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An Analysis of Conceptual Color Matching

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Western Michigan University

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AN ANALYSIS OF CONCEPTUAL COLOR MATCHING

by

James T. Northrop

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
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AN ANALYSIS OF CONCEPTUAL COLOR MATCHING

James T. Northrop, M. A.

Western Michigan University, 1971

The key pecking responses of six pigeons were reinforced in the presence of a bisected response key when both halves were of equal wavelength; responses to non-matching presentations were not reinforced. Subsequent generalization tests involving novel non-matching stimuli were conducted in extinction. The results indicated the acquisition of a conceptual color matching discrimination; however, post-discrimination training peak shifts may interfere with the demonstration of the concept of color matching.
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I would like to extend my appreciation to my committee members, Dr. Richard Malott, Dr. Jack Michael, and Dr. Paul Mountjoy.

In particular, I would like to thank Kay Malott for her invaluable assistance and editorial comments.

James T. Northrop
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Behavioral psychology has long studied basic discrimination learning using lower organisms. The results appear acceptable when considering simple learning tasks; however, the area of conceptual behavior has been considered to transcend a stimulus-response analysis.

Keller and Schoenfeld define conceptual behavior as "generalization within classes and discrimination between classes..." (Keller and Schoenfeld, 1950). If, after training a discrimination between one or more members of one stimulus class and one or more members of a second stimulus class, the discrimination generalized to novel instances of both classes, one would term the behavior conceptual.

Herrnstein and Loveland (1964) trained pigeons to respond to pictures of people and not to respond to pictures which did not contain people. The subjects demonstrated the concept of "pictures of people" by appropriate differential responding to novel instances of the two stimulus classes. This study, while illustrative of concept acquisition, failed to define the relevant stimulus dimensions thereby precluding a simple stimulus-response analysis.

One procedure which would represent an effective analytic approach to conceptual behavior is that of color matching. Malott and Malott (1970) and Liebold (1969) have studied the concept of color matching. A color matching discrimination provides a well-defined stimulus dimension, wavelength, for analysis of conceptual processes.

In the Malott and Malott (1970) study, pigeons' key peck responses were reinforced when both halves of the key were red or when both

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halves were violet; these are examples of matching stimuli. Responses to the key when red and violet were present simultaneously were not reinforced; the red and violet combinations are considered non-matching stimuli. Following this training, generalization tests were conducted wherein the matching and non-matching combinations of blue and yellow were presented. The results indicated conceptual matching behavior in that maximal responses occurred to the novel matching combinations; response rates to non-matching test stimuli were consistently lower than those to matching combinations.

The Malott and Malott (1970) study demonstrated the acquisition of a color matching concept; however, the generalization tests were conducted over only two wavelength values. The study by Liebold (1969) initiated tests over the entire wavelength continuum. Liebold reinforced responses in the presence of bluegreen, green, yellow and red matching stimuli. Responses to non-matching combinations of bluegreen and green were not reinforced. Generalization testing was conducted in which the matching and non-matching combinations of all the training values were presented. In addition, yellow-green was utilized in the tests in non-matching combinations. During each test one of the training colors, the "constant" color, was continuously present on one or the other key half; the color on the other half, the "variable" color, was successively varied over all of the training colors. The relative response rates were plotted as a function of the variable colors. When green was held constant during testing, the subjects responded maximally when yellow-green was present on the opposite key half; the gradient was also quite flat over the longer variable wavelength combina-
tions. There was, however, ample evidence for generalization of matching in the tests with the other training colors held constant.

Liebold attributed the inconsistent data obtained from the green constant test to the peak shift phenomenon (Hanson, 1959). Hanson's data indicate that, after discrimination training, the peak of the generalization gradient will occur at a stimulus value displaced from the original stimulus associated with reinforcement, in a direction away from the training stimulus associated with extinction. In the case of the Liebold study, when green was held constant, maximal responses occurred to the yellow-green variable stimulus. This represents a shift from the matching green variable stimulus in a direction away from bluegreen which was associated with extinction when combined with green in training.

