painted wood with clear perspex lids. It consisted of a 14·0 cm long, 6·5 cm wide, and 9·0 cm high starting box separated by a guillotine door from a 26·5 cm long, 20·5 cm wide, and 9·0 cm high runway ending at a 7·5 cm wide airgap. The runway then continued as two parallel alleyways 20·5 cm long and separated by a 1·5 cm wide partition. Two top hinged, removable stimulus doors, 7·5 cm high and 9·0 wide could be placed 12·5 cm from the airgap in each alleyway. The runway continued for 20·5 cm past the two alleyways before opening into the goal-box which was 23·0 cm long, 20·5 cm wide and 15·0 cm high. A 60 W globe was located 10·0 cm in front of the stimulus doors, immediately above the perspex lid. For training, black, dark grey, and white painted aluminium doors were available. Their brightness readings using a spot photometer in the normal experimental lighting conditions were 0·5, 1·2, 1·7 and 2·0 log foot-lamberts respectively.

Procedure

Pretraining. During the 10 days of pretraining, animals were tamed, reduced to and maintained at 85% of their ad lib weight, and trained to run through black-white vertical striped doors for food. All animals experienced locked doors on some occasions. Manual guidance was given throughout in order to equalize experience with both positions.

Training. Animals were given 10 non-correction trials a day in groups of three giving an inter-trial interval of approximately 3 mins. The position of the stimuli were varied according to a Gellermann series. The negative stimulus door was always locked. Correct responses were rewarded by 30 s access to wet mash. After incorrect responses animals were retained in the apparatus for 10 s. The criterion of learning was 18/20 correct responses over two days.

Design. There were two groups of 6 animals each. Those in the easy group were trained on the black-white discrimination until they had reached criterion. They were then reversed to criterion on the light grey-dark grey discrimination: e.g. if white had been positive, after transfer dark grey became positive. Half of the animals initially had white positive, and the other half had black. The animals in the difficult group were given initial training using the light grey-dark grey stimuli. Each animal was randomly paired with an animal in the easy group and was reversed on the same day as its partner was shifted. Training continued to criterion. Half of the animals were initially trained with light grey positive and the other half with dark grey.

Results

Mean results are given in Table I. Days to criterion include the two criterion days. Statistical tests yielded the following results:

(1) the easy group had significantly fewer correct trials by a t-test on the first shift day than the difficult group, $t = 5{\cdot}43$, $df = 10$, $P < 0{\cdot}001$;

(2) the easy group took significantly fewer days by a t-test to reach the shift criterion than the difficult group, $t = 4{\cdot}31$, $df = 10$, $P < 0{\cdot}005$.

TABLE I

	Days on initial task	Correct trials on first shift day	Days to shift criterion
Easy group	6·33	1·67	16·17
Difficult group	6·33	4·33	22·00

Discussion

The results indicate that the performance of the easy group was significantly worse than that of the difficult group on the first shift day but despite this the easy group took significantly fewer days to reach criterion. Since according to the stimulus generalization interpretation, the performance of the easy group should have been inferior at all stages of learning, the former result is predicted but the latter is not. The most obvious explanation of both results is that the shift learning of the easy group was mediated by a higher level of attention to the correct dimension resulting in an initial greater difference in the response strengths to the two cues and subsequently followed by a more rapid rate of change.

That the conditions were similar to those normally pertaining in successful easy-to-hard effect paradigm experiments, can be seen from the first shift day results. Had there not been a reversal shift, an identical result would have indicated that the easy group had performed significantly better rather than significantly worse than the difficult group, giving the normal easy-to-hard effect.

The present results are probably analogous to those obtained by Mackintosh and Little (1970) using pigeons. They found that subjects "reversed" to a difficult task from an easy task (as was the easy group of the present experiment) eventually performed more accurately than control subjects given all their training on the difficult task with no reversal.

The contradiction between the theoretical position supported by the results of Singer *et al.* (1969) and the present results requires an explanation. Three-stimulus learning may have forced animals to respond to the absolute properties of the stimuli rather than to relationships. (Singer *et al.* provide evidence that this may have occurred.) This mode of responding may generalize to all stimuli on the same dimension. If one assumes that abolute responding is more difficult for some or all animals than either relational responding or a combination of relational responding and absolute responding (as will be the case if some animals must adopt a mode of responding not naturally adopted), then this may negate any advantage accruing to the easy-to-hard three-stimulus group due to a higher level of attention to the relevant dimension.

The author wishes to thank Dr A. H. Winefield for invaluable discussions.

References

LAWRENCE, D. H. (1952). The transfer of a discrimination along a continuum. *Journal of Comparative and Physiological Psychology*, **45**, 511–6.
LAWRENCE, D. H. (1955). The applicability of generalization gradients to the transfer of a discrimination. *Journal of General Psychology*, **52**, 37–48.
LOGAN, F. A. (1966). Transfer of discrimination. *Journal of Experimental Psychology*, **71**, 616–8.
MACKINTOSH, N. J. and LITTLE, L. (1970). An analysis of transfer along a continuum. *Canadian Journal of Psychology*, **24**, 362–9.
PAVLOV, I. P. (1927). *Conditioned Reflexes* (translated by G. V. Anrep). London: Oxford University Press.
SINGER, B., ZENTALL, T. and RILEY, D. A. (1969). Stimulus generalization and the easy-to-hard effect. *Journal of Comparative and Physiological Psychology*, **69**, 528–35.
SPENCE, K. W. (1936). The nature of discrimination learning in animals. *Psychological Review*, **43**, 427–9.

Revised manuscript received 5 *April* 1972

Exp. Psychology Galley 10

Quarterly Journal of Experimental Psychology (1972) 24, 000–000

THE EFFECT OF TASK DIFFICULTY AND CRITERIA OF LEARNING ON A SUBSEQUENT REVERSAL

J. SWELLER

Department of Psychology, University of Adelaide

Two experiments using rats were carried out in which it was shown that a quadratic function can best describe the relation between amount of initial discrimination training and speed of reversal learning for both a difficult visual and an easy spatial task. The results are used to explain the rarity of the over-learning reversal effect (ORE) using easy tasks such as position discriminations. Implications for the attention theory are also discussed.

Introduction

For several years now it has been known that the ORE very rarely occurs in position discrimination tasks. (See reviews by Lovejoy, 1966; Mackintosh, 1965; Paul, 1965; Sperling, 1965.) Since rats normally learn these tasks more rapidly than visual discrimination problems, and since very easy visual discrimination problems also normally fail to show the effect, it has been hypothesised by attention theorists that a difficult discrimination is a necessary condition for the ORE. (Lovejoy, 1966; Mackintosh, 1969; Sutherland and Mackintosh, 1971). The theory assumes that the main effect of overtraining is to increase attention to the relevant dimension. If the relevant dimension is an obvious one as in the case of an easy discrimination, attention to this dimension may be so high at criterion, that overtraining has a minimal effect.

The two experiments reported in the present paper are intended to indicate that the relationship between the degree of original learning and reversal learning is in fact similar for both a difficult visual and an easy spatial discrimination providing that the correct amount of initial training is employed.

