POSITION PREFERENCE AND DISCRIMINATION LEARNING

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INTRODUCTION

One can date the beginnings of modern investigations into the nature of discrimination learning with the publication of Lashley's (20) book "Brain Mechanisms and Intelligence". In this book, Lashley denied the simple associationistic, mechanistic principles postulated by earlier writers, such as Thorndike (35) and Watson (38). Lashley suggested that, particularly in discrimination learning, the "random or chance behavior" present prior to the manifestation of a correct solution was organized, purposeful, intelligent behavior. Considering the form of the learning curve in discrimination learning, the performance suggested that the practice preceding the formation of the association was irrelevant. Observing the behavior of the organism involved in such problem-solving behavior, he noted that what was ordinarily classified as random, chance behavior relative to the correct solution might represent attempted solutions of the problem.

Krechevsky (14) found this suggestion compatible with his neo-gestalt point of view, and in a series of experiments (15, 16, 17, 18) attempted to specify the variables which were postulated by Lashley. Krechevsky labeled these attempted solutions "hypotheses". He investigated the pre-solution behavior of the rat in a discrimination apparatus and showed

that, in most cases, the animals responded systematically to position, alternation, etc., prior to the sudden emergence of discrimination. These systematic responses, or "hypotheses", were evidence for Krechevsky in his argument against trial-and-error association theories of learning. Krechevsky's description of the rat's behavior was incorporated by Tolman (36) into his general theory, which was at that time the most adequate statement of the neo-gestalt point of view.

Spence (28) analyzed Krechevsky's data from a neo-behavioristic point of view and developed a theory which accounted for the same phenomena and at the same time was compatible with the S-R reinforcement theory being formulated by Hull (11). Spence asserted that the pre-solution "chance" behavior was not haphazard in the same sense that Krechevsky imputed to earlier behaviorists, and he agreed with Krechevsky that it was important to understand the variables underlying this behavior. However, the postulation of "hypotheses" merely described the behavior; it neither predicted nor explained.

Discrimination learning is a type of simple trial-and-error learning, in which each trial is reinforced immediately if correct, and not reinforced if incorrect. It is a complex situation, in that the irrelevant aspects of the stimulus complex are also strengthened when they happen to coincide with the "correct" cue aspect of the situation. Discrimination learning involves the differential strengthening of the "correct" elements of the stimulus complex relative to the total stimulus complex until it attains sufficient strength to determine the response. Making important assumptions, including differential initial reaction potentials, differential acquisition and extinction gradients, and utilizing the Hullian principles of reinforcement and inhibition, Spence then was able to derive Krechevsky's data, and showed that the postulation of "hypotheses" was not necessary to explain the data.

A controversy developed, with Krechevsky and the neo-gestaltists (19, 21) maintaining that discrimination learning was a non-continuous process. Spence and the neo-behaviorists (8, 25, 30, 31, 33) denied this and asserted that discrimination learning, and all learning, was a continuous process. A great many empirical studies were carried out by adherants of both schools with results generally supporting the continuity position. At the present writing, the controversy in this particular form has been, more or less, resolved.

It is not the intent of this thesis to reopen the continuity - non-continuity controversy, but rather to submit Spence's assumptions to an empirical test and to show that there are certain phenomena in discrimination learning that do not follow from the laws derived from these assumptions. Much of the data that has bearing on the general problem of discrimination learning has been obtained utilizing the experimental design which was agreed upon as the "experimentum

crucis" of the continuity - non-continuity controversy. These data have relatively little bearing on the problem of discrimination learning *per se*, but find their chief pertinence in determining whether or not discrimination learning is a continuous process. This writer accepts the position that learning is a continuous process and that this has been amply confirmed.

THE TWO MAJOR THEORETICAL POSITIONS

I. The Neo-Gestalt Position

In 1929 Lashley (20) wrote:

> "There are many indications that..... in the discrimination box, responses to position, to an alternation, or to cues from the experimenter's movements usually precede the reaction to light and <u>represent attempted solutions</u> that are within the rat's customary range of activity..... The form of the learning curve is the more significant when considered in relation to such behavior..... It suggests that the actual association is formed very quickly and that both the practice preceding and the errors following are irrelevant to the actual formation of the association."

This statement suggests that not only are the effects of practice during the pre-solution period in a discrimination problem relatively non-important in the eventual solution of the problem, but that the problem is eventually solved in a seemingly "insightful" manner. The method of plotting the data disguises "attempted solutions", which are incorrect relative to the to-be-learned problem. The basis of this formulation comes from direct observation of the typical discrimination learning curves. Different from other learning curves, the performance curves in a discrimination problem usually take the following form: There is an initial period of performance, generally some 40 to 50 trials, at chance level; that is, depending upon the number of choices available, the animals respond to the "correct" choice no more

often than they do to the "incorrect" choice or choices. Following this, there is a sudden increase in correct choices rapidly leading to criterion performance. Lashley noted at the time that this was merely his observation after having carried out many experiments of this type, and that he knew of no method for the proper analysis of the pre-solution behavior.

Krechevsky (14) felt that he had devised a method for the analysis of the pre-solution behavior. He noted that in a typical two-choice discrimination apparatus some animals responded for a time consistently spatially; that is, running right or left for a protracted number of trials. Some animals responded consistently for a period of time or trials in an alternative fashion; that is, right, left, right, left, right, left, etc. Other animals responded for a time consistently (in a brightness discrimination apparatus) to the brighter or the darker of the stimuli; that is, they consistently ran toward the light. Setting a fairly broad limit to the level of chance, three standard deviations above or below mathematical chance, Krechevsky analyzed the records of individual rats and discovered that this persistent response, that is position, alternation, brightness, was consistently different from chance behavior.

In attempting to account for these results, Krechevsky postulated the concept of "hypotheses" to describe these "attempted solutions". This accounting, it was noted, is on a descriptive level and it was not implied by the use of the term "hypotheses" that he had introduced any anthropomorphic error. "Hypotheses" were defined as having the following behavioral characteristics:

> "1. behavior which is systematic;
> 2. behavior which is purposive (displaying an 'if-then' character);
> 3. behavior which involves some degree of abstraction;.....
> 4. behavior which does not depend entirely upon the immediate environment for its initiation and performance."

Tolman and Krechevsky (37) recognized a distinct similarity between their theoretical positions and published a theoretical article specifying the similarities and differences of the two positions. In general, the difference was one of degree and not of kind. In considering any two levels of selectivity in a problem-solving sort of situation, the term "means-end-readiness" may be used for the wider and more general level of selectivity, while the term "hypotheses" may be reserved for any one or more narrower, more specific, selectivity appearing at the next level and within the range of wider selectivity. The characteristics of problem-solving behavior noted by Krechevsky above were redefined and relabeled as follows:

> "1. an animal in any given situation does not respond to all the stimuli present..... but at all times his behavior is systematic and selective as to stimuli and response pattern;
> 2. this selectivity of stimuli, and of responses relative to them, varies with the experience of the animal..... so that.....

it would appear that this selection is a tentative one and that it changes relative to whether or not it results in the animals reaching successfully and easily some final goal situation (i.e., the selectivity is 'docile');

3. the initial selectivity is..... perhaps innate. In other words it is 'self-initiated';
4. such selections also depend upon the motivation conditions of the animal in the sense that those selectivities which an animal originally exhibits and the changes which appear in them both hinge upon his motivating conditions".

Krechevsky (15, 16, 17, 18), utilizing his unique method of analysis carried out a number of empirical studies to confirm the position that problem-solving behavior was: 1. systematic; 2. docile; 3. self-initiated; and 4. selective. In a four-choice successive discrimination box with differential brightness cues as the problem to be discriminated, Krechevsky gathered evidence which he interpreted as supporting his general position.

These results and the conclusions drawn from them fitted in very well with the neo-gestalt viewpoint. Behavior was not haphazard, elementary, or mechanistic. The organism's approach to the solution of a problem was organized, integrated and purposeful. Tolman (36) incorporated these findings and interpretations into his more general theory of behavior.

II. The Neo-Behavioristic Position

The theoretical formulation developed by Tolman and Krechevsky was antagonistic to the theory then being developed by the neo-behaviorists. In 1936, Spence (28) published his S-R reinforcement explanation of discrimination learning. In this article, Spence set forth the postulates and general laws which have served as the basis for the explanation of discrimination learning phenomena, within this theory, to this date. Spence agreed with Lashley and Krechevsky in saying that the pre-solution behavior of the animal in a discrimination apparatus was not haphazard and that the evolution of the response to the correct stimulus was not a fortuitous occurrence. He, however, denied vigorously that the introduction of a concept, such as "hypotheses" and the implication that learning was somehow "insightful", added anything to our understanding of the process, nor could it lead to reliable predictions of behavior in these situations.

Utilizing the parts of the then incomplete Hullian theory of behavior, Spence developed an explanation of discrimination learning consistent with this theory. In this theory, discrimination learning was treated as a type of simple trial and error learning with each response sequence reinforced immediately, if correct, and hence strengthened, or non-reinforced, if not correct, and thus weakened. The difficulties encountered in the learning of the correct response were due to the fact that various irrelevant stimulus aspects were at times associated with the to-be-learned stimulus. When this coincidence occurred, the irrelevant cues were also strengthened. Discrimination learning to the relevant cue did not become manifest until there was enough of a differential built up so that the response to the relevant cue would occur consistently.

> "Discrimination learning..... involves, rather, the relative strengthening of the excitatory tendency of a certain component of the stimulus complex as compared to that of certain other elements until it attains sufficient strength to determine the response."

Spence introduced, at this point, two extremely important notions. The first of these was the principle of reinforcement. This principle, as it was used, assumed that if a reaction was followed by a reward, the excitatory tendency of the immediate stimulus components were strengthened or increased by a certain increment "I". It is noted here that this notion of reinforcement is somewhat different from the notion of drive reduction later specified by Hull (11) in his theory as the "law of primary reinforcement". The formulation we are dealing with here merely states that the reward is defined as the occurrence of a final or consummatory response. A second important principle, which was of major importance, was the notion of inhibition. If the response was not rewarded, the immediate stimulus components associated with the reaction were weakened by a decrement

"D". It was noted in a later paper by Spence (31) that this occurred if, and only if, there was some excitatory tendency for this stimulus. This may occur as a result of prior learning or learning in the present situation. The total excitatory potential, at any one time, for a given stimulus complex was the algebraic sum of the excitatory potentials of the component stimuli. In the case of discrimination learning where we may have, and in a certain sense develop, antagonistic excitatory tendencies, the stimulus complex having the greatest excitatory potential at the moment will be responded to.

