JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1970, 13, 301-316 NUMBER 3 (MAY)

GENERALIZATION AND RESPONSE MEDIATION OF A CONDITIONAL DISCRIMINATION[1]

DAVID A. ECKERMAN

UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL

Fifteen pigeons were given conditional discrimination training in which a colored sample stimulus determined which of two line comparison stimuli (vertical and horizontal) was correct. As part of the conditional discrimination procedure, birds were required to make an "observing response" to the sample stimulus presented on a wide key. The location on this key of the required observing response for the two sample stimuli differed by 0, 3, or 6 in. (0, 7.6, or 15.2 cm) for three groups of birds. Accuracy of conditional discrimination performance was directly related to the amount of separation. In subsequent generalization tests with novel sample stimuli, both observing-response location and comparison responding changed within the same region of the wavelength continuum from that appropriate for one of the training samples to that appropriate for the other. A maintained generalization test (continued reinforcement for training stimuli) revealed this relation more strongly. A test in which observing-response location was the only sample stimulus of a conditional discrimination revealed stimulus control by this observing response, supporting a response mediation interpretation of the data.

Several models of stimulus control have relied upon response mediation. Schoenfeld and Cumming's "instructional response" (1963), Lawrence's "coding response" (1963), Hull's "pure stimulus acts" (1930), and Osgood's "signs" (1953, p. 392) are operants that have been proposed as mediators of external stimulus control. A problem plaguing each of these proposals, however, is the obscurity of the hypothesized responses. Only rarely, apparently, have overt mediating responses been noted. Blough (1959) came closest to observing directly response mediation of a visual discrimination when he found that two pigeons developed a response mediation of a delayed matching-to-sample problem. They were able to maintain accuracy at much longer delays than the usual 2 to 5 sec by emitting topographically different response patterns during delay periods following the two samples. Such a performance had developed even though no responding was required during these periods. Because operanda were not arranged to measure these behaviors and because the mediators were easily disturbed by attempts to photograph, even these mediating patterns were not available for close study.

The experiments of Cumming, Berryman, and Cohen (1965); Cohen (1965); Berryman, Cumming, Cohen, and Johnson (1965); and Cohen (1969) give impetus to the study of response mediation of the stimulus control exhibited in conditional discriminations. By conditional discrimination is meant a discrimination in which a standard or sample stimulus designates which of a number of comparison stimuli is correct. The control exerted by this sample is called "instructional" by Cumming and Berryman (1965). The experiments noted were concerned with the transfer of this instructional control to novel sample stimuli. They report that for four different conditional discrimination procedures, a novel color was (1) confused with one of the training colors when presented as a sample, but (2) discriminated from the training color when presented as a comparison stimulus.

[1]This report is based on a dissertation submitted in partial fulfillment of the requirements for the Ph.D., Columbia University, 1966. The author is indebted to W. W. Cumming for his guidance and criticism during the course of the research, to Robert N. Landon for his extensive aid in computer analysis of the data, and to Carol Eckerman for careful reading of the manuscript. The work was supported by Grant MH-10384 from the National Institute of Mental Health, USPHS to William W. Cumming. Analysis of data and preparation of the manuscript were partially supported by Grant MH 15540 from the National Institute of Mental Health, USPHS to the author. Reprints may be obtained from the author, Department of Psychology, University of North Carolina, Chapel Hill, N.C. 27514.

Data from these studies were interpreted in terms of the response mediation model diagrammed in Fig. 1. This model assumed (1) that each training sample (S_i and S_{ii}) came to control a different pattern of observing (R_i and R_{ii}) that served to code the sample and (2) that stimulus consequences of these coding responses (S_{ri} and S_{rii}) combined with comparison stimuli (CO_n and CO_m) to control responding to the comparisons. The interpretation Cumming *et al.* suggest for the transfer data is that the novel color produced the coding response for one of the old sample stimuli and that once this coding response was emitted, its stimulus consequences controlled comparison choices.

The present experiment sought to make coding responses in a conditional discrimination overt by requiring sample-specific observing responses. By making the proposed mediating responses overt, study of their properties by direct rather than inferential methods becomes possible. The basic procedure resembled the series of events diagrammed in Fig. 1. In a trial, one of the two sample colors was presented and a sample-specific observing response was required (peck in place I (R_I) for sample color I; place II (R_{II}) for sample color II) before comparison stimuli (horizontal *vs.* vertical lines) were presented. The first peck at one of the comparison stimuli terminated the trial and produced either reinforcement or blackout. The role of the sample-specific observing responses was studied by comparing acquisition of the conditional discrimination for birds having different kinds of observing responses (Exp. 1); by comparing generalization of both observing response topography and comparison choice to new sample stimuli (Exp. 2 and 3); and by observing accuracy in a conditional discrimination procedure where response topography was the only sample stimulus available (Exp. 4).

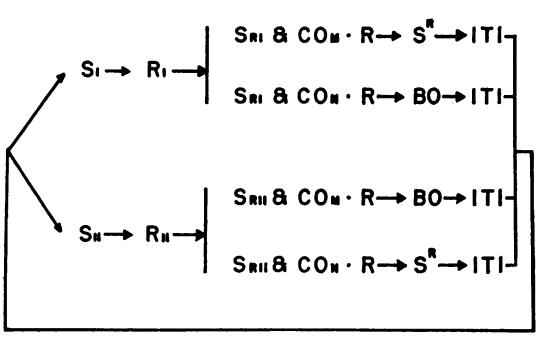

Fig. 1. A diagram of the response mediation model of conditional discriminations.

EXPERIMENT 1: ACQUISITION OF THE CONDITIONAL DISCRIMINATION

METHOD

Subjects

Fifteen experimentally naive White Carneaux cock pigeons, ranging in age from 5 to 6 yr, were maintained throughout the experiment at 75% of their free-feeding weight. Experimental sessions were given only if a subject's weight was within 2% of this value. Birds were individually housed with free access to water and grit in home cages. A seed mixture (50% Kaffir corn, 40% vetch, 10% hemp) served as both the reinforcer and the maintaining diet.

Apparatus

The experimental chamber was 12.75 in. high by 14.5 in. wide by 10.75 in. deep (32 by 37 by 27 cm). Chamber illumination was provided by two 7-w bulbs mounted behind a white Plexiglas ceiling. Three response-key openings and a feeder opening were cut in one 14.5 in. (37 cm) wide wall; a TV camera opening and an exhaust fan duct were cut in other walls. The response-key wall was covered by a thin layer of black matte finish vinyl (albedo of 0.025) that covered all mounting screws for apparatus positioned on this wall. This equipment is described below.

The observing response key. The observing response-key opening was a horizontal slot centered at a height of 8.5 in. (22 cm) above the floor, having a 0.75 in. (19 mm) height and a 9.75 in. (25 cm) length. Mounted behind this slot were twenty 0.5 in. (12.7 mm) wide Plexiglas paddles strung from a common axle above the slot. Microswitches were positioned behind these paddles, each microswitch being activated by movement of one of the paddles. Excursion and force requirements varied between keys and from time to time. The range of minimum values was 4 to 12 g (0.039 to 0.118 N) over 0.02 to 0.15 in. (0.5 to 3.8 mm). Forces and excursions did not covary; nor were they systematically related to position along the key. Maximum excursion was limited by a stop to 0.37 in. (9.5 mm). The

position of the pecking response within this 9.75 in (251 mm) slot was recorded as the number of the switch activated. When two adjacent switches were simultaneously activated, a separate type of response was recorded and later included in the tally for the right-hand key of the pair. Peck position was recorded as a binary code on a paper tape perforator. Because of limiting pulse length for correct punching of position, a maximum rate of recording was imposed. Recorded responses were always separated by at least 100 msec; the minimum switch closure leading to activation of recording and control systems was 2 msec.