Experiment I

Visual discrimination

Method

Subjects. The subjects were 24 experimentally naive male hooded rats approximately 120 days old at the beginning of the experiment. An additional eight subjects were eliminated during pretraining for responding too slowly.

Apparatus. The two-choice, swinging-door apparatus is described in detail elsewhere (Sweller, 1972). Dark grey and light grey painted aluminium doors were used. Their brightness readings using a spot photometer in the normal experimental lighting conditions were 1·2 and 1·7 log foot-lamberts respectively.

Procedure. During the 10 days of pretraining, animals were tamed, reduced to and maintained at 85% of their *ad lib* weight, and trained to run through black–white vertical striped doors for food. All animals experienced locked doors on some occasions. Manual guidance was given throughout in order to equalise experience with both positions.

Following pretraining animals were given 10 non-correction trials a day in groups of three, giving an inter-trial interval of approximately 3 min. The position of the stimuli was varied according to Gellermann series. The negative stimulus door was always locked. Correct responses were rewarded by 30 s access to wet mash. After incorrect responses animals were retained in the apparatus for 10 s.

Design. Animals were randomly assigned to one of four groups of 6 animals each. Half in each group were trained with light grey positive during the initial discrimination while the other half were trained with dark grey positive. Groups 2D and 5D (precriterion groups) received 2 and 5 days' discrimination training before reversal respectively (pilot studies had indicated that it was most unlikely that any overt sign of learning would cocur on Day 5): Group C was trained to a criterion of 18/20 correct responses over two successive days before being reversed: Group OT was trained to the same criterion and then given an extra 150 trials before reversal. The reversal criterion for all animals was 18/20 correct responses over two successive days.

Results

Initial training. No animals in Group 2D or Group 5D showed any overt sign of learning before reversal. On the last day of initial training animals in Group 2D had a total of 29 correct out of 60 responses while those in Group 5D had a total of 30 correct. The maximum number of correct responses was 7 out of 10, scored by one animal in Group 5D.

Group C and Group OT both took 8·83 days to reach criterion (excluding criterion days) on the initial task.

——TAKE IN FIGURE 1—— 3.1. See pp. 88-89

Reversal training—days to criterion. Trend analyses were carried out using orthogonal polynomials. The independent variable—mean number of days on the initial discrimination—was transformed using an $X^1 = (X-1)/X$ transformation in order to "compress" the large difference in number of initial trials between the overtrained animals and the other groups.

The results indicated a significant quadratic component, $F = 5{\cdot}17$, $df = 1, 20$, $P < 0{\cdot}5$. No other trends were significant. Figure 1 graphs the relationship.

In order to facilitate the comparison of the present results with those of previous studies, individual orthogonal comparisons between groups were also carried out. These indicated that (a) Group 2D learned more rapidly than a combination of Groups 5D, C, and OT, $F = 5{\cdot}78$, $df = 1, 20$, $P < 0{\cdot}05$; (b) Group 5D learned more slowly than a combination of Groups C and OT, $F = 4{\cdot}12$, $df = 1, 20$, $P = 0{\cdot}053$; (c) there was no significant differences between Groups C and OT, $F < 1$.

Days of position responding. There was no significant difference in position responding (where position responding is defined as 10 out of 10 responses to one position on any particular day), $F < 1$ (see Table I).

Perseveration to old positive stimulus. There was no significant difference in perseveration (measured by the number of incorrect trials before the first correct trial) between Groups C and OT, $t = 1{\cdot}43$, $df = 10$, $P > 0{\cdot}10$ (see Table I). Perseveration scores for Groups 2D and 5D are meaningless since no overt sign of learning had occurred during the initial discrimination for these groups.

TABLE I

Reversal means

Group	N	Days of position responding	Perseverative trials
2D	6	9·67	—
5D	6	12·33	—
C	6	8·83	11·00
CT	6	7·83	16·33

Experiment II

Spatial discrimination

Method

The subjects were 40 experimentally naive male hooded rats approximately 120 days old at the beginning of the experiment. An additional 13 rats were eliminated during pre-training for responding too slowly and three were eliminated after not obtaining any correct responses during the first three days of initial discrimination training.

The apparatus and pretraining procedure were identical to those employed in Experiment I. The same doors were used during training as were used during pre-training. Both doors were locked on the first trial of the first day for all subjects and the side chosen was subsequently designated the negative stimulus. In all other respects the procedure for each individual trial was identical to that employed in Experiment I.

There were four groups. Groups 2, 4 and 10 were reversed immediately after any 2, 4 and 10 consecutive correct trials respectively. Group OT was reversed after 10 consecutive correct trials plus an additional 50 trials. (Since there were 10 trials per day one would hence expect 90% of the animals to be reversed during a day's run, and 10% at the beginning of a day.) The reversal criterion was any 10 consecutive correct trials for all groups.

Results

Group means are given in Table II.

TABLE II

Group	N	Initial discrimination: Trials to criterion 4	Initial discrimination: Trials to own criterion	Reversal Perseveration trials
2	9	—	6·22	3·67
4	11	9·18	9·18	9·00
10	10	11·10	11·10	7·40
OT	10	9·20	10·00	9·20

Initial training. Using Criterion 2 proved to be an unreliable method of detecting learning. Evidence for this comes from the fact that (a) a total of eight animals in Groups 4, 10 and OT made a total of 23 errors after reaching Criterion 2 and before reaching Criterion 4; and (b) two animals in Group 2 reversed in 0 trials. It is hence probable that chance factors played an important role in the attaining of this criterion. This may be contrasted with Criterion 4: (a) only one animal in Groups 10, and OT made any errors (2) after reaching Criterion 4 and before reaching Criterion 10; (b) the lowest number of perseverative errors before the first correct response in reversal for Group 4 was three. Hence this particular animal made a total of seven consecutive responses to one side. One may conclude that it is improbable that chance factors played a significant role in the attaining of Criterion 4. For this reason, for comparative purposes, mean trials to Criterion 4 are included in Table II for Groups 10 and OT as well as mean trials to each group's own criterion. A similar number of trials was required by Groups 4, 10 and OT to reach Criterion 4, $F < 1$.

Reversal training—trials to criterion. Trend analyses using orthogonal polynomials with an $X^1 = (X - 1)/X$ transformation of the independent variable (mean number of trials on the initial task) indicated a significant quadratic component, $F = 10{\cdot}42$, $df = 1, 36$, $P < 0{\cdot}005$. No other trends were significant. Figure 4·1 graphs the relationship.

Individual orthogonal comparisons indicated that (a) Group 2 learned more rapidly than a combination of Groups 4, 10 and OT, $F = 12{\cdot}17$, $df = 1, 36$,

—TAKE IN FIGURE 4·1— See Pp 115-116

$P < 0{\cdot}005$; (b) Group 4 learned more slowly than a combination of Groups 10, and OT, $F = 4{\cdot}79$, $df = 1, 36$, $P < 0{\cdot}05$; (c) there was no significant difference between Groups 10 and OT, $F < 1$.