It was further postulated that the curves of acquisition and of extinction were of differential shapes. Hull (11) concluded that the curve of acquisition was probably S-shaped, suggesting that the relative strengthening effect of a single reinforcement was least at the beginning of learning and as it approached an asymptote. Reinforcements would yield the greatest increments in the middle of learning. Spence postulated that the shape of the inhibition gradient was either linear or logarithmic, thus the inhibitory effects of a single non-reinforcement would be greatest at or near an asymtote. That is, a non-reinforcement would yield a greater decrement in excitatory potential for stronger tendencies than for weaker ones.

After specifying these assumptions, Spence then proceeded to show how in the discrimination learning procedure

the curves of performance would show an initial period of response at or near chance and following this, there would be a sudden increase in the percentage of correct responses leading rapidly to criterion performance. It was assumed that the experimentally naive animal was introduced into the apparatus with position and brightness responses already fairly well established, generally with the position habit being stronger. Since, as a control feature, the to-be-learned brightness cue was being randomly and systematically varied spatially, the prepotent position response would coincide 50 percent of the times with the to-be-learned brightness cue. Since the position habit was assumed to be of greater initial strength, decrements would be greater than the increments to the brightness habit which was being consistently reinforced. This differential training would soon yield a consistent response to the positive brightness cue. However, it was shown that during the course of this development there would be sequences of responses in which it appeared as if the animals were responding to some sort of "hypothesis".

McCulloch and Pratt (25) had already shown that in weight discrimination, if the cue leading to reinforcement were switched prior to solution, this led to an increase in the number of errors during the course of the solution in the new problem. They also showed that this increase in the number of errors was proportional to the number of reinforcements received in the period of training prior to switching of the positive cue aspect. These results were direct confirmation for the S-R reinforcement position. Spence (29, 30, 31) carried out a number of discrimination experiments with chimpanzees using form and brightness discrimination problems and the cue reversal design; in all cases he showed the confirmation of his theoretical position.

III. The Development and "Resolution" of the Continuity - Non-Continuity Controversy

This became the critical area of disagreement between the continuity and the non-continuity theorists. The continuity theorists maintained that the response tendencies, habits were built up through simple association with reinforcements in a cumulative fashion. The non-continuity theorists asserted that the eventual manifestation of solution behavior depended upon some integrative, insightful process of the organism which was relatively independent of the manipulations of the environment by the experimenter. The effects of switches in the positive aspects of the stimulus during the pre-solution trials were relatively unimportant in the eventual solution of the problem.

Krechevsky (19) designed an experiment to test Spence's challenge, i.e.,

> "One of these implications [following from Krechevsky's theory] is that if the values

> of the cue stimuli are reversed, i.e., the positive stimulus made negative and vice versa, before the animal begins to show any learning whatever, it should not necessarily make for any slower learning of the reverse problem, for, according to this theory the animal selects and concentrates, in turn, on certain aspects of the experimental situation as offering possibilities of providing a solution and does not react to the real cue aspect until just at or just preceding the time of solution." (28)

Using a Lashley jumping apparatus and stimuli consisting of differential cards with vertical or horizontal rows of black squares on white backgrounds, Krechevsky trained three groups of animals. The animals were motivated to jump by "punishment", i.e., whipping or tail beating, and if the response were incorrect, received further "punishment" by nose-bumping and a fall into a net. A correction technique was used in that, following an incorrect jump, the animal was replaced on the jumping stand and allowed to jump again until a correct response was made. This was the definition of response and allowed for an analysis in terms of errors. A control group (I) was trained to jump to the horizontal card, two experimental groups (II, III) were trained positively to the vertical cards, one group for twenty trials and the other for forty trials. They then were switched to training with the horizontal card made positive.

The experimental question was whether the training on the vertical card would retard the learning on the horizontal card when compared with the learning of the control group. The animals which had had twenty trials on the reverse problem learned the new problem in fewer trials and with less errors (initial or repetitive) than the control group; on the other hand, the animals which had had forty trials on the reverse problem required more trials than the control group to learn the converse problem when the "truncated" data were examined. Krechevsky reasoned that forty trials was too long a sequence to expect the behavior to remain "pre-solution". In this series, he suggested that the animals had already started to react to the significant discriminanda with the consequence that reversal after the fortieth trial resulted in negative transfer. Krechevsky interpreted these results as favoring the non-continuity theory since the comparisons between groups I and II were significant and the comparisons between I and III were indeterminate because both theories predict the results.

Spence (32) criticized Krechevsky's interpretation of these results by writing that the data obtained by comparing group III with the control group confirmed the continuity position and were not indeterminate as Krechevsky had implied. The "pre-solution" period, as originally defined, referred to the behavior in the problem situation being examined. If one were to say that the previous training affected this behavior negatively -- he would have to assume the continuity position. The training on the converse problem had, in fact, interfered with the learning on the new problem. Considering the results of the comparison of group II with the control group, Spence maintained that the relevant cue aspects were not attended to by the subjects in the early trials of the experiment, and that these scores must also be truncated for legitimate comparisons. However, when this was done the differences still remained. In a theoretical article dealing with the phenomena of transposition, Spence (29) noted that a crucial consideration in the S-R analysis of learning was that one must be sure that the relevant stimuli are received on the animal's sensorium each trial from the very first.

> "Obviously, if the stimulus does not occur to the animal, it cannot acquire associative connections. The design of discrimination apparatus has been directed towards the forcing of the reception of the relative stimulus aspects from the beginning of training..... In the case of visual discrimination of forms or figures,..... this condition does not necessarily hold. In these instances the animal is required to learn, in addition to the final selective approaching response, the appropriate (perceptual) response which leads to the reception of the relevant stimulus aspects."

In discriminations of this sort (jumping stand apparatuses) the initial learning involved an orientation process for the organism in which it learned to orient to the relevant stimulus aspects in order that a specific receptor-exposure occur.

In concluding his criticism of the Krechevsky experiment, Spence asserted that the results were confirmatory for the continuity theory and indeterminate for the non-continuity theory. The Lashley jumping apparatus, Spence maintained, because of the procedure used, that is, correction training and punishment for motivation, and the nature of the response measure involved, was not optimal for investigation of this theoretical problem.

Lashley (21) rejected Spence's objections to the jumping stand apparatus as an adequate means for studying visual discrimination phenomena. He pointed out that the rat's visual field included something more than 300 degrees and that the binocular field covered between 50 and 100 degrees depending upon convergence. When an animal oriented to jump in the apparatus in question, the image of the differential stimulus necessarily fell on the binocular field of the retina. Therefore, Spence's objection to Krechevsky's procedure regarding the necessity of the stimulus impinging on the sensorium at the moment of response was gratuitous.

Ehrenfreund (5) conducted experiments attempting to invalidate Lashley's objection to Spence's criticism of Krechevsky's experiment. Using a modified Lashley jumping stand, he trained two groups of animals to discriminate between upright and inverted triangles. A non-correction method was used and punishment, i.e., "whipping", was not employed to facilitate the jumping response. In the first experiment, with the jumping platform placed in its normal position relative to the apertures, he trained one group with forty reinforced trials to one of the stimuli; the other group received 50 percent reinforcement on each stimulus

form. In the test period the positive cue was reversed and no differential effects of the pre-reversal training were observed. These results agreed with the data reported by Krechevsky. In the second experiment, the jumping platform was raised relative to the apertures so that the animal was re-oriented toward the center of the stimulus card rather than toward its bottom edge. The same differential training was followed. The results obtained from this procedure yielded marked differences between the two groups. There was a significant amount of interference with the group which had been given the forty consistently reinforced trials to the negative cue. These results supported the continuity position and gave confirmation to Spence's criticism of Krechevsky's experiment. The continuity position required that specific receptor-exposure fixations providing discriminably different excitation of the retina were necessary in order for discrimination learning to occur.

Spence (33), using the data obtained by Bollinger (4), presented more evidence in support of the continuity theory. In this experiment, two groups of animals were trained in an elevated type of discrimination apparatus. Prior to discrimination learning, the animals were trained to strengthen position habits in the presence of neutral cues. Following this, the black and white alleys were introduced and the animals were differentially trained as follows: The experimental group was given twenty trials, in which the response to the negative stimulus of the learning situation was reinforced. The control group was rewarded 50 percent of the time on both the white and black stimuli during the twenty trial pre-learning period. Following a further period of training, in which the position preference was eliminated, the regular problem was presented. The control group learned the black-white discrimination in significantly less trials and with significantly fewer errors than did the experimental group. These results gave strong confirmation to the continuity position, at the same time disconfirming the non-continuity position.

Following this, a series of experiments were carried out by neo-gestalt theorists attempting to find more or other empirical evidence for the non-continuity approach. Leeper (24), Bitterman and Coate (2), and Richie, et al. (27) all found evidence which tended to support the continuity position.

With these studies, continuity or non-continuity of discrimination learning diminished as a controversial issue in this specific form, i.e., the effects of reversal of cue values following some training (3). The continuity position has been more or less accepted as the theoretical position which predicts the behavior in discrimination apparatuses the most accurately. The non-continuity position has been, more or less, included in this theory as a behavioral description of the organism in the apparatus.

SPENCIAN THEORY AND ITS CONSEQUENCES

I. Spence's Theory

Numerous studies have already been discussed at length which have purported to investigate the "nature" of discrimination learning. Unfortunately, these studies have flowed from a controversy which reflected differing theoretical biases, so that the interpretation of the data gathered reflects the attitudes and motivations of the theorists more than they have shed light on the "nature" of discrimination learning.

The purpose of this thesis is to deal specifically with the assumptions underlying the Spencian explanation of discrimination learning, which are as follows:

> "1. The strength of an S...R connection is increased when followed by reward, i.e., the occurrence of a final or consummatory response, by an increment, "I", which varies according to the function
>
> $$I = \frac{K}{e^{(s-50)^2/2t^2}}$$
>
> in which K and t are constants dependent upon the individual learner, and s is a variable representing the strength of the S...R connection at any point in the learning process.[1]

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1. This formula is descriptive of an "S" shaped growth function. In general, this has been incorporated into the Hullian theory.

