CONDITIONAL DISCRIMINATION LEARNING IN THE PIGEON¹

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Four pigeons received conditional discrimination training in which reinforcement contingencies were related to specific combinations of color and form, but were unrelated to either color or form considered separately. During discrete-trial training, each response in the presence of two of four color-form displays produced reinforcement and terminated the trial; responding to the other two displays was never reinforced, and each such response prolonged the particular trial on which it occurred. Subsequently, the subjects received multiple-schedule training in which responding to either of the displays previously associated with reinforcement was now reinforced on a variable-interval schedule, and extinction was the schedule again correlated with the other two displays. After differential responding to the stimuli was clearly evident, intensity of the combination displays was changed in subsequent training sessions. Complex stimulus control was generally maintained across variation in intensity, although there were temporary disruptions in performance associated with onset of some of the intensity changes. Finally, a component-stimulus test revealed considerably more responding to the forms than to the colors.

The past few years have seen a marked increase in the extent to which the concept of attention has been employed in explanations of behavior (see Mackintosh, 1965). However, as Johnson and Cumming (1968) recently noted, the word *attention* is used in a variety of ways and situations. In particular, the word has frequently been used in recent experiments with complex stimuli when it has been shown that responding is controlled by only a fraction of a set of component stimuli which are equally correlated with presentation of a reinforcing stimulus. As Johnson and Cumming (1968) implied, for the concept to be useful in a functional analysis of such behavior "... it is important to determine the conditions under which stimulus control is obtained by one or a few specified dimensions but not by other specified dimensions of the stimulus correlated with reinforcement."

In two experiments, Reynolds (1961) showed that responding of the pigeon to a complex (color-form) display may be controlled by the presence of only one component stimulus (either color or form, but not both). The second of these experiments further indicated that responding was controlled by the

intensity (not color) of a small lamp mounted beside the color-form display. However, using colored backgrounds and horizontal and vertical lines, Johnson and Cumming (1968) obtained data suggesting concurrent but unequal stimulus control by both line and color after compound stimulus discrimination training similar to that employed by Reynolds.

The present experiment attempted to establish a "conditional" discrimination with the pigeon; *i.e.*, a discrimination in which the appropriateness of responding is defined by two or more features of the environment (Lashley, 1938; Cumming and Berryman, 1965). However, by using stimuli like those employed by Reynolds (1961) to establish a conditional discrimination with the pigeon, the present experiment attempted: (a) to show that Reynolds' demonstration of attention was not specific to the kind of stimuli used, and that under different training conditions different results would be obtained, and (b) to provide further information about the stimulus-compounding ability of the pigeon. Assuming that the conditional discrimination is established, a component stimulus test would then permit an evaluation of the assumption that orthogonal components of compound stimuli, necessarily sharing in control of discriminative responding, will be the occasion for comparable rates of responding when pre-

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sented separately. This assumption appears to be the basis for the use of response rates to component stimuli as an index of stimulus control by elements comprising a compound stimulus.

Subjects were exposed to four different color-form stimuli, with the basis for discriminative responding residing with specific combinations of color and form. The four stimuli were produced by combining two forms (triangle and circle) and two colors (red and green) into all possible color-form pairs. The assignment of compound stimuli to be correlated with a reinforcing stimulus was done in such a manner that no single form or color was consistently related to reinforcement. To illustrate, for a given subject triangle-red and circle-green might constitute the two compound stimuli associated with reinforcement, while triangle-green and circle-red constituted the two nonreinforced displays. Thus, discrimination between these stimulus compounds requires differential responding to combinations of stimulus elements, rather than to single elements.

METHOD

Subjects

Four experimentally naive, adult male White King pigeons were maintained on a restricted feeding schedule at approximately 80% of free-feeding body weight. One of them, number 166, died at the start of the second stage of the experiment.