Perseveration. Orthogonal comparisons indicated that Group 2 perseverated less than a combination of Groups 4, 10 and OT, $F = 7{\cdot}24$, $df = 1, 36$, $P < 0{\cdot}01$. There were no other significant differences.

Discussion

The general pattern of the trials to reversal criterion results for both experiments is identical. As initial discrimination training increased, reversal to criterion first required more trials but subsequently required less. This result parallels that obtained by Iwahara and Sugimura (1960) using human subjects. It is possible that this quadratic function holds over a wide range of tasks and subjects.

Of importance with respect to the ORE, was the fact that the inflexion point in both experiments occurred at considerably lower levels of initial discrimination training than those normally associated with the non-overtrained group in conventional ORE paradigm experiments. The ORE was not obtained in either experiment using the more conventional criteria, but was obtained using lower levels of initial training. This result is probably analogous to that obtained by Sperling (1970). She found a significant difference between animals trained to a criterion based on 12 trials and those trained to a criterion based on 24 trials or else overtrained, but no significant difference between the 24 trials based criterion animals and overtrained subjects.

The fact that the ORE was obtained using a low criterion on an easy spatial task, suggests the possibility of a relation between task difficulty and criteria of learning such that lower criteria on easier tasks are equivalent to higher criteria on difficult tasks. By using similar criteria for all tasks irrespective of their difficulty, experimenters may have in effect overtrained both groups of the easy ORE paradigm experiments (such as position) eliminating any differential effect on reversal.

As the ORE was not obtained using Group C in Experiment I, this may at first sight tend to contradict the above hypothesis. It should nevertheless be pointed out that the criterion is relatively high. Since the task was learned in approximately the same number of trials as Sperling's (1970) simultaneous discrimination, it is possible that a conventional ORE could have been obtained using a criterion similar to her lower criterion. This would still be far higher than Criterion 4 of Experiment II.

The attention theory (Sutherland and Mackintosh, 1971) can best handle the present data by assuming that even on an easy task (as well as a difficult task), the choice response reaches asymptote before the attending response, resulting in more rapid reversal for groups given additional training. This assumption necessitates the further assumption that differences in task difficulty are primarily (though not necessarily entirely) due to differences in rate of change of the relevant attending response, rather than differences in its base value. At present the theory assumes that for easy tasks, attention to the relevant dimension is relatively high even before training commences, and hence reaches asymptote either simultaneously with, or even before the choice response. This would not allow the ORE to occur in easy spatial tasks no matter what criterion was used.

It might also be noted that the results of Experiment I may possibly be derivable from Spence's (1936) theory of discrimination learning. This theory predicts that during a visual discrimination, naive animals will build up strong position habits before criterion is attained. It may hence be argued that Group 5D learned the reversal more slowly than the other groups due to stronger position habits.

There are two problems associated with this interpretation. First, probably at the completion of criterion training and certainly at the completion of overtraining, the differences in the habit strengths of the positive and negative cues are far greater according to the theory, than the maximum difference in habit strength between the left and right goal boxes during the pre-criterion phase. Consequently, reversal should still be more difficult for Groups C and OT. The second problem is that this explanation is inapplicable to Experiment II, for which a similar pattern of results was obtained.

Exp. Psychology Galley 12

The writer wishes to thank Dr A. H. Winefield for valuable discussion.

References

Iwahara, I. and Sugimura, T. (1960). Discrimination reversal as a function of degree of original learning. *Psychologia*, 3, 21–26.

Lovejoy, E. (1966). Analysis of the overlearning reversal effect. *Psychological Review*, 73, 87–102.

Mackintosh, N. J. (1965). Selective attention in animal discrimination learning. *Psychological Bulletin*, 64, 124–150.

Mackintosh, N. J. (1969). Further analysis of the overtraining reversal effect. *Journal of Comparative and Physiological Psychology*, 67, (2 Pt. 2).

Paul, C. (1965). Effects of overlearning upon single habit reversal in rats. *Psychological Bulletin*, 63, 65–72.

Spence, K. W. (1936). The nature of discrimination learning in animals. *Psychological Review*, 43, 427–49.

Sperling, S. E. (1965). Reversal learning and resistance to extinction: A review of the rat literature. *Psychological Bulletin*, 63, 281–97.

Sperling, S. E. (1970). The ORE in simultaneous and differential reversal: Acquisition task, acquisition criterion, and reversal task. *Journal of Experimental Psychology*, 84, 349–60.

Sutherland, N. S. and Mackintosh, N. J. (1971). Mechanisms of animal discrimination learning. New York: Academic Press.

Sweller, J. (1972). A test between the selective attention and stimulus generalisation interpretations of the easy-to-hard effect. *Quarterly Journal of Experimental Psychology*, 24, 352–5.

Received 27 *May* 1972

Journal of Experimental Psychology, 1973, in press.

THE EFFECT OF AMOUNT OF INITIAL TRAINING ON CONCEPT SHIFT PROBLEMS

J. Sweller

Department of Psychology
The University of Adelaide

The writer wishes to thank Dr. A.H. Winefield for valuable discussion.

Abstract

Two concept learning experiments using adult human Ss were carried out. The first indicated that the overtraining reversal effect (ORE) could be obtained by the use of a very low Task 1 criterion of learning rather than a conventional criterion. The second indicated that while low criteria on serial shift learning tasks could result in eventual nonlearning, higher criteria could result in exceedingly rapid learning of the same tasks. The results were discussed in terms of the S's hypothesis testing strategies.

Levine (1969) found that in a concept learning task, the effect of negative feedback following a response almost invariably resulted in Ss abandoning the hypothesis held on that particular trial. One might expect the same sort of effect to occur on the first trial of a shift learning task. If trained to a reliable criterion on the initial task, Ss should be holding a hypothesis which will be disconfirmed on the first shift trial (assuming that there is no overlap between the correct response sets for the two tasks).

It can nevertheless be predicted that if training on the first task is extended for a sufficiently long period (i.e. overtraining), the originally correct hypothesis, while abandoned, will still be used to help find the new solution. Lesser Task 1 training may result in the hypothesis not only being abandoned, but not even being used as a starting point for new hypotheses. Evidence for this could be obtained from the speed with which the shift task is learned under conditions where the correct initial task hypothesis is related in some way to the correct shift task hypothesis.

Experiment 1. This experiment tested the prediction using a reversal shift. A stimulus universe sufficiently large to allow nonrepetition of any stimulus on the initial task was used in order to ensure that all Ss who learned the task did so by testing the correct hypothesis rather than by simple rote learning. A multiple rather than a dual response universe was employed in order to retain statistical reliability while using one correct response as a criterion of learning.

Method. The Ss were 16 students who were fulfilling an introductory psychology course requirement. Four additional Ss were eliminated after failing to solve the initial task within 64 trials.

The stimuli consisted of all the numbers between 11 and 88 (inclusive) with the exception of those numbers containing a 0 or a 9. There are 64 such numbers.

A Kodak Carousel slide projector projected each item onto a screen 120cm away giving a 10cm by 5cm image. The S sat immediately to the right of the projector.

The slides were ordered randomly in the projector with the exception that each stimulus occurred once and once only in the first 64, and that the 25th.-40th. stimuli were then repeated in the same order. This made a total of 80 slides, in a sequence which could be repeated indefinitely.

