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Generalization of a Matching Discrimination

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GENERALIZATION OF A
MATCHING DISCRIMINATION

by

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One of the criticisms which has been directed against behavioristic stimulus-response psychology is that, although S-R theory applies to simple learning situations, it cannot account for complex or conceptual behavior. As a result, one important subject for researchers in operant conditioning to study is the way in which simple stimulus-response pairings can lead to conceptual behavior.

Much research on complex conceptual behavior involves unanalyzed stimulus dimensions which make it difficult to study behavior in terms of component or underlying stimulus-response processes. Herrnstein and Loveland (1964) reported a study in which they successfully trained pigeons to respond to the presence of human beings in pictures and not to respond to pictures which did not contain people. The birds mastered the concept of "human beings," but the concept formation involves unknown stimulus relationships. In the present study only matching and nonmatching frequencies of light are dealt with. Using a known physical stimulus dimension an attempt may more readily be made to analyze a complex or relational discrimination in terms of simpler stimulus-response processes.

Keller and Schoenfeld (1950) define conceptual behavior as "generalization within classes and discrimination between classes..." (p. 155). After training a discrimination between one or more members of one stimulus class and one or more members of another stimulus class, if the discrimination generalized to novel members of the two stimulus classes, then we say a concept has been established.

There are two types of discriminations, absolute (simple) and conditional (complex). Absolute discriminations may be formed on the basis of changing one aspect of the stimulus, such as frequency. Training a subject to respond in the presence of a red key and not to respond in the presence of a green key would be an example of a simple discrimination. Conditional discriminations involve changing two or more elements of the stimulus. The status of each value of one aspect of the stimulus depends on the value of another aspect of the stimulus. A relational discrimination is a conditional discrimination in which a rule is involved in the pairing of values of the stimulus aspects. An example of a relational discrimination is stimulus matching. Responses may be reinforced when both halves of a response key are the same frequency and not reinforced when each half is a different frequency. The important element of the stimulus is not the absolute frequency, but the relationship between the frequencies on each half of the key. The present study deals with the relational discrimination of stimulus matching.

In a previous study by Malott, Malott, and Svinicki (1967) responses in the presence of the matching combinations of violet, blue, yellow, and red were reinforced equally (equivalence training). Following this training, generalization tests were conducted in which the matching and nonmatching combinations of two training colors were presented. Although the results indicated that the rates were higher in the presence of the matching stimuli, the difference was very slight and a statistical test was necessary to show significance.

In a subsequent study, Malott, Malott, and Svinicki (1968) specifically trained a matching discrimination and tested outside the range of the training frequencies. Responses were reinforced when both halves of a key were blue-green, or green, and extinguished when the nonmatching combinations of blue-green and green were present. Then a generalization test was conducted, presenting the four combinations of red and yellow. The rates in the matching combinations were higher than in the nonmatching combinations, indicating a generalization of the matching discrimination. However, presenting novel frequencies in the generalization test resulted in a response decrement (Guttman and Kalish, 1956). This response decrement impaired the reliability of the results. Two-thirds of the gradients could not be constructed because not enough responses were emitted.

In this study an effort was made to combine the best features of the two previous experiments: high rates in the tests and reliable generalization of the matching discrimination. Specifically, the equivalence training procedure of the first experiment was combined with the discrimination procedure of the second experiment. Responses were reinforced in the presence of the matching combinations of red, yellow, green, and blue-green, and extinguished for the nonmatching combinations of green and blue-green only. The test stimuli for each test consisted of one color paired with all of the other training colors. Thus for each test there was only one matching combination.

Ideally, if the discrimination is perfectly acquired (no responses to S-s), and if it generalizes perfectly to the novel combinations, all responses should be made to the matching stimulus and none to the nonmatching combinations. However, even during training, responses were emitted in the S-s. Evidence for matching in this experiment, therefore, is indicated by maximum responding in the matching stimulus and progressively decreasing response rates as the color on the variable half of the key becomes increasingly different from the constant color on the other half of the key.

One objection which might be raised against such evidence is that the lower rates in the nonmatching stimuli might be a result of response decrement induced by novel color combinations. It is an established fact that response rates decrease if novel colors are presented in a test (Guttman and Kalish, 1956). Possibly response rates would also decrease if familiar colors are presented in novel combinations. A study by Malott and Malott (1967) is relevant to this point. In their experiment, responses were reinforced in the presence of matching combinations of red and violet (no discrimination training). The four combinations of red and violet were then presented in a generalization test. If there had been a response decrement to the novel nonmatching combinations of red and violet, the rates would have been lower than in the matching combinations. However, the rates were the same in all four combinations. Therefore, lower rates in the nonmatching combinations of the present experiment would indeed be evidence of matching behavior.