2. The strength of an S...R connection is decreased or weakened by failure of reward by a decrement, "D", which varies according to the function D = as-b, in which a and b are constants for an individual learner and s is a variable representing the strength of the S...R connection at any point in the learning process.[2]

3. The strength of an S...R connection or of the excitatory tendency of an S to arouse an R varies between the limit-values 0 and 100.

4. In the case of antagonistic, i.e., mutually exclusive, stimulus-response connections there will result a competition in which that having the greatest strength will prevail.

5. The total excitatory strength of a stimulus complex is the sum of the excitatory tendencies of the component stimuli."

From this, it can be clearly seen that the major assumptions are 1. and 2., which are primary to the logical deduction of Spence's explanation, and also comprise two of the major principles in Hull's system. When one assumes, as Spence does, that the naive animal enters the discrimination apparatus with response tendencies of differential strengths, the aforementioned principles allow one to generate deductions which account for the performance of the animal in such apparatuses.[3]

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2. This formula describes a straight line function. Spence notes that this may not be the empirical case and he suggests that a logarithmic function may obtain. He uses the straight line function for the sake of simplicity of calculation, but, in Hull's theory, the plot of the inhibition function is a negatively decelerated logarithmic function. In either case, the derivations that follow from this assumption still hold.

3. This is not made clear in the specific statement

Spence uses the following paradigm: Let the following symbols represent the excitatory potentials of the various components of the stimulus complex leading to the approach response, R_a. In this particular case, the animal is to respond spatially (discriminate) between a circle and a triangle. S_{lb} will represent the excitatory potential of the left goal box, S_{rb} will represent the excitatory potential of the right goal box. The two stimuli to be differentiated in his problem are designated circle S_c and triangle S_t.[4] It is assumed that the excitatory potentials of the stimuli, S_{rb} and S_{lb} are relatively strong, but unequal (90.00 and 90.20), and that the excitatory potentials of the stimuli, S_c and S_t, are considerably weaker and for the sake of simplicity equal in strength (10.00 and 10.00). On the first trial, with the stimulus, S_c, positive, the total excitatory potential for the left goal box is the sum of the excitatory potential, S_{lb} and S_c. When this response receives a reinforcement, then on the following trial its excitatory potential will have been increased. If, on the

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of the assumptions. However, in his calculations which demonstrate the mechanics of evolution of the to-be-learned response, these differential strengths are specified, i.e., the assumed excitatory potentials of the spatial cues are designated as 90.00 and 90.20, respectively; the excitatory potentials of the differential figures are designated as 10.00 and 10.00, respectively.

4. The to-be-discriminated differential stimuli in the above explanation are a circle and a triangle. The same explanation (general principles) hold for any simple set of discriminanda.

second trial, S_{lb} is hooked up with S_t and hence fails to yield reinforcement, the total excitatory potential for this stimulus complex will be decreased. The important consideration to be noted here is that S_{lb} is of a relatively high magnitude initially, so that the decrement following its failure of reward when hooked up with S_t is greater than the increment of this component of the stimulus complex when it is hooked up and rewarded with S_c. This difference between increments and decrements is a result of the differential hypothetical curves. As the training continues, with S_c always leading to reinforcement and S_t always failing of reinforcement, the respective excitatory potentials are built up and weakened, so that a point is reached where S_c will elicit or evoke the response, R_a, consistently, regardless of its spatial position. That is, the total excitatory potential of the stimulus complex, S_c, in combination with either S_{rb} or S_{lb} is of such a magnitude that it will always exceed the total excitatory potential of S_t in combination with either S_{rb} or S_{lb}.

During the course of the training with the stimulus, S_c, positive and always leading to reinforcement, and the stimulus, S_t, negative and always leading to non-reinforcement, there will be trial sequences when the animal will appear to be responding to either of the two spatial cues and possibly even to some sort of alternation cue. When the magnitude of the stimulus complex, S_c, plus either S_{rb} or S_{lb}

is so great that failure of reinforcement would not decrease the sum potential to a magnitude less than that of S_t plus S_{lb} or S_{rb}, the behavior of the animal will appear as if some sort of "insight" has been achieved.

In order that this hypothetical paradigm yield results consistent with the S-R reinforcement theory, the constants that Spence assigns to the various functions are of an arbitrary nature. It is also recognized that the situation analyzed is of a very simple sort. These two qualifications, notwithstanding, Spence points out that the actual determination of the constants will be an empirical matter and, even in more complex problem situations, these same principles will serve to properly explain them; that is, deduce the hypotheses and predict the results.

Unfortunately, when one stays within the total S-R reinforcement theory, the assumptions made by Spence lead to deductions inconsistent with this theory.

II. Formal Consequences of Spence's Theory

In addition to the law of primary reinforcement, Hull's theory specifies the notion of secondary reinforcement, which states that whenever a stimulus occurs in close temporal contiguity with a reinforcing state of affairs, there will result an increment to the tendency for that stimulus to evoke that response sequence which led to the reinforcement. This principle was conceived in order to account for the

empirical data of studies which involved partial reinforcement. Since habits trained under partial reinforcement proved extremely resistant to experimental extinction, the concept of secondary reinforcement was formulated in such a way that the non-reinforced trials also produced increments for the irrelevant cue aspects to evoke the response in question.

In previous studies, Humphreys (13) and this writer (6), both have demonstrated that not only are habits trained under conditions of partial reinforcement extremely resistant to extinction, but they also have very flat stimulus-generalization gradients. This implies that in a simple discrimination apparatus with the discriminanda on a similarity continuum, there will be generalization of excitatory potential from the positive to the negative stimuli, and marked generalization if conditions of partial reinforcement obtain.

In Spence's hypothetical case, although he is dealing with a discrimination between forms, he asserts that these principles hold for any set of discriminanda; that is, black versus white cards, horizontally versus vertically striated cards, etc. When he assumes that the spatial stimulus, S_{lb}, is prepotent and the differential stimuli, S_c (positive) and S_t (negative), are being alternated spatially, randomly but <u>equally</u>, he has set up a partial reinforcing situation. For one would expect that during the early part of training, the animal would respond more or less consistently to the prepotent stimulus, S_{lb}, with S_c and S_t approximately equally in close temporal contiguity with it. S_{lb}, when associated with S_c, results in a reinforcing state of affairs, and since S_t is on a similarity continuum with S_c, it too, should acquire increments to its excitatory potential through the principles of generalization and secondary reinforcement. Therefore, the paradigm that Spence sets up follows only from a very few principles of the Hullian system and is not consistent with the total system. If it were, one should expect that the prepotent stimulus, S_{lb}, would remain prepotent and prove resistant to experimental extinction rather than gradually weaken and be replaced by the positive form cue as the prepotent stimulus.

III. Empirical Weaknesses in the Confirmation of Spence's Theory

The S-R reinforcement theory makes certain predictions with respect to the number of trials to extinction. In Spence's hypothetical paradigm, with acquisition and extinction gradients of similar but reversed shapes, one would expect, for a relatively simple situation, that if an excitatory potential led to reinforcement a certain number of times, it would require approximately the same number of non-reinforcements to bring the excitatory potential back down to its original magnitude.

In order to guarantee that during the pre-solution training the animals were responding with strong spatial habits, Bollinger (4) and Ehrenfreund (5), both utilized the following design: In the same apparatus that was later used for discrimination learning, they trained groups to respond consistently to spatial cues, i.e., locomote right or left, jump right or left, in the presence of neutral visual cues. In the former case, twenty such reinforced trials were given and in the latter case, forty such reinforced trials. Then, in the presence of the differential visual cues, the subjects were given pre-solution training; that is, the experimental groups were given consistently reinforced trials to one of the visual cues. Following this, a period of training designated as position-reversal was carried out. In this training, the position habit established in the initial training was extinguished or equated for. However, the criterion for extinction was an extremely weak one. In the Bollinger study, three successive responses or four out of five successive responses to the side opposite to the one initially strengthened was considered as having effected a position-reversal. In Ehrenfreund's study, five successive responses to the side opposite the one originally strengthened in the initial training was considered as criterion for having effected position-reversal.

Holding to Spence's paradigm and to his assumptions regarding the shapes of the acquisition and extinction gradients, it can readily be seen that these relatively weak criteria are inadequate for assuming position-reversal. It would be entirely possible within the S-R reinforcement theory to predict such short trial sequences, particularly following the number of reinforcements involved, as still not reflecting any marked weakening of the initially strengthened spatial response.

It is the intent of these latter two sections to point out short-comings, 1) of a formal nature, and 2) of an empirical nature that are intrinsic in Spence's arguments for his theory of discrimination. It could be pointed out that these arguments were advanced some time ago and that the S-R reinforcement theorists, at that time, could not have had the foresight to envisage the empirical research of the future. Hull (12), in the last statement of his theory, and Spence (34), as recently as 1952, have reiterated the principles of discrimination learning as originally set forth by Spence in 1936 with very few minor modifications.

The next section of this thesis will suggest modifications in the S-R reinforcement theory which will lead to the prediction of more empirical data. It is hoped that it will be more internally consistent.

MODIFICATIONS FOR THE S-R REINFORCEMENT THEORY

I. An Interference Theory of Extinction

In the previous section, it has been pointed out that there are contradictions in prediction if one stays consistently within the S-R reinforcement theory. In particular, those predictions from the theory with regard to discrimination learning have been examined. It can be clearly seen that some modifications in the assumptions are necessary in order that the theory remain internally consistent and not predict phenomena contrary to the facts of experience.

Spence's notion of inhibition, which derives from the Pavlovian (26) notion, and which is specified as assumption 2. in the previous section, seems to be the critical assumption with regard to this paradoxical state of affairs. If one were to take an interference rather than an inhibitory position with regard to extinction, the inconsistencies that have been noted would disappear. That is, if one were to assume that rather than the "knocking out", suppression, or decreasing of the excitatory potential for the negative cue, there is a build-up of an excitatory potential for the negative cue which resulted in avoidant responses (responses incompatible with the approach responses), then one should be able to develop a more satisfactory explanation.