The comparison response keys and stimuli. Two round openings 0.9 in. (22.5 mm) diameter were cut below the observing response key at a height of 6.3 in. (16 cm), 2.5 in (6.5 cm) to the right and left of the panel midline. Lehigh Valley clear plastic pecking keys were mounted behind these openings (required force of 10 g (0.098 N). Display cells were mounted 0.25 in. (6.4 mm) behind the keys. Displays were all of a black line 0.1 in. wide (2.4 mm) diameter of a white circle. The orientation of the line varied between displays.

The feeder. A Lehigh Valley (# 1347) feeder was mounted behind a 2 by 2.4 in (5 by 6 cm) hole centered below the response keys at a height of 4 in. (10.5 cm).

The sample stimuli. The observing-response key could be back-illuminated by monochromatic light provided by passing collimated light through Bausch and Lomb second order interference filters. The modal wavelength of the filter was 506 or 583 nm. After passing through the filter, light passed a shutter into a row of four -6 diopter cylinder lenses oriented to spread the light beam horizontally while retaining its 1.75 in. (4.5 cm) height. The beam then fell on a compensating neutral density filter (equating brightness across the width of the key) and a white diffusing surface. Light passed from this surface to back-illuminate the sand blasted Plexiglas paddles of the observing-response key.

An effort was made to equate brightness of the various monochromatic lights, taking Blough's (1957) pigeon luminosity function, the color temperature of the bulb, and the per cent transmission functions for the various filters into account. Brightness was manipulated by addition of Wratten Neutral Density filters.

Procedure

Initial training. After training on a punchboard (Ferster and Skinner, 1957, p. 32), birds were hopper trained and shaped to peck the observing response key illuminated with white light. On Day 1, birds were given 40 reinforcements (3-sec access to grain) for responses anywhere within the 9.75-in. (52 cm) wide observing-response key. On Day 2, forty reinforcements were delivered according to a variable-interval schedule of reinforcement where the average inter-reinforcement interval was 15 sec (VI 15-sec). Again a response on any location within the white observing response key was effective. On Day 3, the same schedule of reinforcement was arranged, but the two monochromatic lights were randomly presented on the key.

Differentiating observing responses to the two colors. During the 15 days of training for this phase, responses on only some locations produced reinforcement. Which location was effective differed for the two colors and for three groups of five birds each. The locations assigned to each group were: Group 1—keys 10 and 11 (keys numbered from right to left) for both colors; Group 2—keys 7 and 8 for the 506-nm light and keys 13 and 14 for the 583-nm light; Group 3—keys 4 and 5 for the 506-nm light and keys 16 and 17 for the 583-nm light. Thus, Group 1 had no differentiation training specific to the stimuli presented, but was trained to peck within the central 1-in. (2.54 cm) region of the key during both colors; Group 2 had an intermediate distance 3 in. (76 mm) and Group 3, a larger distance 6 in. (152 mm) between the region appropriate during one color and that appropriate during the other.

By the end of this stage, sessions were composed of 100 trials in which the observing-response key was illuminated an equal number of times with each of the two training colors. The first response in the location appropriate to the color and the group that met a VI 15-sec schedule contingency produced reinforcement (2-sec access to grain) and extinguished the key light. Fifteen seconds after reinforcement ended, the next color was presented on the observing-response key and the VI 15-sec timer started.

Shaping responses to the comparison keys. After the above procedure was completed, the observing-response key was covered with tape, and responding was shaped to the comparison keys. On each of 80 trials, one of the comparison keys was illuminated with either the horizontal (0°) or vertical (90°) stimulus. The first peck on the illuminated key produced reinforcement (2-sec access to grain) and an intertrial interval of 5 sec. Twenty reinforcements were obtained for a peck at each comparison stimulus on each key.

Conditional discrimination training. For the next 40 sessions, a conditional discrimination procedure involving both responses to the observing-response key and responses to the comparison keys was in effect. Sessions were composed of 80 trials. A trial commenced with onset of the 506-nm or 583-nm light on the observing-response key. Responses to the appropriate region of the observing-response key (same as that shaped during differentiation training) led, according to a VI 15-sec schedule of reinforcement, to onset of the comparison stimuli, a horizontal (0°) and a vertical (90°) line. Each orientation appeared on the left an equal number of times in each 20 trials. Once the comparison stimuli were presented, observing responses no longer had any effect, though the colored light remained on the observing-response key until the end of the trial. The first response to either comparison stimulus produced either reinforcement (2-sec access to grain) or blackout (2 sec with all illumination extinguished). For the 506-nm stimulus, a response to the 0° comparison produced reinforcement; for the 583-nm stimulus, a response to the 90° comparison produced reinforcement. The correct comparison appeared equally often on right and left keys within each block of 20 trials. After reinforcement or blackout, a 15-sec intertrial interval (keys dark, houselight lit) preceded onset on the next trial. No correction procedure was used. One of three stimulus orders was chosen for each day.

VR 3 reinforcement of the conditional discrimination. The next 10 sessions followed the same conditional discrimination procedure except that (1) no blackouts were scheduled and (2) reinforcement was not given for each correct response. Reinforcement was scheduled according to a variable-ratio 3 schedule of reinforcement (VR 3) for correct comparison responses (Nevin, Cumming, and Berryman, 1963). The first response to a comparison stimulus still terminated a trial. Thus, the maximum reinforcement density possible was one reinforcement per three trials. Incorrect and non-reinforced correct comparison responses produced a 17-sec intertrial interval. Reinforcement continued to be 2-sec access to grain and preceded a 15-sec intertrial interval.

RESULTS

Initial training procedures. All birds were shaped to peck the observing-response key within the first experimental session. Responding was observed at all locations along the key, although responding toward the center of the key was more frequent. Performance did not become highly stereotyped over the initial training sessions; average deviation in position (from the median response location) ranged from 0.8 in. (20.3 mm) to 2.9 in. (71.1 mm). The average Redundancy[2] (Attneave, 1959) for frequency distributions of responding across the key was 0.250.

The differentiation training of Days 4 to 17 shifted the locus of responding to specific regions of the observing-response key. The regions were dependent upon the color presented and the group membership of the subject. Relative frequency distributions of responding on the various key locations are shown in Fig. 2 for the last day of differentiation training. The distributions for the two colors were similar for Group 1 but differed for both Group 2 and Group 3. Further, distributions for the two colors overlapped more for Group 2 than for Group 3. These averaged distributions adequately characterize the performance of each of the birds. It should be noted that the stereotypy in performance was not strikingly altered by the separation in regions

[2]Redundancy is a measure of variability that seems especially applicable to topography, since it is designed for nominal scale data. Redundancy is 0.0 for data equally distributed among all possible categories and is 1.0 for data that fall into one category exclusively.

$$\text{Redundancy} = 1 - \left| \frac{\sum_{i=1}^{i=k} -p_i \log_2 p_i}{\log_2 k} \right| \text{ for } p_i > 0$$

where p_i is the proportion of data in category i and k is the number of categories (in the present analysis $k = 20$).