The present study represents another improvement over the studies by Malott, Malott, and Svinicki (1967, 1968) mentioned above. In those studies four combinations of two colors were presented in the test. This test demonstrated the transfer of the matching discrimination to only two colors, a small segment of the wavelength continuum. The present experiment permits analysis of the generalization of the matching discrimination for many colors because in the generalization tests one color was held constant on one half of the key, while the color of the other half was varied over five wavelengths, covering an extensive portion of the visible wavelength continuum.

In summary, this study of conceptual behavior involves the acquisition of a matching discrimination and the generalization of this discrimination to novel stimuli. A technique is used to overcome the problems of over-all response decrement during generalization tests. The tests will permit analysis of behavior over a greater range of the visible wavelength continuum than previous studies.

METHOD

Subjects

The subjects were three experimentally naive white King barren hen pigeons, housed in individual cages. They were fed at the end of each experimental session or once daily when sessions were not conducted so that at the start of each experimental session, they would be at 70% of their free-feeding weight. Purina Pigeon Grains were used to maintain weight and served as the reinforcer. Grit and water were continuously available in the home cage.

Apparatus

A Lehigh Valley Electronics pigeon test chamber #1519c was used with the houselight off and the observation window covered. Only one response key was operative and it consisted of a transparent plastic paddle in back of a hole 1 in. in diameter. Visual stimuli were presented behind the paddle with an Industrial Electronic Engineers, Inc. one-plane readout model #10-3710- 000L and G. E. 47 lamps. Kodak Wratten filters were used to provide stimuli. Their numbers were: #65 for 501.2 nanometers (nm) (blue-green), #74 for 533 nm (green), #99 for 554.6 nm (yellow-green), #73 for 571.0 nm (yellow), and #72-b for 605.7 nm (red). The key was divided in half by a vertical black line 1/4 in. wide. The color on each half of the key could be varied independently of the other half. Masking noise was presented through a speaker in the chamber. An exhaust fan provided ventilation and additional masking noise.

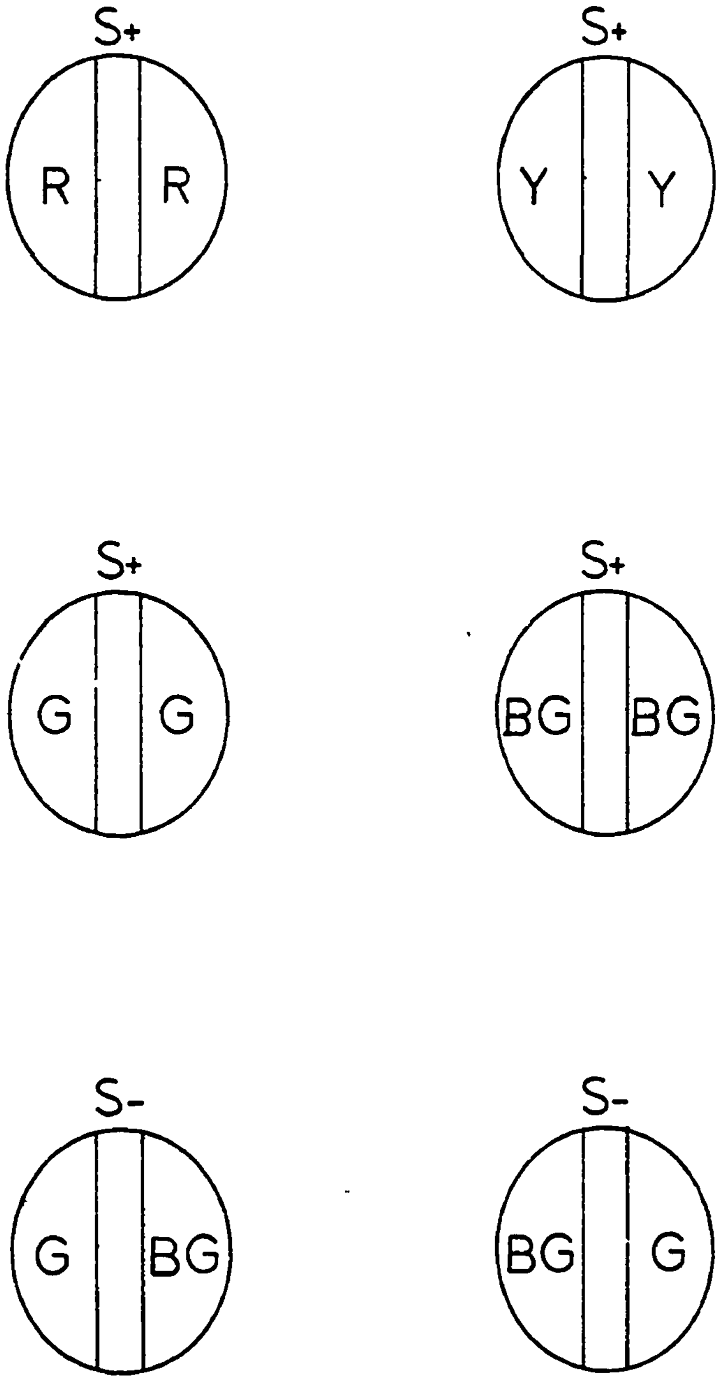
Programming during training was done automatically with solid state digital switching circuitry. During generalization tests, the stimuli were manually controlled. Time, responses, and reinforcements in each stimulus presentation were recorded with electromechanical equipment.