The current study was undertaken to investigate the interpretation of failures to demonstrate matching behavior in terms of the peak shift phenomenon. Responses were reinforced in the presence of four matching stimuli and extinguished in the presence of two non-matching stimuli, as in the Liebold study; however the non-matching stimuli were composed of the shortest and longest available wavelengths for one group, and intermediate wavelengths for another group. The group trained with non-matching stimuli of short and long wavelengths would not be expected to show peak shifts because the shifts would be toward values outside the range of test values. The group trained with non-matching stimuli of intermediate wavelengths would be expected to show peak shifts during the green and yellow constant tests; the peaks would be anticipated to occur at bluegreen and red respectively.
A further purpose of the present study was to eliminate the influence of brightness discriminations on the study of color matching behavior. Both in the Liebold (1969) and the Malott and Malott (1970) studies, the generalization of matching which was observed may have been due to similarities in brightness between training and test stimuli. Testing for a matching concept must involve novel stimulus values. If the matching discriminations were based on brightness, and if the test stimuli, although novel in wavelength, were not of novel brightness, the acquisition of a concept of color matching may not have been demonstrated.

In the current study, neutral density filters were systematically placed over either half, all or none of the stimulus presentations used in training. In this manner the availability of reinforcement was not correlated with matching non-matching brightness combinations.
METHOD

Subjects

The subjects were six experimentally naive, White Carneaux, barren hen pigeons housed in individual cages. They were maintained at 70% of their free-feeding weight with grit and water continuously available in the home cage. Purina Pigeon Grains were used to maintain weight and served as the reinforcer.

Apparatus

Two Lehigh Valley Electronic pigeon test chambers #1519c were used with the observation windows covered and the houselights off. These were called Chambers A and C. In each chamber, white masking noise was presented through a speaker in the chamber wall. Only one response key, the left, was operative. The response key was a transparent plastic paddle in back of an aperture 2.5 cm in diameter. Visual stimuli were projected behind the paddle with an Industrial Electronics Engineers, Inc. one-plane readout (Series #10) and General Electric 47 lamps. Kodak wratten filters were utilized to vary the dominant wavelength. Their numbers were: #65 for 501.2 nanometers (nm) (bluegreen), #99 for 554.6 nm (green), #73 for 571.0 nm (yellow) and #72-b for 605.7 nm (red). The key was bisected by a vertical black line 0.6 cm in width. The wavelength on each half of the key could be varied independently of the other half. Kodak #96, neutral density 0.1 and 0.2 filters were used to vary intensity. When the 0.2 density
filter was placed over the brightness stimulus (green) it appeared, to two human observers, to be approximately equal in brightness to the dimmest stimulus (red). During training the 0.2 density filter was placed in front of the projector and behind the response key such that the left half of the key, the right half, both halves, or neither half was covered.

When intensity was varied during testing, 0.1 and 0.2 density filters were combined with the filter for green inside the projector so that the intensity of the green stimulus on each half of the key could be varied independently of the other half. Conditions in which no neutral density filter was present will be called "bright", those with the 0.1 density filter - "medium", and with the 0.2 density filter - "dim".

Programming was done automatically through the use of BRS-Foringer solid-state digital switching circuitry. Time and responses in each stimulus and reinforcements were recorded with Sodeco electro-mechanical counters.

Procedure

Subjects trained and tested in Chamber A were called group A and subjects trained in Chamber C were called group C. Through the use of standard operant conditioning techniques the subjects were trained to eat from the food magazine and to peck the key. Reinforcement consisted of 3 sec access to the food magazine with the magazine light on. While establishing the key peck response, a continuous reinforcement schedule was in effect. During initial training on continuous rein-
forcement, four matching stimuli (S+s or stimuli associated with rein-
forcement) were successively and repeatedly presented in the following
order: bluegreen on both halves of the key (B-B), green on both
halves (G-G), yellow on both halves (Y-Y), and red on both halves
(R-R). These stimuli are represented in Figure 1. Each stimulus ter-
minated at the end of reinforcement and the session lasted until 50
min had elapsed or 50 reinforcements had been delivered, whichever
occurred first.

Following a session with a rate of 20 or more responses per min
on CRF, a random interval (RI) schedule of reinforcement (Farmer, 1963)
was introduced. Expected RI schedule values were produced by vary-
ing the probability of reinforcement of the first response in succe-
sive four sec intervals. For example, when the probability of reinf-
forcement was 1/2, the expected value was 8 sec; when the probability
was 1/8, the expected value was 32 sec. Expected RI values of 8, 16
and 32 sec were used in that order. A criterion of one session in each
schedule value with a response rate of 25 responses per min or greater
was used for advancement to the next higher schedule. Presentations
of the four S+s were 2 min long and the order of presentation was ran-
dom with the stimuli having equal probabilities of occurring. Session
lengths for RI 8, 16 and 32 were 10, 20 and 26 min respectively.

