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**AN INTERPRETATION OF THE DEVELOPMENT OF A
PERCEPTUAL SET IN S - R TERMS**

**DELOS D. WICKENS
THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION**

SEPTEMBER 1952

WRIGHT AIR DEVELOPMENT CENTER

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**AN INTERPRETATION OF THE DEVELOPMENT OF A
PERCEPTUAL SET IN S - R TERMS**

Delos D. Wickens
The Ohio State University Research Foundation

September 1952

Aero Medical Laboratory
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Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report was prepared at the Ohio State University under the contract AF 18(600)-78 between the Air Research and Development Command and the Ohio State University Research Foundation. The contract was initiated under Research and Development Order No. 694-44, "Learning and Transfer in Reference to Training Aid Design" and is administered by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, with Dr. Gordon A. Eckstrand acting as Project Engineer. The actual theory contained in the report was developed during the writer's regular seminar at the Ohio State University. Because of the possible applicability of the theory to the nature of the problems investigated in the above-mentioned contract, it is being submitted as a WADC Technical Report.

ABSTRACT

This report is an effort to interpret the development of certain types of perceptual biases in terms of modern stimulus-response theory, and thus to integrate this class of behavior with concepts that have been found to be widely useful in handling other kinds of behavior. The specific type of situation with which this theoretical formulation is concerned is that in which certain classes of stimuli are seen as being relevant to problem solution and others as irrelevant. The paper is concerned primarily with predicting what will happen when the subject is transferred to a new situation where opportunity for the operation of these relevancies and irrelevancies occur.

The major assumptions employed were those of stimulus and response generalization, and the acquisition of excitatory tendencies through reinforcement and of inhibitory tendencies through non-reinforcement. A number of experimental predictions were generated by use of these concepts.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:



ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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AN INTERPRETATION OF THE DEVELOPMENT OF A PERCEPTUAL SET IN S - R TERMS

INTRODUCTION

A recent experiment by Eckstrand (2) dealing with the general problem of the design of synthetic training devices, demonstrated that preliminary training can exert a selective influence on which of the cues available in a later task will be used by the subject in learning this later task. Similar results were previously obtained by Lawrence (7,8) using animals. Transfer of this type has frequently been explained as arising from perceptual biases or habits of attention built up during the preliminary training. Although concepts of this sort seem occasionally to be used by S-R theorists, they do not on the surface seem to be compatible with the Hull type S-R theory (6). Hull's theory tends to emphasize specific stimuli, specific responses, and the particular connections established between them. The concepts of perceptual bias or attention seem far more general in nature, and appear to be contradictory to the specificity of Hull's system.

The behavior under consideration will be illustrated by an analysis of an experimental situation similar to the one used by Eckstrand. Subjects are presented singly with stimuli to which they are to react by pressing one of three keys. For each stimulus one and only one key or response is correct. Actually there are nine different stimuli, but they are made by combining three forms with three colors. The solution to the problem consists of responding only to the color aspect of the stimulus regardless of form. The experimental design is illustrated in Table 1.

TABLE 1

DESIGN OF THE STIMULUS RESPONSE RELATIONSHIPS IN THE HYPOTHETICAL
EXPERIMENT USED TO DEVELOP A PERCEPTUAL BIAS TO RESPOND TO
THE DIMENSION OF COLOR IN A TRANSFER SITUATION

Relevant Stimuli	Irrelevant Stimuli			Correct Response
	F ₁	F ₂	F ₃	
C ₁	Yellow Triangle	Yellow Circle	Yellow Square	R _a
C ₂	Green Triangle	Green Circle	Green Square	R _b
C ₃	Blue Triangle	Blue Circle	Blue Square	R _c

We will assume that the colors employed are yellow, green and blue, and that the forms are triangle, circle and square. To the yellow stimulus the only response that is reinforced is R_a , regardless of the form with which it is associated, and any other response is not reinforced. The green stimulus is reinforced only if R_b is made, and the blue only if R_c is made. Hereafter these colors will be referred to by the letter C and appropriate subscript, and the forms by the letter F and appropriate subscript.

The results of the experiment by Eckstrand suggest that after subjects have solved this problem and are given a new problem in which different colors and different forms are employed, they will solve it with greater ease than if the first problem had not been presented and solved(2). Speaking loosely one is inclined to say that they have learned to pay attention to color, or have developed a concept that color is the key to the solution of the problem. The question is whether it is possible to predict this behavior from molecular S-R concepts.

It may be well to point out some of the possible advantages of interpreting the behavior in S-R terms. One advantage is that there is a large body of other behavioral data which has been usefully interpreted in S-R terms. If it is possible to employ the same concepts in a new area of behavior, an obvious economy of thought is achieved. Ultimately we are interested in the type of variables of which behavior is a function, so that we may manipulate these variables to increase efficiency. S-R psychology in general, with its reference to objective stimuli and directly measurable responses, would seem to offer concrete opportunities for performing these environmental manipulations and determining their effect upon response characteristics. In this paper we shall first attempt to sketch out how some basic concept of S-R psychology may operate in this type of situation, and will conclude with a group of concrete behavioral predictions which can be made by the employment of these concepts.

The following assumptions will be made in applying S-R theory to this area of behavior:

1. If reinforcement occurs following a response to a stimulus, the tendency to make that response to that stimulus is strengthened. The strengthening is nonselective in nature, and it occurs for those aspects of the total stimulus which are arbitrarily wrong as well as those which are arbitrarily right.
2. Conversely, if the response is not followed by reinforcement, the tendency to make that response will decrease (1).
3. Stimulus generalization will occur under both the strengthening and the weakening conditions, and the gradient generalized will be of the Hovland type (5). Actually the exact form of the generalization gradient is not important at this stage of the analysis, and if later research should indicate that the concave gradient does not hold generally, no major modification would need to be made.

