DISCRIMINATION LEARNING AND ATTENTION (1972)

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"Discrimination implies a capacity for variability in behavior and a correlation between changes in behavior and changes in environmental stimulation. The process by which these correlations arise, where they otherwise were absent, is called discrimination learning" (Trabasso and Bower, p. 1).

In experimental analysis there are four types of discrimination situations which share the common feature that: two stimuli which are sufficiently similar that generalization between them occurs are treated differently. The organism must learn to distinguish between them and respond differently. Actually, any number of stimuli which are similar might be held within the framework of several types of discrimination situations existing in complex combinations; the situation need not be restricted to only two stimuli to hold true, although since this is the simplest illustration of the basic processes involved, it is most commonly used for demonstration.

"Discrimination learning is the process resulting from differential reinforcement of somewhat similar stimuli" (Logan, p. 137). In the classical case, one CS might be followed by one US while a second CS is followed by another US. For simplicity, however, studies are generally limited to the case of differential reinforcement of something versus nothing.

The four contexts in which the process of discrimination learning can be studied are:

1) Differential Classical Conditioning:

When two conditioned stimuli occur in an irregular and unpredictable order and one is followed by the unconditioned stimulus and the other is not, this is differential classical conditioning. Pavlov, in a number of experiments, trained dogs to salivate when another member of the same class was presented. The outcome was termed differentiation.

2) Differential Operant Conditioning:

Differential Operant Conditioning occurs when on some occasions one stimulus is present and one schedule is in force while on other occasions, a similar stimulus is present but a different schedule is in force.

3) Differential Instrumental Conditioning:

In a situation where the consequences of making the response in one situation are different from those in another situation, one has differential instrumental conditioning. Differential instrumental conditioning is demonstrated when performance by an organism in two situations is different and appropriate to the reward or nonreward experienced there.

4) Simultaneous Discrimination:

The above types of differential conditioning involve sometimes one stimuli being presented and sometimes the other being present when only one is reinforced. It is a "go-no-go" decision. In the fourth type of differential conditioning, simultaneous discrimination learning, the two stimuli are presented at the same time and the consequences of responding to one are different from the consequences of responding to the other. This is thought of as stimulus selection.

With the description of types of discrimination situations the operations which may be performed by an experimenter on the environment have been revealed. Differential reinforcement is associated with similar stimuli but it is an empirical question as to whether and how rapidly an organism may learn to respond differently.

Pavlov, Kohler and Lashley set the stage as a starting point for a set of problems involving discrimination learning. They had, however a strong interest in inferring neurophysiological processes from behavioral data. Pavlov believed that inferences from behavioral data to cortical events could be made. He argued that just as it was possible to make inferences about the machinery controlling reflex behavior from a detailed analysis of the laws of reflex, so it would also be possible to understand the structure and functions of the conditioned reflex.

Similarly, Kohler's interest in behavior, while including a much wider range of responses was closely tied to an interest in the physiological events underlying perception. Although Kohler's interest in showing continuities between simple perception experiments and more complex problem-solving and memory experiments, the simple behavioral research was intended to shed light on physiological events. Finally, Lashley, who was perhaps the most eminent American neuropsychologist, spent a lifetime trying to make physiological sense out of behavioral data.

American research on conditioning or American research on conditioning and discrimination learning, has veered away from Pavlov's conception of conditioning as a technique for the study of physiological processes (Kimble, 1961) and also away from any assumption that one could use behavioral experiments to make crucial tests about brain processes.

From the first, conditioning was regarded by some in America primarily as a learning situation stripped to the essentials: one in which the simple and most basic learning and transfer of training processes could be observed. With this information, it was then possible to use these principles to predict the outcomes of more complex learning situations. The peak of this effort was reached by Hull and others when his first paper in this field appeared. These principles of learning and transfer from conditioning experiments were applied to maze learning, discrimination learning, verbal learning and problem solving.

The major landmarks in the psychology of learning for the past forty years involve the use of many of these similarities and differences between various types of learning problems and the degree to which laws observed in simple situations such as Pavlov's and Thorndike's problem box are useful in accounting for the facts of the more complex. Books like Hull's *Principles of Behavior* (1943), Hilgard and Marquis's *Conditioning and Learning* (1940) and Kimble's revision of the latter book (1961) all employ this general approach.