The stimuli were presented to the Ss, one at a time. Subjects were told that they were to respond to each stimulus by calling out any number between 0 and 110 and that the E would then tell them the correct number that should have been said. They were instructed to learn the relation between the stimulus and the correct response. The stimuli remained in front of the Ss during feedback. The initial task, consisted in adding the sum of the two digits of which each number was composed, to the number itself, e.g. The correct response to the stimulus "23" was "28". Subjects who had not learned this task within 64 trials were eliminated from the experiment. The reversal task consisted of subtracting the sum of the two digits from the number itself. Hence the hypotheses or rules necessary for the solution of both tasks had a large number of common elements.

There were two groups. The first group was trained to a criterion of at least 1 correct response plus 1 perseverative trial before being reversed (Group 1). This meant that while Ss had to respond on the basis of the first task for at least two consecutive trials before being reversed, for the second trial they did not obtain feedback on the basis of the first task, but on the basis of the reversal. Initial task feedback continued in the case of Ss who made a single correct response followed by an error. Hence while the E's criterion was two consecutive correct responses - a criterion most unlikely to be attained purely by chance - The S was in effect reversed after one correct response.

The second group was trained to a criterion of 10 consecutive correct responses before being reversed (Group 10). The reversal criterion was 10 consecutive correct responses for both groups.

Results. Analyses of trials to criterion were done on logarithmic transformed data. Group 1 took a mean (arithmetic) of 14.75 trials to reach the initial task criterion (excluding the criterion trial) while Group 10 took 22.12 trials. There was no significant difference between groups on this measure, $t < 1$. No S in Group 10 made any errors after two consecutive correct responses indicating that the criterion used for Group 1 represented learning rather than chance factors.

Group 1 took a mean of 14.25 trials to reach the reversal criterion while Group 10 took 1.12 trials. There was a significant difference between groups on this measure, $t(14) = 3.42$, $p < .005$.

Additional information concerning the problem solving process in this type of task may be obtained from the responses made during the presolution period of Task 1. On the last trial before criterion, while the Ss had not discovered the correct solution to the task, they were nevertheless not responding in a completely random manner. On this particular trial, all sixteen of the Ss responded with a number that was higher than the stimulus number.

This may be contrasted with the responses on the first trial of Task 1. On this trial, ten of the Ss simply read out the stimulus number, four responded with a lower and two with a higher number. Clearly, before actually discovering the relevant rule, Ss realised that the correct response number was always higher than the stimulus number.

There is no evidence that Ss were able to further narrow down the correct response prior to solution. It was hypothesised that just before criterion, they may have noticed that the larger the two stimulus digits, the greater the difference between the stimulus number and the correct response number. Using the last trial before criterion, three Pearson r correlations were carried out with the difference between the stimulus number and the S's response as one variable in each case, and the first digit, the second digit or the sum of the two digits as the other variable. Values of r (14) = -.17, -.32, and -.31 were obtained respectively. These are all in the wrong direction and not significant, $p > .10$.

Discussion. The shift task results indicated that amount of training strongly influenced the extent to which negative feedback induced Ss to completely abandon a previously held hypothesis. The overtraining reversal effect (ORE) obtained was probably caused by most Group 1 Ss not only abandoning their Task 1 hypothesis, but also failing to use it in the solution of the reversal. Since seven of the eight Group 10 Ss tested the new correct hypothesis on the second reversal trial and the eighth S on the third reversal trial, it can readily be concluded that while these Ss immediately abandoned their Task 1 hypothesis, they nevertheless used it to help find the solution to Task 2.

The present results may also have relevance for more conventional ORE paradigm experiments. The effect could obviously not have been obtained using Group 10 as a criterion (lesser trained) group. This may explain why some experiments (e.g. Lowenkron and Driessen, 1971) failed to obtain the ORE when using Ss who were hypothesis testing. Low initial task criteria may be necessary under these conditions.

Experiment 2. This experiment was designed to indicate that differences in speed of shift learning due to differences in the amount of training on previous tasks could be substantially increased by using serial shift tasks rather than a single shift. A serial shift learning task with specific and similar rules required for the solution of each shift, may greatly magnify the difference between a low and a high criterion group, as compared with a situation in which there is only one shift task.

Method. The Ss were 20 students who were fulfilling an introductory psychology course requirement. Seven additional Ss were eliminated after failing to solve the initial task within 64 trials.

The stimulus materials, apparatus, and general procedure were identical to Experiment 1. There were five tasks with half of the Ss (Group 1) being trained to Criterion 1 (as in Experiment 1) and the other half (Group 10) to Criterion 10 on each task. Training was terminated for those S who did not reach criterion within 40 trials on any of the shift tasks. The first task consisted of adding the sum of the two digits of which each number was composed, to the number itself (as in Experiment 1): the second task consisted of the first task manipulation, minus 2: the third task consisted of the first task manipulation, plus 5: the fourth task consisted of the first task manipulation, plus 2: the fifth task consisted of the first task manipulation, minus 1. Hence the correct response to stimulus "23" would have been "28", "26", "33", "30", and "27", respectively for each of the 5 tasks.

Results. The data are summarised in Table 1. The letter N refers to the number of Ss attaining criterion on each task. Since training was terminated for Ss who did not reach criterion on any particular task, the number of Ss given each shift task (Tasks 2, 3, 4 and 5) is equal to

Table 1.

		Task 1	2	3	4	5
	N	10	5	1	1	1
Group 1	Mean trials to criterion	15.4	-	-	-	-
	N	10	10	9	9	9
Group 10	Mean trials to criterion	14.8	5.3	3.33	2.67	1.55

the N for the preceding task. Mean trials to criterion for Group 10 only includes Ss who learned the task in question. The criterion used for this measure was Criterion 1 - two consecutive correct responses.

All trials to criterion analyses were done on logarithmic transformed data. There was no significant difference in trials to criterion between the two groups on Task 1, $t < 1$. The enormous differences between the groups on all subsequent problems (caused by almost all Group 1 Ss being unable to learn these problems) obviously precluded the use of a similar analysis for the shifts. A Fisher exact probability test indicated a significantly decreased number of Group 1 as compared to Group 10 Ss, who learned Task 2, $p < .05$. The same effect was also found for Tasks 3, 4, and 5, $p < .01$.

Excluding the one S in Group 10 who failed to learn Task 3 (see Table 1), a significant decrease in trials to criterion across tasks was found, $F (4, 32) = 9.58$, $p < .005$. A similar analysis for Group 1 was not possible since only one S reached Task 5.

Presolution behaviour on Task 1 largely replicated the Experiment 1 data. On the last precriterion trial, eighteen of the twenty Ss responded with a number that was higher and two with one that was lower than the stimulus number. In contrast, on the first trial, ten of the Ss read out the stimulus number, five responded with a lower and five with a higher number.

For the last precriterion trial, again no relation was found using the difference between the stimulus number and the response as one variable, and the first digit, the second digit, or the sum of the two digits as the other variable. Values of $r (14) = -.05$, $+.25$, and $+.15$ were obtained respectively. None of these are significant, $p > .10$.