4. The increment in habit strength gained from one reinforcement is equal to the decrement resulting from one non-reinforcement. This assumption is not crucial, and it is made only for purposes of simplifying the exposition. Exact empirical data concerning this assumption are lacking.

5. The learning is continuous in nature and not dependent upon the subject's hypothesis (9). Indeed, the central position taken in this paper is that hypotheses are not the cause of the learning, but are in the nature of the subject's verbal expression of the habits which have been acquired.

THE CONDITION OF EQUAL ASSOCIATION OF PARTICULAR RELEVANT AND IRRELEVANT STIMULI

Using these assumptions we will now consider the strength of the various habits the subject has acquired after 27 presentations. We will assume that during these 27 presentations each of the nine stimuli has been presented three times, and each of the three responses has been made once to each of the nine stimuli. There is nothing essential about this sequence of events, and the arguments presented would hold for another pattern of responses as well; it is arbitrarily chosen for purposes of simplifying the exposition.

Table 2 summarizes the results of this procedure in terms of the occurrence of reinforcement and non-reinforcement associated with each stimulus-response relationship. It will be noted that reinforcement is given for the response R_a only when it was made in the presence of the stimulus C_1 . At all other times this response occurred, it did not receive reinforcement. A similar state of affairs holds for C_2 and R_b and for C_3 and R_c .

TABLE 2
THE PATTERN OF REINFORCEMENT AND NON-REINFORCEMENT
ASSOCIATED WITH EACH STIMULUS AND EACH
RESPONSE FOLLOWING 27 TRIALS

Stimuli		Responses		
Color	Form	R_a	R_b	R_c
C_1	F_1	+	-	-
	F_2	+	-	-
	F_3	+	-	-
C_2	F_1	-	+	-
	F_2	-	+	-
	F_3	-	+	-
C_3	F_1	-	-	+
	F_2	-	-	+
	F_3	-	-	+

We will now consider what effect this sequence of events has on the tendency to evoke the R_a response only over the entire dimension of color. Three reinforcements of this response were given at point C_1 on the continuum, and this will produce a generalization gradient of excitatory tendencies across the entire continuum. This is the gradient shown above the zero line in Figure 1. However, three nonreinforcements were given at points C_2 and C_3 and these generate the two curves below the zero line.¹ If these three gradients are summated algebraically, the resultant tendencies to make R_a across the entire dimension of color are shown in Figure 2. It is apparent that there is a tendency to make this response to stimuli in a range close to C_1 , but to avoid making the response in the ranges surrounding C_2 and C_3 .

A similar result will occur for C_2 and its response R_b and for C_3 and its response R_c . When these three separate S-R connections are placed upon the same continuum, the curves shown in Figure 3 are generated. The curves indicate that there is a tendency for one or the other responses to be evoked by new stimuli along most of the C dimension. Thus, if a group of new colors were employed, these colors would tend to evoke this class of responses.

Turning now to the effects of the training upon the F stimuli, we find that the results are quite different in nature. As shown in Table 2 every stimulus has been given one reinforcement to every response, but it has also been given two nonreinforced trials for every response. In other words, the inhibitory tendencies are at every point more frequent than the excitatory tendencies at that point. The net result of this treatment is inhibition across the entire continuum, and the curve shown in Figure 4 is generated. This curve will be the same for all of the F stimuli.

The structure of this training has therefore developed habit tendencies within the subject such that if he is presented with a new problem using new colors and new forms, responses are not likely to be evoked by the aspect of form, but they are likely to be evoked by the aspect of color. This kind of behavior has the characteristics of a perceptual set to respond to color.

THE EFFECT OF NUMBER OF TRIALS

As the subject begins to respond correctly in this situation, and reinforcements pile up to the exclusion of nonreinforcements, a change will occur in the nature of the response tendencies to both the C and the F stimuli.

One effect the increasing proportions of correct responses will have upon the tendencies to respond to the relevant or C stimulus is to decrease the inhibition associated with any particular C stimulus and

1. It is apparent from this and other figures that we have represented the stimuli as being equidistant from each other along the dimensions of both form and color. The arguments presented in the text are not, however, restricted to such a state of affairs.