Procedure

Using standard operant conditioning techniques, the subjects were trained to eat from the food magazine and to peck the key. Reinforcement consisted of three sec access to the food magazine with the magazine light on. While the key-pecking response was being established a continuous reinforcement (CRF) schedule was in effect in which every response was reinforced. During these sessions on CRF, only the matching combinations of the four wavelengths were presented: red on both halves of the key (R-R), yellow on both halves (Y-Y), green on both halves (G-G), and blue-green on both halves (BG-BG). Examples of these stimuli are shown in Figure 1. The combinations were repeatedly shown in that order and each stimulus terminated at the end of a reinforcement.

After five sessions with CRF, a discrimination procedure was introduced. Each session started with R-R and thereafter the four matching combinations (S+s) were presented in random order. Responses to these stimuli were reinforced as before and the stimulus terminated at the end of reinforcement. Each matching stimulus was followed by one of two nonmatching stimuli (S-s), also in random order: green on the left with blue-green on the right half of the key (G-BG), or blue-green on the left with green on the right half (BG-G). The S-s were terminated after 30 sec of no responding and followed by a matching stimulus. All sessions lasted for 50 min or

Figure 1. Examples of matching and nonmatching combinations of colors used during discrimination training.


S+
R
R
S+
Y
Y
S+
G
G
S+
BG
BG
S-
G
BG
S-
BG
G

until 50 reinforcements had been delivered, whichever occurred first. Sessions were conducted five days per week.

A measure of discrimination for each subject was gained by dividing the response rate in the S-s by the rate in the S+s for each session. After this ratio appeared stable over six successive sessions of CRF (as determined by visual inspection of a graph), the average interval between the successive periods of the availability of reinforcement was then increased each day until a random interval (RI) of 64 sec was reached (RI 8, 16, 32, 64). With the RI 64 sec schedule the probability of reinforcement for the first response in each successive 4 sec period was 1/16 (Farmer, 1963). If, however, the discrimination ratio on any one schedule was greater than the mean ratio on the last 6 days of CRF discrimination training by a value of .1 or more, the subject was left on the interval value of the previous day until the ratio returned to being less than .1 above the mean CRF ratio. If the overall rate in the S+s fell below 25 responses per min on any one schedule, that schedule remained in effect until the rate recovered.

The response rates in the S+s were inspected four days prior to a test. If the rates in the presence of one or more of the stimuli were consistently low in comparison to the others, the schedule of reinforcement for these stimuli was set to RI 32 for one day. Four days of essentially equal rates in the S+s were required before a test. (This procedure was initiated after A-10-18 and A-10-16 had each been given one test.)

After at least six days of a stable ratio on RI 64 and four days of equal rates in the S+s, the subjects were tested for generalization of matching behavior to new combinations of the wavelengths. The test was preceded by 10 min of warm-up exactly like training. For each test one color was paired with all the other colors. For example, in one test, yellow was always present on either half of the key (yellow constant); the color of the other half was varied between red, yellow, yellow-green (not used in training), green, and blue-green. The combinations of colors were:

Y-Y, Y-R, Y-G, Y-YG, Y-BG
Y-Y, R-Y, G-Y, YG-Y, BG-Y

Note that the Y-Y combination was used twice. Each test trial was of 20 sec duration. During the 10 sec inter-trial interval, the stimulus projector, and thus the entire test chamber, was dark and the responses were no longer recorded. The ten test stimuli were presented in random order in blocks of 10 trials with each stimulus presented once in each block. The test was composed of 8 blocks of trials. Reinforcement was withheld throughout the entire test session.