The difference between Pavlovian and the Hullian use of the facts of conditioning are as follows: Pavlov considered the facts of conditioning (observed) explained when a parallel cortical process (unobserved) could be described. If the number of observed events was large compared with the number of unobserved events this was an indication of the power of the explanatory system. Hull considered the results of (e.g.) maze learning explained when a set of principles derived in part from the facts of conditioning could be shown to be consistent with the maze data. The two enterprises are the same because in both cases there is a working back and forth between a set of assumptions and a set of data. They differ in that Pavlov's assumptions are statements about physiological processes whereas Hull's are statements about general functional properties of the organism. Pavlov's is a theory with implications for physiological events occurring inside the animal. Hull's implies that the laws relating the behavior of the animal to the environment would be the same in simple situations (i.e., the laws of conditioning) and in more complex ones such as mazes and insight problems.

The general method required to produce a discrimination involves the extinction of generalized responses by nonreinforcements while the strength of the response to some particular stimulus is maintained by reinforcement. Two more specific procedures have been identified. These are called the methods of successive and simultaneous presentation.

In Pavlov's method of contrasts, now more often called the method of successive presentation of stimuli, only one of the two stimuli to be discriminated is presented on each trial. Reinforcement follows one stimulus and not the other, with the result that the subject comes to respond to one of the two stimuli and inhibit the response to the other. As originally conceived, the method was applied within the framework of the classical conditioning procedure and was used to establish discriminations between different stimuli in the same modality, such as two tones of different pitches. It is also the technique basic to establishment of conditioned inhibition in which a CS is reinforced if presented alone but not if presented with another (conditioned inhibitor).

Skinnerian methods of discrimination training are also modified versions of the method of successive presentation of stimuli. Responses in the presence of a positive discriminative stimulus (S^D) are reinforced; and responses in the presence of a negative discriminative stimulus (S^Δ) which is usually the absence of S^D, are not reinforced. In instrumental learning situations, the development of discriminations is more commonly studied in experiments where the positive and negative stimuli are presented simultaneously. The simplest of these is the position discrimination required in a simple T- or Y- maze in which the animal is reinforced for going to one side or the other.

Influences of motivation upon learning and performance through the drive stimulus, a concept which accords recognition to a set of facts indicating that drive states have many of the properties ascribed to stimulation, expresses a good example. “Animals can learn a response discrimination where the only differential element is the nature of severity of the deprivation; for example rats can be taught to turn left in a T maze when they are hungry and to turn right when thirsty or to make one response while under severe deprivation and a different response while under moderate or low deprivation of the same commodity” (Hilgard and Bower, p. 360).

There are two important differences between the successive and simultaneous procedures for studying discrimination learning: “l) Since the two stimuli are presented simultaneously in the latter procedure, the relational characteristics of the stimuli may be easier for the subject to notice than when the stimuli are present separately; 2) In simultaneous discrimination the choice is usually between two reactions (for example, turning right or left) rather than between reaction and restraint. Each of these reactions, thus, may have a double determination, being an approach to one of the stimuli and at the same time a reaction away from the other” (Kimble, p. 363).

In operational terms, discrimination learning appears to be a combination of two simpler operations. Trials with the positive or reinforced stimulus (S+) are conditioning trials and the trials with the negative or non-reinforced stimulus (S-) are extinction trials. Given this fact, it is not surprising that several theorists have proposed explanations of discrimination learning which involve the concepts of conditioning and extinction. Among such conditioning-extinction theories, the most important of those are Spence (1936, 1937a, 1937b) and Hull (1939, 1943, 1952). Conditioning-extinction theory, as originally developed by Spence and Hull, entails the following assumptions:

1) That every reinforcement leads to an increment in the (excitatory) tendency to repeat the reinforced response.

2) That every non-reinforcement leads to an increment in the (inhibitory) tendency not to respond.

3) That both of these tendencies generalize to other stimuli.

4) That the magnitude of the inhibitory tendency is less than that of the excitatory tendency.

5) That the excitatory and inhibitory tendencies interact algebraically.

6) That the discriminatory reactions are based on the resolution of the competing tendencies in favor of the reaction to the stimulus which has the stronger tendency conditioned (or generalized) to it.

In order to make predictions about the outcome of specific experiments, it is necessary to add a seventh assumption to the list above:

7) That the stimuli manipulated by the experimenter are in fairly direct control of the subject's behavior (Kimble, p. 364).

The fact that an organism responds differently to two situations implies the existence of differential stimuli and that these differential elements, in part, are controlling its behavior. This does not mean, however, that all differential elements are equally controlling; some elements may exert a powerful controlling influence and others none at all. Recognizing the possibility of differential control, a distinction is made between "nominal" stimulus variables or the full set of differential elements and the effective or "functional" stimulus variables which, in fact control the behavior.