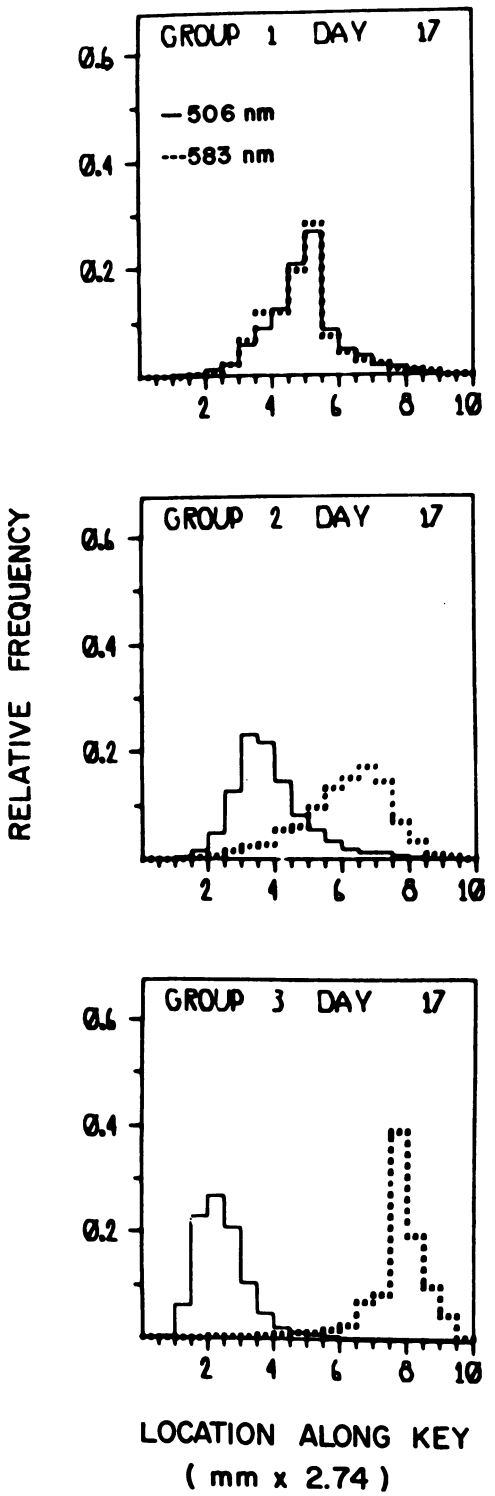

Fig. 2. Relative frequency distributions of response locations averaged over all birds in each of the experimental groups for the last session of differentiation training.

(Group 1 *vs* 2 *vs* 3). The average Redundancy of these distributions is 0.389.

During Session 18, responding was established on the two comparison keys and the two comparison stimuli (0° and 90° lines). Shaping was not required. Latencies did not differ by the end of training for either key or either stimulus. Responding on a dark comparison key was not observed after the fifth trial.

Responding on the observing-response key during conditional discrimination training. During conditional discrimination training, requirements for responding on the observing response key were identical to those for differentiation training. Responding produced conditioned reinforcement (comparison stimulus presentation), rather than primary reinforcement. The performance remained highly stable across this procedural change and over the entire conditional discrimination training, although for Group 3 the variability of responding increased for one session after the change from CRF to VR 3 reinforcement. Redundancy averaged 0.435 for the last session of conditional discrimination training.

Responding to comparison stimuli during conditional discrimination training. Figure 3 presents the average accuracy of comparison choice on each session for each of the three groups. Throughout training the three groups differed in accuracy. Group 3 (with widest separation between observing responses for the two samples) acquired most rapidly and

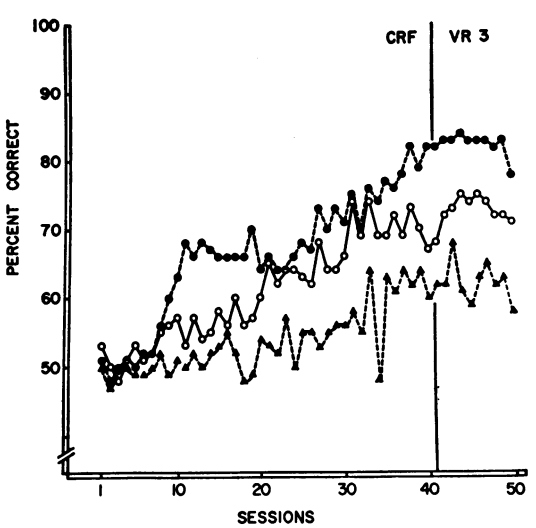

Fig. 3. Acquisition of the conditional discrimination.

to the highest level of accuracy. Group 2 was intermediate, and Group 1 lowest in accuracy. The effect of changing from CRF to VR 3 was minimal except for Group 2 which showed a decrease in accuracy of 6.4%. The average change for the other groups was 0.7%. A Kruskal-Wallis one-way analysis of variance on the individual bird's accuracies over the last five sessions shows the probability of such a difference between groups resulting from chance to be less than 0.001. The individual bird's accuracies (Table 1) thus confirm the group differences. Whereas the group accuracy functions show a gradual and fairly steady increase, however, individual functions show abrupt changes in accuracy with many reversals and differences in accuracy for the two sample colors. Figure 4 presents individual functions for Group 3 to illustrate these differences.

Table 1

Ranked final accuracy levels and type of pre-acquisition pattern of responding.

Rank	*Bird No.*	*Group*	*Average Accuracy (%)*[1]	*Pre-Acquisition Pattern*[2]
1	227	3	91	HINK
2.5	230	3	84	HINK
2.5	223	3	84	HINK
4.5	216	1	79	OP
4.5	226	2	79	HINK
6	218	3	77	OP
7.5	219	1	75	OP
7.5	222	2	75	OP
9	217	2	74	LONK
10	224	3	69	OP
11	229	2	67	OP
12	220	2	64	LONK
13	225	1	56	OP
14	228	1	53	?
15	221	1	42	?

[1]Average accuracy over the last three training sessions.

[2]HINK designates above 90% Near-Key Preference, LONK designates between 70 to 85% Near-Key Preference, and OP designates over 90% Overall Position Preference observed before the conditional discrimination was acquired. A "?" indicates birds not included in these three categories.

Figure 4 also introduces two measures of the bird's performance other than per cent accuracy; overall position preference is the per cent deviation from equal distribution of responding on the right and left comparison keys. The near-key preference represents a more complex variety of position preference observed for Groups 2 and 3 birds. Since these birds were required to respond away from the center of the observing response key, they were actually closer to one comparison key than the other when the comparison stimuli were presented. The near-key preference measure is the per cent deviation from equal distribution of responding to near and far comparison keys. Three of the five birds in Fig. 4 initially displayed very high near-key preferences; two birds displayed very high overall position preference.

In Table 1, the pre-acquisition behavior of each bird has been classified. All except two of the birds fall within one (and only one) of these categories. There is a relation between the variety of observing response required and the type of pre-acquisition behavior shown; further, there is a relation between the pre-acquisition behavior and the accuracy achieved on the conditional discrimination. The three Group 3 birds that developed high near-key preferences, for example, reached the highest accuracy, and the one Group 2 bird that developed a high near-key preference showed the highest accuracy for Group 2. Group 1 birds were prevented from developing a near-key perference because neither comparison key was physically closer after an observing response. It was possible for them to develop overall position preferences, however, and birds that did so reached higher accuracy on the conditional discrimination.

Discussion

The conditional discrimination accuracies of the present experiment were lower than those of previous studies of conditional discrimination performance in pigeons (Cumming and Berryman, 1965). The lower accuracy cannot be attributed to the particular stimulus dimensions used, for Carter, Cumming, and Eckerman (1968) obtained above 90% accuracy in conditional discriminations involving these same stimuli (*i.e.*, color samples and line comparisons). Nor can the lower accuracy be attributed to the observing response requirements of the present study. In prior studies, birds were required to peck in the same location regardless of which sample was presented, a requirement identical to that for the lowest accuracy group of the present study (Group 1). The lower accuracy does not result, then, from any interference produced

