THE EFFECT OF OVERLEARNING ON THE REVERSAL OF SIMPLE AND COMPLEX VISUAL DISCRIMINATIONS IN JAPANESE QUAIL (COTURNIX COTURNIX JAPONICA)

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ABSTRACT

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By

Jennifer G. Fidura

The overlearning reversal effect (ORE) was first demonstrated in a black-white discrimination with rats. Since that time there have been numerous attempts to find facilitation of reversal learning following overtraining on an original discrimination. The ORE is contrary to the assumptions of the traditional S-R position that a) habit strength is directly related to the number of reinforcements, b) speed of extinction is inversely related to habit strength, and c) reversal learning is simply a matter of extinguishing one habit and learning a new one.

The most successful explanations of ORE have concentrated on modifying the third assumption. However, any theoretical approach to the phenomenon of ORE must include hypotheses to account for the many failures to find the effect experimentally. As a general rule ORE is found in visual discriminations with rats, but not found in spatial discriminations. Lovejoy and Mackintosh have hypothesized that if the S̲ continues to attend to the relevant dimension during that period of reversal while it is learning to make the new choice response, reversal will be relatively rapid. On the other hand, if the S̲ stops

attending to the relevant dimension during reversal, reversal learning will be more difficult.

The determining factor in the occurrence of ORE, therefore, is the saliency of the relevant dimension. In a discrimination of a dimension of low saliency the overtraining will increase the probability that the S will continue to attend to the relevant dimension and, consequently, facilitate reversal.

Experiment I

This experiment assessed the effects of overtraining on the reversal of two different discriminations with Japanese quail. Twenty-four Japanese quail learned either a simple or complex color or form discrimination in a commercial operant chamber. One half of the Ss received overtraining to a predetermined criterion on the relevant dimension. All Ss were then given the reversed discrimination.

The ORE which was expected following overtraining on the more difficult form discrimination was not found. Two interpretations were offered for these results: first, the criterion for original learning (15 consecutive correct trials) was so difficult that all Ss received some amount of overtraining; second, the overtraining procedure itself was not sufficient to facilitate reversal.

Experiment II

This experiment was designed to assess the validity of the two interpretations offered for the results of Experiment I. Eight

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Japanese quail were run using a procedure identical to that used above except that the criterion for original learning was eight consecutive correct trials and none of the Ss received overtraining. The reversal scores were compared to the appropriate scores for those Ss which received no overtraining from Experiment I. Again, no ORE was found.

The results indicated that the criterion for learning in Experiment I was not so difficult that all Ss received overtraining which might have facilitated reversal. The data did suggest that the overtraining procedures employed in the two experiments did not significantly increase selective attention to the relevant dimension and, consequently, the facilitiation of reversal.

Approved M. Ray Denny

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CHAPTER I

Experiments and Theories

Riley (1968) suggests that the phenomenon of overlearning reversal effect (ORE) has attracted more attention and, consequently, more research effort in the last ten years than any other facet of discrimination learning. Although prior to 1953 Harlow (1949) had described the appearance of learning sets and Lawrence (1949, 1950) had formulated an explanation for the speed of reversal based on the acquired distinctiveness of cues, there was no direct empirical evidence for the facilitation of reversal following additional training trials. Reid (1953) was the first to demonstrate ORE using a simple brightness discrimination with rats. He trained three groups of animals to a criterion of 18 in 20 correct trials on a black-white discrimination. One group received no further training, a second group received 50 additional trials, and the third received 150 overtraining trials. When the relative positiveness of the cues was reversed, the group which had received 150 additional trials reversed their choice response more rapidly than either of the other two groups. Thus it appeared that the overlearning of a simple brightness discrimination facilitates the learning of the reversal of the original discrimination. This effect has become known as the overlearning reversal effect (ORE).

The effect of overlearning on reversal performance which was found by Reid (1953) is not only contrary to the direct relationship between the number of trials and the difficulty of reversal found experimentally by McCulloch and Pratt (1934), Spence (1945), and many others, but also to the traditional S-R position as a whole (Riley, 1968). Three assumptions made by the traditional S-R theorists are directly involved: a) habit strength is directly related to the number of reinforcements, b) speed of extinction is inversely related to habit strength, and c) reversal learning is simply a matter of extinguishing one habit and learning a new one in its place (Lovejoy, 1966; Fidura, 1966). Since these assumptions would not allow for the prediction of ORE it would seem obvious that at least one of them is in error.

Riley (1968) calls ORE one of the "most explained phenomena" in psychology today. However, prior to any analysis of the various explanations and interpretations which have been given for this effect, a brief review of the literature should be given. Two experiments by Lawrence (1949, 1950), while not a direct attempt to study this effect, are relevant in terms of later attempts to explain ORE. Lawrence (1950) was the first to recognize the importance of reversal learning and the role that the "acquired distinctiveness of cues" might play (Mackintosh, 1965). The concept of the acquired distinctiveness of cues which he used to explain the results of a reversal study was formulated in an earlier study (Lawrence, 1949). In this first study he used one of three stimulus dimensions in a simultaneous discrimination study with rats. The three dimensions were black vs. white cues, rough vs. smooth floors, and large vs. small goal boxes.