A review of the area of (S+, S-) go/no go discrimination learning, Bloomfield, 1968; Deutsch, 1967; Jenkins, 1965; Terrance 1966 a, b) reveals confusion in the word inhibition and disagreement concerning what can be demonstrated by generalization tests and by tests which are presumed to isolate any response suppression effects which may occur during discrimination learning. The term inhibition has been used in two ways. Among others, Pavlov (1927) and Spence (1960) use the terms "inhibition" and "excitation" to describe hypothetical factors which underlie responding; inhibition suppresses responding, excitation encourages responding. Others, such as Jenkins (1965) and Terrace (1966b) use the terms descriptively at a behavioral level; inhibition is defined as the control of responding by S-, excitation is defined as the control of responding by S+. To say that a stimulus controls responding is simply to say that a generalization test which is given along a continuum which contains that stimulus will yield a non-flat gradient by virtue of the fact that that stimulus is contained on the continuum. In such a case, the variations in responding which account for the non-flat gradient occur because the stimuli used in the generalization test lie at varying distances from the controlling stimulus.

According to theories incorporating concepts of excitation and inhibition (e.g., Spence, 1960) the level of responding at a stimulus is a joint function of the inhibition and the excitation present at that stimulus (including the case where either of these might be at a zero level and hence may not be required theoretically). If it were possible selectively to eliminate one of these mechanisms then the resulting change in responding would be attributable to the loss of control by this mechanism. Terrace (1963) showed that responding to S- increased following the administration of the tranquilizing drug chlorpromazine. A test for inhibition is most useful when applied to the stimuli which have previously produced a gradient around S+ or S- on a dimension orthogonal to the alternative stimulus. If the generalization gradient is eliminated following the administration of the drug, the control demonstrated by the generalization test was due to inhibition. If the gradient is not eliminated, then that control was due to excitation. Hence, according to whether the drug eliminates the gradient, we can tell whether the gradient showing control by a particular stimulus was a gradient due to changes in inhibition or changes in excitation.

In summary, a generalization test around S+ or S- on a dimension orthogonal to the alternative stimulus can determine whether a specific attribute of that stimulus controls responding. And a test for inhibition, perhaps a drug test, at a stimulus can determine whether inhibition is present at that stimulus. But only a test for inhibition along a dimension which has previously produced a gradient around a stimulus can determine whether that stimulus exerts control through inhibition.

In the case where the stimuli to be discriminated are presented simultaneously and in situations involving choice reactions, an alternative explanation of discrimination exists. This is relational theory which is closely related to the cognitive view of learning. It holds that the development of a discrimination depends upon a comparison of the stimuli to be discriminated and that the response of the organism is to the relationship between them. The most empirical predictions to which this theory leads are that: a) simultaneous presentation, which favors the act of comparing stimuli will lead to the more rapid development of a discrimination than the successive presentation of stimuli; and b) since the discrimination is a response to a relationship transposition or transfer, the response will occur to pairs of stimuli not involved in the original discrimination but standing in the same relationship to each other. Also, relational theorists hold that the development of discrimination involves, on the part of the organism, the adoption of a series of hypotheses which are successively discarded until the correct one is hit upon.

Relational theory holds that a comparison actually does occur, between the stimulus now present and a memory trace of the alternative stimulus and that such comparison is harder to make than one with both stimuli present. This is the reason that relational theory predicts relatively greater difficulty with successive discriminations. Absolute stimulus theory predicts no difference.

Experimental comparisons of the two forms of discrimination learning have produced all possible results. The implications of the various outcomes for discrimination learning theory seem to be:

1) Both of the initial theoretical alternatives, relational theory and absolute stimulus theory, lead to erroneous predictions, indicating that both must be modified in order to explain the contrary results.

2) Since opposite outcomes have been obtained, it would seem that the relative effectiveness of the two procedures must depend upon the operation of other variables. One of the variables important appears to be the similarity of stimuli to be discriminated. In easy discrimination, there is little or no difference, but in difficult discriminations the simultaneous method is superior.

3) In certain experiments deriving from the simultaneous-successive discrimination issue, another problem has been raised. This problem involves the nature of the stimuli controlling responses in the discrimination situation.

All theories in this area begin with the implicit assumption that the organism perceives the stimuli presented. This statement, however, obscures certain differences of emphasis which separate absolute stimulus and relational theory. Absolute stimulus theory holds that it is sufficient if the stimulus energy reaches appropriate receptors. Relational theory on the other hand, assumes that the animal must, in addition “pay attention” to one stimulus in question, a conception which modern physiological research makes less mysterious than it once was (Lindsley, 1957).

The absolute stimulus theory seems to say that all stimuli impinging upon the receptors of the organism should control the response in some measure. Some relational theorists have extended this conception and have attempted to put the absolute stimulus theorists in the position of saying that small incidental differences between two stimuli will be discriminated, even if reinforcement is in no way contingent upon a response to one of these stimuli as opposed to the other.