Upon meeting criterion on RI 32, a discrimination procedure was
introduced. In addition to the four matching stimuli, two non-matching
stimuli (S-s or stimuli associated with extinction) were presented.
For group A the S-s were bluegreen on the left half of the key with
red on the right (B-R) and bluegreen on the right half with red on the left (R-B). For group C the S- s were green on the left with yellow on the right, (G-Y) and green on the right half with yellow on the left (Y-G). Each stimulus presentation was 2 min long, and the order of presentation was randomized. The probability that each individual S+ would appear was 0.125 and the probability for each S- was 0.25. In this manner S+s were present half of the time and S-s were present the other half. The schedule of reinforcement in the S+s was RI 32; responses were not reinforced in the S-s. Session lengths were 50 min; this consisted of a 12 min warm-up at the beginning of the session, followed by a 2 min time-out, and then resumption of training. During the time-out, the white noise was present but the stimuli were turned off and responses had no programmed effect. The time-out was included in order to make training sessions more similar to testing sessions (described below) in which time-outs were necessary. Data from the warm-up were eliminated from analysis.

During discrimination training the response rate in each individual S+ was calculated; a combined rate in all S+s (number of responses to all S+s/time in all S+s) was also calculated. When the rate in any individual S+ was less than 80% of the combined S+ rate for the last two consecutive sessions or any three of the last six sessions, the schedule for that stimulus was lowered to RI 16 for one session; the schedule for the remaining stimuli remained RI 32.

Throughout all training, intensity was varied in order to prevent a discrimination based on the relative brightness of the two
halves of the key. The neutral density 0.2 filter was placed in front of the projector to successively produce the following conditions: filter on the right half of the key only (bright-dim or B-D), filter over both halves (D-D), filter over the left half only (D-B) and no filter (B-B). Neutral density filter conditions were held constant within sessions; they varied between sessions, repeatedly in the order shown. Note that, because of this variation in intensity, when the two halves of the key matched in wavelength, they did not necessarily match in intensity. Reinforcement was, therefore, correlated with matching wavelengths but not with matching intensities.

A generalization test was conducted when the following criteria were met during discrimination training: 1) The combined S− response rate (number of responses to both S−s/time in both S−s) was less than 30% of the combined S+ response rate for each of the last three consecutive sessions. 2) No stimulus was associated with the lower (RI 16) schedule for any of the last three consecutive sessions. 3) The response rate in each S+ was at least 80% of the combined S+ rate for at least two of the last three days, and 4) the combined S+ response rate was 25 responses per min or greater for the last three consecutive sessions. In addition to these criteria, a minimum of 10 discrimination training sessions was required prior to the first test. A minimum of three training sessions was required between test sessions.

Prior to the first generalization test, training sessions were conducted seven days per week. Earlier pilot work showed that such
consistent daily training was important in the early acquisition of the discrimination. After the first test, training sessions were conducted at least six days per week. A training session always occurred on a day preceding a test day.

Each test was immediately followed by the standard 12 min warm-up exactly like training, followed by a 2 min time-out, during which the program boards were changed. Generalization testing was conducted in extinction. Individual stimulus presentations were 30 sec long during the tests. Eight wavelengths and three intensity generalization tests were conducted on separate days.

During each wavelength test, one of the four wavelength values used in training appeared on one or the other half of the key in each stimulus presentation throughout the test. This wavelength was termed the constant wavelength (C) as it was always present; however, the position varied. On the opposite half of the key the four wavelength values were successively presented. The combinations were presented seven times in the following order:

CG, RC, CB, YC, CR, GC, CY, BC.

Hence, during a "Yellow Constant" test, the stimulus sequence was:

YG, RY, YB, YR, GY, YY, BY.

As can be seen, there are eight stimuli based on the position, left or right, of the constant wavelength, combined with the variable wavelength on the other half. The constant wavelength varied between tests with all four wavelengths appearing as constant colors. No neutral density filters were used in wavelength tests. The response totals
for each combination were recorded during the first 12 min and the last 16 min of each 28 min test.