The rats were then given transfer tests using two independent dimensions in a successive discrimination; the relevant dimension was correlated with reinforcement and the irrelevant dimension was randomly paired with the relevant dimension and not correlated with reinforcement. For the positive transfer group the relevant dimension in the successive discrimination was the same stimulus dimension learned in the previous simultaneous discrimination. The negative transfer group had the dimension learned in the simultaneous discrimination as the irrelevant dimension in the transfer test, and the control group had two entirely new sets of stimuli. The results show that the positive transfer group did significantly better in the transfer test than either the negative transfer group or the control. The results also show that the negative transfer group and the control did not differ significantly.

Lawrence (1949) uses the concept of acquired distinctiveness of cues to explain the positive transfer, _i.e._, a mediating process was established during the first discrimination problem which tended to enhance the distinctiveness of the relevant dimension. In other words, at the outset of the transfer test the previously learned dimension, which for the positive transfer group was still the relevant dimension, was more distinctive than any new dimension. "As a result of the enhanced distinctiveness of the relevant cue in the test situation, the new instrumental responses were associated with the familiar cue more rapidly than with the unfamiliar one (Lawrence, 1949, p. 783)." The design of this experiment was such as to rule out other explanations of the transfer in terms of a) carry-over of the same instrumental response, b) learned ability to solve discrimination problems, c) external inhibition, or d) acquired reward or acquired drive (Fidura, 1966).

One portion of Lawrence's mediating process hypothesis was not confirmed by the data. No significant differences were found between the negative transfer group and the control group. Lawrence (1949) makes two assumptions: a) the stimulus which is conditioned to the differential response has been modified by the mediating process, and b) the relationship between this modified stimulus input and the response is governed by the traditional S-R laws. If this is the case, the negative transfer group should have done poorly because of the strong association value (the acquired distinctiveness) of the irrelevant dimension should have interfered with learning. However, since the negative transfer group did not differ from the control there is some indication that those situations influenced by what Lawrence chooses to call the acquired distinctiveness of cues may not follow the traditional S-R laws (Fidura, 1966).

Lawrence (1950) trained one group of rats in a successive discrimination to respond to a black-white dimension (relevant) and to ignore the presence or absence of chains hanging in the goal-box entrance (irrelevant dimension). He trained a second group of rats on the converse of this discrimination. Following the original discrimination he trained all animals on a simultaneous discrimination with both dimensions relevant and redundant. He then gave two tests, an opposition test and a reversal test. In the opposition test the positive attribute of each dimension was opposed so that the direction of choice would indicate which dimension was influencing performance. Finally, all animals re-learned the simultaneous discrimination with each dimension presented alone; one half of the subjects learned the discriminations with the positive attribute of each dimension reversed.

The results of the opposition test show that the animals respond generally in terms of the dimension which had been relevant in their original training. The results of the reversal test show that the animals not only learned the non-reversed discrimination faster on the dimension which for them had originally been the relevant one, but also that they reversed faster on that dimension than on the previously irrelevant dimension. Lawrence again interprets these results "in terms of the concept of acquired distinctiveness of cues which postulates that discrimination learning is essentially a two-stage process, the first stage of which is a change in the perceptual characteristics of the stimulus (Lawrence, 1950, p. 187)." As had been mentioned, Reid (1953) found ORE in the results of the reversal of a simple brightness discrimination. Since that time others have found similar results with rats (Capaldi & Stevenson, 1957; Komaki, 1961; Mackintosh, 1962, 1963a, 1965b; North & Clayton, 1959; Pubols, 1956; and others). D'Amato and Jagoda (1961) found a marginally significant ORE using a brightness reversal, but D'Amato and his co-workers have not been able to replicate that result (D'Amato & Schiff, 1965).

The results of a comparison between overtrained and non-overtrained rats in a simple position reversal are not as conclusive. In twenty-two studies cited by Mackintosh (1965) only slightly less than 1/3 showed any facilitation of reversal following overtraining (Capaldi, 1963; Ison & Birch, 1961; Pubols, 1956; Theios & Blosser, 1965a; and others). Of the other 2/3 of the studies most showed some retardation of reversal following overtraining (Clayton, 1963a, 1963b; D'Amato & Jagoda, 1962; D'Amato & Schiff, 1964; Galanter & Bush, 1959; Hill, et al., 1962; Komaki, 1962; Mackintosh, 1965c; and others) including four studies in which the retardation was significant (Hill & Spear, 1963; Hill, et al., 1962; Krechevsky & Hozik, 1932; Mackintosh, 1965c). Lovejoy (1966) has summarized these results by saying that facilitation of reversal following overtraining on a brightness discrimination (ORE) will usually, but not always be found, and when the reversal is of a simple position discrimination ORE will usually not be found.

The facilitation of reversal learning which is found following overlearning is contrary to the traditional assumptions of the S-R theorists that: a) habit strength is directly related to the number of reinforcements, b) the speed of extinction is inversely related to the habit strength, and c) reversal learning is simply a process of extinguishing an old habit and learning a new one in its place. In attempting to explain the seemingly contradictory results found in studies of ORE no attempts have been made to modify the first assumption, a few attempts have been made to change the second assumption, and even more to change the third (Lovejoy, 1966; Fidura, 1966).