If an animal is trained to discriminate between two stimuli, such as two shades of gray, by reinforcing a response (say) to the lighter, it is a typical finding that this discrimination will transfer to other pairs of stimuli and that the animal will continue to select the lighter. Moreover, this effect occurs even if the originally positive stimulus is paired with a still lighter one. That is, instead of choosing the originally reinforced stimulus, the animal now selects the new stimulus which bears the same relationship to the originally positive stimulus as the originally positive stimulus did to the negative stimulus. This transfer of discrimination to new pairs of stimuli is called transposition.

In the course of studies on transposition one important fact has come to light. As the test stimuli are made more and more different from the training stimuli, there is a gradual weakening of the transposition effect. This phenomenon has been crucial in the development of a nonrelational explanation of transposition and explanation based upon the generalization of excitation and extinction.

Building on the relationship between the degree of transposition and the difference between training and test stimuli, Spence (1936, 1937b) developed a theory.

In Spence’s theoretical treatment of discrimination areas of the visual stimuli used in the experiment are represented along the baseline. During the training, response to 256 is rewarded response to 160 extinguished. As a result of reinforcing 256 the generalization represented by the solid lines results. That is tendencies to react positively are generalized to the neighboring stimuli in proportion to the heights of the solid lines above each stimulus size. The non-reinforcement of 160 leads to a generalization of inhibition represented by the broken lines, extending also to stimuli on either side of 160. The resulting reaction tendencies, obtained by subtracting the negative from the positive, are indicated by each stimulus size (Spence, 1937b). The use of the diagrams to explain the results of transposition experiments is described in the text.

This representation depicts theoretical generalization gradients for excitation and inhibition along a size dimension. It should be emphasized that certain of Spence’s deductions are independent of the exact form of the generalization gradients. Spence has himself suggested other shapes (Spence 1942a). It also seems very probable that different species, different stimulus dimensions, different discrimination measures and perhaps, different individual organisms will require different generalization functions.

The numbers on the baseline have hypothetical meaning, however in Spence's example they represent areas of visual stimuli. The gradients of excitation and inhibition are established by training with stimulus 256 as S+ and stimulus 160 as S-. Now, suppose a test for transposition is made with a pair of stimuli 256 and 409. It is evident that the strength of a tendency to react to 409 is greater than that to react to 256. Therefore, the organism will choose 409 in spite of the fact that 256 was the positive stimulus during training. For this pair of stimulus transposition should occur. This is predicted, however, without any assumption that the organism perceives the relationship "relatively larger." Suppose now that the pair of stimuli 655 and 1049 is presented. The response strengths to these stimuli are 6.7 for 655 and 2.5 for 1049. In this case, the reaction should be to the smaller of the two stimuli. That is, the opposite of transposition should occur.

The crucial test of Spence's theory opposed to relational theory lies in the results of experiments designed to examine the details of transposition behavior as a function of the difference between training and test stimuli.

Several studies have demonstrated that the tendency for an animal to respond relationally in a transposition test decreases with the difference between test and training stimuli, may show the predicted reversal (T.S. Kendler, 1950; Ehrenfreund, 1952).

Strongest support for Spence's theory is derived from the experiment by Ehrenfreund. It is clear that results are in excellent agreement with predictions derivable from Spence's theory. 1) There is a general tendency for the amount of transposition to decrease with increases in the difference between training and test stimuli. 2) There is also a point at which the opposite of transposition occurs in that the curves fall below the 50 per cent point.

Test Condition: Amount of transposition as a function of the difference between training and test stimuli. The test conditions, A, B, C and D represent a series of approximately equal steps away from the training stimuli (Ehrenfreund, 1952).

Lawrence and DeRivera (1952) have presented much less favorable results to Spence's theory. While Ehrenfreund's data are generally favorable to an absolute stimulus theory, supporting it in rather considerable detail, Lawrence and DeRivera obtain results which support the relational interpretation, though occasional failures for the predictions from this theory hold. One possibility is that some combination of the two theories will ultimately have to be developed (Stevenson and Bitterman, 1955).

Another way of handling transposition is that of a redefinition of the stimulus concept. If a. stimulus is anything which can serve as a cue to which a response can be conditioned (Miller, 1959), it is an open question as to whether relationships can function in this way.

If this should be true, however, then the phenomenon of transposition could be nothing more than a special case of stimulus generalization in which the stimulus dimension is one of similarity of relationships. In more mechanistic terms this idea could be reduced to a matter of mediational generalization.