Adelman (1) has shown that in a simple straight-alley

learning situation, if the animals are allowed to learn a response which is compatible with the approach response and which allows them to escape the non-reinforcing cues, the latencies of the running response to the negative cue remain asymptotic. However, if the animals are not allowed to escape from the non-reinforcing cues, the response latencies increase until finally, the animals fail to leave the starting box entirely. It is, therefore, postulated that there is being built up, during the course of extinction, an incompatible response tendency which is associated with the cues of non-reinforcement resulting in experimental extinction of the original learned response.

An interference theory of extinction requires that certain modifications be made in the primary postulate set of the S-R reinforcement theory in order that one may generate deductions which coincide with the empirical evidence. Some such modifications have already been suggested by Lawrence (22, 23). In the following, a modified set of assumptions will be specified and the deductions with regard to discrimination learning will be examined:

1. In a stimulus complex the various stimulus aspects have an initial order of distinctiveness in the sense that some of the components of the stimulus complex are already associated with instrumental behavior.
2. Those stimuli which are reinforcers (food for a hungry animal, water for a thirsty animal) and which act as

unconditioned-stimuli are the most distinctive; presence or absence of these stimuli are crucial for the determination of the behavior of the animal in the stimulus complex with respect to learning.

3. After a learned instrumental response sequence has achieved some measurable magnitude, in a given stimulus complex, the removal of the reinforcer will result in the elicitation of characteristic avoidant responses, much in the same manner as a noxious unconditioned-stimulus.

4. Those components of the stimulus complex associated with the unconditioned-stimulus of non-reinforcement will, after some trials, tend to elicit the avoidant responses.

These assumptions say, in effect, that the "experimentally naive" animal is naive only with respect to the specific experimental problem. The animal already has fairly well established response tendencies (approach and avoidance) to stimuli in its environment. Of those stimuli, those which are members of the class of reinforcers are the most distinctive or discriminable. When these stimuli are employed in an experimental situation to evoke a response which the experimenter may desire to associate with some other stimulus, the presence or absence of the reinforcer is the crucial component of the stimulus complex and the most discriminable. The cues associated with the presence or absence of the reinforcer will, after learning, elicit those responses which were originally elicited by the reinforcers; that is, approach responses to the presence of reinforcers and avoidant responses to the absence of reinforcers.

II. Application to the Spencian Paradigm

Analyzing Spence's theoretical paradigm and using these assumptions, the theoretical explanation of the animal in the typical discrimination apparatus would be as follows: It will be assumed, as Spence does, that the prepotent stimuli (except for the reinforcer) in the experimental apparatus are spatial, in this case, left (S_{lb}) or right (S_{rb}) goal box. The experimental discriminanda, in this case, are differential brightnesses, black card (S_b) and white card (S_w), which are equal in strength but of a much lower magnitude than of the spatial stimuli. In order that one can determine that the animals are responding differentially to the experimental discriminanda, they (S_b and S_w) will equally and randomly appear in both spatial possibilities. The stimulus, S_b, will be positive and hence always have associated with it a reinforcer.

On the trials prior to the manifestation of the correct response at criterion level, with the spatial cue, S_{lb}, prepotent and coinciding with the stimulus, S_b, the animal will respond to this complex and both components of the complex will receive increments. On the next trial, with S_{lb} still

prepotent and the cue, S_w, associated with it, the animal will respond to this complex and experience non-reinforcement with the concomitant elicitation of characteristic avoidant responses associated with the elements of the stimulus complex; that is, there will be an increment to the tendency for the stimulus-complex, S_{lb} and S_w, to elicit avoidant responses. On the next trial, the animal will respond to the stimulus-complex, S_{rb} and S_w, and experience non-reinforcement. In this case, there is another increment to the tendency for the stimulus, S_w, to elicit characteristic avoidant responses which are now associated with S_{rb}.

If this description is a valid one for this phenomena, then it can be seen that during the course of such discrimination learning, what is occurring is as follows: Those stimuli, in this case, S_b, consistently associated with reinforcers are being strengthened; those stimuli consistently associated with non-reinforcement, in this case, S_w, are receiving increments to the tendency to elicit avoidant responses. Those stimuli which are neither consistently associated with reinforcement or non-reinforcement, in this case, S_{lb} and S_{rb}, are replaced in the hierarchy of distinctiveness since they are no longer critical for the determination of response.

In order that this state of affairs evolve, it follows that there must be a response sequence with the spatial stimulus prepotent in order that the response associated with

it achieve some measurable strength. This is necessary in order that stimuli associated with the non-reinforcement of the spatial response become associated with the elicitation of the characteristic avoidant responses resulting from such non-reinforcement. In other words, there must be some tendency, either present or developed, to the irrelevant cue aspects, in order that non-reinforcement of response to these elements evoke avoidant responses and lead to the growth of the incompatible response tendencies with respect to the irrelevant components of the stimulus complex.

Applying the above considerations to Spence's paradigm, it would be predicted that there would be a trial sequence at the beginning of learning which would be characterized by chance performance. However, different principles would be used to explain this phenomena. Spence assumed that the spatial excitatory potentials were relatively high, i.e., 90.00 and 90.20, respectively. He asserted that the chance performance was a result of the protracted number of trials necessary to effect a consistent differential in excitatory potential between the positive form stimulus in association with a spatial cue and the negative form stimulus plus a spatial cue in an incremental-decremental fashion. The interference theory specified previously would assert that since the differential between spatial excitatory potentials was very slight, the protracted number of trials at chance performance would result from the number of reinforcements necessary for one of the two spatial possibilities to become prepotent. An S-R connection of some magnitude was specified as being necessary in order that failure of reinforcement result in the elicitation of avoidant responses and the consequent build up of incompatible response tendencies with respect to the irrelevant stimulus components.

III. The Role of Stimulus-Generalization in the Interference Theory

Discrimination learning can be considered as the converse of generalized learning. This implies that a discrimination between stimuli on a similarity continuum results when the effects of generalization have been minimized or counteracted. After such a process has been carried out, then, and only then, can differential response to the cues involved become manifest.

The inhibition theory was criticized because it failed to take into account the phenomenon of stimulus-generalization under conditions of partial reinforcement. The interference theory discussed in this section also fails to consider stimulus-generalization as a relevant variable. However, this position is justified by consideration of the following points:

1. If the conditions for the elicitation of characteristic avoidant responses are met, then there has been training under conditions of continuous reinforcement.

Generalization gradients obtained under such conditions are relatively steep, therefore with differential stimuli at extreme ends of a continuum (black vs. white) there should be a <u>minimal</u> amount of generalization.

2. In addition, it has been assumed that added cues have been introduced into the situation. The negative stimulus always has associated with it the cue of non-reward, the positive stimulus always has a reinforcer associated with it. The addition of these highly distinctive cues makes for more discriminable differences between the stimuli due to the contribution of these critical cues to the stimulus complex. The resultant stimulus interaction <u>counteracts</u> the effects of generalization due to similarity of stimuli.

The above considerations clarify the interference position with regard to the contribution of stimulus-generalization as a relevant variable in discrimination learning. It is not the intent of this thesis to develop an entire theory but to supply a test for its various assumptions in a particular case, i.e., discrimination learning.

IV. Differences in Prediction Leading from An Interference Position

It is now evident that there are clear-cut differential predictions resulting from the consistent application of either of the two theories. The inhibition theory specifies that the excitatory potentials of the irrelevant components of the stimulus complex must be extinguished or minimized before there will be any consistent response to the experimental discriminanda. The interference theory specifies that the irrelevant components of the stimulus complex must have either some initial potential or some potential developed before the irrelevant cue aspects can be discriminated out of the total complex and responses made on the basis of the experimental discriminanda.

It is appropriate at this point to quote Spence with regard to the relation of a theory and the facts it is proposed to explain.

> "It is not,....., the theoretical concepts themselves and their hypothetical relations (principles) that must necessarily coincide or agree with the facts of experience but it is the logical consequences or deductions that follow from the theories. The test of the adequacy of any theoretical structure is that the logical consequences that flow from it coincide with events of experience, i.e., the learning behavior of the animal in this instance."

STATEMENT OF THE PROBLEM

The problem in this thesis is to design and carry out an experiment which will test the assumption of both an inhibition and an extinction theory with respect to discrimination learning. The experiment specifically tests the differential predictions with respect to the manner in which the irrelevant cue aspects of the stimulus-complex become non-determinant in discrimination learning. The experiment is a brightness discrimination in an apparatus involving a spatial response. The experimental groups will receive differential amounts of strengthening for the irrelevant spatial response. Following this they will be switched to brightness discrimination. The control groups will not receive experimental strengthening of the spatial response. The differential predictions of the two theories are as follows:

I. The interference theory predicts that consistently strengthening the irrelevant spatial response in the presence of the to-be-learned brightness stimuli will lead to significantly faster brightness discrimination learning.

II. The inhibition theory predicts that strengthening the irrelevant spatial responses in the presence of the to-be-learned brightness stimuli will lead to the significant retardation of the manifestation of the brightness discrimination.

The interference theory bases this prediction on the following assumptions: 1) When the cues associated with a particular spatial response are associated with reinforcers, there will be increments to the potential for those cues to elicit approach responses; 2) After the approach tendency has been strengthened, non-reward will elicit characteristic avoidant responses and the cues associated with non-reward will also tend to elicit avoidant responses; 3) During the course of strengthening the spatial response in the presence of the brightness cues, it is assumed that both of the brightness cues will receive increments to their potential to elicit approach responses; 4) When the problem is switched to a brightness discrimination, the positive brightness will continue to elicit approach responses and the negative brightness will elicit avoidant responses. These conditions will lead to faster brightness discrimination learning for these subjects, due to this training, than for subjects that had no consistent strengthening of the spatial response in the presence of these cues.

The prediction for the inhibition theory is based on the following assumptions: 1) Before a brightness discrimination can become manifest, those excitatory potentials which are prepotent and irrelevant must be reduced to magnitudes which do not contribute determinately to the total excitatory

potential of the stimulus-complex; 2) If the prepotent, irrelevant excitatory potentials are relatively high, it will require some number of trials to effect such a reduction; 3) If the prepotent, irrelevant stimuli are further strengthened beyond their initial magnitudes, the number of trials to reduce their potential to a non-determinate level will be increased. Therefore, strengthening the excitatory potential of the irrelevant spatial stimuli will increase the number of trials before brightness discrimination can become manifest.