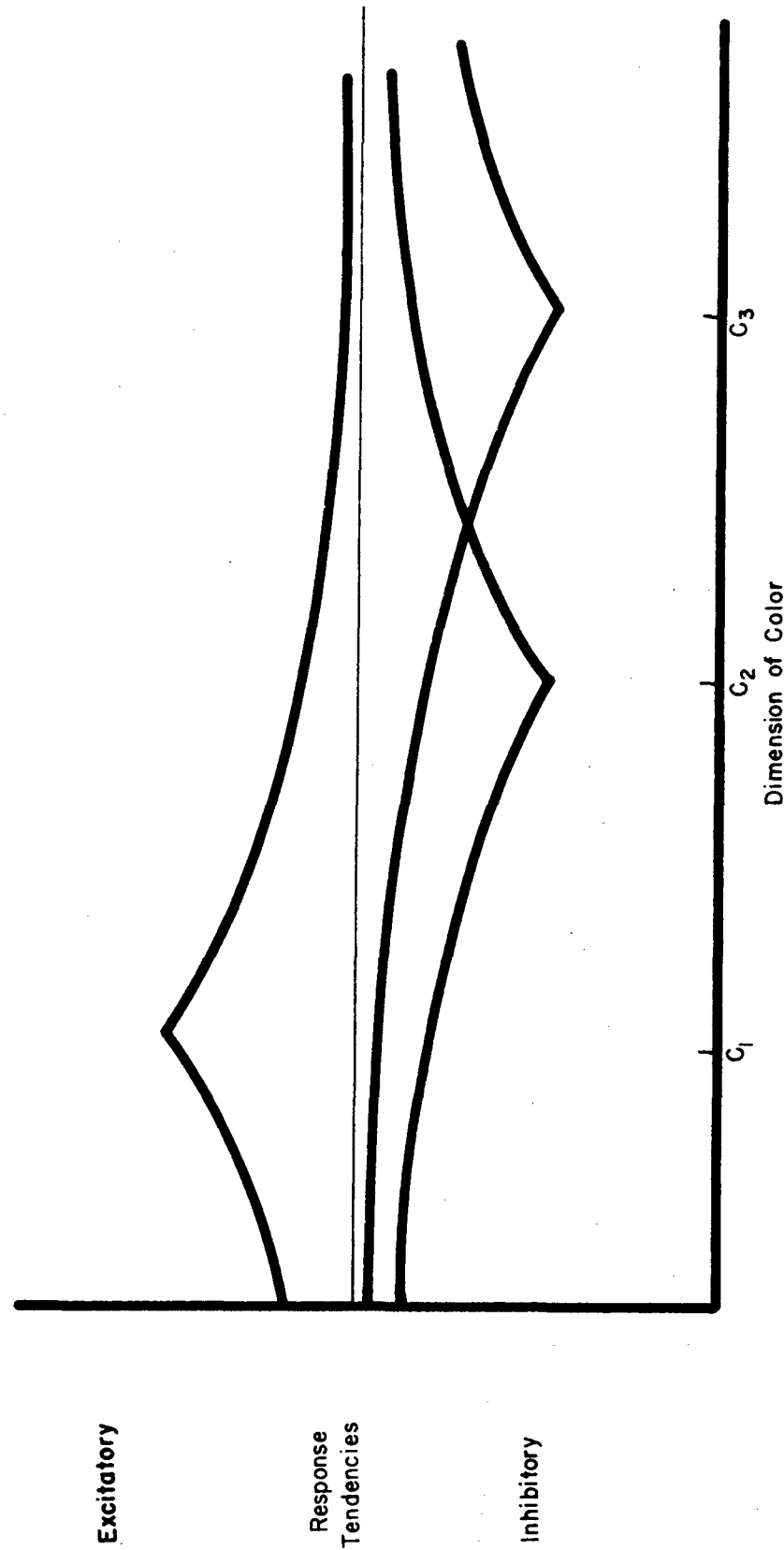


Figure 1. The separate inhibitory and excitatory tendencies to make the response R_q across the dimension of color.

Excitatory

Response
Tendencies

Inhibitory

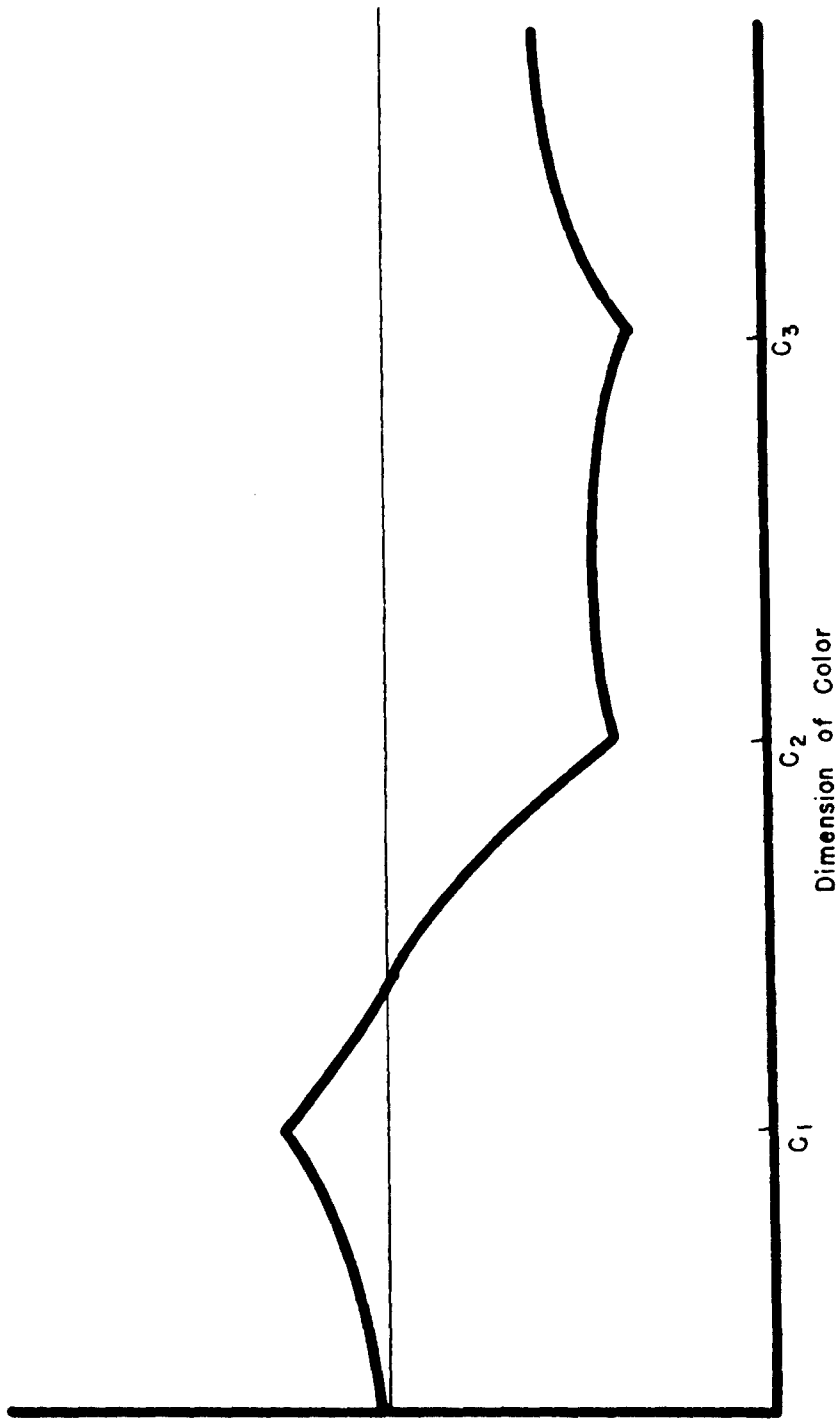


Figure 2. The algebraic sum of the inhibitory and excitatory tendencies to make the response R_d across the dimension of color.