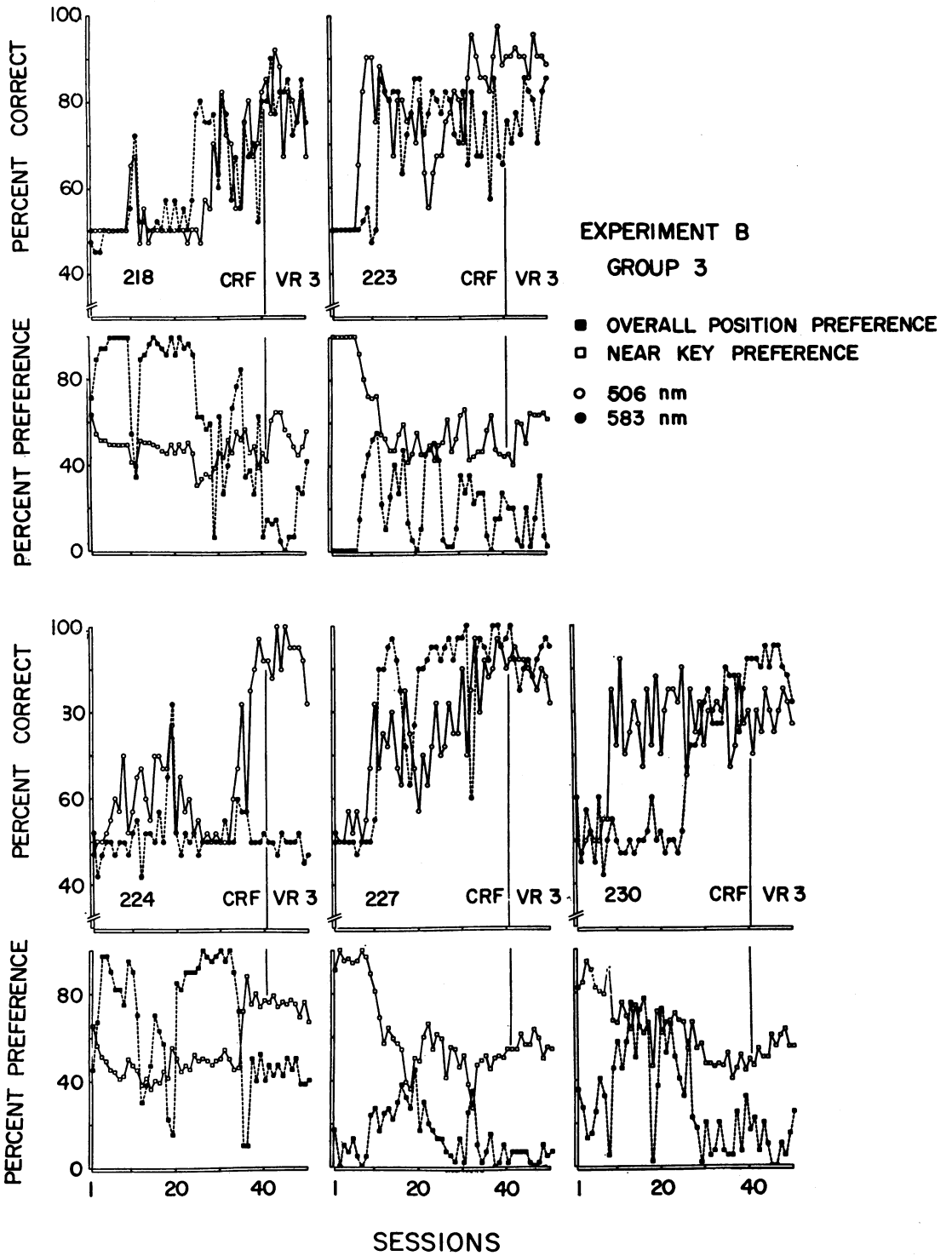

Fig. 4. Accuracy and position preference functions for individual birds in Group 3 during conditional discrimination training.

by similarities in observing responses to the two samples. Two apparatus characteristics, however, may account for the lower accuracy: the wide sample display area or the low position of the comparison keys. Whatever the source of the lower accuracy, it is hoped that its only influence is to lower the baseline upon which the experimental manipulation's effects are observed.

The data support the notion that conditional discrimination acquisition follows a period of systematic pre-acquisition performance more readily than it follows a period of non-systematic pre-acquisition performance (Cumming and Berryman, 1965). There is a further suggestion that the variety of pre-acquisition performance may be correlated with subsequent conditional discrimination accuracy. Whether this relation is causal or not remains problematical. It is difficult to understand, for example, how a performance shown early in training could determine the accuracy of performance after 50 days. At this point, it seems simpler to view the relation between pre-acquisition performance and conditional discrimination accuracy as correlational and not necessarily causal.

Experiment 1 demonstrated a relation between the variety of observing response required and the conditional discrimination accuracy: birds with sample-specific observing responses (Groups 2 and 3) acquired the discrimination more rapidly and to a higher level of accuracy. The result is in accord with the mediational interpretation of conditional discrimination performance, which will be discussed at the end of the article.

EXPERIMENT 2: GENERALIZATION OF THE OBSERVING RESPONSE AND CONDITIONAL DISCRIMINATION: TEST DURING EXTINCTION

METHOD

Apparatus and Subjects

Same as those for Exp. 1 except that 506, 525, 548, 565, and 583 nm interference filters and line orientations of 0, 30, 45, 60, and 90 degrees were used.

Procedure

After completion of Exp. 1, the next three sessions consisted of a generalization test conducted during extinction. Any of five wavelengths of light could be presented on the observing-response key; and any of five comparison orientations could appear. Since the same orientation was never presented simultaneously on both comparison keys, 20 comparison pairs were possible. Every pair was scheduled to appear with every color once in each 100-trial session. Within each block of 20 trials, every comparison pair appeared once and each color, four times. Due to an error, when the 30°, 45°, or 60° comparison stimuli were paired, white light appeared on the sample key whenever the 506-nm color was intended. Data are thus available for responding to white light as well as for responding to the five colored samples.

A trial commenced with presentation of one of the five colored lights on the observing response key. A peck anywhere on this key meeting the VI 15-sec requirement produced the comparison stimuli. The first response on an illuminated comparison key extinguished the stimuli and started a 17-sec intertrial interval (houselight on). No reinforcements or blackouts were scheduled.

A "limited hold" condition was placed on trials. If no comparison response occurred within 5 min after trial onset, the trial was terminated and the next trial was presented after an intertrial interval. After at least 10 consecutive cancellations by the limited hold condition, a session was terminated.

RESULTS

Generalization of observing-response location. The extinction generalization test provided data on generalization of responding on the observing key in the presence of novel sample stimuli. Figures 5 and 6 plot two measures of responding under each of the colors, summed over all test sessions: Figure 5 presents median response locus and Fig. 6 presents a measure of variability of the distribution (Redundancy).

Group 1. The median response location and variability of performance remained fairly constant across the sample stimulus dimension for this group except that performance was characteristically more variable during presentation of the white-light sample.

Group 2. The median response location changed gradually across the sample stimulus dimension for all but Bird 217. Several of the

medians are intermediate between the reinforcement regions of the observing response key. These intermediate medians do not represent a bimodality in performance under the intermediate stimuli, but reflect an increased proportion of responding at central response locations. For all Group 2 birds, variability of response locus was greater for novel sample stimuli. For the white-light stimuli, variability was also high and median response location was intermediate for four of the five birds.