Apparatus

The experimental chamber measured 13-in. long by 12-in. deep by 11-in. high, and was contained within a modified picnic ice chest. A Lehigh Valley Electronics pigeon key (LVE 1348) and grain feeder (LVE 1347) were mounted behind a $\frac{7}{8}$ -in. diameter circular aperture, and a 2- by 2.25-in. rectangular opening, respectively, in an aluminum stimulus panel which served as one wall of the experimental chamber. The response key was located 8.5 in. from the floor and 3 in. left of the midline of the stimulus panel; the aperture for the food magazine was located 3 in. from the floor and centered on the midline. A 7-w lamp behind a 4- by 4-in. piece of $\frac{1}{8}$ -in. white Plexiglas was mounted in the ceiling toward the rear of the chamber and served as an overhead houselight.

An IEE one-plane digital readout permitted transillumination of the response key with either white-line forms, colors, or both simultaneously. The lines of the forms measured exactly $\frac{1}{8}$ -in. wide, and the forms were designed to fit precisely within a $\frac{3}{4}$ -in. diameter circle. Experimental contingencies and recording were automatically controlled by a system of relays, timers, and counters located in an adjacent room.

Procedure

Following magazine training, subjects' pecks on the response key were shaped and each of 50 responses produced 3-sec access to the grain feeder. For each of the next 26 sessions, a discrete-trial discrimination training regimen was in effect. Four compound (color-form) stimulus displays, triangle-red, triangle-green, circle-red, and circle-green, were used throughout training. For each subject, each response in the presence of two of these displays (the S^D displays) produced grain reinforcement; in the presence of the other two (the S^A displays), responding was never reinforced. For Subjects 165 and 168, the S^D displays were triangle-green and circle-red, while S^A displays were triangle-red and circle-green. These stimulus-reinforcement conditions were reversed for Subjects 166 and 167.

During discrete-trial training a session consisted of 15 presentations of each stimulus display in quasi-random order. The length of each presentation was 20 sec for the first eight training sessions, 30 sec for the next two, and 1 min for the remainder of discrete trial training. If a response did not occur during presentation of an S^D , the houselight and stimulus display were turned off for 10 sec (a timeout) and the trial was repeated until a response occurred. A response during an S^D period produced reinforcement (3-sec access to mixed grain), terminated the trial, and initiated the 10-sec timeout which separated each trial. A response during presentation of either S^A initiated a trial-prolonging contingency which delayed termination of the particular trial during which the response occurred. During discrete-trial training, the trial-prolonging contingency was equal to the scheduled trial duration; thus, an S^A trial terminated only when a subject refrained from responding for the entire trial duration.

From the twenty-seventh session through the forty-first, 1-min S^D and S^A presentations alternated randomly, and reinforcement was programmed on a variable-interval (VI) 30-sec schedule. A 10-sec trial-prolonging contingency was in effect during S^A periods to ensure that each S^A presentation ended with a sustained period of nonresponding. Throughout VI training, each stimulus display was presented 14 times during each daily session. Starting with the forty-second session, the individual stimulus exposures were lengthened to 2 min, and reinforcement was arranged on a VI 1-min schedule. Beginning with Session 58, the trial-prolonging contingency was lengthened to 1 min.

To evaluate the possibility that discriminative responding was based upon brightness differences in the four displays, variation in the brightness of each individual display was provided from Session 70 to Session 92. In each of these sessions, the voltage across the GE 1820 readout bulbs was reduced for half the presentations of each display by switching a resistor in series with the bulbs. Thus, each compound stimulus appeared at two levels of brightness in each session, and the order of presentation of the normal and reduced brightness levels varied quasi-randomly. The normal operating voltage across the bulbs was 27 v. For Sessions 70 to 85 the reduced voltage across the bulbs was 16 v (Brightness 3), for Sessions 86 to 87 it was 19 v (Brightness 2), and for Sessions 88 to 92 the reduced voltage was 22.5 v (Brightness 1). To the experimenters the colors and forms were all clearly visible across the three brightness levels, and differences between levels were easily differentiated.