Attempts to explain the occurrence of ORE by modifying the assumption that the speed of extinction is inversely related to habit strength have been based on evidence that the resistance to extinction is, in fact, not a monotonic function of the number of reinforced trials (Madison, 1964; North & Stimmel, 1960; Siegel & Wagner, 1963; Wagner, 1963). This evidence, however, does not provide an adequate explanation of why ORE is found in some discriminations and not in others, nor does it explain why within some experiments on ORE there are some data which support the original assumption. Mackintosh (1965) states that all investigators who have actually published data on the resistance to choice response extinction of over-trained and non-overtrained subjects have found that overtraining does increase the resistance to extinction (Komaki, 1961; Mackintosh, 1962, 1963a, 1963b, 1965b; Reid, 1953). One of the measures which has been used to determine the resistance to extinction is the length of the initial error run after reversal (Hill, *et al.*, 1962; Mackintosh, 1962). Some have argued (*e.g.*, Sperling, 1965) that more rapid extinction might follow the initial increased resistance to extinction of the overtrained subjects. Mackintosh (1963b) showed that to reach an extinction criterion of 50% accuracy over a block of ten trials it took animals which had received overtraining longer.

In summary then, it would seem reasonable to divide the reversal of a discrimination problem into two phases: Phase 1 is the extinction of the tendency to choose the original positive stimulus (now the negative stimulus) and Phase 2 is the acquisition of the tendency to choose the positive stimulus. Attempts to explain ORE by saying that overtraining decreases the time, in terms of number of trials, required for the animal to complete the first phase and, therefore, increases the speed of reversal have been shown to be without experimental support. In fact, the data would seem to show the opposite to be true.

Of the attempts to modify the third assumption, namely that reversal learning is merely a process of extinguishing an old habit and learning a new one in its place, the most general type of explanation has been of the "learning set" type (Fidura, 1966; Lovejoy, 1966). Such explanations have been used by Reid (1953), Spence (cited by Reid, 1953) and Harlow (1959). Reid's interpretation took the form of a two-stage hypothesis. He hypothesized that at the same time as the animal was learning a choice response it was also learning, at a slower rate, the habit of "response discrimination, _i.e._, learning to respond to a set of stimuli of which the specific stimulus is a member (Reid, 1953, p. 107)." The response to the stimulus set occurs at a greater distance from the reinforcement than does the simple approach or avoidance of a particular stimulus value and, therefore, the acquisition of the response of discrimination is slower due to the greater delay of reinforcement. If after reversal, the subject contines to make the appropriate response of discrimination it will be more likely to select the new correct choice after extinction of the original choice response than will an animal which has not learned the appropriate cue-discrimination response (Riley, 1968). Since overtraining allows more trials for the response of discrimination to become conditioned to the appropriate cues, over-training should facilitate reversal. Note, however, that this explanation will not account for the absence of ORE in position reversals.

Spence (cited by Reid, 1953) suggested that perhaps the overtraining had the effect of equalizing position preferences, and that the overtrained subjects would be less likely to revert to a position preference during the early stages of reversal. Pubols (1956) found ORE in an experiment similar to Reid's (1953), but was able to reject Spence's hypothesis because the position preferences for all animals had been equalized.

Riley (1968) mentions two attempts to explain the negative cases, that is those cases in which ORE is expected but does not appear in the data. Paul (1965) suggests that the occurrence of ORE depends to a large part on the consequences of an incorrect response. He says that in the instances when ORE has not been found the result of an incorrect response is an unbaited goal-box. When ORE has been found, on the other hand, the consequence of an incorrect response was a locked door in the majority of the cases. Paul (1965) assumes that in order for ORE to occur the results of an error response must be very dissimilar from those of a correct response. Why ORE should be found in these experiments is not clear.

Theios and Blosser (1965b) have suggested still another explanation for the negative cases. They have hypothesized that

> "resistance to extinction is determined by the strength of the habit, which is a function of the number of times the particular act in question has been performed. This resistance is, however, diminished by the disruptive effects of non-reward. And this disruption in turn is a function of the number of times the subject has been rewarded in the goal box and the amount of the reward it has received on each of these occasions. Thus, if the subject has received a reward many times and the reward has been substantial, disruption will be great and the resistance to extinction correspondingly reduced. This analysis, then, really assumes the growth

> of two habits, one of running down to the goal box and a second which might be called expectation of reward (Riley, 1968, p. 149)."

Theios and Blosser use these two habits to explain ORE in the following way: They assume that the instrumental approach habit grows more quickly than the expectation of reward, but that if the incentive is fairly substantial both will reach a similar asymptote. ORE is likely to be found under these conditions because with the increased numbers of trials the difference between the habit strength and the reward expectancy will be less than with a lesser number of trials. However, studies using a small reward do not show ORE because the reward expectancy does not reach a high level and the disrupting effect of errors in reversal is small.

To test their hypothesis Theios and his colleagues (1964, 1965a, 1965b) have conducted several experiments which seem to support his position. This hypothesis does not account for all of the results obtained by Mackintosh and others.

Mackintosh (1965) in his review of the literature on selective attention in animal discrimination learning offers the following rather intuitive argument for a mechanism of attention:

> "Animals (particularly lower animals) have nervous systems of limited size and therefore of limited capacity for processing and storing information. Thus they are confronted with the problem of selection. At some stage they must discard irrelevant or redundant information so as not to interfere with the storage of important information. This line of argument would seem to provide a general rationale for postulating, as Broadbent (1958) does, the existence of filtering devices in the nervous system; and if this approach is justified, it is undoubtedly of first importance to general behavior theory. To put it at its simplest, if animals do not respond to all features of their stimulus input,

> then a sharp distinction must be drawn between physical stimuli impinging on an animal in any given situation and the effective stimulus which controls the animal's behavior in that situation. Failure to consider this distinction might lead to explanations of behavior being offered which are at best incomplete and at worst totally misconceived... It may be granted, then, both that there are plausible grounds for postulating a central mechanism of attention, and that the question of attention is an important one (Mackintosh, 1965, p. 124)."