Group 3. The performance of birds in Group 3 was different from that seen in Group 2. The response location for intermediate wavelengths was not intermediate, but was within either one reinforcement region or the other. The shift in response locus took place between 525 and 548 nm for all except Bird 223. This bird produced the one intermediate

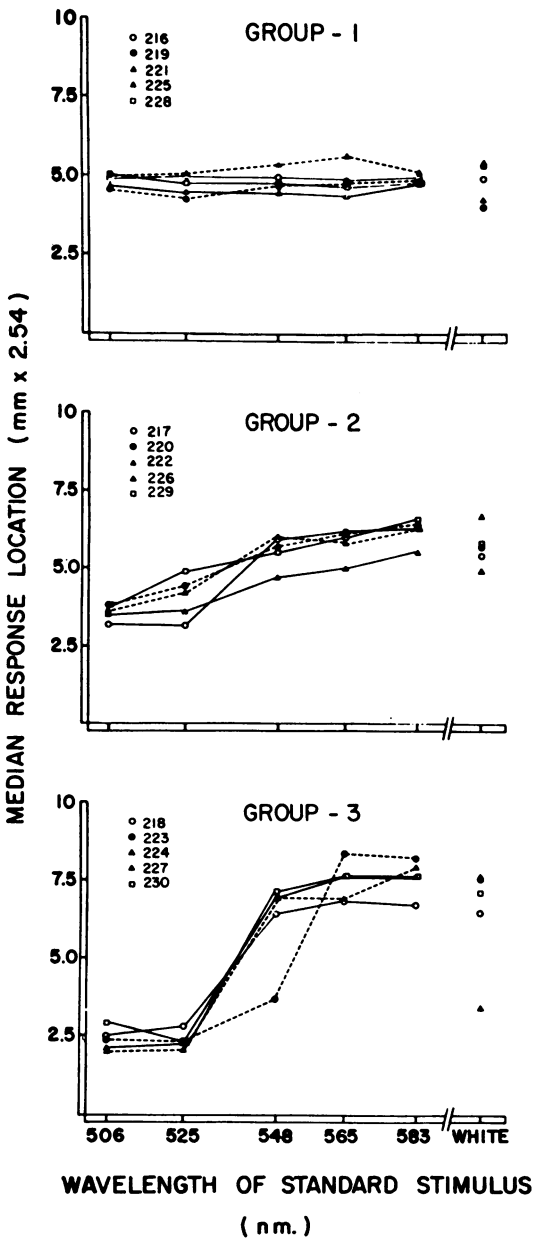

Fig. 5. Median response location for the wavelengths given in the extinction generalization test. The number by each symbol identifies the individual bird.

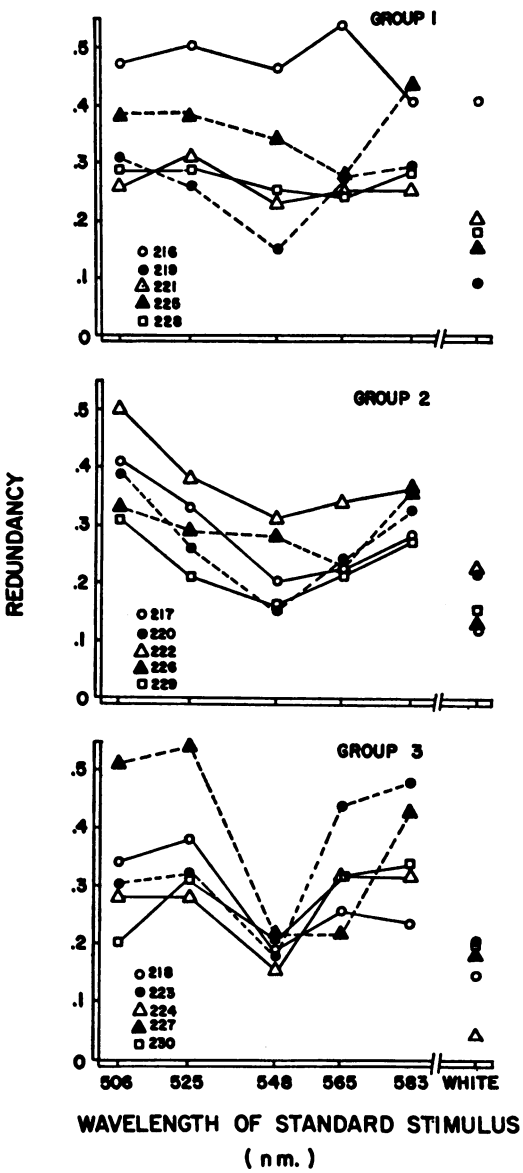

Fig. 6. Redundancy of relative frequency distributions of response location in each of the wavelengths of the extinction generalization test. The number by each symbol identifies the individual bird.

median location obtained (548 nm). This intermediacy reflects a bimodality in the frequency distribution of response location, rather than an increased frequency of responding at intermediate response locations. For the white-light stimulus, the median response was similar to that of the 583-nm sample (Bird 224 being the exception).

Generalization of instructional control. The extinction generalization test also provided data on the stimulus control of comparison choice. Two varieties of generalization may occur: (1) generalization among samples: generalization of the instructional control exhibited by one of the sample colors to some novel sample color, and (2) generalization among comparisons: a gradient of generalization along the line orientation dimension for comparison choices made in the presence of the same sample color. These two kinds of generalization could both be assessed because novel comparison orientations as well as novel sample stimuli were given. The measure P_{co} was used to assess both types of generalization: $P_{co} = (R/T)100$, where R is the number of times a response was made to a particular comparison stimulus (irrespective of which other comparison stimulus was paired with it) and T is the total number of times that comparison was presented (irrespective of which other comparison stimulus was paired with it). If the performance displayed complete adherence to some "rule" such as "peck the most vertical", P_{co} values for the five comparison values would be 100%, 75%, 50%, 25%, and 0%. The function across these points has a slope of 1.1%/degree, and represents a maximum slope for the P_{co} gradients. Obtained slopes were less than this maximum, presumably because of (a) the non-perfect accuracy on the conditional discrimination and (b) the generalization among comparison stimuli themselves.

In Fig. 7, P_{co} functions are averaged for all birds that showed greater than 75% accuracy in the last three days of conditional discrimination training. (Other birds were excluded because their behavior was apparently uncontrolled by color or line orientation). Separate functions are presented for each of the five sample colors and each of the three groups; each data point represents an average of 14

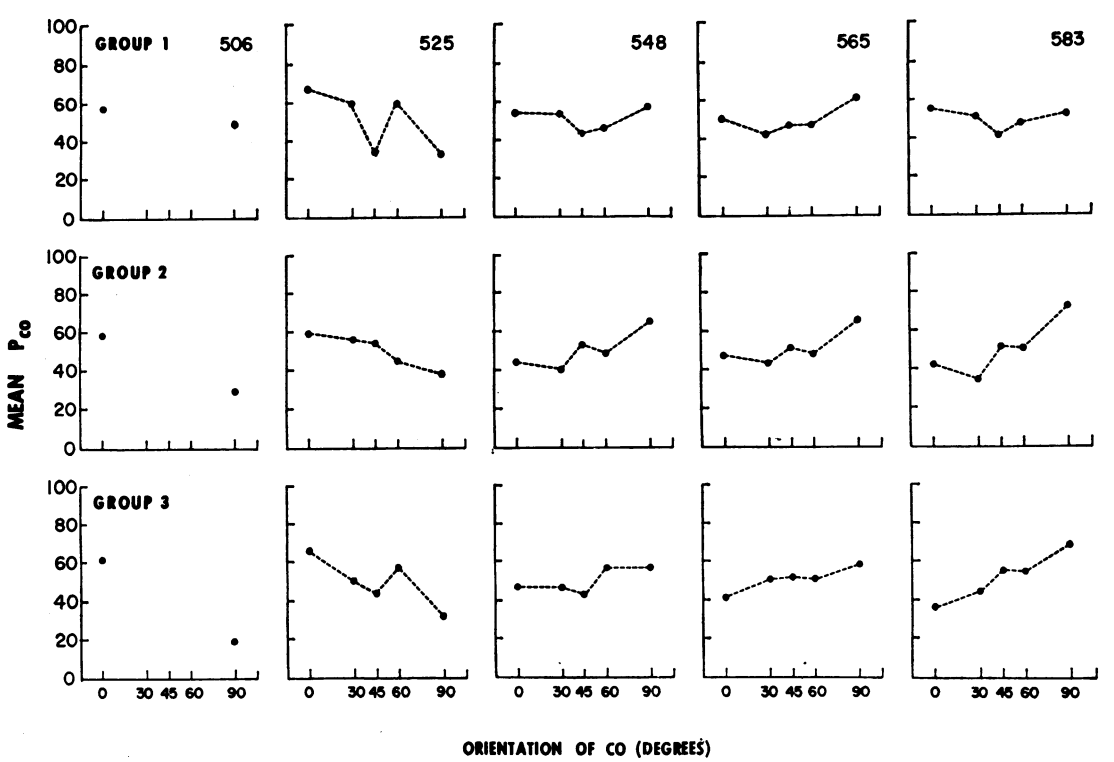

Fig. 7. Averaged functions for high-accuracy birds relating the probability of response to comparison stimuli (P_{co}) for each of the five wavelengths given in the extinction generalization test.

trials for each bird. P_{co} values for 30°, 45°, and 60° comparisons have been omitted for the 506-nm sample because of the experimental error noted in the procedure section. The averaged functions include the following numbers of subjects: Group 1 (2), Group 2 (3), Group 3 (4).