During Session 93, the four component stimuli were presented separately for randomly alternating 1-min periods. Thus, each color uniformly lighted the response key, and each form appeared against an otherwise darkened background. Each component stimulus was presented 12 times during the session, with half of these presentations at the original training brightness and the other half at a reduced brightness level (Brightness 2). The grain hopper was inoperative throughout this session.

RESULTS

As shown in Fig. 1, all subjects acquired the conditional discrimination under the discrete

trial contingencies. During initial training sessions, responding to the S^A compound stimuli resulted in grossly different exposure times to the S^D and S^A pairs, thereby providing an opportunity for substantially different numbers of correct and incorrect responses. Because of the contingencies, no more than 15 responses could occur to either S^D during a given session, but there was no restriction on the number of S^A responses which could occur. Even after the discrimination was well-formed, different exposure times to the S^D and S^A stimuli resulted; an S^D trial was terminated with the first response to occur, while S^A presentations were terminated only by waiting out the trial length. In spite of this increased opportunity for errors, it may be seen that during the last few sessions of discrete trial training there were generally fewer error responses to each of the S^A stimuli than correct responses to either S^D . In passing, it may be of interest to point out that casual observation revealed gross response latency differences to the two pair of stimuli developed very early in training, and response latencies would therefore have provided a more sensitive index of discrimination.

The transition to intermittent reinforcement and fixed duration of S^D presentations is shown in Fig. 2. In examining these data it should be noted that the S^A contingencies did not change from those employed at the end of discrete trial training, except that the trial-prolonging contingency was shortened to 10 sec. Regardless, for Subjects 165 and 168 there is a marked increase in the number of S^A responses early in intermittent reinforcement training.

Although there were consistent intrasession differences in the number of responses to the S^D and S^A stimuli for all subjects after the first few sessions, the performance of Subject 165 suggested that its discriminative responding could be resulting from stimulus effects of reinforcement during the S^D periods; *i.e.*, responding was typically at a very low rate until grain was presented, and subsequent responding during that stimulus period was at a very high rate. This appeared to be a case of discrimination based upon the correlation between antecedent reinforcement and the probability of subsequent reinforcement during a single stimulus presentation (Jenkins, 1965). In a further attempt to force the dis-

Fig. 1. Number of responses to each of the nonreinforced color-form combination stimuli over successive sessions of discrete-trial conditional discrimination training. Of the four specific combination stimuli, triangle-red (ΔR), triangle-green (ΔG), circle-red (OR), and circle-green (OG), the specific pair correlated with the nonreinforced condition is indicated for each subject. Also, the maximum number of responses which could occur to the combination displays correlated with reinforcement (*i.e.*, the S^D displays) is indicated by the dashed line.

crimination by lowering response rates to the S^A stimuli, the 10-sec trial-prolonging contingency in effect during S^A periods was increased to 1 min. As Fig. 2 shows, the initial result was a marked increase in S^A responding for Subjects 165 and 166, but no substantial change in the number of errors for Subject 168. As shown in the figure, this disruption in performance was temporary, and the number of errors in subsequent sessions closely approximated the levels before the change-over delay (COD) was increased.

Figure 3 shows that the initial effect of reducing the brightness of the displays was a temporary disruption in discriminative responding for all subjects, with the discrimination recovering within a few sessions. Sixteen sessions later, when the brightness level

was again changed, no marked disruptions occurred for any subject. Nor was there a disruption two sessions later when a third brightness change was imposed. By the end of the twenty-three sessions employing two brightness levels of each display, all subjects showed clear and consistent differential responding to the two pairs of compound stimuli despite varied intensities.

Results of the component stimulus test are shown in Fig. 4, where rate of responding to each color and form at the two levels of brightness is shown for each subject. In each case, gross differences in response rate to the four stimuli occurred for each subject, with responding to the colors at a uniformly low level while in general, considerable responding occurred to the forms.

Fig. 2. Maintenance of the conditional discrimination under conditions of intermittent reinforcement of responding to the S^D displays.