Mackintosh (1965) employs such a mechanism in his interpretation of the results of Lawrence's (1950) reversal test, in which animals learned the reversal of the discrimination on which they had originally been trained faster than they learned the reversal of the originally irrelevant dimension. He explains these results in terms of the following three assumptions:

> "(a) that pretraining with _A_ relevant and _B_ irrelevant securely established attention to _A_; (b) that by the end of simultaneous discrimination training on the combined problem, subjects were attending to _A_ with a very high probability and to _B_ with a very low probability; (c) that, consequently, during reversal to _A_, choice responses would extinguish faster than attention to the relevant cue while, during reversal to _B_, attention to the relevant cue would extinguish faster (Mackintosh, 1965, p. 136)."

In other words, using the two-stage model described by Lawrence (1950) and by Mackintosh (1965) the following might be true: If an animal is trained to approach _A_ and avoid _A'_ and is then reversed on the discrimination problem, the first number of trials following reversal will be primarily error trials. During this time both the attention to the relevant dimension and the choice response may extinguish; it is not, however, necessary to assume that the extinction will be completed simultaneously. If the attention to the

_A_-_A_' dimension extinguishes before the choice response then "reversal learning can only be slow and laborious, since both attention and choice response must be built up _de novo_ (Mackintosh, 1965, p. 135)." However, if the choice response to _A_ extinguishes before the attention to the _A_-_A_' dimension extinguishes, then the reversal is more quickly learned.

> "At first sight, it does not seem as if a two-stage model must necessarily predict one of these alternatives rather than the other; thus there is no need for it to predict that reversal learning should be relatively easy. It is clear, however, that one definite prediction can be made; if attention extinguishes before choice responses, reversal will be slower than if choice responses extinguish before attention, and any procedure that increases the probability of attending without equally increasing the response strength, will facilitate reversal (Mackintosh, 1965, p. 135)."

From Lawrence's (1950) experiment it was seen that original training with one cue relevant, _e.g._, the black-white cue, and another cue irrelevant not only gave faster discrimination when the black-white dimension was presented alone, but it also gave faster reversal on the black-white dimension presented alone. The original training, then, was enough to prevent extinction of attention to the relevant stimulus dimension prior to the extinction of the choice responses. This explanation can become a model for the interpretation of the ORE data.

Lovejoy makes this attentional explanation of ORE slightly more specific:

> "It is argued that in order to solve a discrimination problem, animals must first learn to attend to the relevant dimension (e.g., brightness), and then they must learn to make the appropriate response once they

> have attended to that dimension... Now surely a rat has a limited information-storage capacity. On a given trial he might remember which side he chose, whether he approached or avoided some special odor, whether he went to black or white... But he will probably not remember all these various attributes of the choice he made. The development which follows is based on the simple idea that a rat can attend to only some of the possible dimensions on any given trial, and that in some sense learning can occur only on those trials when the subject is attending to the relevant dimension (Lovejoy, 1966, p. 89)."

Lovejoy (1966) offers the same explanation for the facilitation of reversal as that given by Mackintosh (1962, 1965) and Sutherland (1959), but he also explains why ORE should occur in some discriminations and not in others. The presence of ORE is not determined by the comparison of the data obtained from a particular experiment against some standard set of data, but rather by the comparison of the reversal scores for the group which received overtraining with the scores for the group which did not receive overtraining. Lovejoy hypothesizes that ORE should be found when the initial probability of attending to the relevant dimension is very low; ORE should not be found when the initial probability of attending to the relevant dimension is high. If the relevant dimension used in a discrimination problem is very salient, i.e., the initial probability that the subject will attend to it is very high (Fidura, 1966), then during the original learning the probability of attending will approach its asymptotic level for all subjects and any overtraining given some of the subjects will not significantly increase this probability. Therefore, ORE should not be found, not because both groups reverse slowly but rather because both groups continue to attend to the relevant dimension and reverse quickly. If, on the other hand, the relevant dimension is not very salient the overtraining given one group can significantly increase the probability that those animals will continue to attend to the relevant dimension throughout reversal thereby facilitating reversal. The subjects which do not receive overtraining are more likely to stop attending to the relevant dimension during reversal and will reverse slowly. Because of the difference in reversal scores ORE will occur.

In studies with rats, discriminations involving a brightness cue when overtraining precedes reversal for some of the subjects, ORE will usually be found. [ORE has also been found in studies with octopuses (Mackintosh & Mackintosh, 1963) and in a study with chicks (Mackintosh, 1965b)]. However, as we have seen, ORE is usually not found in studies when position is the relevant cue. This could be expected when the relative saliency of kinesthetic cues and visual cues to a rat are compared.

Since the appearance of ORE is determined (according to Lovejoy and Mackintosh) by the initial probability that the animal will attend to the relevant dimension, it is readily apparent that relatively minute changes in the experimental procedure of in the apparatus could greatly change this probability and have a corresponding effect on the results of the experiment. Without considering any other variables this fact alone could probably account for the discrepancies found in the literature.