Excitatory

Response
Tendencies

Inhibitory

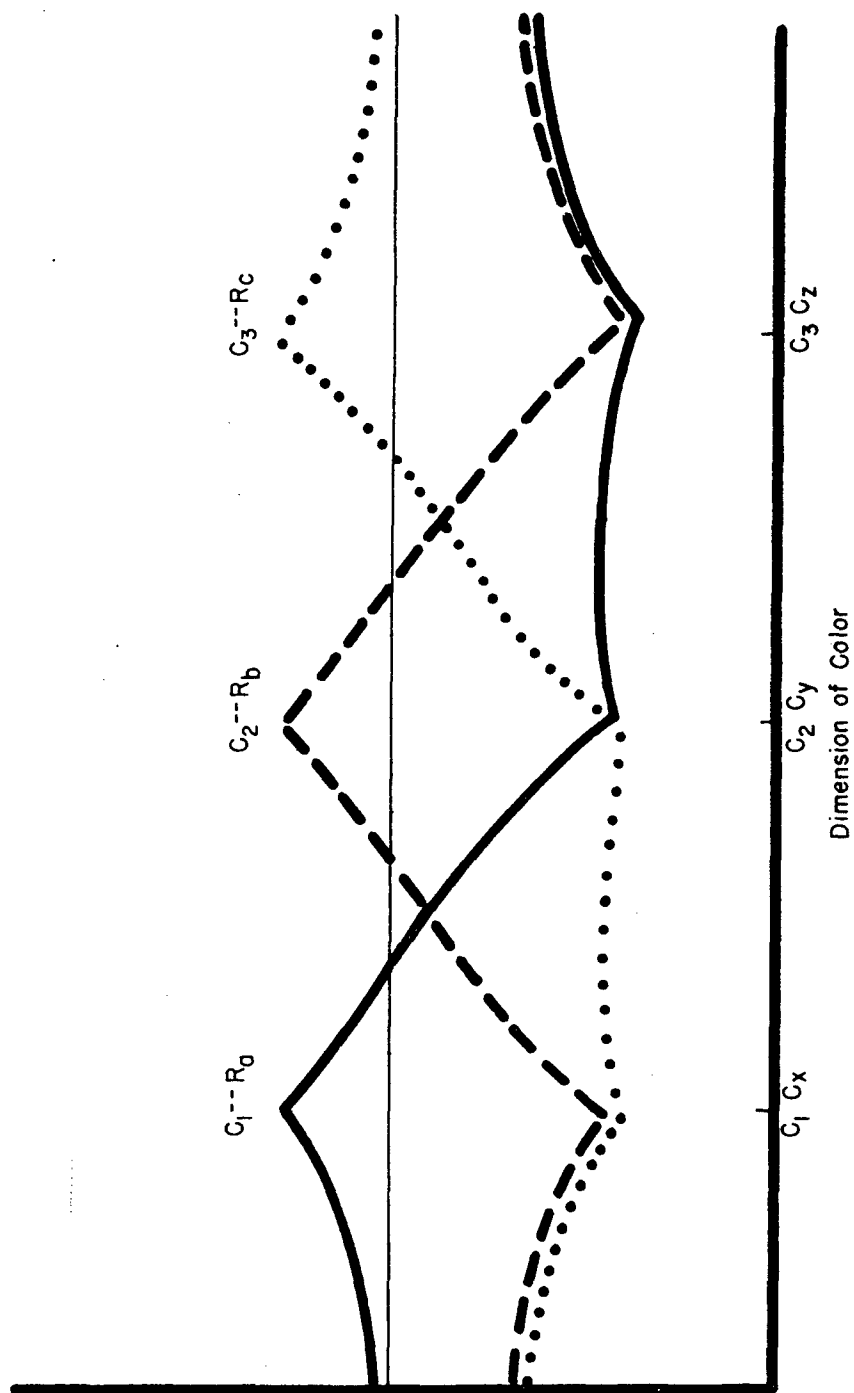


Figure 3. Response tendencies for all color stimuli across the color dimension.