DISCUSSION

The fact that differential responding developed to the color-form displays is not unequivocal evidence of stimulus control by color and form. Conceivably, slight differences in intensity of the four displays could also provide a basis for discriminative responding. However, although a major disruption in discrimination accompanied the initial sessions employing two levels of display intensity, the relatively rapid recovery of high levels of discriminative responding, and the failure to obtain disruptions after subsequent intensity changes, indicate that differential responding was not under the control of absolute inten-

Fig. 3. Responding to the compound stimuli during sessions in which each display appeared at two levels of brightness.

sity values of the compound stimuli. Also, the fact that each display appeared at several intensities without appreciably changing dis-

Fig. 4. Mean rate of responding to red (R), triangle (Δ), circle (O), and green (G), the separate components of the compound displays. During this test, each component stimulus was presented at the normal level and a reduced (Brightness 2) level.

criminative responding appears to negate the possibility that stimulus control developed on a relative intensity basis (*e.g.*, "respond to the brightest or dimmest display"). Thus, with intensity differences in the displays ruled out as a basis for the obtained performance, the present results appear to demonstrate the formation of a conditional discrimination in the pigeon based upon combinations of color and form.

Boneau and Honig (1964) reported establishing a conditional discrimination with the pigeon based upon presence or absence of a vertical line and red or green colored backgrounds. Such a demonstration coincides with

pigeon experiments on selective attention, which have also employed lines and colors as compound stimuli. For example, both Eckerman (1967) and Johnson and Cumming (1968) obtained what appears to be concurrent (but unequal) stimulus control by lines and colors in a component stimulus test. However, in the experiment by Reynolds (1961) described earlier, responding to a color-form display appeared to be under the exclusive control of either the color or form component of the combination display. The present results show that under different training conditions, responding of the pigeon may come under the control of both form and color, and that the all-or-none nature of the attentional phenomena reported by Reynolds (1961) was therefore not specific to the kind of stimuli he employed.

Stimulus control by components of a complex display is frequently assessed with a component stimulus test like that which concluded the present experiment (for example, Reynolds, 1961; Eckerman, 1967; Johnson and Cumming, 1968). In such tests, differences in the rate of responding to component stimuli typically serve as the basis for assigning stimulus control to one or more of the elements. Implicit in the use of this procedure in studies of attention is the assumption that equal rates of test responding reflect equal stimulus control, and different rates reflect differential control, by the elements when they appear as a compound stimulus. The present results of the component stimulus test question the general validity of this assumption. Since conditional discrimination training required the development of dual control by both form and color, similar rates of responding to all component stimuli might have been expected during testing. However, during testing, the presentation of either form component was the occasion for considerably more responding than occurred to either colored stimulus. Clearly, in the present case, it would be difficult to argue that these findings reflect unequal stimulus control by form and color which operated during conditional discrimination training. Rather, these data suggest that differences in response rates to separate orthogonal components of compound stimuli may at times arise from conditions other than stimulus control differences among elements comprising the compound stimulus.

REFERENCES

- Boneau, C. A. and Honig, W. K. Opposed generalization gradients based upon conditional discrimination training. *Journal of Experimental Psychology*, 1964, **68**, 89-93.
- 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.
- Eckerman, D. A. Stimulus control by part of a complex S^A. *Psychonomic Science*, 1967, **7**, 299-300.
- Jenkins, H. M. Measurement of stimulus control during discriminative operant conditioning. *Psychological Bulletin*, 1965, **64**, 124-150.
- Johnson, D. F. and Cumming, W. W. Some determiners of attention. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 157-166.
- Lashley, K. S. Conditional reactions in the rat. *Journal of Psychology*, 1938, **6**, 311-324.
- Mackintosh, N. J. Selective attention in animal discrimination learning. *Psychological Bulletin*, 1965, **64**, 124-150.
- Reynolds, G. S. Attention in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 203-208.

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