Such as, if an organism learns to respond to the relationship S_1/S_2, in which S_1 and S_2 are other different stimuli presented to an animal simultaneously or are two different parts of single stimulus when correct response depends upon the relationship between these parts. If it is assumed that the act of comparing these two stimuli, r_o, provides proprioceptive stimuli which function as discriminative stimuli, the following S-R analysis applies:

$$S_1/S_2 \text{ -------->} \; r_o \text{ --------->} \; {}^{S}S_1/S_2 \text{ --------->} R$$

This assumes that the response (R) is mediated by an internal stimulus (${}^{S}S_1/S_2$) which is somehow peculiar to the relationship involved. To say that the organism “recognizes” or “perceives” the relationship is little different from making this assumption. Now, if the organism is confronted with a new pair of stimuli (S_3 and S_4) bearing the same relationship to each other as S_1 did to S_2, it could be argued that the following holds:

$$S_3/S_4 \text{ -------->} \; r_p \text{ --------->} \; {}^{S}S_3/S_4$$

If ${}^{S}S_3/S_4$, on some continuum with ${}^{S}S_1/S_2$ but differs in absolute value, there should be generalization of the response (R) to the new relationship and the degree of transposition should depend on the similarity of training and test stimuli. There should, however, be no reversal of the transposition function with increasing differences between training and test pairs as Spence’s theory requires.

More recently Riley, Sherman and Mc Kee (1966) examined Zeiler’s (I963b) account of transposition after intermediate size training in terms of adaption-level (AL) and offered a two-process hypothesis. Zeiler suggests an AL interpretation that is based on an ad-hoc weighting of the stimuli presented during training and testing. Zeiler’s adaption-level (AL) interpretation of transposition in children following training on an intermediate size problem is compared with Sevenson and Bitterman's (1955) conclusion that S learns to respond to both relational and absolute properties of the stimulus. He concludes that based on an analysis of Zeiler's data and new data that while it is not necessary to assume a changing to AL to account for the facts of intermediate size learning and transfer, it is necessary to assume that S's response in training and test is determined both by absolute and relative properties of the stimuli. The degree to which these properties control behavior depends upon factors such as background characteristics and instructions.

In answer, Zeiler comments "the absence of evidence for learning of the middle size relationship in any but the study with adults and the multiple training set with experiments prevents the two-process theory from being a convincing explanation of the intermediate size problem (ISP). But, because of the growing catalog of situational variables that cause absolute learning, the ratio theory is also not convincing" (Zeiler, p. 257).

The failure of Reiley et al. to replicate Zeiler's (1963a) finding can be understood as a function of differences in absolute learning. Zeiler's (1966) experiment indicated that the learning fit the ratio theory while Riley et al. reported behavior that suggested a more precise perception of the size of the positive training stimulus. A few years ago, Zeiler reported difficulties in replicating his original experiment and suggested that attentional factors might explain the discrepancies (Zeiler, 1963b).

Spiker (1970) described an extension of the Hull-Spence theory of discrimination learning and demonstrates how the new version handles several of the problems that earlier versions were unable to cope with in a simple way. Two modifications are proposed in the basic axioms of Hull-Spence discrimination learning theory. The principle of stimulus generalization is changed from an exponential to a linear function for both habit and inhibition. The principle of stimulus interaction is substituted for the additive axiom used by Spence and for the principle of afferent neural interaction proposed by Hull. With these two modifications and other principles in the theory, prediction equations were derived for several types of problems involving discrimination learning and transfer. The modified theory is shown to predict that successive conditional reaction and mixed simultaneous successive problems can be learned. Also, an illustration of the way in which response produced cues can be quantitatively incorporated into the theory is presented. Finally, a method is described for obtaining maximum livelihood estimates of the parameters in the prediction equations. A generally favorable evaluation of the theory results from a comparison of its predictions with the outcomes of some two dozen experimental studies.

Finally, information on stimulus selection in discrimination learning was discussed in a set of experiments by Wagner, Logan, Haberlandt and

Price (1968) finding that a partially reinforced cue was a less effective stimulus when in isolation after being experienced as a common cue in components which were comprised of elements which had been more highly correlated with reinforcement than when it had been experienced with somewhat similar compounds that did not contain elements more highly correlated with reinforcement. The general consensus was that supporting evidence interpretable in terms of theories incorporating a basic stimulus-selection process than in conditioning-extinction was that supporting evidence interpretable in terms of theories incorporating a basic stimulus-selection process than in conditioning-extinction terms was found.

In summary, it would appear that a continued search for better methods and new innovative ideas to clarify both forms of discrimination learning are sorely needed.

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