Figure 7 reveals that the slope of the P_{co} function was maximally negative under the 506-nm sample and maximally positive under the 583-nm training sample. Intermediate sample colors typically had intermediate slopes for Groups 2 and 3. For Groups 2 and 3, the point of change in sign of the slope was consistently the same as that which produced the largest shift in median response locus for responding on the observing-response key (between 525 and 548 nm). The P_{co} functions for Group 1 do not differ greatly from those obtained for Groups 2 and 3, although the slopes do not change in as orderly a fashion across the wavelength continuum. The slope again changed sign between 525 and 548 nm.

Discussion

The extinction test demonstrated the generalization of observing responding to novel sample stimuli. This generalization was nearly complete for Group 3; that is, intermediate stimuli yielded observing responding similar to that emitted to one of the training stimuli. These results replicate the prior observations of Cumming and Eckerman (1965) with the same response dimension (location of a key peck within a 10-in. key), the observations of Cross and Lane (1962) with human humming, those of Migler and Millenson (1969) with a two-lever discrimination, and those of Migler (1964) with rats' pausing behavior. The lower Redundancy for the intermediate stimuli of the present experiment shows, however, that the differentiated patterns of training were not entirely duplicated for these intermediate stimuli. Further, birds with intermediate separation between observing-response patterns (Group 2) showed a different variety of generalization: intermediate stimuli produced responding intermediate between that for the training stimuli. This last observation suggests that response class overlap may be an important determinant of the generalization of differentiated responding.

The generalization of sample control observed in this extinction test differed from that observed in the previous experiments (e.g., Berryman *et al.* 1965; Cohen, 1965, 1969; Cumming *et at.* 1965). In the prior studies, novel samples produced comparison choice very similar to that produced by one of the former training samples; in the present study, novel samples produced comparison choice intermediate to that produced by training samples. The differences in procedure are too many to allow meaningful suggestions about the different results. The stimulus dimensions and values, the number of sample and comparison stimuli, and the reinforcement conditions present during the test all differed. The present data, indicate, however, that one or more of these variables critically determines the form of generalization of sample control.

The fact that control of comparison responding varied continuously as sample color was changed suggests a difference between this generalization and that of response locus for Group 3. The difference is less apparent, however, when response variability measures are considered; novel sample colors produced less stereotyped observing responding at the same time that they produced intermediate comparison choice. Further, one very strong similarity between the two generalization measures is apparent: observing response location showed its greatest change in the same color region in which the slope of the P_{co} gradient changed sign.

EXPERIMENT 3: A MAINTAINED GENERALIZATION TEST FOR OBSERVING RESPONDING AND COMPARISON CHOICE

Method

Apparatus and Subjects.

Same as in Exp. 2.

Procedure

Birds were retrained for seven sessions under the procedure of Exp. 1, except that blackout duration was increased from 2 to 30 sec in the last four sessions. A second generalization test series was then given, consisting of three 50-trial sessions. Five wavelength stimuli were again presented (506, 525, 548, 565, and 583 nm), but only the training comparison stimuli (0° and 90°) were used. Each sessions included five presentations of each of the 10 stimulus

combinations (each of five sample colors with the 0° stimulus of the 0-90° pair on the right comparison key and again with 0° on the left comparison key). A trial commenced with the onset of one of the five wavelengths of light on the observing-response key. If this wavelength was one of the training values (506 or 583 nm), only responses in the appropriate regions of the key led to onset of the comparisons. If the wavelength was one of the three intermediate colors (525, 548, or 565 nm), a response anywhere on the key meeting the VI

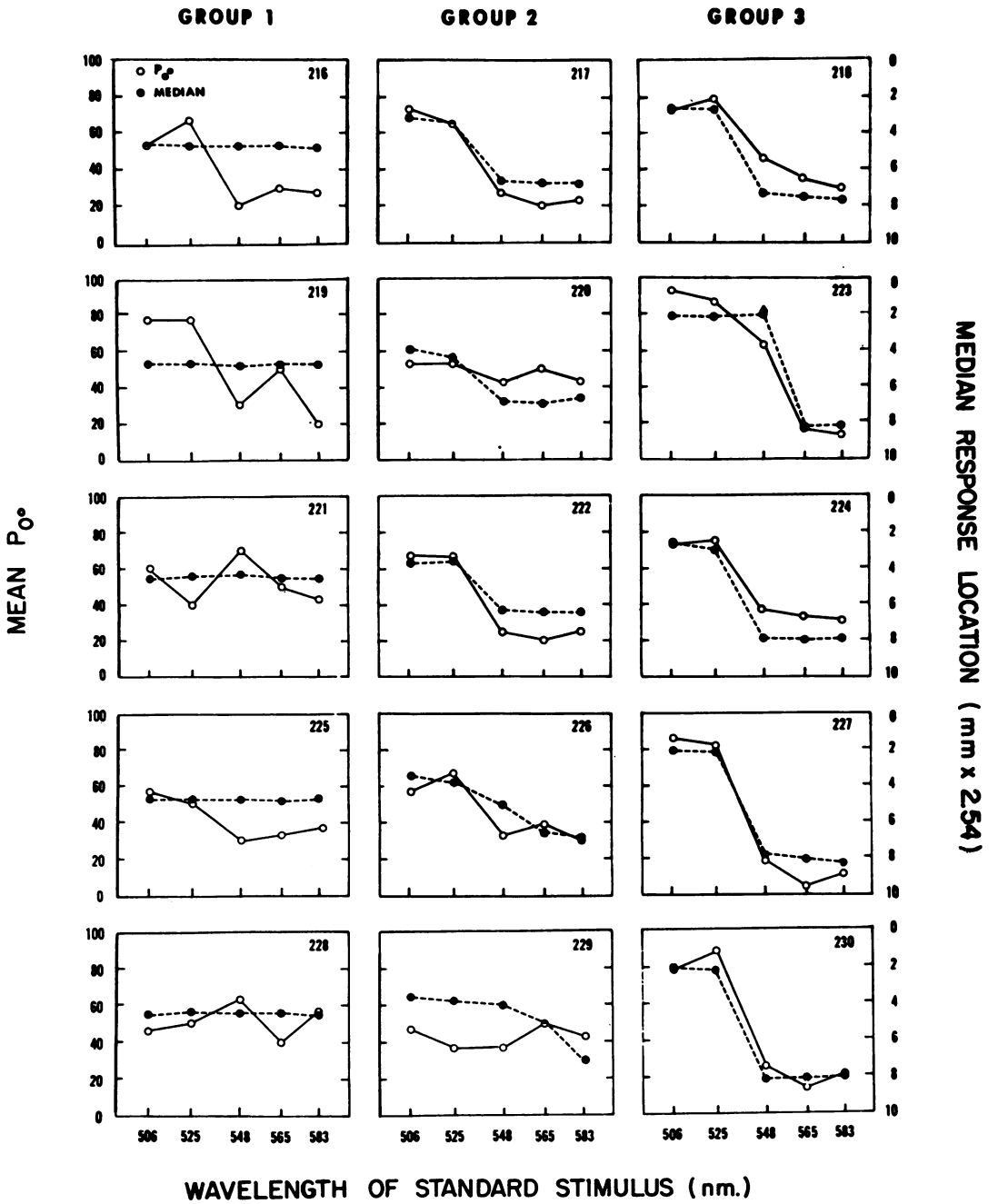

Fig. 8. Observing response location and probabilty of response to the 0° comparison for each of the five wavelengths of the maintained generalization test. The number in the upper right-hand corner of each panel identifies the bird.