The intensity generalization tests were similar to the wavelength tests except in that green appeared on both halves of the key throughout and intensity was varied. One of the three intensities was held constant on one or the other key half throughout a test while the three intensities appeared successively on the other half. The six possible combinations were repeatedly presented in the following order:

CM, DC, CB, MC, CD, BC,

where C represents the constant intensity, B stands for bright, M for medium, and D for dim. The constant intensity varied between tests with all three intensities appearing as constant intensities. Response totals for each of the intensity combinations were recorded at the conclusion of the 12 min tests.

The order of the tests is shown in Table 1. The four wavelengths appeared as constant colors in the first four tests; three intensity tests followed; wavelength tests were then repeated. Brightness testing followed one series of color tests because the prolonged exposure of the subject to a green matching stimulus during the brightness tests may have served to weaken the responses to the green matching combination which would affect color test data. A minimum of 50 responses to the stimulus combination having the greatest number of responses was required; otherwise the data were discarded and the test was repeated after re-training.
**TABLE 1**

Sequence of Generalization Tests

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Type of Test</th>
<th>Constant Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wavelength</td>
<td>Yellow</td>
</tr>
<tr>
<td>2</td>
<td>Wavelength</td>
<td>Bluegreen</td>
</tr>
<tr>
<td>3</td>
<td>Wavelength</td>
<td>Green</td>
</tr>
<tr>
<td>4</td>
<td>Wavelength</td>
<td>Red</td>
</tr>
<tr>
<td>5</td>
<td>Intensity</td>
<td>Medium</td>
</tr>
<tr>
<td>6</td>
<td>Intensity</td>
<td>Bright</td>
</tr>
<tr>
<td>7</td>
<td>Intensity</td>
<td>Dim</td>
</tr>
<tr>
<td>8</td>
<td>Wavelength</td>
<td>Yellow</td>
</tr>
<tr>
<td>9</td>
<td>Wavelength</td>
<td>Bluegreen</td>
</tr>
<tr>
<td>10</td>
<td>Wavelength</td>
<td>Green</td>
</tr>
<tr>
<td>11</td>
<td>Wavelength</td>
<td>Red</td>
</tr>
</tbody>
</table>
RESULTS

Data obtained from both groups of subjects during discrimination training are presented in Table 2. The initial letters in subject labels define the group to which they belong. The first column of measures shows that group A (S-‘s comprised of B and R) tended to have a lower discrimination ratio, in the sessions prior to the first test, than did group C (S-s comprised of G and Y). There is, however, overlap between the groups in this measure. Group A also required fewer discrimination sessions prior to the first test (second column). Group A tended to require fewer discrimination training sessions for completion of testing (fourth column); however, again there was overlap between groups in the measure. Although the differences between groups are not great, these three measures imply that the discrimination was more easily formed in group A than in group C; this is to be expected since the S- training colors for group A (B and R) were further apart than were those for group C (G and Y). The groups do not appear to differ in the consecutive discrimination sessions in which the discrimination ratio was at or below 0.3 immediately prior to the first test (third column).

Only subject A-25-1 required repetition of a test; the first Y-constant test was repeated because of low response rates during the initial test. Generally, any differences which exist between groups are not great, with the exception of the more rapid progress of group A.

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<thead>
<tr>
<th>Subject</th>
<th>Discrimination Ratio on Day Preceding Test 1</th>
<th>Number of Discrimination Sessions Preceding Test 1</th>
<th>Number of Discrimination Sessions at or Below 0.3 Immediately Prior to Test 1</th>
<th>Number of Discrimination Sessions After Test 1</th>
<th>Tests Repeated by Number</th>
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<tr>
<td>A-25-1</td>
<td>0.004</td>
<td>13</td>
<td>11</td>
<td>36</td>
<td>1</td>
</tr>
<tr>
<td>A-25-2</td>
<td>0.029</td>
<td>25</td>
<td>3</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>A-25-3</td>
<td>0.075</td>
<td>10</td>
<td>3</td>
<td>62</td>
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</tr>
<tr>
<td>C-25-1</td>
<td>0.038</td>
<td>30</td>
<td>7</td>
<td>101</td>
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<tr>
<td>C-25-2</td>
<td>0.106</td>
<td>26</td>
<td>7</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>C-25-3</td>
<td>0.227</td>
<td>39</td>
<td>3</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

* Testing not completed
The generalization gradients from the first battery of wavelength tests for group A (trained with bluegreen and red S-combinations) are presented in Figure 1. The stimulus presentation to which the maximum number of responses occurred was taken as 100% and responses to the remaining presentations were calculated as percentage of maximum; these are presented on the ordinate. The color held constant and the test number appear to the right of each row of the axes, while the variable colors appear on the abscissa. The gradients obtained from each of the three subjects are arranged in columns. Data were collected during two portions of each test; the gradients obtained during the first 12 min are indicated by the closed circles, while gradients obtained from the final 16 min are represented by the open squares. Response totals for each portion of the tests are presented within each pair of axes; the first 12 min total appears above that from the final 16 min.