SUBJECTS

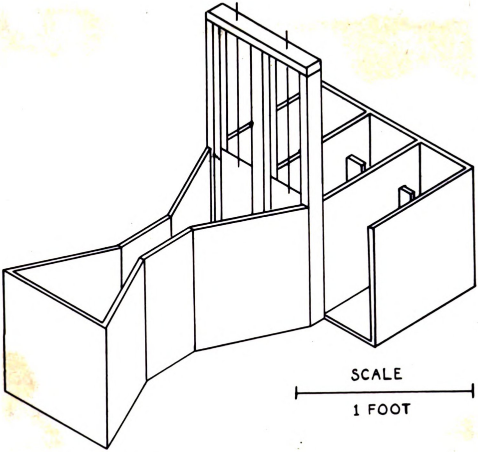
The subjects in this experiment were 46 experimentally naive, hooded rats, 90 to 120 days old, drawn from the colony maintained by the Department of Psychology at Michigan State College. The subjects were assigned to their respective groups in a random fashion, approximately equally distributed with respect to age, sex and initial position preference.

APPARATUS

The apparatus was a modified Grice-type (7) discrimination box; it is shown in isometric projection in Figure 1. The box was constructed of ½-inch plywood throughout, and was covered on top by hardware cloth screen. The starting chamber was a triangular box, 8 inches wide at the base, joined at its open apex to an alley 2 inches wide and 4 inches long. The alley led into a triangular shaped reaction chamber at its apex and this chamber had an 8-inch wide base opening into the 2 goal-boxes presented on any one trial. The starting chamber, alley and reaction chamber were 16 inches long from the rear wall of the starting chamber to the entrance to the goal-boxes. Two guillotine doors, 4 inches wide and 9 inches tall, could be lowered between the reaction chamber and the goal-boxes, thus preventing egress from the goal-boxes. The goal-boxes were 3 adjacent boxes of equal dimensions; any two adjacent boxes opened into the reaction chamber. The dimensions of the goal-boxes were 4 inches wide and 8 inches deep. The overall length of the apparatus from the rear wall of the starting chamber to the far wall of the goal-box was 24 inches. All the side walls of the apparatus, starting chamber, alley, reaction chamber, goal-boxes were 8 inches high.

The starting chamber, alley, reaction chamber and

FIGURE 1.



ISOMETRIC PROJECTION OF THE APPARATUS

guillotine doors were unpainted. The goal-boxes were painted as follows: The two outside boxes were painted flat white on all of the inside surfaces; the center box was painted flat black on all of the inside surfaces. There was a baffle in each goal-box, which consisted of a 5 x 2 x $\frac{1}{2}$ inch piece of plywood which was attached to the left wall of the box, 2 inches from the end wall and flush with the floor of the box. Food reinforcers, when placed in a goal-box, were placed behind this baffle so that they could not be seen by the subjects from any point outside the boxes. The goal-boxes could be moved one position right or left, such that a white goal-box could be presented right or left relative to the black goal-box on any given trial. Light was provided by an unshaded, 200-watt bulb hung 5 feet above the guillotine doors.

The rat was introduced into the starting chamber from which it passed through the alley, into the reaction chamber and under one of the guillotine doors into a goal-box. The door was lowered as soon as the animal placed both of its hind feet into the goal-box.

PROCEDURE

I. Preliminary Training

All animals were adapted to a 24-hour feeding schedule for at least 3 days prior to the start of preliminary training. They were fed in their home cage and received a mixture of Purina Dog Chow (their normal diet) and Zinns Food Pellets (which were used as reward objects). An amount of food equal to 8 grams per animal was introduced into the home cage during this procedure at the same time each day.

After at least 3 days of the former procedure, the subjects were placed into an unpainted alley, the floor of which was littered with Zinns Food Pellets. The alley was constructed of 2 end boxes, 4 inches wide, 6 inches high and 8 inches long, placed with their open ends together so that they composed an alley 16 inches long. The animals were placed in this alley for approximately one hour prior to their normal feeding time. While in the alley, they were handled individually by the experimenter and allowed free feeding of the reward pellets; following this, they were replaced in the home cage which contained their daily ration. This procedure was followed for 4 days, after which the animals were placed in individual feeding cages, which contained their daily ration, for one hour prior to being returned to their home cage in which only water was available.

II. Determination of the Position Preference

This procedure followed on the first day after the end of the preliminary training. The 2 unpainted end-boxes were separated and placed in the goal-box position of the apparatus with several pellets of reward food in each of them. Each subject was introduced into the apparatus at the starting chamber and allowed to enter either the left or right goal-box. <u>This response was recorded and was designated as the position preference</u>. The animal was then removed from the end-box and placed in the individual feeding cage and allowed to feed for one hour after which it was placed in the home cage.

III. Experimental Procedure

Five groups of animals, 2 control and 3 experimental, were used. The groups were counter-balanced, approximately equally, between males and females and between assignment to black or white positive sub-groups. The white goal-box was alternated from left to right in the following order: L R L R R L R L L R. The guillotine door was lowered as soon as the animal entered the goal-box, i.e., placed both of its hind feet into the goal-box. <u>This was the criterion of a response and defined a trial</u>. <u>No retracing was permitted</u>. If the animal, after being placed in the starting chamber, failed to respond within 6 minutes it was removed from the apparatus and discarded.[5]

On the first day following position preference determination all animals received 3 trials. On the second day, all animals received 7 trials, and on all subsequent days, the animals received 10 trials per day until the criterion of 9 of 10 correct responses on any one day was achieved. On the first trial that the animal was rewarded, it was allowed to stay in the goal-box for 6 minutes or until it ate the food pellet. On all subsequent trials, after responding, each animal remained in the goal-box for 30 seconds regardless of whether or not there was a reward object there. Trials were relatively distributed; there was an interim of at least 60 seconds between trials.

A reward consisted of one pellet of Zinn's Food, weighing approximately 0.05 gram, placed behind the baffle. The animals were run under 22 hours of food deprivation and were placed in individual feeding cages and allowed one hour free feeding following the day's running before being placed into the home cage.

5. This never occurred after trial 10. Fifteen such animals were discarded during the course of the experiment, most of them before trial 5. Two animals died and one animal escaped during the experiment. None of the data collected on the animals mentioned above was considered in the data analyzed for this experiment.

EXPERIMENTAL DESIGN

Five groups of animals were employed, 2 control and 3 experimental. The control groups were designated as C-0, C-24, and the experimental groups as E-12, E-24, E-48.

C-0 received no experimental strengthening of the position preference. On the first day following position preference determination, the positive cue for this group was either white or black; this condition prevailed until each animal in the group achieved the criterion. E-12 was given 12 trials with the preferred side positive (food reward was always in either the right or left-goal-box); following this training, they switched to brightness discrimination learning (food reward was always in either the black or white-goal-box). E-24 received 24 trials with the preferred side positive and then was switched to brightness discrimination learning. C-24 was matched against E-24 for sex, litter and original position preference. C-24 received 24 pre-brightness discrimination trials with the position response not consistently reinforced. Animals in this group were rewarded each time their match-mate in E-24 was rewarded; the reward object was present in both goal-boxes so that regardless of the response, the subject was rewarded if its match-mate was. That is, if animal 1 in

E-24 received reinforcement on trials 1, 5, 6, 7, then animal 1 in C-24 received reinforcement on trials 1, 5, 6, 7. C-24 controlled against the incidental variables introduced by the procedure; that is, number of trials, number of rewards, and pattern of reinforcement. C-24 received the same number of trials, number of reinforcements and pattern of reinforcement prior to brightness discrimination learning that E-24 did with no consistent strengthening of the position preference. E-48 received 48 trials with the preferred side positive and then was switched to brightness discrimination learning. C-0, E-12, E-24 and C-24 contained 10 subjects; E-48 had 6 subjects.

The experimental design is presented schematically in Figure 2.

FIGURE 2

EXPERIMENTAL DESIGN

Group	Position preference training	B - W Discrimination learning
C - 0	---	Continuous training on B - W problem with either brightness positive
E - 12	12 trials with preferred side +	"
E - 24	24 trials with preferred side +	"
C - 24	24 trials with rewards matched against mates in E - 24. Position preference not differentially rewarded	"
E - 48	48 trials with preferred side +	"

RESULTS AND DISCUSSION

I. Analysis of the Total Experiment

The results of the brightness discrimination learning, in general, conformed to the predictions. Experimental groups E-12 and E-24 learned the brightness problem in about the same mean number of trials, 38 and 41 respectively. The control groups C-0 and C-24 needed approximately a mean number of 15 more trials than did the experimental groups E-12 and E-24 to learn the brightness discrimination problem, 56 and 55 trials, respectively. The experimental group E-48 required a mean number of 85.3 trials to learn the brightness discrimination problem which was a markedly greater number of trials than any of the other groups required. These data are presented in Table I.

These data were submitted to a test for homogeneity of variance[6] and an F-ratio of 2.8 was obtained with 5 and 9 degrees of freedom, which is not significant at the .05 level of confidence, indicating that the data were homogeneous and were amenable to comparison by the analysis of variance technique. Such an analysis was carried out and

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6. This procedure is suggested by Guilford (9) on page 232. It requires that an F-ratio be obtained by dividing the smaller variance into the larger variance. In the above case, the smallest variance was divided into the largest variance assuming that all other combinations would yield F-ratios of a lesser magnitude.