Discussion. The shift data indicate that under appropriate conditions a simple change in criterion level can have the consequence of a totally reversed pattern of results in serial shift learning. With the exception of the one S who failed to reach Task 5, Group 10 Ss demonstrated a rapidly decreasing trend of trials to criterion across tasks. Group 1 Ss on the other hand, not only found successive shift tasks more difficult, but in most cases, within the limitation imposed by the maximum number of trials allowed before the discontinuation of training, found the latter shift tasks insoluble. Half of the Ss could not solve Task 2, and of the remainder, only one was able to solve the subsequent tasks.

Levine (1971) and Ress and Levine (1966) also demonstrated nonlearning by some Ss of a task which other Ss under different conditions found exceedingly easy. They discovered that if Ss were trained on a series of complex position discrimination, they tended to find a subsequent simple discrimination (e.g. large circle-small circle), insoluble. Levine (1971) theorised that as a consequence of the position discriminations, Ss were testing hypotheses from a set which did not include the new relevant hypothesis. This either retarded or prevented discovery of the solution.

Experiment 2 may indicate that under Group 1 conditions, Ss not only failed to use earlier successful hypotheses to help formulate new ones as in Experiment 1, but in addition rejected the entire relevant hypothesis set (where the hypotheses in the set consisted of adding the sum of the two digits to the number itself plus or minus a constant). Unlike Levine's tasks, they did this despite having previously tested a correct hypothesis (or hypotheses) from the set and subsequently receiving feedback consistent with another hypothesis from the same set. Group 10 Ss on the other hand presumably used previously correct hypotheses or rules to help formulate subsequently correct rules. They were consequently testing hypotheses from within the set, allowing them to find the shift task solutions rapidly.

REFERENCES

Levine, M. Neo-noncontinuity theory. In G.H. Bower & J.T. Spence (Eds.). The psychology of learning and motivation. New York: Academic Press, 1969.

Levine, M. Hypothesis theory and nonlearning despite ideal S-R-reinforcement contingencies. Psychological Review, 1971, 78, 130-140.

Lowenkron, B. & Dreissen, E.C. Solution mode in concept identification problems and magnitude of the over-learning reversal effect. Journal of Experimental Psychology, 1971, 89, 85-91.

Ress, F.C. & Levine, M. Einstellung during simple discrimination learning. Psychonomic Science, 1966, 4, 77-78.

BIBLIOGRAPHY

AMSEL, A. Frustrative nonreward in partial reinforcement and discrimination learning: Some recent history and a theoretical extension. Psychological Review, 1962, 69, 309-328.

BENSBERG, G.J. Jr. Concept learning in mental defectives as a function of appropriate and inappropriate "attention sets". J. Ed. Psych., 1958, 49, 137-143.

BERLYNE, D.E. Conflict, arousal, and curiosity. New York: McGraw Hill, 1960.

BEVAN, W. & SAUGSTAD, P. Breadth of experience, ease of discrimination and efficiency of generalisation. Brit. J. Psych., 1955, 66, 13-19.

BIEDERMAN, G.B. The overlearning reversal effect: a function of the non-monotonicity of the negativity of S- during discriminative training. Psych. Sci., 1967, 7, 385-386.

BIRCH, D. A motivational interpretation of extinction. Nebraska Symposium on motivation, 1961, 9, 179-202.

BIRCH, D., ISON, J.R. & SPERLING, S.E. Reversal learning under single-stimulus presentation. J. Exp. Psych., 1960, 60, 36-40.

BIRNBAUM, I.M. Discrimination reversal, extinction, and acquisition after different amounts of overtraining. Am. J. Psych., 1967, 80, 363-369.

BJORKMAN, M. & OTTANDER, C. Improvement of discriminative ability by training. Reports from the Psych. Lab., University of Stockholm, 1959, No.66.

BOGARTZ, W. Effects of reversal and nonreversal shifts with CVC stimuli. J. Verb. Learning and Verb. Behav., 1965, 4, 484-488.

BROOKSHIRE, K.H., WARREN, J.M. & BALL, G.G. Reversal and transfer learning following overtraining in rat and chicken. J. Comp. & Physiol. Psych., 1961, 54, 98-102.

BRUNER, J.S., MANDLER, J.K., O'DOWD, D. & WALLACH, M.A. The role of overlearning and drive level in reversal learning. J. Comp. & Physiol. Psych., 1958, 51, 607-613.

BUSS, A.H. Rigidity as a function of reversal and non-reversal shifts in the learning of successive discrimination. J. Exp. Psychol., 1953, 45, 75-81.

CAPALDI, E.J. Overlearning reversal effect in a spatial discrimination task. Perceptual & Motor Skills, 1963, 16, 335-336.

CAPALDI, E.J. & STEVENSON, H.W. Response reversal following different amounts of training. J. Comp. & Physiol. Psych., 1957, 80, 195-198.

CAUL, W.F. & LUDVIGSON, H.W. The effect of overlearning on response shifting. Psych. Sci., 1964, 159-160.

CLAYTON, K.N. Overlearning and reversal of a spatial discrimination by rats. Perceptual & Motor Skills, 1963, 17, 83-85.(a).

CLAYTON, K.N. Reversal performance by rats following overlearning with and without irrelevant stimuli. J. Exp. Psych., 1963, 66, 255-259.(b).

CLAYTON, K.N. The overlearning reversal effect: Dependent on a confound with drive? Paper presented at the Southeastern Psych. Assoc. Meeting, Atlanta, April, 1965.

COATE, W.B. & GARDNER, R.A. Sources of transfer from original training to discrimination reversal. J. Exp. Psych., 1965, 70, 94-97.

CROSS, H.A. & TYER, Z.E. The overlearning reversal effect in preschool children as a function of age. Psych. Sci., 1966, 6, 175-176.

DANKS, J.H. & GLUCKSBERG, S. Effects of level of initial training on reversal shift performance and clustering in free recall: A test of the mediated association hypothesis. J. Verb. Learning & Verb. Behav., 1968, 7, 373-379.

D'AMATO, M.R. & JAGODA, H. Effects of extinction trials on discrimination reversal. J. Exp. Psych., 1960, 89, 254-260.

D'AMATO, M.R. & JAGODA, H. Analysis of the role of overlearning in discrimination reversal. J. of Exp. Psych., 1961, 61, 45-50.

D'AMATO, M.R. & JAGODA, H. Overlearning and position reversal. J. of Exp. Psych., 1962, 64, 117-122.

D'AMATO, M.R. & SCHIFF, D. Further studies of overlearning and position reversal learning. Psych. Rep., 1964, 14, 380-382.

D'AMATO, M.R. & SCHIFF, D. Overlearning and brightness discrimination reversal. J. Exp. Psych., 1965, 69, 375-381.

DEUTSCH, J. & BIEDERMAN, G.B. The monotonicity of the negative stimulus during learning. Psych. Sci., 1965, 3, 391-392.

EIMAS, P.D. Effect of overtraining and age on intra-dimensional and extradimensional shifts in children. J. Exp. Child Psych., 1966, 3, 348-385.(a).