With one exception, all of the gradients obtained with bluegreen held constant (first row) show a peak at the matching bluegreen variable component; the exception is the gradient from the final 16 min of the test for subject A-25-3, which has a peak located at green.

The data from the green-constant tests (second row) show that at least one gradient peaks at the matching green variable stimulus for each subject. Subject A-25-1's gradients are peaked at green during both portions of the test. Subject A-25-2's gradients for the first 12 min of testing has a peak at green, while the peak for the last portion of the test is at red; however, the gradient with a peak at
FIGURE 1

Generalization gradients obtained from the first battery of B, G, Y and R constant wavelength tests for Group A.
red had only 33 responses at maximum and is probably unreliable. Subject A-25-3 shows an initially flat gradient over bluegreen and red; during the last portion of the test the gradient has become sharper with a peak at green.

The yellow-constant gradients all show peaks at the matching variable color, yellow, with the exception of A-25-3's gradient for the first portion of the test, which has a peak at green.

The red constant gradients all show peaks above the matching variable color, red. The gradients for all of the subjects during both portions of the test are quite steep.

A summary of the gradients from the first battery of wavelength tests for group A is in order. The gradients of subjects A-25-1 and A-25-2 have peaks at the matching variable wavelength in all cases of reliable gradients. The data for subject A-25-3 are less clear. While the gradients from the red-constant test have peaks at the matching variable color, red, those for the other three tests are less easily characterized and there appears to be a lack of discrimination among bluegreen, green and yellow. All of the gradients in all of the tests are sharper during the second portion of testing, than during the first portion.

Figure 2 presents the data from the second series of wavelength tests administered to group A. All gradient peaks are at the matching variable wavelength, with a general sharpening of the gradients apparent during the final 16 min of each test. The gradients from this
FIGURE 2

Generalization gradients obtained from the second battery of BY, G, Y and R constant wavelength tests for Group A.
second series of tests are generally sharper than those from the first.

Figure 3 presents the data from the first series of wavelength tests for group C (trained with S-Ś composed of yellow and green).

With one exception, all gradients from the bluegreen-constant test have peaks at the matching variable wavelength. The exception is the gradient from the first 12 min of testing of subject C-25-2 which has a peak at green.

When green was held constant all of the subjects' gradients, during the first 12 min were displaced, appearing at the bluegreen variable color. The peak of the gradient from the final portion of the test for subject C-25-1 is at the matching wavelength, green; however, this gradient has only four responses at maximum and should probably be considered unreliable. The gradient from the final portion of testing for subject C-25-2 continues to have a peak at the bluegreen variable color. Subject C-25-3 responded maximally to the matching combination during the final 16 min of the test; however bluegreen and red variable colors controlled high rates of responding as well.

When yellow was held constant, only subjects C-25-2 produced gradients with peaks at the yellow variable color. Responses to the red variable color represented above 98% of those to the matching combination, while an intermediate number of responses occur to the blue-green variable color. The gradients for subjects C-25-1 and C-25-3 are peaked at red throughout the test.
FIGURE 3

Generalization gradients obtained from the first battery of B, G, Y and R constant wavelength tests for Group C.
Subjects C-25-1 and C-25-3 responded maximally to the red variable color during both portions of the first red-constant test. Subject C-25-2 showed a peak at the yellow variable color with a high rate of responding to the red variable color during the first 12 min. During the last 16 min the gradient of C-25-2 is peaked above the red variable color.

A summary of the gradients from the first series of wavelength tests for group C follows. The gradients from the bluegreen and red-constant tests all peak at the matching variable wavelength by the end of the tests. On the other hand, the gradients from the yellow-constant tests have a strong tendency to peak at red. As with Group A, group C's gradients for most tests are sharper for the last portion of testing than for the earlier portion.