TABLE I

THE ASSIGNMENT OF CUES, DISTRIBUTION OF SEXES, AND THE NUMBER OF TRIALS TO LEARN THE BRIGHTNESS DISCRIMINATION PROBLEM FOR ALL GROUPS

Group	N	Positive cue	Sex	Mean number of trials	S.D.
C - 0	10	6w - 4b	5m - 5f	56	10.19
E - 12	10	4w - 6b	5m - 5f	38	13.41
E - 24	10	6w - 4b	5m - 5f	41	10.24
C - 24	10	6w - 4b	5m - 5f	55	9.20
E - 48	6	3w - 3b	5m - 1f	85.3	14.90
Totals	46	25w - 21b	25m - 21f		

the results were as follows: An F-ratio of 17.46 was obtained indicating significance beyond the .01 level of confidence for the appropriate degrees of freedom when comparing the differences between groups. This indicates that there were significant differences between the performances of the various groups. Two other analyses were carried out with respect to the equation of sex differences and training toward the differential brightnesses. An F-ratio of .20 was obtained when comparing for differences between male and female animals in all groups. An F-ratio of .0006 was obtained when comparing animals trained to the black and animals trained to the white in all groups. Both of these F-ratios are considerably smaller than the ratio required for significance at the .05 level of confidence for the appropriate degrees of freedom. The above data are presented in Table II.

The data presented above indicate that there were significant differences between the various groups of animals trained in this experiment. The two control features, present in all groups, i.e., approximate equation for sex and specific brightness which was employed as a positive cue, were not particularly necessary since these variables did not contribute to differences in the animals' performance.

TABLE II

ANALYSES FOR DIFFERENCES BETWEEN GROUPS, SEXES, BRIGHTNESSES

Source	d.f.	Mean square	F
Total	45		
Groups	4	2519.34	17.46**
Within	41	144.24	
Total	45		
B - W	1	32.07	.00064
Within	44	497.63	
Total	45		
M - F	1	74.36	.20556
Within	44	361.74	

**Significant at .01 level of confidence
*Significant at .05 level of confidence

II. Comparisons Between Groups

Since it was determined that there were differences between the groups, and that these differences were not the result of differential performance due to sex or brightness per se, the data were submitted to a series of analyses of variance and the results are as follows: The two control groups C-0 and C-24 were not significantly different from one another. The experimental groups E-12 and E-24 while not significantly different from one another, learned the brightness discrimination problem in significantly fewer trials than did the control groups. Experimental group E-48 required a significantly greater number of trials to learn the experimental problem than did all other groups, both experimental and control. These data are presented in Table III as a matrix of F-ratios.

But for the performance of E-48, these results conform to the predictions made by the interference theory of discrimination learning. It was predicted that strengthening of the irrelevant spatial response, in the presence of the brightness cues, would lead to significantly faster brightness discrimination learning. This would come as a result of the association of the cue of non-reward with the negative brightness following the strengthening of the position response. The performance of E-48 did not conform with these predictions. A description and examination of the type of

TABLE III

MATRIX OF F-RATIOS FOR COMPARISON BETWEEN GROUPS

	C - 0	E - 12	E - 24	C - 24
E - 12	10.26**			
E - 24	9.68**	.2842		
C - 24	.0476	9.82**	7.87*	
E - 48	15.28**	34.69**	34.92**	17.05**

**Significant at .01 level of confidence
*Significant at .05 level of confidence

error that was made by E-48 may explain this state of affairs.

After having built up a relatively strong approach-tendency, the response latencies of E-48 dropped considerably and remained asymptotic. The animals, in this group, ran very quickly and unhesitantly into the goal-box on the preferred side. When they "discovered" that it was the goal-box of the negative brightness, there was an immediate attempt to reverse directions and escape. There was no attempt to "look" for food behind the baffle. As soon as the animal had entered the goal-box, however, the guillotine door was lowered so that escape or retracing was not possible. During the animal's entire 30 seconds in the goal-box containing the negative cue, its performance was marked by extreme activity and emotionality. There was a great deal of biting and clawing behavior directed at both the guillotine door and the overhead hardware cloth screen. The data obtained from the performance of the E-48 group was quite possibly due to the combination of a relatively strong approach-tendency and the nature of the response as defined. Had the positive or negative cues been brought out spatially further into the reaction chamber or had the experimenter delayed the lowering of the guillotine door, but one or two seconds, it would be expected that E-48 would have learned the problem in much the same number of trials as did the other two experimental groups. Therefore, the performance of E-48, with respect to E-12 and E-24, is accounted for tentatively as an artifact of the apparatus.

There is another possible interpretation for the performance of E-48 as compared with the performances of groups E-12 and E-24. The interpretation given above assumed that the "avoidant" potential developed incrementally, corresponding with either a linear or logarithmic function. The failure of E-48 to perform according to this assumption was explained as being an artifact of either the apparatus or procedure, or both. The other possibility would be that "avoidant" potential increases toward an optimum and then decreases; in other words, the "avoidant" potential corresponds with a curvilinear function. If this were the case, one could assume that the optimum for "avoidant" potential was reached somewhere between 24 and 48 trials. It, therefore, could be expected that E-48 would require more trials than either E-12 or E-24 to learn the problem since the former had been trained beyond the optimum point.

A curvilinear explanation would require further empirical investigation for confirmation. In any case, the determination of the gradient of "avoidant" potential was not the goal of this experiment. The confirmation of either explanation would not alter the basic assumptions that were tested in this investigation.

III. Analysis of Performance for Group C-24

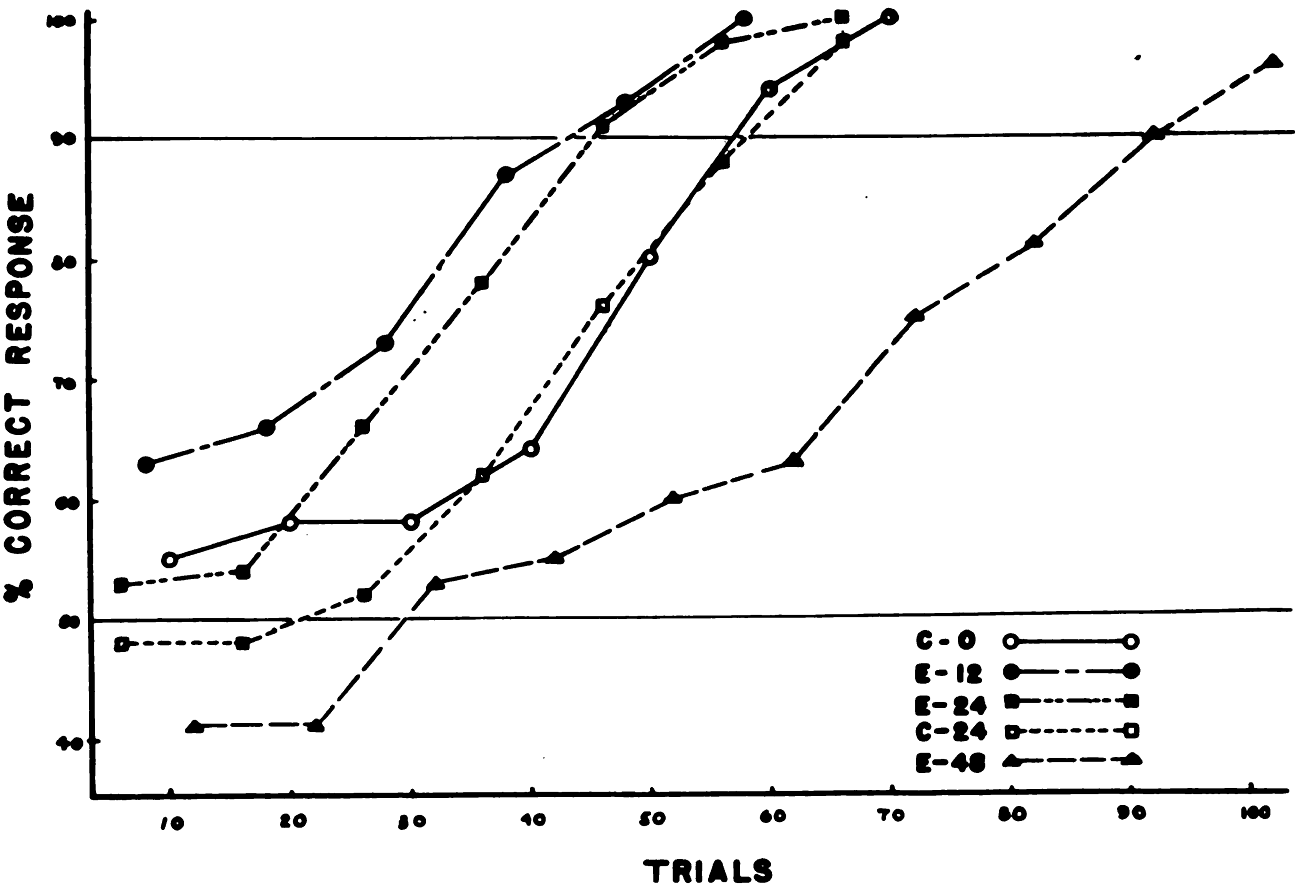
With respect to the performance of the control group C-24 it will be recalled that while these animals received an equal number of trials, rewards, and pattern of reward as did experimental group E-24 prior to the brightness discrimination learning, they did not learn the brightness discrimination any faster than did control group C-0 which had had no such training. These data lead to the conclusion that the pre-brightness training for C-24 was, in fact, indiscriminate and non-determinate with respect to the later brightness discrimination learning problem. Spence (32) criticized Krechevsky (19) for having compared the data of the experimental groups with the control group while not taking into account the fact that the control group had had more trials on the problem than the experimental groups. Therefore, he concluded that the legitimate comparison necessitated "truncating" the data of the control group to equate for this differential experience. After treating the data in this fashion some of Krechevsky's conclusions were vitiated.

There is an important difference between the present experiment and Krechevsky's. In this experiment, the animals were given training in the apparatus to a cue which was later irrelevant to the solution of the problem. In Krechevsky's experiment, the animals were given training in the apparatus to cues which were later reversed with respect to their "correctness". Nonetheless, in both cases, Spence's criticism, with respect to the differential amount of experience and the consequent dropping-out of "emotional" responses to the apparatus as a result of this experience, may be justified. The results obtained in this experiment do not show this, i.e., Spence's criticism is not applicable in the present experiment since no difference was obtained between control groups C-0 and C-24. Therefore, "experience" per se, is not a variable producing differential effects in this study.

IV. Curves of Performance

The curves of performance are shown in Figure 3. Inspection of these curves show that while they are for the most part linear, there is a tendency, as they approach criterion, for them to flatten out and increase according to a negatively accelerated function. In general, the shapes of these curves are similar to the hypothetical curve utilized by Spence in his theoretical explanation. Hayes (10) has recently proposed an argument which would suggest a re-examination of these curves. He suggests that in discrimination learning, since most of the curves obtained are plotted against an axis of percent correct response, the obtained curves are an artifact of this method of plotting. He shows that in a number of hypothetical cases and with a

FIGURE 3.