Excitatory

Response
Tendencies

Inhibitory

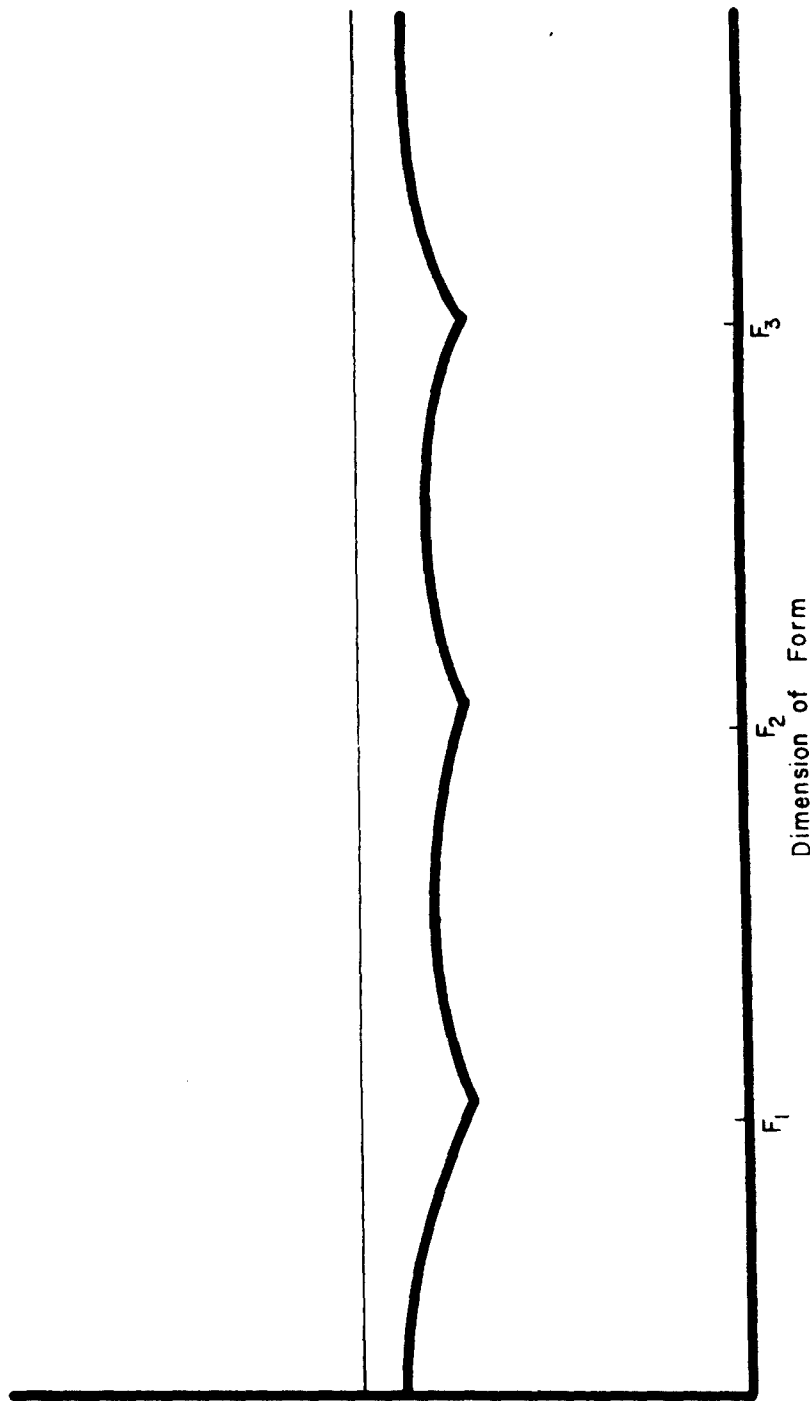


Figure 4. The algebraic sum of the inhibitory and excitatory tendencies to make any response across the dimension of form.

the two wrong responses. In our example considerable inhibition has been built up for the S-R connections of $C_1 - R_b$ and $C_1 - R_c$. As these erroneous responses are dropped out because of the increasing strength of the $C_1 - R_a$ connections, less and less inhibition will accrue to them. As these responses cease to be given altogether, some dissipation of the inhibitory tendencies may occur through the sheer passage of time. As a result the inhibitory portion of the curve associated with particular stimuli and particular responses will decrease.

This effect will be even more marked in the instance of the F or irrelevant stimuli. These stimuli ride along with the relevant ones and each time a correct response is made to the relevant stimulus, the associated irrelevant stimulus profits from the consequent reinforcement. Gradually the inhibitory potentials associated with the irrelevant stimuli will be wiped out and they will be replaced by excitatory potentials. The patterns of distribution of the excitatory potentials associated with these stimuli across the dimension will differ markedly from that characteristic of the relevant stimuli. The distribution for the relevant stimuli is asymmetrical, with particular stimuli being positively associated with certain responses and negatively associated with others. Since, however, each irrelevant stimulus is associated equally often with each relevant stimulus, and thereby reinforced at each response point, the distribution of tendencies will be symmetrical. Each F stimulus will develop an equal tendency to produce each response.

In summary, as N increases (and in the ordinary course of events the number of correct or reinforced responses increases), the irrelevant stimuli will begin to acquire excitatory tendencies. Since, however, particular relevant S-R connections already have a head start, we should not expect that subjects would eventually fall into error and begin responding to the irrelevant or F stimuli.

THE EFFECT OF RESPONSE GENERALIZATION

According to the concept of response generalization, when a particular S-R connection is reinforced, the tendency to give similar responses to the stimulus is also strengthened. Although this concept suffers in usefulness because of the difficulty of rating responses on their degree of similarity, it has some empirical support (10, 11). In the present hypothetical experiment, one would seem justified in assuming that the pressing of one key is highly similar to pressing another key. If such is the case, this mechanism would, as the subject begins to respond correctly, serve to decrease even more the inhibition originally built up for particular relevant stimuli and the wrong responses. Thus when to C_1 the response R_a is made and reinforced, excitatory potential spreads to R_b and R_c . The magnitude of increment would not be as great for these two responses as for R_a , however. This mechanism would so raise the excitatory level that the gaps of inhibition shown between C_1 and C_2 and also between C_2 and C_3 in Figure 3 would no longer exist. Thus response generalization together with the recovery from inhibition mentioned above would further increase the tendency to make key pressing responses across

the entire dimension of color. It would also tend to eliminate some of the asymmetry of the pattern of response potential associated with the C stimuli. Since the F stimuli are already symmetrical, the mechanism would simply add a constant to the distribution of habit potential, without changing the symmetry of the distribution.