15-sec contingency produced the comparisons. The first response to a comparison stimulus extinguished the wavelength and line stimuli and started an intertrial interval (17 sec). For training wavelengths, the comparison response also produced either reinforcement (2-sec access to grain) or blackout (2 sec) according to the training contingencies; for intermediate wavelengths no reinforcement or blackout was presented.

Results

Figure 8 presents the average median observing-response location and the per cent of responses to the 0° comparison ($P_{0°}$) during the generalization test as a function of wavelength for each bird.

Group 1. Average median response location was constant across wavelength for all birds. Those birds that previously displayed above chance accuracy in the conditional discrimination (Birds 216, 219, and 225) show a step-like $P_{0°}$ function; both 506 and 525 nm have high $P_{0°}$ values and 548, 565, and 583 nm have low $P_{0°}$ values.

Group 2. Only three of the 25 median observing-response locus values for Group 2 are outside the reinforcement region of the observing-response key; there was an abrupt shift from one observing-response type to the other as wavelength varied. Again, those $P_{0°}$ functions that have non-zero slope have high values for both 506 and 525 nm and a low value for 548, 565, and 583 nm.

Group 3. All 25 median observing-response locus values fall within the reinforcement regions of the observing key. Note that Bird 223 alone shifted observing-response locus between 548 and 565 nm. The other four birds shifted between 525 and 548 nm. Only two $P_{0°}$ values are intermediate between a high level characterizing lower wavelengths and a low level characterizing higher wavelengths. These two intermediate values are the 548-nm value for Birds 218 and 223.

The intermediate $P_{0°}$ value for Bird 223 should be interpreted in terms of a bimodality of responding on the observing-response key for this 548-nm stimulus. The median response location for seven of the 30 trials in 548 nm was on the "583-nm" side of the observing response key. On all these seven trials, a response was made to the 90° comparison. When $P_{0°}$ is computed for the remaining 23 trials it compares favorably with $P_{0°}$ values for 506 and 525 nm (plotted as an open triangle in Fig. 8). There was thus a strong correlation between observing responding and responding to comparison stimuli.

The intermediate $P_{0°}$ value for Bird 218 is related to a strong position preference for the right-hand comparison key (26 of 30 trials). It might be argued then, that position, wavelength, and line orientation were jointly controlling the bird's responding and that at the 548-nm sample color the relative control by position was increased.

Discussion

The maintained generalization test, as the extinction test, showed for Group 3 an abrupt shift in observing-response locus from that appropriate for 506 nm to that appropriate for 583 nm. During the maintained test, the shift for Group 2 birds was rapid as well, and responding at intermediate response locations was infrequent.

The pattern of comparison choice also changed abruptly from that appropriate for 506 to that appropriate for 583 nm. Bird 218 alone showed an intermediate $P_{0°}$ that did not correlate with a bimodality of response location. The fact that the maintained test produced a more orderly and homogeneous performance than the extinction test supports Blough's (1969) stated predeliction for steady-state over transitional measures of stimulus control. Further, the fact that the maintained test produced sample-stimulus control similar to that of prior studies (*e.g.*, Berryman *et al.* 1965; Cohen, 1965, 1969; Cumming *et al.* 1965) suggests that the mediation hypothesis discussed later is more compatible with data obtained for maintained performance than for performance in transition.

EXPERIMENT 4: CONDITIONAL DISCRIMINATION WITH RESPONSE POSITION AS THE ONLY SAMPLE STIMULUS

Method

Apparatus and Subjects

Four of the birds from Exp. 3 were used. Apparatus was the same.

Procedure

Four birds, chosen from the highest accuracy subjects, were given 11 sessions where

the only sample stimulus was the required position for responding on the observing-response key. In these sessions, each of 80 trials commenced with presentation of a white light (1.25 log ft-lamb) on the observing-response key. A response on this key was required for presentation of the comparison stimuli. This response had to meet both a VI 15-sec and a response location requirement. On half the trials, a response in the region of the key formerly required in the 506-nm sample led to onset of comparisons. On the other half, a response in the region formerly required in the 583-nm sample led to onset of comparisons. The order of required responses was scrambled. Both 0° and 90° comparisons were presented on each trial. The first response on an illuminated comparison key produced either reinforcement (2-sec access to grain) or blackout (30 sec). If the required observing response had been in the region formerly required for the 506-nm sample, the 0° comparison was correct. If the required observing response was that formerly required for the 583-nm sample, the 90° comparison was correct. This relation between observing-response locus and the correct comparison was identical to that previously arranged when the colored sample was also presented. Thus, this procedure tested the adequacy of the position of "observing" response in determining choice of comparison stimuli.

Results

The four birds all showed above-chance accuracy. Figure 9 plots the per cent of trials with a correct comparison choice. Separate functions are presented for trials that required a "right-hand" observing response and for trials that required a "left-hand" observing response. It should be emphasized that this white-light procedure represented a considerable departure from previous procedures; birds took 130% to 362% longer than in Exp. 1 to complete the initial session. There was a strong tendency to respond on the "583-nm" side of the observing-response key in the white light (a tendency also observed during the extinction generalization test of Exp. 2). The preference for left-hand observing responses gave way during the initial session to an "alternation" pattern of observing responding. Despite the radical shift in procedure, accuracy for Birds 217, 223, and 230 averaged between 65% and 72% (an average drop of only 15% from previous accuracy with colored sample stimuli). Accuracy for these birds was as high during the first 20 trials of the initial session as during the last 20. Accuracy varied over sessions but showed no consistent improvement.

Bird 227 showed near-chance accuracy during the first session; almost all observing responses were to the "583-nm" side of the key (wrong for one-half the trials) and a near-key preference characterized its comparison responding. Accuracy rose on the second day and stabilized at 85 to 90%.

Discussion

The above-chance accuracy of comparison responding with position of observing response as the sample stimulus suggests that observing-response position had gained instructional control during prior conditional discrimination training. The comparable accuracies for the first and last blocks of the initial session argue against attributing the above-chance accuracy to learning taking place during the test, as does the lack of a consistent increase in accuracy across the 11 training sessions. The one bird that showed an increase did so in the second session; the increase was a sudden change from chance to above 80% accuracy, which paralleled a redevelopment of responding at both positions of the observing-response key.

DISCUSSION OF THE MEDIATION HYPOTHESIS

The present data offer several lines of presumptive evidence for a mediation interpretation of simultaneous conditional discriminations. The strongest support is found in Exp. 4, where observing-response location was found to control choice of comparisons even though prior training had not required such control. Such a finding represents support because the mediation hypothesis assumes that sample-specific responses acquire control of comparison choice.