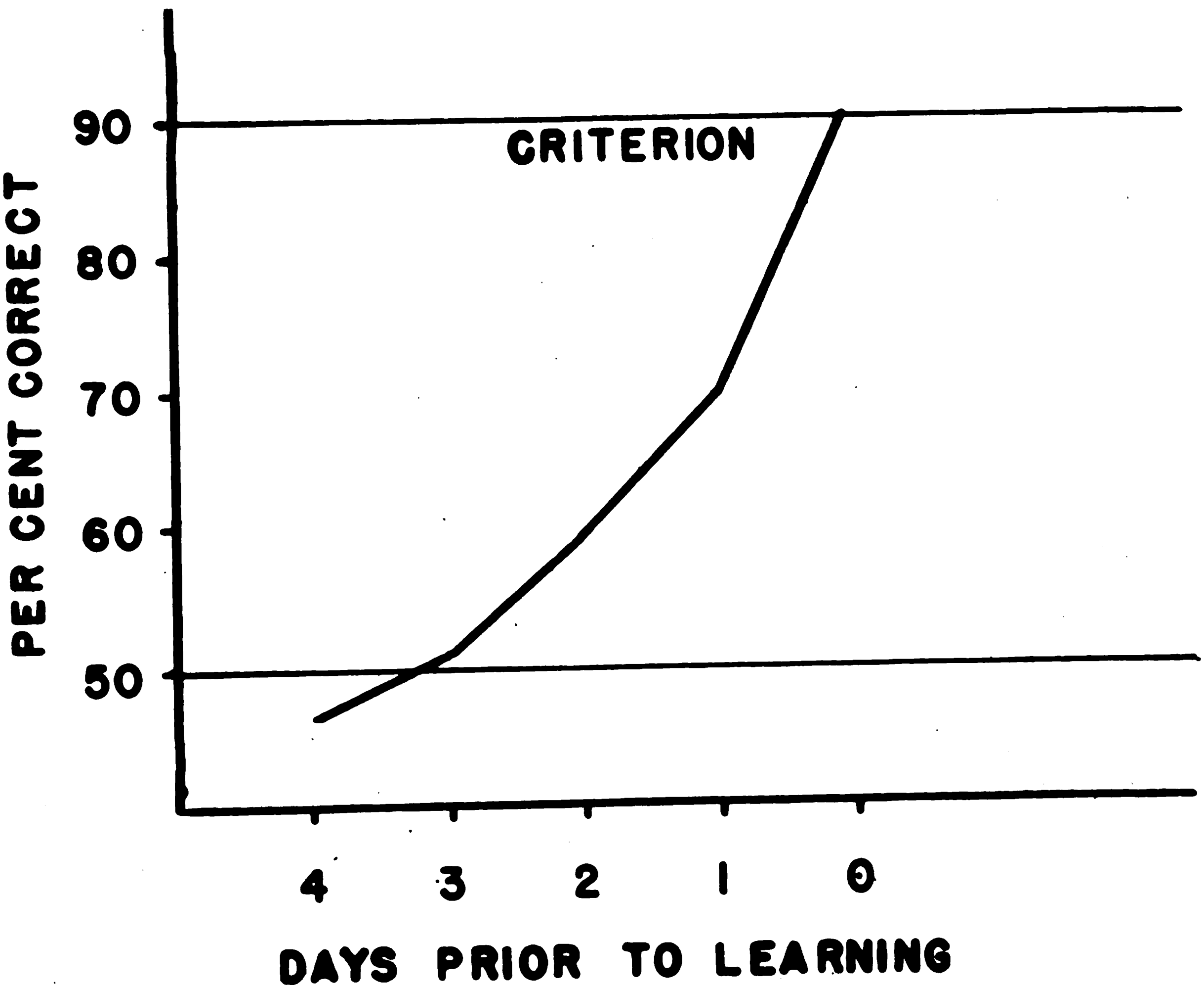


THE CURVES OF PERFORMANCE DURING
BRIGHTNESS DISCRIMINATION LEARNING.

number of different situations using this method of plotting, the negative accelerations are a result of the inclusion in the plot of the data of those members of the groups that have already achieved criterion performance. For instance, in examining the curve of performance for group E-24 in Figure 3, the flattening out of the gradient after trial 50 is the result of computing this plot with 8 members of the group having already achieved criterion and assuming that they will continue to perform at criterion level. Hayes points out instances where this assumption may be gratuitous and he suggests, therefore, that a more accurate picture of the shape of the gradient of discrimination learning may be obtained by plotting each individual's performance, with respect to percent correct response, on the days or trials prior to criterion performance. In this way, those members of a group that have already achieved criterion performance would not be contributing to the plot of the percent correct for the total group prior to criterion achievement. The data of all 46 animals in this experiment were subjected to just such a plotting and the gradient obtained is shown in Figure 4.

When the curve shown in Figure 4 is compared with the standard performance curves in Figure 3, a marked difference is noted. Contrary to the standard curves of performance, and those which are necessary for Spence's paradigm to be consistent, the curve obtained by plotting the data according to Hayes' suggestion is positively accelerated.

FIGURE 4.



THE BACKWARD CURVES OF PERFORMANCE
DURING BRIGHTNESS DISCRIMINATION LEARNING.

V. Analysis of the Position Preference Training

With respect to the position preference training, two possibilities were considered. The interference theory based its predictions on the assumption that some learning must occur during this training in order that non-reward elicit avoidant responses. Secondly, it was possible that during position preference training, the to-be-positive cues were differentially reinforced so that the superior performance of the experimental groups was an artifact of this accidental strengthening.

The data of the position preference training were analyzed in order to determine whether or not there were evidences for learning to the positive spatial cue. It was assumed that had there been no learning the animals would have responded at approximately chance levels to the spatial cues. As an instance, group E-12 would have responded to the preferred side no more often than six times had there been no learning, and probably significantly less than six times had they been responding to some other incidental cue. The deviations from chance expectancy were calculated. These deviations were tested for the probability that such deviations from chance expectancy could occur by chance alone. The probabilities obtained ranged from 4 chances in 1000 for E-12 to 6 chances in 100 for E-48. These data are presented in Table IV. Inspection of these data revealed that there

TABLE IV

ANALYSIS OF THE POSITION PREFERENCE TRAINING OF THE EXPERIMENTAL GROUPS FOR EVIDENCES OF LEARNING

Group	Chance expectancy of reward	Mean number of rewards obtained	Difference	σ_M	$\frac{\text{Diff.}}{\sigma_M}$	P
E - 12	6	7	1	.44	2.27	.030
E - 24	12	14.3	2.3	.83	3.25	.004
E - 48	24	28.16	4.16	2.73	1.88	.068

were evidences for learning to the spatial cue during position preference training and justified the assumption that this learning contributed to the performance during brightness discrimination learning.

The analyses which were run, in order to determine the contribution of the second possibility, are considered in the following discussion.

All the animals showed an initial preference for the black goal-box. This was evidenced by the fact that of the 36 animals which received pre-brightness training, a mean number of 9.19 rewards were received in the black goal-box as opposed to a mean number of 5.61 rewards in the white goal-box. This difference suggested the distinct possibility that the animals that received pre-brightness training may have been differentially reinforced with respect to the later positive cues. If this were the case, the possibility existed that this differential may have contributed to the differences obtained between groups with respect to brightness discrimination learning. That is, the superior performance of groups E-12 and E-24 may have been due to the fact that they received differential reinforcement for the cues which were later positive or negative in the brightness learning problem.

The data were anlayzed in order to determine whether or not the state of affairs discussed above existed during the course of the pre-brightness discrimination training. In any one group, the mean number of rewards received during the pre-brightness training that favored the brightness cue which was positive in the latter part of the experiment, was compared with the mean number of rewards favoring the brightness cue that was negative in the latter part of the experiment. It was found that none of the four groups receiving such treatment differed significantly in this respect; therefore, it can be asserted that although there were more rewards received in the black goal-box than in the white goal-box, this did not result in any significant differential when analyzed in terms of which of the brightnesses were positive or negative in the latter part of the experiment. These data are presented in Table V.

There is at least one further consideration to be taken into account when evaluating the pre-brightness training of the groups E-12, E-24, C-24 and E-48. Spence's theory would predict that there would be a correlation between the number of rewards that an animal had associated with the later to-be-positive cue and the number of trials required by the animal to reach a criterion in a problem where this cue was positive.

In order to get at this sort of prediction, the pre-brightness training data were analyzed in the following manner: Each animal was assigned a weighted score which represented the differential between rewards in favor of the later positive cue, i.e., if an animal received 7 rewards

TABLE V

ANALYSIS OF THE PRE-BRIGHTNESS DISCRIMINATION TRAINING WITH RESPECT TO POSSIBLE DIFFERENTIAL STRENGTHENING OF THE CUES LATER POSITIVE OR NEGATIVE IN BRIGHTNESS DISCRIMINATION LEARNING

Group	Rewards favoring positive brightness			Rewards favoring negative brightness				
	M	σ	σ_M	M	σ	σ_M	σ_{dM}	t
E - 12	3.7	1.34	.44	3.3	1.68	.56	.71	.56
E - 24	7.5	1.74	.58	7.2	2.40	.80	.98	.30
C - 24	6.8	2.71	.9	7.9	3.5	1.16	1.46	.67
E - 48	13.3	6.26	2.8	14.8	4.42	1.98	3.42	.43

**Significant at .01 level of confidence
*Significant at .05 level of confidence

on the black cue and 3 rewards on the white cue, the black cue being positive in the brightness discrimination training, a weighted score of +4 was assigned to it. If, on the other hand, the white cue was positive in the brightness discrimination learning, a weighted score of -4 was assigned to it. This procedure was carried out for all 36 animals which received pre-brightness discrimination training. These scores were then correlated with the number of trials required by each animal to learn the brightness discrimination. Correlations were only run in one direction attempting to predict the number of trials to learn the brightness discrimination from knowledge of the number of associations each animal had had with the positive cue. These data are presented in Table VI.