THE EFFECT OF UNEQUAL ASSOCIATION OF PARTICULAR RELEVANT AND IRRELEVANT STIMULI

Under actual life conditions it is very likely that the complete symmetry of association of the irrelevant cues with the relevant cues may not occur. In fact it is probable that in the usual life situation symmetry of the sort that can be attained in laboratory experiments is the exception rather than the rule. More often than not, the natural situation is one in which one particular irrelevant stimulus is more frequently associated with one particular relevant stimulus than with any of the others. Thus the experimental design previously described might be modified so that F_1 was associated with C_1 60 per cent of the time that C_1 occurs, and is associated with each of the other stimuli 20 per cent of the time. F_2 could be linked to C_2 , and F_3 to C_3 , in a similar fashion. If this were done, then each F stimulus would receive a greater proportion of reinforcements and a smaller proportion of nonreinforcements for one particular response than for the other two. Each of the F stimuli would acquire relatively stronger tendencies to elicit one particular response than to elicit either of the other two responses.

The same procedure may be employed for this type of situation as that described in the first section, the procedure in which each set of color stimuli is associated with each response an equal number of times. In the present case to achieve proper counterbalancing each C stimulus will be associated with each response five times and is reinforced or nonreinforced according to whether or not that response is correct for that stimulus.

The results for the present arrangement of relevant and irrelevant stimuli in terms of frequency of reinforcement and nonreinforcement for each F stimulus are given in Table 3. In this table the first major column denotes the stimuli presented; this column is subdivided into the color and form aspects of the stimulus. The numbers in parenthesis indicate the frequency of presentation for each aspect. Thus C_1 is presented a total of 15 times, 9 times with F_1 and 3 times each with F_2 and F_3 . The next group of columns designate the responses made and whether or not they are reinforced. Note that R_a is always reinforced if made in the presence of C_1 , but responses R_a and R_b are never reinforced if C_1 is present.

TABLE 3

THE FREQUENCY OF REINFORCEMENT OR NONREINFORCEMENT
ASSOCIATED WITH EACH IRRELEVANT STIMULUS
IN THE 3 - 1 - 1 DESIGN

Stimuli Presented		Responses Made					
		R_a		R_b		R_c	
Color	Form	+	-	+	-	+	-
C_1 (15)	F_1 (9)	3			3		3
	F_2 (3)	1			1		1
	F_3 (3)	1			1		1
C_2 (15)	F_1 (3)		1	1			1
	F_2 (9)		3	3			3
	F_3 (3)		1	1			1
C_3 (15)	F_1 (3)		1		1	1	
	F_2 (3)		1		1	1	
	F_3 (9)		3		3	3	

Referring to this table, it will be seen that the pattern of reinforcement, and nonreinforcement with relation to the F stimuli and R_a is such that F_1 receives a preponderance of reinforcement with this response and the other two F stimuli receive a preponderance of nonreinforcements. These are summarized for R_a in Table 4.

TABLE 4

A SUMMARY OF THE POSITIVE AND NEGATIVE TENDENCIES TO GIVE R_a FOR
EACH OF THE IRRELEVANT STIMULI IN THE 3 - 1 - 1 DESIGN

Stimulus	Response Tendency	
	+	-
F_1	3	2
F_2	1	4
F_3	1	4

If the usual response strength curves are drawn for the tendency to make R_a across the continuum, the results obtained are those which are shown in Figure 5. These are summated algebraically in Figure 6. A similar treatment for F_2 and R_b , and for F_3 and R_c , would also result in this asymmetrical patterning, R_b having its excitatory peak in conjunction with F_2 , and R_c in conjunction with F_3 . It is apparent that the overall curves to be drawn for these F stimuli would be similar to the curves in Figure 3. They would differ, however, in that the magnitude of excitatory potential would not be as high as in the former curve.

As the proportion of times is increased that any given irrelevant stimulus is associated with a particular relevant stimulus, the amount of excitatory potential acquired by the irrelevant stimuli increases. Thus if the proportion had been 6 - 1 - 1 rather than 3 - 1 - 1 in the above example, the asymmetry of the habit loadings of the irrelevant stimuli would be even more marked and would become even more similar to the loadings for the relevant stimuli. This fact, incidentally, should make the learning of the task more difficult for the subjects, since greater competition between the relevant and the irrelevant stimuli would exist under these conditions than under the conditions of symmetrical association.

The present analysis implies that there is a basic inadequacy in the perceptual type of interpretation which classifies stimuli as either relevant or irrelevant. This S-R interpretation leads to the assumption of a continuity between the poles of the two extremes which for convenience will be called relevant or irrelevant.

EXPERIMENTAL PREDICTIONS

A number of experimentally testable predictions are generated by this formulation of perceptual activities, and several of them may be considered briefly.

1. Perceptual biases will be influenced by the number of choices and stimuli. The curves shown in Figure 4 would suggest that if the subjects were required to learn a new task in which the previously irrelevant stimuli are relevant, they would have greater difficulty in learning than would a control group who had had no previous experience with these stimuli. In perceptual terms one might state that they had learned to disregard these stimuli. The magnitude of this negative transfer effect will be a function of the numbers of stimuli and responses there were in the original task. This because the greater the numbers of different stimuli and responses, the greater is the likelihood that a particular response will be wrong. If only two choices are available, the transfer effect acquired by irrelevant stimuli will not be negative but will be zero in value. In this situation, the irrelevant stimuli are associated equally often with reinforcement and nonreinforcement for