EIMAS, P.D. Effects of overtraining, irrelevant stimuli, and training task on reversal discrimination learning. J. Exp. Child Psych., 1966, 3, 315-323.(b).

EIMAS, P.D. Overtraining and reversal discrimination learning in rats. Psych. Rec., 1967, 17, 239-248.

ENGLUND, S.A. & LUNDBERG, I. Discrimination learning: Some restricting criteria and illustrative experiments. Reports from the Psych. Lab., Univ. of Stockholm, 1963, No. 142.

ERLEBACHER, A. Reversal learning in rats as a function of percentage of reinforcement anddegree of learning. J. Exp. Psych., 1963, 66, 84-90.

FIDELL, S. & BIRCH, D. The effect of overtraining on reversal learning under conditions of no reinforcement. Psych. Sci., 1967, 8, 27-28.

FURSTENAU, P. & SCHAEFFER, B.A. Overtraining, extinction, and reversal in the rat. J. Comp. & Physiol. Psych., 1970, 71, 292-297.

FURTH, H.G. & YOUNISS, J. Effect of overtraining on three dimensional shifts in children. J. Comp. & Physiol. Psych., 1964, 57, 290-293.

GIBSON, E.J. Improvement in perceptual judgements as a function of controlled practice or training. Psych. Bull., 1953, 50, 401-431.

GIBSON, E.J. Development of perception: Discussion of depth compared with use of graphic symbols. Monogr. Res. Child Devel., 1963, 28, 5-23.

GIBSON, E.J. Principles of perceptual learning and development. New York: Appleton Century Crofts, 1969.

GIBSON, J.J. & GIBSON, E.J. Perceptual learning: Differentiation or enrichment? Psych. Rev., 1955, 62, 32-41.

GOLLIN, E.S. Reversal learning and conditional discrimination in children. J. Comp. & Physiol. Psych., 1964, 58, 441-445.

GOODWIN, W.R. & LAWRENCE, D.H. The functional independence of two discrimination habits associated with a constant stimulus situation. J. Comp. & Physiol. Psych., 1955, 48, 437-443.

GRANT, D.A. & BERG, E.A. A behavioural analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card sorting problem. J. Exp. Psych., 1948, 38, 404-411.

GRANT, D.A. & COST, J.R. Continuities and discontinuities in conceptual behaviour in a card sorting problem. J. Gen. Psych., 1954, 50, 237-244.

GUY, D.E., VAN FLEET, F.M. & BOURNE, L.E. Jr. Effects of adding a stimulus dimension prior to a nonreversal shift. J. Exp. Psych., 1966, 72, 161-168.

HARROW, M. & FRIEDMAN, G.B. Comparing reversal and non-reversal shifts in concept formation with partial reinforcement controlled. J. Exp. Psych., 1958, 55, 592-597.

HEAL, L.W. The role of cue value, cue novelty, and overtraining in the discrimination shift performance of retardates and normal children of comparable discrimination ability. J. Exp. Child Psych., 1966, 4, 126-142.

HEIMER, W.I. & TATZ, S.J. Practice effects, knowledge of results and transfer in pitch discrimination. Technical Report: Navtradevcen IH-52, Port Washington, N.Y., 1966.

HILL, W.F. & SPEAR, N.E. A replication of overlearning and reversal in a T maze. J. Exp. Psych., 1963, 65, 317.

HILL, W.F., SPEAR, N.E. & CLAYTON, K.N. T-maze reversal after several different overtraining procedures. J. Exp. Psych., 1960, 59, 198-204.

HOCHMAN, S.H. The effects of overtraining on a reversal and nonreversal shift. Psych. Sci., 1966, 4, 235-236.

HOOPER, R. Variables controlling the overlearning reversal effect (ORE). J. Exp. Psych., 1967, 73, 612-619.

HOUSE, B. & ZEAMAN, D. Reversal and nonreversal shifts in discrimination learning in retardates. J. Exp. Psych., 1962, 63, 444-451.

HULL, C.L. Principles of Behaviour. New York: Appleton-Century, 1943.

ISON, J.R. & BIRCH, D. T-maze reversal following differential end box placement. J. Exp. Psych., 1961, 62, 200-202.

IWAHARA, S. & SUGIMURA, T. Discrimination reversal as a function of degree of original learning. Psychologia, 1960, 3, 21-26.

IWAHARA, S. & SUGIMURA, T. The effect of different amounts of training upon shifted discrimination learning as a function of intellectual level. Psychologia, 1962, 5, 93-98.

KELLEHER, R.T. Discrimination learning as a function of reversal and nonreversal shifts. J. Exp. Psych., 1956, 51, 379-384.

KENDLER, H.H. & D'AMATO, M.F. A comparison of reversal shifts and nonreversal shifts in human concept formation behaviour. J. Exp. Psych., 1955, 165-174.

KENDLER, H.H. & KENDLER, T.S. Mediation and conceptual behaviour. In: Spence & Spence, The psychology of learning and motivation, Vol.2., pp.197-244. Academic Press: New York, 1968.

KENDLER, H.H. & KENDLER, T.S. Vertical and horizontal processes in problem solving. Psych. Rev., 1962, 69, 1-15.

KENDLER, H.H. & KENDLER, T.S. Developmental processes in discrimination learning. Human Develop., 1970, 13, 65-89.

KENDLER, H.H., KENDLER, T.S. & SANDERS, J. Reversal and partial reversal shifts with verbal material. J. Verb. Learning & Verb. Behav., 1967, 6, 117-127.

KENDLER, H.H. & KIMM, J. Reinforcement and cue factors in reversal learning. Psych. Sci., 1964, 1, 309-310.

KENDLER, H.H. & KIMM, J. Reversal learning as a function of the size of reward during acquisition and reversal. J. Exp. Psych., 1967, 73, 66-71.

KENDLER, H.H. & LACHMAN, R. Habit reversal as a function of schedule of reinforcement and drive strength. J. Exp. Psych., 1958, 55, 586-591.

KENDLER, H.H. & MAYZNER, M.S. Jr. Reversal and nonreversal shifts in card sorting tasks with two or four sorting categories. J. Exp. Psych., 1956, 51, 244-248.

KENDLER, T.S., KENDLER, H.H. & LEARNARD, B. Mediated responses to size and brightness as a function of age. Amer. J. Psych., 1962, 75, 571-586.

KOMAKI, H. The facilitative effect of overlearning in discrimination learning by white rats. Psychologia, 1961, 4, 28-35.

LAWRENCE, P.A. The transfer of a discrimination along a continuum. J. Comp. & Physiol. Psych., 1952, 45, 511-516.

LAWRENCE, D.H. The applicability of generalisation gradients to the transfer of a discrimination along a continuum. J. Gen. Psych., 1955, 52, 37-48.

LAWRENCE, D.H. & MASON, W.A. Systematic behaviour during discrimination reversal and change of dimensions. J. Comp. & Physiol. Psych., 1955, 48, 267-271.

LEBOW, M.D. Age, degree of training, and type of extra-dimensional shift in normally intelligent humans. J. Exp. Ed., 1971, 39, 46-53.