A second line of support is the concordance between generalization functions for observing-response location and comparison choice. This concordance was most marked for the maintained test, though also present during

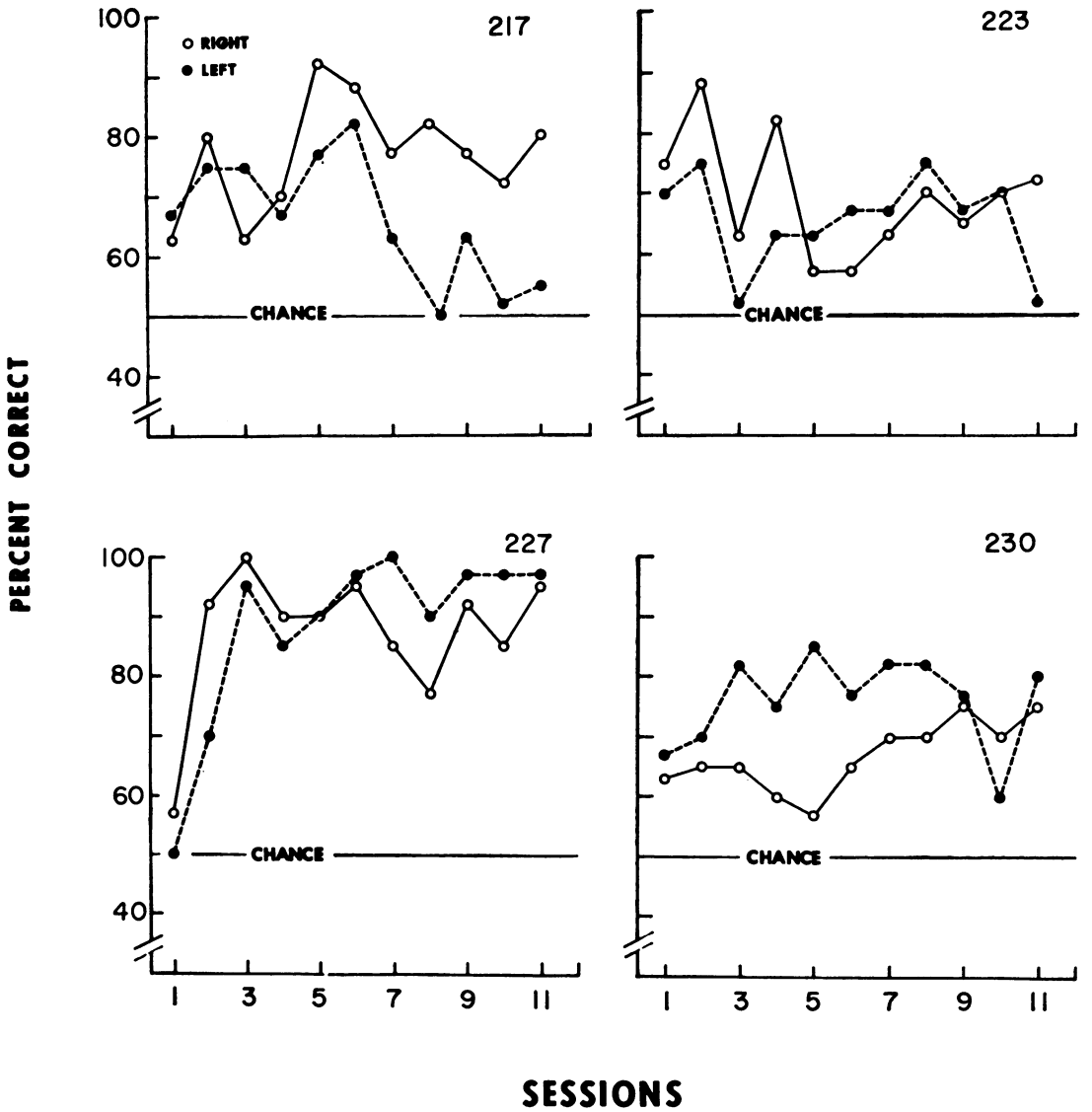

Fig. 9. Accuracy functions for individual birds when observing response location was the only stimulus. The number in the upper right-hand corner of each panel identifies the bird.

the extinction test. A correlation between the two behaviors is required because the mediation hypothesis asserts a causal relation between them. Two results that might at first seem contrary to the mediation hypothesis are not: (1) That Group 1 birds showed generalization of comparison choice similar to that for groups that required sample-specific observing responses is not evidence against the mediation hypothesis. The hypothesis asserts that the development of sample-specific behaviors takes place before the conditional discrimination is acquired, whether these behaviors are required or not. Inasmuch as these inferred behaviors show generalization like that of response location, their control for comparison choice should be similar to that for birds with experimenter-required sample-specific behaviors. (2) The reduced control of comparison choice during the extinction test would be a problem for the mediation hypothesis except for the observed decrease in stereotypy of the observing responding. The reduced control of comparison choice may reflect a decrement in the sample-specific response stereotypy and a resulting de-

crement in its response-produced stimulus control.

Acquisition performance provides a third line of support for the mediation hypothesis. Required sample-specific observing responses facilitated acquisition of the conditional discrimination. A mediation interpretation might assert that sample-specific responses were more readily available to serve as mediating responses for birds with required sample-specific response locations. Further, the greater overlap between observing-response patterns for Group 2 could render these patterns less distinctive and hence less readily available as mediators. The requirement of similar responding in both samples for Group 1 birds might actually have retarded acquisition of sample-specific responding.

The mediation hypothesis is not readily subjected to test. It serves as a framework for describing the observed broad generalization of instructional-control at a time when narrow generalization of comparison-control is also observed. The present experiment does not test the hypothesis. It does, however, affirm a consequent of the mediation hypothesis in at least three distinct ways while offering no strong contradictions to it.

REFERENCES

Attneave, F. *Applications of information theory to psychology*. New York: Holt. 1959.

Berryman, R., Cumming, W. W., Cohen, Leila, and Johnson, D. F. Acquisition and transfer of simultaneous oddity. *Psychological Reports*, 1965, **17**, 767-775.

Blough, D. S. Delayed matching in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1959, **2**, 151-160.

Blough, D. S. Spectral sensitivity in the pigeon. *Journal of the Optical Society of America*, 1957, **47**, 827-833.

Blough, D. S. Generalization gradient shape and summation in steady-state tests. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 91-104.

Carter, D. E., Cumming, W. W., and Eckerman, D. A. *Some properties of the complex discriminated operant: Is the matching relation a unique case of the conditional discrimination?* Paper read at the Eastern Psychological Assn., Washington, 1968.

Cohen, Leila. *Some data on the transfer of matching-to-sample without differential reinforcement*. Paper read at Eastern Psychological Association, Atlantic City, April, 1965.

Cohen, Leila. Generalization during acquisition, extinction, and transfer of matching with an adjustable comparison. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 463-474.

Cross, D. V. and Lane, H. L. On the discriminative control of concurrent responses: the relations among response frequency, latency, and topography in auditory generalization. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 487-496.

Cumming, W. W. and Berryman, R. The complex discriminated operant: Studies of matching-to-sample and related problems. In D. I. Mostofsky (Ed.), *Stimulus generalization*. Stanford: Stanford University Press, 1965. Pp. 284-330.

Cumming, W. W. and Eckerman, D. A. Stimulus control of a differentiated operant. *Psychonomic Science*, 1965, **3**, 313-314.

Cumming, W. W., Berryman, R., and Cohen, Leila. Acquisition and transfer of zero-delay matching. *Psychological Reports*, 1965, **17**, 435-445.

Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.

Hull, C. L. Knowledge and purpose as habit mechanisms. *Psychological Review*, 1930, **37**, 511-525.

Lawrence, D. H. The nature of a stimulus: some relationships between learning and perception. In S. Koch (Ed.), *Psychology: a study of a science*. Vol. 5; New York: McGraw-Hill, 1963. Pp. 179-212.

Migler, B. Effects of averaging data during stimulus generalization. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 303-307.

Migler, B. and Millenson, J. R. Analysis of response rates during stimulus generalization. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 81-87.

Nevin, J. A., Cumming, W. W., and Berryman, R. Ratio reinforcement of matching behavior. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 149-154.

Osgood, C. E. *Method and theory in experimental psychology*. New York: Oxford University Press, 1953.

Schoenfeld, W. N. and Cumming, W. W. Perception and Behavior. In S. Koch (Ed.), *Psychology: a study of a science*. Vol. 5; New York: McGraw-Hill, 1963. Pp. 213-252.

Received 3 April 1968.