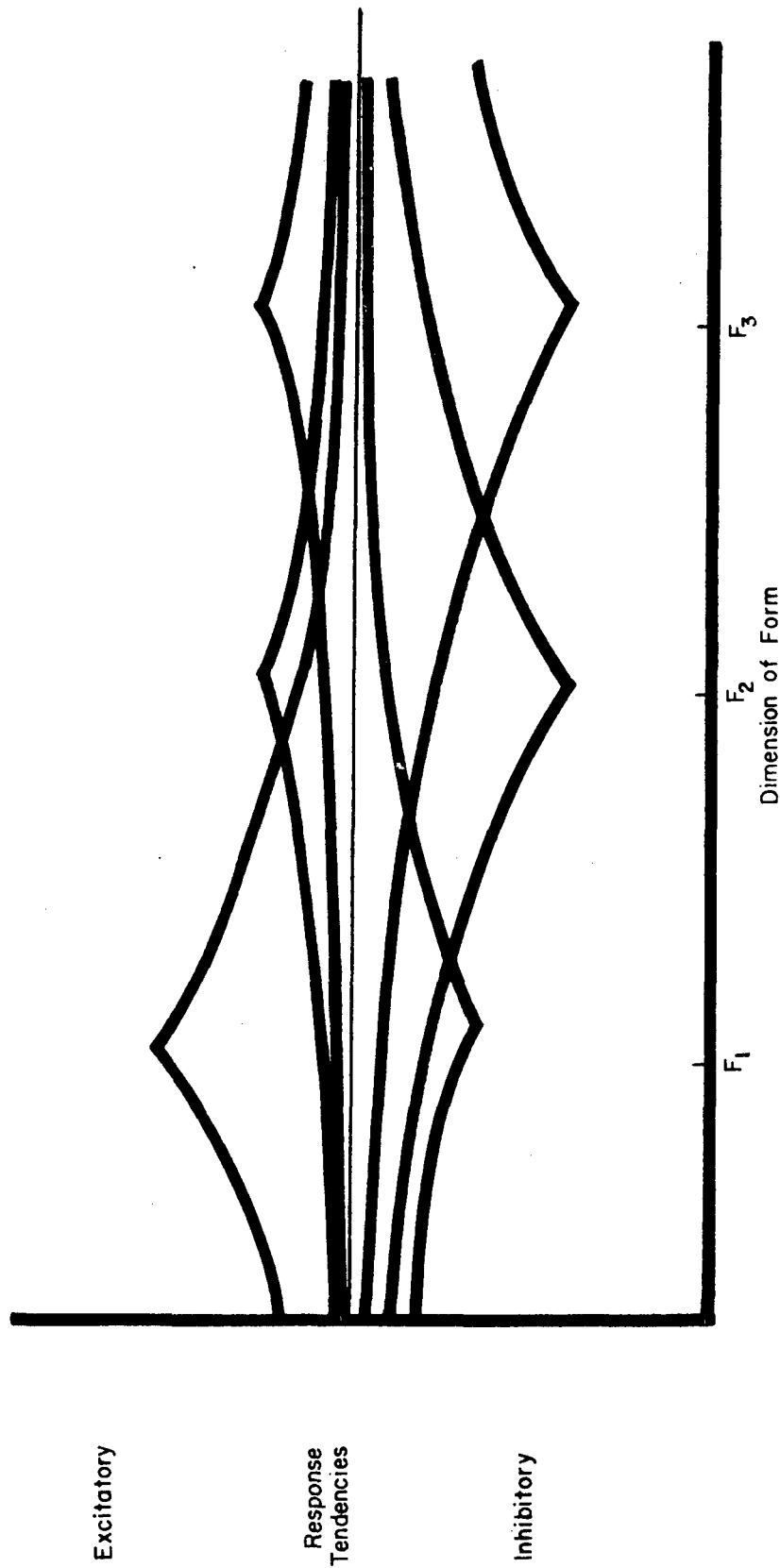


Figure 5. The separate inhibitory and excitatory tendencies to make the response R_q across the dimension of form in the asymmetrical distribution of irrelevant cues.