After every test the subjects were once again stabilized on the training schedule for at least six sessions. For Tests 2, 3, and 4, green, blue-green, and red, respectively, were held constant on one half of the key.

RESULTS AND DISCUSSION

The generalization gradients are shown in Fig. 2. The stimulus to which the subject responded the most was taken as 100% and the percentage for the rest of the stimuli calculated accordingly; these values appear on the ordinate. Wavelength appears on the abscissa. The dotted vertical line passes through the point on the abscissa representing the variable wavelength which matches the constant wavelength. Each gradient represents data obtained from one test for one subject. Data from the first and second exposure to each test are represented by open and closed points respectively. Table 1 shows the number of responses occurring at the peak of each gradient.

Unfortunately, all four gradients could be obtained only from A-10-18. Due to illness, both A-10-16 and A-10-17 stopped responding, yielding only two gradients.

In the first BG constant test, the peaks of the gradients are at BG, lowest at G and YG, and intermediate at R and Y (upper left in Fig. 2). Since the response rates in all colors are lower than BG, matching is indicated, in spite of the fact that the rates in Y and R are higher than would be predicted (higher than YG and G) on the basis of simple stimulus generalization over wavelength.

For both subjects the peak of the gradient occurs at YG in the G constant test (upper right in Fig. 2). Response rates are very low in BG. The rates in G, Y, and R are equivalent and only slightly below the rate in YG. There is no evidence for matching, since the peak is at YG and the gradients are fairly flat except at BG (S- in training).

Figure 2. Generalization gradients obtained from BG, G, Y, and R constant tests (A-10-16: circles, A-10-17: triangles, A-10-18: squares).