Riley (1968) in his review of the various interpretations which have been offered for ORE lists three objections which might be made to the type of explanation offered above: a) while a two-stage mediational theory might account for most of the available data and might be intuitively attractive, it is more complex than non-mediational theories; b) the relative determinants of the speed with which this mediational process develops are not made explicit; and c) what is the relationship between the learning of a reversal and the learning of a non-reversal shift. In elaboration on the first criticism, Riley says that a mediational process of selective attention is intuitively attractive because it "seems to agree with most observers' phenomenology (Riley, 1968, p. 151)." However, this theory still requires the assumption that the stimulus which controls the subjects' behavior is changed in some way during learning. This assumption is needed in addition to all others required by non-mediational theories.

The second objection made by Riley (1968) is an attempt to compare the overtraining procedure to the repeated discrimination problems used in "learning set" experiments. The question involves the relative speed with which overtraining can facilitate reversal as compared to the number of problems needed to establish a learning set. As has been shown above the learning set theory would predict ORE in every case and cannot, therefore, account for the data.

The third objection is based on the work of Kendler and Kendler (1962) who have said that young children and rats (Kelleher, 1956) can shift dimension more easily than they can reverse the values of a dimension. However, no overtraining was involved in these studies and the results could be predicted by the Lovejoy-Mackintosh hypothesis. Marsh (1964) has shown that ORE can be found in studies with young children.

It would seem, then, that the only valid objection is that which can be made to any two-stage theory. Since the Lovejoy-Mackintosh hypothesis appears to account adequately for a majority of the data, perhaps the addition of the process of selective attention might be justified.

CHAPTER II

Experiment I

Lovejoy (1966) has hypothesized that the crucial determinant of ORE is the initial probability that the subject will attend to the relevant dimension. If this probability is initially very high and approaches its asympototic level before the subjects meet the criterion for the completion of original learning then overtraining will show little facilitative effect on reversal performance. All subjects, the overtrained and the criterion (non-overtrained) subjects, will extinguish the original choice response and learn the new positive stimulus before their attention to the relevant dimension extinguishes (Mackintosh, 1965).

On the other hand, if the original probability of attending to the relevant dimension is low, overtraining will facilitate reversal learning. Overtraining will increase the probability that the subjects will continue to attend to the relevant dimension during reversal and will facilitate the reversal learning as compared to the performance of the criterion subjects. The criterion subjects, however, are more likely to stop attending to the relevant dimension in favor of a more salient dimension.

The above hypothesis is based primarily on the results of studies done with rats. In order to select a dimension which is very salient for a rat and also to select a less salient dimension, the experimenter is forced to use cues in two different sense modalities, visual and kinesthetic. Though it is known that rats respond more readily to spatial cues than to visual cues, there is not enough information about the mechanism of selective attention in animals to assess what interactions might exist between the sense modality and the attentional process. For that reason, any test of the Lovejoy-Mackintosh hypothesis might best be made using stimuli in a single sense modality.

The following test of the hypothesis used two visual stimuli in a study with birds. Japanese quail (*Coturnix coturnix japonica*) are excellent subjects for this type of research for several reasons: a) they adapt readily to laboratory conditions and a pecking response can be rapidly conditioned (Fidura & Gray, 1966; Fidura, 1966); b) they are primarily visually oriented animals and do possess acute color vision; and c) data are available on the relative probability that Japanese quail will attend to several visual stimuli in an experimental situation identical to the one used in this study (Fidura, 1966, 1969; Fidura & Gray, 1966).

Fidura & Gray (1966) assessed the acquisition of three commonly used simultaneous visual discriminations by Japanese quail. The pecking response was learned prior to any discrimination training so that the differences found in the number of trials needed to reach acquisition criterion could be attributed to the relative initial probability that the subjects would attend to the relevant dimension. They found that a form discrimination was the most difficult, followed by pattern, and that a color discrimination was the least difficult to learn. The results are presented in Table 1.

Fidura (1966 & 1969) did further studies using a similar design with complex rather than simple stimuli. The complex stimuli were made up of the attributes of the three dimensions mentioned above presented simultaneously on the two pecking keys; the attributes of the dimensions varied randomly and independently between the keys making 2^3 possible stimulus combinations.

For a given subject one dimension was relevant and correlated with reinforcement and the other dimensions were irrelevant and, therefore, randomly paired with reinforcement. The results were similar to those found by Fidura & Gray (1966); the form discrimination was the most difficult, followed by pattern and then color. The results are presented in Table 2.

The following two conclusions might be drawn from these studies which would be pertinent to this experiment: a) in this particular experimental chamber for these subjects the most salient stimulus is color and the least salient is form; b) the addition of irrelevant dimensions to color does not significantly affect the speed of learning, but the addition of irrelevant and more salient dimensions to form greatly decreases the speed of learning. Since the initial probability of attending to the color dimension is high, the acquisition of the discrimination is simply a matter of learning the correct choice. However, since the probability of attending to form is relatively low, the subject must first learn to attend to the relevant dimension and then to make the correct choice response. The greater the number of irrelevant dimensions the more difficult this

TABLE 1.--Means and standard deviations of total and error trials to the first criterion trial for each dimension. (N=22)*

	Relevant dimension		
	Color	Pattern	Form
Mean	27.5	123.5	360.6
sd	26.9	80.2	180.4
N	22	22	22

*From Fidura & Gray, 1966

TABLE 2.--Means and standard deviations of total trials to criterion on complex discriminations.*

	Relevant dimension		
	Color	Pattern	Form
Mean	21.9	412.4	1361.4
sd	22.9	164.0	647.5
N	9	9	9

*From Fidura, 1966

becomes and the greater the number of trials needed to reach criterion.