Figure 4 presents the data obtained from the second series of wavelength tests for subjects in group C. All of the gradient peaks are above the matching variable wavelength. Subject C-25-1, while responding maximally to the matching variable color in the bluegreen constant test, showed a very high rate to the red variable component also, during the first 12 min of the test; the gradient, however, underwent extreme sharpening during the final 16 min. Subjects C-25-1 and C-25-3 did not progress as rapidly as C-25-2, with respect to training and, therefore, did not complete all of the second battery of tests.

The data obtained from the brightness tests did not give evidence for a matching discrimination based on brightness. Most subjects
FIGURE 4

Generalization gradients obtained from the second battery of BY, G, Y and R constant wavelength tests for Group C.
responded maximally to non-matching combinations of brightness, and in addition, responded at a high rate to all of the presentations. Those subjects responding most to the matching brightness presentation also responded at a high rate to the other combinations. One must, however, consider the fact that the brightness tests were 12 min long, while the wavelength tests were of 28 min duration. Thus, if brightness gradients were to undergo the sharpening evident in wavelength tests, brightness matching may be indicated; however, more data are needed to properly analyze this possibility.
DISCUSSION

The data indicate that two of the subjects trained with S-s composed of bluegreen and red had a matching concept in the first series of tests. The third subject failed to show a consistent discrimination among the colors bluegreen, green and yellow during the initial tests. Griffin (1971) in a study similar to the present one, has obtained evidence that subjects will demonstrate more matching behavior as the number of consecutive training sessions with the discrimination ratio at or below 0.3 increases; his data implied that 10 or 11 such sessions may be necessary to insure good matching behavior. Table 2 (third column) shows that subject A-25-1 was the only subject in the present experiment to reach this criterion; this subject also showed perfect matching behavior in all of the tests. Subject A-25-3 had only three such sessions and the lack of matching behavior may be due to a poorly acquired discrimination. It was also noted that this subject had extremely variable discrimination ratios throughout training.

Gradients obtained from the subjects trained with S-s composed of green and yellow showed less matching behavior during the first series of tests than those for the subjects trained with S-s composed of bluegreen and red. The lack of matching in the former subjects appears to be explained by the notion that when S- colors are held constant during testing, peak shifts, away from the matching variable wavelength, in a direction opposite the non-matching S- color, will occur in a manner analogous to Hanson's (1959) data.
With respect to subjects trained with green and yellow S- components, when green was held constant during testing the peaks were displaced appearing at the variable color of bluegreen. This is in a direction away from the S- value of yellow as would be predicted from Hanson's data. When yellow was held constant during testing the gradient peaks occurred at the variable color of red, which also represents a displacement away from the S- value of green.

Hanson's data also indicated that as the difference between the S+ and S- is increased, the peak shift disappears. In the case of the bluegreen and red S- group the distance between the S+ and S- in the testing situation is very great and therefore peak shift would not be expected and the data obtained confirm this.

The consistent demonstration of matching behavior in all subjects during the second series of wavelength tests may be due to any or all of the following factors. First, the increase in the number of training sessions may enhance the acquisition of the concept of matching, sharpen the generalization gradients leading to greater reliability of peak location, and lead to the elimination of peak shifts. Relevant to the latter point, Terrace (1966) has demonstrated that peak shifts disappear with increased amounts of discrimination training.

A second factor to be considered in explaining the increase in matching behavior is that of time spent in the test situation. Most of the data obtained from the generalization tests in this study show a sharpening of the gradients within tests. A similar factor may be
operating across tests and the consequent sharpening of gradients may lead to a more reliable estimate of peak location.

A third factor is the existence of implicit discrimination training between training S+s and the test stimuli. In the training situation all matching stimuli are consistently correlated with the availability of reinforcement, while in testing, all non-matching combinations are eventually correlated with extinction. This implicit form of discrimination training between all matching and non-matching stimuli may have produced the perfect matching behavior observed in the second series of wavelength tests. The present data cannot be used to separate these three factors.

Generally the lack of intensity matching and the demonstration of color matching in the initial tests of the group trained with S-s composed of bluegreen and red indicate that a concept of matching may be acquired under the present training conditions. The data obtained from subjects trained with S-s composed of green and yellow support Liebold's peak shift interpretation of similar results in his study. Of additional importance, and also related to the shifting of peaks is the choice of training values; selection of stimulus values may determine the subsequent demonstration of a color matching concept.
REFERENCES


Hanson, H. M. Effects of discrimination training on stimulus generalization. *Journal of Experimental Psychology*, 1959, 58, 323-333.