LEVINE, M. Neo-noncontinuity theory. In: G.H. Bower & J.T. Spence (Eds.). The psychology of learning and motivation. New York: Academic Press, 1969.

LEVINE, M. Hypothesis theory and nonlearning despite ideal S-R reinforcement contingencies. Psych. Rev., 1971, 78, 130-140.

LOGAN, F.A. Transfer of discrimination. J. Exp. Psych., 1966, 71, 616-618.

LOVEJOY, E. Analysis of the overlearning reversal effect. Psych. Rev., 1966, 73, 87-103.

LOVEJOY, E. Attention and discrimination learning. San Francisco: Holden-Day, 1968.

LOWENKRON, B. Nonoutcome trial behaviour: A predictor of solution shift performance and the effects of overtraining. J. Exp. Psych., 1969, 81, 484-488.

LOWENKRON, B. & DRIESSEN, E.C. Solution mode in concept identification problems and magnitude of the over-learning reversal effect. J. Exp. Psych., 1971, 89, 85-91.

LUDVIGSON, H.W. & CAUL, W.F. Relative effect of over-learning on reversal and nonreversal shifts with two and four sorting categories. J. Exp. Psych., 1964, 68, 301-306.

LUKASZEWSKA, I. Some further failures to find the visual overlearning reversal effect in rats. J. Comp. Physiol. Psych., 1968, 65, 359-361.

MACKINTOSH, N.J. The effects of overtraining on a reversal and nonreversal shift. J. Comp. & Physiol. Psych., 1962, 58, 555-559.

MACKINTOSH, N.J. The effect of irrelevant cues on reversal learning in the rat. Brit. J. Psych., 1963, 54, 127-134.(a).

MACKINTOSH, N.J. Extinction of a discrimination habit as a function of overtraining. J. Comp. & Physiol.Psych., 1963, 56, 842-847.(b).

MACKINTOSH, N.J. Selective attention in animal discrimination learning. Psych. Bull., 1965, 64, 124-180.(a).

MACKINTOSH, N.J. Overtraining, extinction, and reversal in rats and chicks. J. Comp. & Physiol. Psych., 1965, 59, 31-36.(b).

MACKINTOSH, N.J. Overtraining, transfer to proprioceptive control, and position reversal. Quart. J. Exp. Psych., 1965, 17, 26-36.(c).

MACKINTOSH, N.J. Further analysis of the overtraining reversal effect. J. Comp. & Physiol. Psych., Monograph, 1969, 67, No.2., Part 2.

MACKINTOSH, N.J. & LITTLE, L. An analysis of transfer along a continuum. Canadian J. Psych., 1970, 24, 362-369.

MANDLER, J.M. Behaviour changes during overtraining and their effects on reversal and transfer. Psychonomic Monograph Supplement, 1966, 1, 187-202.

MANDLER, J.M. The effect of overtraining on the use of positive and negative stimuli in reversal and transfer. J. Comp. Physiol. Psych., 1968, 66, 110-115.

MANDLER, J.M. & HOOPER, W.R. Overtraining and goal approach strategies in discrimination reversal. Quart. J. Exp. Psych., 1967, 19, 142-149.

MARQUETTE, B.W. & GOULET, L.R. Mediated transfer in reversal and nonreversal shift paired-associate learning. J. Exp. Psych., 1968, 76, 89-93.

MARSH, G. Effects of overtraining on reversal and non-reversal shifts in nursery school children. Child Dev., 1964, 35, 1367-1372.

McALLISTER, M.J., CAPEHART, J.E., ROGERS, C.A. A transfer approach to the ORE. Perceptual and Motor Skills, 1970, 30, 971-977.

McCLELLAND, D.C. Studies in serial verbal discrimination learning, IV: Habit reversal after two degrees of learning. J. Exp. Psych., 1943, 33, 457-470.

NOBLE, C.E. Measurements of association value (a), rated associations (a'), and scaled meaningfulness (m') for the 2100 CVC combination of the English alphabet. Psych. Rep., 1961, 8, 487-521.

NORTH, A.J. & CLAYTON, C.A. Irrelevant stimuli and degree of learning in discrimination learning and reversal. Psych. Rep., 1959, 5, 405-408.

OHLRICH, E.S. & ROSS, L.E. Reversal and nonreversal shift learning in retardates as a function of overtraining. J. Exp. Psych., 1966, 22, 622-624.

PAUL, C. Effects of overlearning upon single habit reversal in rats. Psych. Bull., 1965, 63, 68-72.

PAUL, C. Effects of overtraining and two noncorrection training procedures upon a brightness discrimination reversal. Psych. Sci., 1966, 5, 423-424.(a).

PAUL, C. Verbal discrimination reversal as a function of overlearning and percentage of items reversed. J. Exp. Psych., 1966, 72, 271-275.(b).

PAUL, C. Verbal discrimination reversal as a function of overlearning and percentage of items reversed: An extension. J. Verb. Learning & Verb. Behav., 1968, 7, 270-272.

PAUL, C. Acquired equivalence of correct alternatives after verbal discrimination learning. J. Exp. Psych., 1970, 86, 123-125.

PAUL, C. & CALLAHAN, C. Effects of overtraining on verbal discrimination shifts: A differentiation-suppression hypothesis. J. Exp. Psych., 1972, 92, 198-206.

PAUL, C, CALLAHAN, C., MERENESS, M. & WILHELM, K. Transfer activated response sets: The effect of overtraining and percentage of items shifted on a verbal discrimination shift. J. Exp. Psych., 1968, 78, 488-493.

PAUL, C. & HAVLENA, J. Effects of overlearning and spatial delay of reinforcement upon a discrimination reversal. Psych. Rep., 1965, 16, 79-83.

PAUL, C., HOFFMAN, C.D. & DICK, S. Acquired (conditional) equivalence: A basis for response-set effects in verbal discrimination reversal performance. J. Exp. Psych., 1970, 85, 361-367.

PAUL, C. & KESNER, R. Effects of overlearning trials upon habit reversal under conditions of aversive stimulation. Psych. Rec., 1963, 13, 361-363.

PAUL, C. & PAUL, H. Transfer activated response sets in verbal learning and transfer. Psych. Rev., 1968, 75, 537-549.

PAVLOV, I.P. Conditioned reflexes (translated by G.V. Anrep). London: Oxford University Press, 1927.

PUBOLS, B.H. Jr. The facilitation of visual and spatial discrimination reversal by overlearning. J. Comp. Physiol. Psych., 1956, 49, 243-248.

REID, L.S. The development of noncontinuity behaviour through continuity learning. J. Exp. Psych., 1953, 46, 107-112.

RESS, F.C. & LEVINE, M. Einstellung during simple discrimination learning. Psych. Sci., 1966, 4, 77-78.

RICHMAN, C.L. & COUZENS, W. Undertraining reversal effect in rats. J. Exp. Psych., 1970, 86, 340-342.

RICHMAN, C.L. & TRINDER, J. Effects of a novel stimulus dimension on discrimination learning. J. Exp. Psych., 1968, 77, 163-165.