This experiment is designed to test the Lovejoy-Mackintosh hypothesis that: a) in simple discriminations ORE should not be found when color is the relevant dimension, but probably will be found when the relevant dimension is form; b) in complex discriminations ORE again should not be found when color is the relevant dimension, but should be found when form is relevant. There might be some doubt of the validity of predicting ORE in the reversal of a simple form discrimination. The hypothesis would suggest that the subjects that received no overtraining will stop attending to the relevant dimension during reversal and start attending to some more salient dimension. However, the procedure used in this experiment will perhaps preclude the subjects' attending to any stimulus except that which is presented on the pecking keys, and will, therefore, destroy any ORE.

The overtraining procedure which will be used in this experiment differs from that used in previous studies. Reid (1953) overtrained two groups of animals; one group had 50 trials in addition to original learning and a second group had 150 overtraining trials. Mandler (1968) gave 150 trials past criterion in a black-white discrimination with rats, and Mackintosh (1969) used 100 overtraining trials in a brightness discrimination in a Grice box. Shepp and Turisi (1969), however, used 100% and 300% of the original learning as overtraining on a discrimination with retardates.

Lovejoy (1966) states that overtraining will facilitate reversal if it increases the probability that the subject will continue to attend to the relevant dimension. The overtraining procedure used in this study was designed specifically to fill that requirement. The subjects learned the relevant dimension presented alone to meet a specific criterion rather than a set number of trials or a percentage of the original learning.

Method

Subjects

The *S*s were 24 male and female Japanese quail, 50-60 days of age at the outset of the experiment. They were maintained at 75-80% of their *ad libitum* body weight by daily compensatory feeding to the 80% level. The *S*s were randomly selected from the colony maintained at the Psychological Laboratory at Michigan State University.

Apparatus

The apparatus consisted of two identical commercial operant chambers each with two pecking keys. The chambers were modified by raising the floor 2 1/8 inches, and by mounting multiple stimulus projectors behind each key. Reinforcement for a correct response was presented in a food hopper located centrally between the two keys near the floor. The presentation of stimuli, reinforcement, and the overall functioning of the apparatus was programmed and controlled by a punched-paper tape-reading device which operated through a system of relays and timers. The *S*s' responses and the total number of trials in one daily session were recorded on digital counters;

presentation of stimuli terminated automatically following the completion of the criterion run of 15 consecutive correct trials.

Procedure

The key-peck response was well established by requiring the Ss to peck at an amber lighted key vs. a simultaneously present non-lighted key for 200 food reinforcements. The amber stimulus alternated randomly between the two keys. Following this pre-training each S was randomly assigned to one of four conditions which varied on stimulus complexity and amount of overtraining. The conditions were as follows:

		Amount of Overtraining	
		Overtraining	No overtraining
Complexity	Simple	N=6	N=6
	Complex	N=6	N=6

Each S learned both a color and a form simultaneous discrimination; the order of the two discrimination problems was randomly determined for each S. All Ss completed one discrimination problem, procedurally consisting of a) original learning with the assigned stimulus complexity and amount of overtraining, and b) reversal of the discrimination at the same level of stimulus complexity, before learning the second discrimination. The relevant dimensions and their reinforced and non-reinforced attributes were as follows:

Dimension	Original Learning		Overtraining		Reversal	
	+	-	+	-	+	-
Color	Red*	Green*	Red	Green	Green	Red
Form	Triangle	Circle	Triangle	Circle	Circle	Triangle

*Note: The red and green were equated for intensity and previous research (Fidura, 1966) has shown that pretraining with an amber light does not affect performance on a red vs. green color discrimination.

Reinforced and non-reinforced attributes varied randomly between the two keys. Complexity was achieved by adding the irrelevant dimension of pattern (horizontal or vertical white lines) to the relevant dimension. The pattern varied randomly and independently of the relevant dimension. Visually the complex stimuli with color relevant appeared as three white lines, either horizontal or vertical, on a red or green background; the complex stimuli with form relevant appeared as three white lines superimposed over a white circle or triangle on a black background.

In all phases of the experiment the criterion of learning was 15 consecutive correct trials. Each S was run 1 hour each day with the exception of those days on which a criterion was met, then they were removed from the apparatus at the completion of criterion and the next phase of the experiment was begun on the following day.

To prevent the Ss from perseverating on one key and receiving 50% partial reinforcement, a type of correction procedure was used. Following error responses the stimulus sequencing system did not advance and the stimulus patterns maintained the same relative positions on the next trial. Each trial began with the presentation of the stimuli on the keys. When the S pecked one of the keys the stimulus lights were turned off and the keys made inoperative for 8 sec.; if the response was correct, reinforcement was available for the first 5 sec. and the stimulus sequencing system advanced. If the response was an error the S had an 8 sec. time-out with no reinforcement.

Overtraining consisted of a discrimination of the relevant dimension presented alone, a procedure identical to the original learning of the simple discrimination. Reversal learning differed only in the relative positiveness of the attributes of the relevant dimension.

Results

Table 3 presents the means and standard deviations of the total trials to criterion, excluding the 15 criterion trials, for all Ss on the original discriminations. (All trials to criterion are computed as trials to the first criterion trial in both experiments.) These results are similar to those found by Fidura and Gray (1966) and by Fidura (1966 & 1969) which are presented in Tables 1 and 2. Table 4 presents the means and standard deviations of the trials to criterion for those Ss which received overtraining following either complex or simple discriminations in original learning. These data show an increase in both mean trials and in variability following simple and complex original discriminations respectively.