Theoretically, the relationship between these two variables is a curvilinear one. An eta correlation was, therefore, computed and a value of .05 was obtained with a standard error of .168. Unless the relationship is linear, eta will always be larger than a Spearman r. By computing eta, therefore, the greatest correlation possible was obtained and this correlation is extremely slight. A Spearman r was also computed and is of the same magnitude as the eta. In neither case can it be said that a strong correlation exists between the two variables as they were treated. Therefore, in this apparatus and under these experimental conditions, Spence's prediction regarding the two variables specified above can be said to be non-confirmed.

TABLE VI

CORRELATIONS BETWEEN THE DIFFERENCES IN FAVOR OF THE POSITIVE CUE IN POSITION PREFERENCE TRAINING AND THE NUMBER OF TRIALS TO LEARN THE BRIGHTNESS DISCRIMINATION

Eta = .05	S.E. of Eta = .1686
r = .04	S.E. of r = .169

CONCLUSIONS AND IMPLICATIONS

I. Conclusions

Two differing theories of discrimination learning were discussed and the results of an experiment were presented which tested the various assumptions of both theories. The experiment was designed so that the two theories would make mutually incompatible predictions with respect to the results.

The interference theory predicted that groups E-12, E-24 and E-48 would learn the brightness discrimination in significantly less trials due to the effects of differentially strengthening the position preference in the presence of the brightness cues, than would groups C-0 and C-24. Moreover, it was further predicted that groups C-0 and C-24 would not differ with respect to rate of brightness discrimination learning. But for the performance of E-48, these predictions were confirmed. The performance of E-48 was explained as an artifact of the apparatus or procedure, or both. An alternative explanation was offered which assumed that the development of an avoidant potential corresponded to a curvilinear function. If this case obtained, it would be assumed that the avoidant potential built up to an optimum somewhere between 24 and 48 trials and then decreased. In order that these predictions obtain it was necessary to

assert that some learning had occurred during the position preference training. This assertion was tested and evidence was obtained to confirm it.

The inhibition theory predicted that group C-0 would learn the brightness discrimination in less trials than groups E-12, E-24, and E-48, in that order. No direct prediction could be made with respect to the performance of group C-24. Since C-24 experienced more trials in the apparatus than C-0, it might be expected that C-24 would learn the problem in less trials than C-0 due to the dropping out of "emotional" responses. On the other hand, it might be predicted that the irrelevant cue components were being strengthened during the pre-training which would lead to C-24 requiring a greater number of trials than C-0 to learn the problem. In neither case would it be predicted that there would be a strong similarity between groups C-0 and C-24 with respect to the rate of learning and the mean number of trials to learn the experimental problem.

Only the performance of group E-48 conformed to the predictions stemming from the inhibition theory. The possibility was tested that these results, (non-conformance with the predictions) occurred due to the coincidental strengthening of the to-be-positive cue during the course of pre-training. This test did not reveal any significant differences with respect to the variable examined. One further prediction from this theory was examined; the inhibition theory predicted that there was a correlation between the number of prior associations with the positive cue and the number of trials necessary to learn a problem involving that cue. A method was devised to calculate such a correlation, but the correlation obtained was very slight.

The curves of performance were plotted in two different manners. In the first case, using the standard percent correct response plotted against the number of trials, more or less "typical" discrimination performance curves were obtained. Although the curves were linear in slope, there was a slight tapering off as they approached criterion which gave the impression of a slightly negatively accelerated function. Curves of this type were predicted from the S-R reinforcement theory. In the second case, using a "backward" method, differently sloped curves were obtained. In the "backward" method of plotting, the subjects that had achieved criterion performance did not contribute to the pre-criterion points. It was, therefore, argued that this latter method gave a truer representation of the shape of the acquisition curves of a brightness discrimination habit. The slope of the curve obtained by the "backward" plot was positively accelerated and was not predictable from the S-R reinforcement theory which tended to utilize negatively accelerated growth functions.

Therefore, it is concluded that under the experimental

conditions defined, and in this particular apparatus, the interference theory generated predictions which were, for the large part, confirmed. The inhibition theory failed, for the large part, to predict the empirical results and was, in that sense, non-confirmed.

II. Implications

The major implication of this study is clear-cut. In order that the S-R reinforcement theory be able to adequately predict the empirical data of experiments of the type carried out, modifications in the postulate set must be made. The modification suggested by this study is the substitution of an interference theory of extinction for an inhibition theory of extinction.

The interference theory suggested by this writer assumes that after the development of an approach tendency, non-reward of the approach response will elicit characteristic avoidant responses. Non-reward, in this case, operates as an unconditioned-stimulus. It is possible that non-reward may be utilized in such a capacity in other experimental designs and apparatuses. In connection with the above, it was implied that the avoidant potential develops (receives increments) according to a curvilinear function. The assumption that avoidant potential develops to an optimum and then decreases is testable and provides an opportunity for empirical confirmation.

During the course of the experiment, the investigator noticed certain consistencies in the animal's behavior which have implications for the S-R reinforcement theory. Although latency measures were not taken, it was noticed that the response latencies of the subjects decreased during the initial trials and then <u>increased</u> just prior to criterion performance. Most of the subjects behaved in the following manner during the brightness discrimination experiment: During the initial trials in the apparatus, they responded consistently to one of the spatial possibilities. This sequence of response was marked by extremely low latencies. During the trial sequence, just prior to manifestation of brightness discrimination, the response latencies increased markedly. Anthropomorphically, it appeared as if the animals were taking time to "really look at" the differential brightnesses. Following this, during criterion performance to the brightness cues, the latencies seemed to decrease again. The judgement of this latter decrease is not regarded as too reliable since the animals reached criterion very quickly after this last noticeable change in latencies.

One of the predictable modalities of response deducible from the S-R reinforcement theory is the latency of response. It is predicted that during learning and as it approaches an asymptote the latency of response will decrease according to a negatively decelerated curve. It is not assumed in the case being discussed that the habits were asymptotic;

however, there is no provision for marked or consistent fluctuation in the theoretical curve which is assumed by the S-R reinforcement theory. The observations of the investigator suggest that there are such marked and consistent fluctuations in this curve and that this variable (response latency in discrimination learning) bears further investigation.

SUMMARY

The history of modern investigations into the nature of discrimination learning was summarized from the publication of Lashley's "Brain Mechanisms and Intelligence" in 1929 to the present time. The history was traced through the development and "resolution" of the continuity - non-continuity controversy. The S-R reinforcement theory which developed from this controversy was examined with respect to its formal development and empirical confirmation. An interference theory of extinction was suggested to overcome difficulties encountered by the inhibition theory of extinction utilized by the S-R reinforcement theory. An experimental design was developed which would lead to mutually incompatible predictions by the two theories in discrimination learning.

The experiment was designed to test the effects of differentially strengthened position habits on brightness discrimination learning. The subjects were 46 hooded rats divided into five groups of 10, 10, 10, 10 and 6 animals. There were three experimental groups and two control groups. The apparatus was a modified Grice-type discrimination box. The treatment was as follows: Experimental group E-12 was given a relatively weak position habit; experimental group E-24 was given a position habit of intermediate strength;

experimental group E-48 was given a relatively strong position habit. Control group C-0 did not receive any experimental strengthening of the position habit. Control group C-24 was matched against experimental group E-24 with regard to the extra amount of training, number of reinforcements, and pattern of reinforcements, without consistently strengthening the position habit. Following this training, all groups were required to learn a black-white brightness discrimination problem in the apparatus to a criterion of 9 out of 10 correct responses per day. A non-correction technique was utilized throughout the experiment.

Application of an analysis of variance revealed the following results: 1) Experimental groups E-12 and E-24 required significantly fewer trials to learn the brightness-discrimination than did control groups C-0 and C-24. Experimental groups E-12 and E-24 were not significantly different from one another. 2) Control groups C-0 and C-24 required significantly less trials to learn the brightness-discrimination problem than did experimental group E-48. Control groups C-0 and C-24 were not significantly different from one another. 3) Experimental group E-48 required significantly more trials to learn the brightness discrimination problem than did all other groups.

With respect to the position habit strengthening procedure the following results were obtained: 1) There was some learning for all experimental groups with regard to the spatial cue during position habit strengthening. 2) There was no differential strengthening of the to-be-positive brightness cue during position habit training. 3) There was a very slight correlation obtained between the number of positive associations with the to-be-positive brightness cue during position habit training and the number of trials to learn the brightness discrimination problem.

Two methods of plotting the curves of performance were used: 1) The standard method of plotting percent correct response for the group against number of trials yielded curves of performance whose slopes were similar to those typically obtained by this method with this sort of problem. These slightly negatively accelerated curves were predictable from the S-R reinforcement theory. 2) By plotting the points from criterion performance backward, thus eliminating the subjects that had already achieved criterion from inclusion in the pre-criterion points, positively accelerated curves were obtained. This suggested that the actual brightness discrimination, when it was made, reached criterion very rapidly. The positively accelerated curve could not be predicted from the S-R reinforcement theory.

The results obtained were interpreted as confirming the interference position with regard to extinction. When irrelevant habits were strengthened in the presence of the to-be-discriminated cues, both (positive and negative) brightness cues received increments to their potential to elicit approach responses. When the problem was switched to a brightness discrimination, the subjects which had position habit training learned faster because the positive brightness continued to elicit approach responses while the negative cue elicited avoidant responses, much in the same manner as a noxious unconditioned stimulus. The interaction of these stimuli led to the faster brightness discrimination for the groups that had position habit training than for the groups which had not received this training. The inhibition theory predicted the reverse of these results and was, in that sense, not confirmed.

The performance of group E-48 was accounted for by offering two alternative explanations: 1) The approach habits were too strong due to the large number of training trials they had during position habit training. Had the differential brightness cues been brought further into the reaction chamber or had "correction" been allowed, group E-48 would have conformed to the prediction. This explanation was dependent on the subjective judgement of the type of error committed by group E-48. 2) The avoidant potential developed according to a curvilinear function with the optimum reached somewhere between 24 and 48 trials and then decreased. The behavior of group E-48 would then have been accounted for by the assumption that they had been trained beyond the optimum point and the further training had reduced the avoidant potential. Both of these alternative explanations are testable and subject to empirical confirmation.

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