ROSS, L.E. The effect of equal reinforcement of the positive and negative discriminanda of a learned discrimination. J. Comp. Physiol. Psych., 1962, 55, 260-266.

SCHADE, A.F. & BITTERMAN, M.E. Improvement in habit reversal as related to dimensional set. J. Comp. Physiol. Psych., 1966, 62, 43-48.

SCHAEFFER, B. & ELLIS, S. The effects of overlearning on children's nonreversal and reversal learning using unrelated stimuli. J. Exp. Child Psych., 1970, 10, 1-7.

SHEPP, B.E. & TURRISI, F.D. Effects of overtraining on the acquisition of intradimensional and extradimensional shifts. J. Exp. Psych., 1969, 82, 46-51.(a).

SHEPP, B.E. & TURRISI, F.D. Effects of training procedures on transfer of observing and instrumental responses in discriminative reversal. J. Comp. Physiol. Psych., 1964, 69, 522-527.(b).

SIEGEL, S. Overtraining and transfer processes. J. Comp. Physiol. Psych., 1967, 64, 471-477.

SINGER, B., ZENTALL, T. & RILEY, D.A. Stimulus generalisation and the easy-to-hard effect. J. Comp. Physiol. Psych., 1969, 69, 528-535.

SITTERLEY, T.E. & CAPEHART, J.E. Human successive discrimination reversal: Effects of overtraining and reinforcement. Psych. Sci., 1966, 4, 293-294.

SLAMECKA, N.J. A methodological analysis of shift paradigms in human discrimination learning. Psych. Bull., 1968, 69, 423-438.

SPERLING, S.E. Reversal learning and resistance to extinction: A review of the rat literature. Psych. Bull., 1965, 63, 281-297.(a).

SPERLING, S.E. Reversal learning and resistance to extinction: A supplementary report. Psych. Bull., 1965, 64, 310-312.(b).

SPERLING, S.E. The ORE in simultaneous and differential reversal. Acquisition tasks, acquisition criterion and reversal task. J. Exp. Psych., 1970, 94, 349-360.

SPENCE, K.W. The nature of discrimination learning in animals. Psych. Rev., 1936, 43, 427-449.

STEINMETZ, J.I. & TURNAGE, T.W. An empirical index for ease of reversal learning. Psych. Sci., 1966, 6, 467-468.

STEVENSON, H.W. & MOUSHEGION, G. The effect of instructions and degree of training on shifts of discrimination responses. Am. J. Psych., 1956, 69, 281-284.

STEVENSON, H.W. & WEIR, M.W. Response shift as a function of overtraining and delay. J. Comp. Physiol. Psych., 1959, 52, 327-329.

STEVENSON, H.W. & ZIGLER, E.F. Discrimination learning and rigidity in normal and feebleminded individuals. J. Personality, 1957, 25, 699-711.

SUGIMURA, T. Discrimination shifts as a function of degree of original learning and materials in the original and shifted discrimination tasks. Japanese Psych. Research, 1960, 2, 51-59.

SUGIMURA, T. Effect of degree of original learning and time interval between two tasks on reversal shift. Psych. Reports, 1965, 16, 618.

SUGIMURA, T. Consecutive intradimensional, extra-dimensional and control of shifts in kindergarten children. Japanese Psych. Research, 1970, 12, 36-43.

SUTHERLAND, N.S. Stimulus analysing mechanisms. In: Proceedings of a symposium on the mechanisation of thought processes. Vol.2. London: H.M.S.O., 1959, pp. 575-609.

SUTHERLAND, N.S. The learning of discriminations by animals. Endeavour, 1964, 23, 148-152.

SUTHERLAND, N.S. & ANDELMAN, L. Effects of overtraining on intra- and extra-dimensional shifts. Psych. Sci., 1969, 15, 253-254.

SUTHERLAND, N.S. & MACKINTOSH, N.J. Mechanisms of animal discrimination learning. Academic Press: New York, 1971.

TEMPONE, B.J., CAPEHART, J., ATWOOD, G.L. & GOLDING, S. The overtraining reversal effect under two types of discrimination. Psych. Sci., 1966, 5, 229-230.

THEIOS, J. & BLOSSER, D. The overlearning reversal effect and magnitude of reward. J. Comp. Physiol. Psych., 1968, 59, 252-257.

THEIOS, J. & BRELSFORD, J. Overlearning-extinction-effect as an incentive phenomenon. J. Exp. Psych., 1964, 67, 463-467.

TIGHE, T.J. Reversal and nonreversal shifts in monkeys. J. Comp. Physiol. Psych., 1964, 58, 324-326.

TIGHE, T.J., BROWN, P.L., & YOUNGS, E.A. The effect of overtraining on the shift behaviour of albino rats. Psych. Sci., 1965, 2, 141-142.

TIGHE, L.S. & TIGHE, T.J. Overtraining and discrimination shift behaviour in children. Psych. Sci., 1965, 2, 365-366.

TURNAGE, T.W. & STEINMETZ, J.T. Criterion level and task difficulty as determinants of reversal learning. Psych. Sci., 1968, 12, 131-132.

TURNER, C. & MACKINTOSH, N.J. Continuity theory revisited: Comments on Wolford & Bower. Psych. Rev., 1970, 77, 577-580.

UHL, N.P. Intradimensional and extradimensional shifts as a function of amount of training and similarity between training and shift stimuli. J. Exp. Psych., 1966, 72, 429-433.

VAUGHTER, R.M. & CROSS, H.A. Discrimination reversal performance in children as a function of pre-reversal experience and overlearning. Psych. Sci., 1965, 2, 363-364.

WALLER, T.G. Facilitation of an extradimensional shift with overtraining in rats. Psych. Sci., 1970, 20, 172-174.

WALLER, T.G. The effect of overtraining on two extra-dimensional shifts in rats. Psych. Sci., 1971, 23, 123-124.

WEYANT, R.G. Reversal learning in rats as a function of the type of discrimination and the criterion of learning. Animal Behaviour, 1966, 14, 480-484.

WINEFIELD, A.H. & JEEVES, M.A. Use of criterial measures in animal discrimination learning experiments. Psych. Rep., 1968, 23, 1335-1338.

WOLFF, J.L. Concept-shift and discrimination reversal learning in humans. Psych. Bull., 1967, 68, 369-408.

WOLFORD, G. & BOWER, G.H. Continuity theory revisited: Rejected for the wrong reasons? Psych. Rev., 1969, 76, 515-518.

YOUNISS, J. & FURTH, H.G. Reversal learning in children as a function of overtraining and delayed transfer. J. Comp. Physiol. Psych., 1964, 57, 155-157.(a).

YOUNISS, J. & FURTH, H.G. Reversal performance in children as a function of overtraining and response conditions. J. Exp. Child Psych., 1964, 1, 182-188.(b).

YOUNISS, J. & FURTH, H.G. Discrimination shifts as a function of degree of training in children. J. Exp. Psych., 1965,70, 424-427.

ZEAMAN, D. & HOUSE, B.J. The role of attention in retardate discrimination learning. In: N.R. Ellis (Ed.) Handbook of mental deficiency. New York: McGraw-Hill, 1963. pp.159-223.