TABLE 3.--Means and standard deviations of total trials to criterion in original learning.

	Relevant dimension			
	Complex		Simple	
	Form	Color	Form	Color
Mean	1339.42	43.67	161.42	25.75
sd	828.93	43.06	132.76	33.89
N	12	12	12	12

TABLE 4.--Means and standard deviations of total trials to criterion in overlearning.

	Relevant dimension			
	Form		Color	
Following	Complex	Simple	Complex	Simple
Mean	62.33	27.33	17.00	2.83
sd	58.00	15.67	28.68	6.94
N	6	6	6	6

Tables 5 and 6 present the means and standard deviations of the trials to criterion in reversal learning as a function of dimension, complexity and amount of overtraining. Tables 7 and 8 present a summary of the analysis of variance of the data presented in Tables 5 and 6. No significant differences were found as a function of the amount of overtraining on the reversal of either color ($F = .281$, *df* 1,20, $p > .20$) or form ($F = .092$, *df* 1,20, $p > .20$). A significant effect was found as a function of complexity in the reversal of the form dimension ($F = 11.236$, *df* 1,20, $p < .005$), but not in the reversal of the color dimension ($F = 1.25$, *df* 1,20, $p > .20$). And no significant interactions were found as a function of amount of overtraining and complexity for either color ($F = .958$, *df* 1,20 $p > .20$) or form ($F = .00024$, *df* 1,20, $p > .20$).

Discussion

The results obtained do not directly support the Lovejoy-Mackintosh hypothesis of ORE. No facilitation of reversal learning was found following overtraining in the group which learned the complex discrimination with form relevant. In fact the trend of the data for this group were in the opposite direction, *i.e.*, there was some small suggestion of retardation of reversal following overtraining. The same was true in the simple form reversal, though in neither case did the level of retardation approach the level of significance.

The results of the original learning for all subjects support the findings of Fidura and Gray (1966) and Fidura (1966 & 1969).

TABLE 5.--Means and standard deviations of total trials to criterion in the reversal of the discrimination with color relevant.

	Simple		Complex	
Following	Overtraining	Criterion	Overtraining	Criterion
Mean	136.33	126.50	139.17	171.67
sd	38.49	30.19	55.13	75.36
N	6	6	6	6

TABLE 6.--Means and standard deviations of total trials to criterion in the reversal of the discrimination with form relevant.

	Simple		Complex	
Following	Overtraining	Criterion	Overtraining	Criterion
Mean	427.33	318.00	1569.67	1471.00
sd	308.57	122.79	1375.70	900.22
N	6	6	6	6

TABLE 7.--Summary table of analysis of variance among mean total trials to criterion as presented in Table 5.

Source of variation	df	ss	ms
Amount of overtraining	1	782.038	782.038
Complexity	1	3480.038	3480.038
(Cells)	3	6929.126	
Overtraining X Complexity	1	2667.05	2667.05
Within-cells	20	55654.499	2782.725
Total	23	62583.625	

TABLE 8.--Summary table of analysis of variance among mean total trials to criterion as presented in Table 6.

Source of variation	df	ss	ms
Amount of overtraining	1	64896.00	64896.00
Complexity	1	7902832.66	7902832.66
(Cells)	3	7967899.34	
Overtraining X Complexity	1	170.68	170.68
Within-Cells	20	14066208.66	703310.433
Total	23	22034108.00	

A similar conclusion to theirs might be drawn:

> "...that is, since the motor response was the same for all dimensions and was well established prior to the beginning of training, differences in the acquisition of the ... dimensions reflect differences in the first or attentional stage of discrimination learning (Fidura, 1966, p. 29-32)."

The results obtained during the overtraining procedure also indicate that the Ss were attending to the color dimension after it was paired with the pattern dimension in the complex original discrimination with a much greater probability than they attended to the form dimension presented either alone or in the complex stimulus. However, these data do show that all Ss were attending to the relevant dimensions with a greater probability following original learning than they were prior to original learning (see Tables 3 & 4).

The finding of a significant difference in the reversal scores on the form dimension as a function of complexity could be predicted by the Lovejoy-Mackintosh hypothesis. The addition of a more salient irrelevant stimulus to a stimulus which is not very salient greatly decreases the probability that the S will attend to the relevant stimulus (see Tables 3 & 6).

Several explanations might be offered for the failure to obtain the expected results, *i.e.*, ORE in the form discriminations, but perhaps the two which deserve primary consideration are those relating to the overtraining procedure and to the criterion established for original learning. The first hypothesis is that though the overtraining procedure was designed to increase the probability that the subject would attend to the relevant dimension without significantly increasing the total response strength (Mackintosh, 1965), the number of trials required for the subject to learn the overtraining discrimination compared to the number of trials required to learn original learning was relatively small. This is particularly true in the form complex group. It might be suggested then that the overtraining was not enough to produce facilitation during reversal.

The second hypothesis provides a perhaps more reasonable explanation of the failure to obtain ORE. The criterion which was established for learning in this experiment was selected so that the data could be directly compared to the results obtained by Fidura and Gray (1966) and by Fidura (1966 & 1969). It might be suggested, however, that 15 consecutive correct trials is a difficult criterion for the subjects to meet. Therefore, some amount of "overlearning" could take place in all groups before the subjects meet the criterion for original learning. The comparatively few trials needed to meet the overtraining criterion would tend to support this hypothesis. The result would be that original learning facilitated reversal learning and no ORE appeared in the data when the groups were compared.