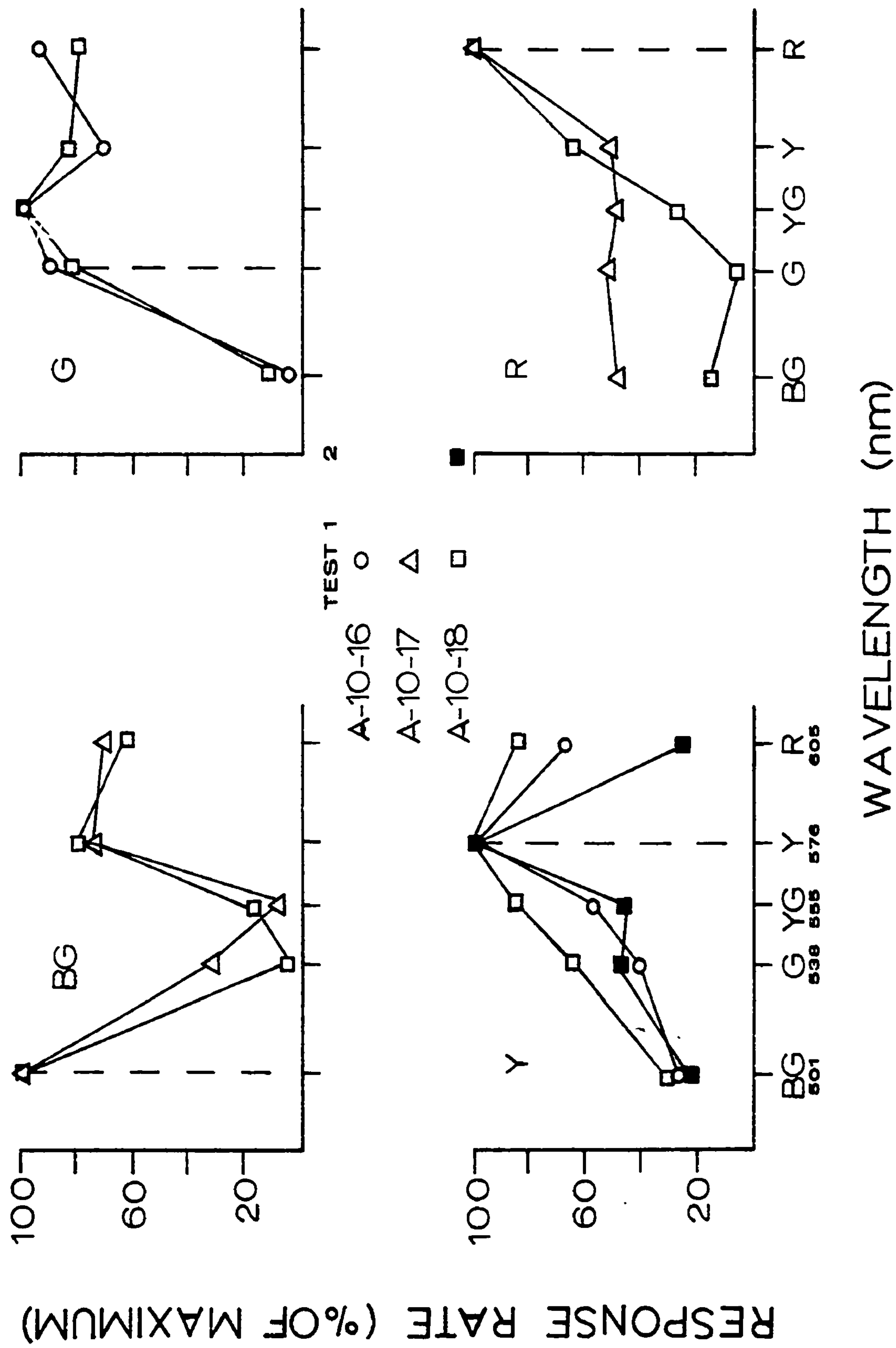

BG
G
Y
R
100
60
20
A-10-16
A-10-17
A-10-18
TEST 1
2
BG 501
G 538
YG 555
Y 576
R 605
WAVELENGTH (nm)
RESPONSE RATE (%OF MAXIMUM)

Table 1

Absolute number of responses
at the peak of each generalization gradient.

Subject	Constant Color in Generalization Test			
	BG	G	Y	R
A-10-16	--	97	234	--
A-10-17	177	--	--	120
A-10-18	51	87	104 240*	199

*Second test

During the first Y constant test, both subjects responded maximally to the matching stimulus with responses decreasing monotonically as a function of the distance from the matching stimulus (lower left in Fig. 2).

In the R constant test for A-10-18, the rate was highest in the matching stimulus, decreasing monotonically as a function of the distance from the matching stimulus, except at BG, where a slight rise may be observed. The peak of responding for A-10-17 also occurred at R, but the rates are essentially equal and near 50% in BG, G, YG, and Y (lower right of Fig. 2).

The Y constant test was replicated with A-10-18. The first and second gradients are essentially identical, indicating that there is no change as a function of training and testing.

The Y and R tests offer strong evidence of matching. The peaks are at the matching stimuli, and the response rates generally decrease monotonically with distance from the matching color.

Three factors could produce the unpredicted gradients in the BG and G tests. YG is very similar to G to the human observer; consequently it is responded to in a manner similar to G. Therefore the rate is high in the G test and low in the BG test.

Equivalence training could be responsible for the equal rates in R, Y, and G in the G constant tests and the relatively high rates in R and Y in the BG constant tests, but since the rates in R and Y were not equivalent in the Y and R constant tests this explanation is improbable.

A third possible explanation might be the peak shift phenomenon discovered by Hanson (1959). Hanson's data indicate that, after discrimination training, response rates in a generalization test will be highest not at the S+ value used during training, but at a value which is displaced from the S+ in the direction opposite from the S-. Since G-BG was the S- during training in the present study, it is conceivable that the peak was displaced from G to YG in the G constant test due to the peak shift phenomenon. The chromaticity diagram implies that the wavelength continuum may be a circular, rather than a linear continuum. Because of the Hanson peak shift phenomenon the peak in the BG test might actually be in the open area of the color circle. This could account for the relatively high rates in the R and Y stimuli.

Only matching behavior can account for the results of the R and Y tests, however.

Because there were enough responses in every test for the construction of a gradient, it can be assumed that the training and testing procedures of this study eliminated the response decrement problem of previous studies.

Further research in this area is indicated and in progress. More subjects need to be trained to quantify the results. The presence of the Hanson peak shift is an interesting speculation and should be further examined. Evidence for its existence is most convincing only in the G constant test. Discrimination training with BG (S+) and G (S-), followed by a generalization test over all colors, would demonstrate the effect of the peak shift around the open end of the color circle. Reliable results of the peak shift phenomenon would also lend indirect evidence for the existence of the color circle as opposed to the linear wavelength continuum.

CONCLUSION

Using four matching stimuli (S+s) and two nonmatching stimuli (S-s), a color matching discrimination was trained. The generalization of this discrimination to novel stimulus combinations established the presence of conceptual behavior. The results of this study indicate that the concept of matching was acquired, even though the equivalence training and the Hanson peak shift phenomenon over the wavelength continuum may have complicated the results.

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