Excitatory

Response
Tendencies

Inhibitory

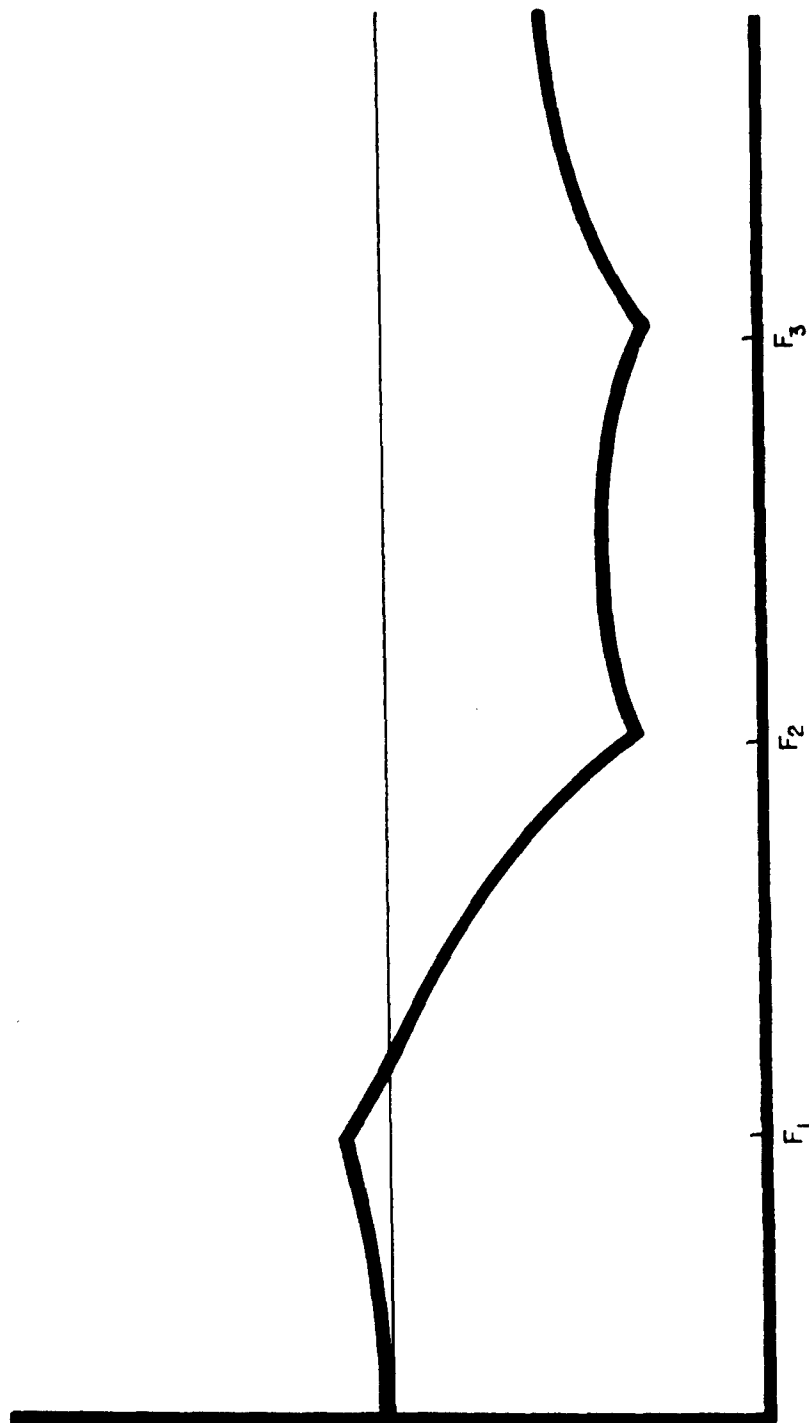


Figure 6. The algebraic sum of the inhibitory and excitatory tendencies to make the response R_0 across the dimension of form in the asymmetrical distribution of irrelevant cues.

either response. This is essentially the result in the experiments conducted by Lawrence (7, 8). As the numbers of responses and stimuli increase, the negative transfer effect for the irrelevant stimuli will increase.

2. Transfer is a function of the location of new stimuli on the dimension and the response required to be made to them (3). In a new task a problem may be set for the subject in which the relevant cues are drawn from the same dimension as those employed in the first task. These stimuli may be located at points C_x , C_y , and C_z in Figure 3. If the response R_a is to be given to C_x , R_b to C_y , and R_c to C_z , then a considerable amount of positive transfer will occur. If, however, the responses required are not consonant with the original learning, (for example, R_a to C_z , R_b to C_x , and R_c to C_y) negative transfer or less positive transfer would occur. This latter hedging statement arises from several considerations. One of these considerations is response generalization which would heighten the tendency to make any response to any of the relevant stimuli. Another is that human subjects may verbalize saying perhaps "Its color" rather than "Yellow for the middle key." If the verbalization is correct, this mediating response that is based on previous learning would be reinforced, strengthening the entire dimension of color. It should be noted that this mediating response is assumed to have been learned, presumably by the sort of process which leads to mediated generalization. If the subject is working with stimuli along an unfamiliar dimension, or one which is not easily verbalized as a dimension, then the predictions mentioned above would hold to a marked degree. Differences between lower animals and humans would also be expected in the relative amount of transfer shown when the new responses are or are not consonant with the previous learning.

In general it may be said that obtained transfer will be highly influenced by the locations of the training stimuli and the new stimuli on the dimension, and by the relationships of the new responses to their stimuli. The obtained perceptual biases are therefore limited in nature.

3. The nature of the new responses will influence transfer effects. The less similar the responses required in the new situation to the responses in the old, the less positive transfer accruing to the previously relevant dimension, and the less negative transfer accruing to the previously irrelevant dimension. In other words, the perceptual biases are limited by the nature of the responses required in the tasks. Stimuli which acquire relevancy or irrelevancy in one type of response situation may not show these same characteristics in another. What is acquired then is not a general "perceptual bias," but a "perceptual bias" in relation to responses. And, again, for the same reasons mentioned above, verbal mediating processes in human subjects weaken the strength of this conclusion, but they would not entirely vitiate it.

4. Increasing the number of trials leads to greater ease in transferring to a previously irrelevant dimension. In a study using the Wisconsin Card Sorting Test - a situation similar to that described in this paper - Grant and Berg have reported such a finding (4).

5. The dependency of the transfer upon the consonance of the S-R connection of the first and second task will decrease with increased training.

6. If irrelevant stimuli are unequally associated with the relevant stimuli, occurring more often with one particular relevant stimulus than with another, the irrelevant stimuli will partake of the characteristics of the relevant stimuli in their distribution of habit strength. Specifically, the following predictions may be made for this type of situation:

a. Learning to respond to the relevant stimulus will be more difficult in the unequally associated than in the equally associated condition. This arises from the supposition that the irrelevant stimuli will be acquiring response strength in a manner similar to that of the relevant stimuli, and that this will lead to response conflicts when an inconsonance exists between the response tendency for the relevant and the irrelevant stimulus.

b. If in a second situation the formerly irrelevant stimuli become relevant, large amounts of either positive or negative transfer will occur. Transfer will be positive if there is a consonance in the new task between the particular response required of the stimulus and the particular response made to it most frequently when it is an irrelevant stimulus in the first task. Conversely, large amounts of negative transfer would be generated if response dissonance existed between the old and new task.

c. The greater the ratio of unequal association, the more marked any of the behavior characteristics described in a and b will become.

SUMMARY

This paper has attempted to interpret in S-R terms the development of perceptual biases of the sort wherein the subject acquires tendencies to respond to certain classes or dimensions of stimuli as opposed to others. The major assumptions employed were those of stimulus and response generalization, and the acquisition of excitatory tendencies through reinforcement and inhibitory tendencies through nonreinforcement. These concepts may be used to predict results in several actual or potential experiments.

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