CHAPTER III

Experiment II

One possible explanation of the results of Experiment I is that for all subjects the learning of the original discrimination incorporated some amount of "overlearning" and, therefore, facilitation of reversal was evident in all subjects' data. Since ORE is a relative measure between two groups of subjects, the effect would not appear in the results if all groups reversed quickly (Lovejoy, 1966).

To test this hypothesis and to employ a slightly different method of overtraining, the following experiment will use a criterion of 8 consecutive correct trials in original learning. The criterion for reversal learning will remain at 15 consecutive correct trials to allow for comparisons between the appropriate groups in Experiments I and II. None of the subjects in Experiment II will receive any overtraining.

A similar procedure has been used by Capaldi and Stevenson (1957). They trained 3 groups of rats on a black-white discrimination in an elevated T-maze. Group 1 was required to meet Criterion 1 (7 out of 8 correct trials) prior to reversal; Group 2 was required to meet Criterion 2 (Criterion 1 plus 8 additional consecutive correct trials) before reversing; and Group 3 was required to have 35 additional correct trials past Criterion 2 prior to reversal.

If the subjects in Experiment I did receive overtraining during original learning then comparisons of the appropriate groups from Experiment II with those in Experiment I should show ORE. The results of this experiment should also help to determine the validity of the overtraining procedure used in Experiment I.

Method

Subjects

The *Ss* were 8 male and female Japanese quail of the same age and stock as those used in Experiment I and maintained at 75-80% *ad libitum* body weight by compensatory feeding.

Procedure

The procedure is identical to that used in Experiment I with the following two exceptions: a) following pretraining the *Ss* were randomly assigned to two conditions which varied only in stimulus complexity (N = 4 in each group) and none of the *Ss* received overtraining; b) the criterion for original learning was 8 consecutive correct trials. All *Ss* learned both a color and a form discrimination at the same level of complexity and the order of which was randomly determined.

Results

The means and standard deviations for the total trials to criterion in original learning are presented in Table 9. There is an obvious reduction in the number of trials needed to reach criterion for the *Ss* in Experiment II as compared to those in Experiment I

(See Tables 3 & 9). Tables 10 and 11 present the means and standard deviations of the total trials to the reversal criterion of 15 consecutive correct trials for color and form respectively. Both the scores for the non-overtrained Ss in Experiment I and the scores for the groups in Experiment II are included.

Multiple t tests were performed as a function of the criterion for original learning. None of the tests were significant and a summary of the results appear in Tables 10 and 11.

Discussion

The results obtained in this experiment do not support the Lovejoy-Mackintosh hypothesis of ORE. No facilitation of reversal learning was found following a criterion of 15 in original learning as was predicted. And this particular method of overlearning, though it differs from that used in Experiment I, apparently does not increase the probability of attending to the relevant dimension significantly.

These results are, however, an indication that the learning criterion of 15 consecutive correct trials used in Experiment I was not so difficult as to incorporate some amount of overtraining for all groups. It would seem that the failure to obtain the expected results is probably due to the relatively small percentage of overtraining received by those groups in Experiment I as compared to the subjects in Experiment II.

TABLE 9.--Means and standard deviations of total trials to criterion in original learning.

	Relevant dimension			
	Complex		Simple	
	Form	Color	Form	Color
Mean	999.25	18.75	93.00	10.50
sd	611.81	23.24	72.89	9.47
N	4	4	4	4

TABLE 10.--Means and standard deviations of total trials to criterion in reversal learning with color relevant.

	Simple		Complex	
Following	Criterion 15	Criterion 8	Criterion 15	Criterion 8
Mean	126.50	131.25	171.67	132.00
sd	30.19	8.99	75.36	48.20
N	6	4	6	4
	$\underline{t} = .362$		$\underline{t} = 1.015$	
	$p > .1$		$p > .1$	

TABLE 11.--Means and standard deviations of total trials to criterion in reversal learning with form relevant.

	Simple		Complex	
Following	Criterion 15	Criterion 8	Criterion 15	Criterion 8
Mean	318.00	342.00	1471.00	1499.75
sd	122.79	212.68	900.22	993.11
N	6	4	6	4

$\underline{t} = .204$ $\underline{t} = .034$

$p > .1$ $p > .1$

CHAPTER IV

Summary of Results

The results of this study do not support the Lovejoy-Mackintosh hypothesis of ORE. On the other hand, neither do the data disprove this hypothesis. The failure to find any significant results in the statistical analysis of the comparison of reversal scores would seem to indicate that this study was not an adequate test of the hypothesis.

It could be that the hypothesis, as stated by Lovejoy and Mackintosh is incorrect. However, inasmuch as this study did not disprove the hypothesis an alternative explanation might be as follows:

> "Eimas (1967, Experiment II) and Erlebacher (1963) trained rats to discriminate between black and white painted goal boxes or goal arms; D'Amato and Schiff (1965) used different levels of diffuse illumination as the discriminanda. The initial probability of attending to the relevant stimuli may have been high in all cases (Mackintosh, 1969, p. 2)."

The hypothesis depends upon the subjects which have not received overtraining on a difficult discrimination problem attending to other irrelevant dimensions during the first phase of reversal. As in the studies cited above, the pretraining method used and the stimulus-deprived environment of the apparatus could have forced all subjects to continue to attend to the stimuli presented on the keys during reversal. If this is true no ORE would be predicted.

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