EFFECTS OF RESPONSE-PRODUCED STIMULI UPON CONDITIONAL DISCRIMINATION PERFORMANCE¹

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In zero-delay matching procedures the performance of three groups of pigeons was examined when exteroceptive stimuli, response-produced stimuli associated with the completion of either of two fixed ratios, or a compound of exteroceptive and response-produced stimuli were available as samples. Exteroceptive samples were found to control a higher level of matching accuracy than response-produced samples, while compound samples controlled a higher level of accuracy than did exteroceptive samples alone. When all subjects were placed on a transfer procedure, during which the previously used red and green samples were replaced by horizontal and vertical lines, the availability of sample-specific fixed-ratios facilitated acquisition of the task.

In discrete trial conditional discrimination procedures, sample stimuli "instruct" the subject as to which of several alternative stimuli is correct (Cumming and Berryman, 1965). A series of studies have suggested that the instructional control exerted by sample stimuli is mediated by sample-specific behavior (*e.g.*, Berryman, Cumming, Cohen, and Johnson, 1965; Cohen, 1969; Cumming, Berryman, and Cohen, 1965; Eckerman, 1970). This hypothesis asserts that, in the accurately performing subject, each sample is correlated with the emission of "observing" behavior. The response-produced stimuli associated with each of the sample-specific observing behaviors serve to code the respective samples. The stimulus consequences of each response code, in turn, control the choice of only one of the several available comparison stimuli. Thus, samples control comparison choice only to the extent that they set the occasion for the emission of coding behavior.

Although the studies of Berryman *et al.* (1965), Cohen (1969), and Cumming *et al.* (1965) presented evidence consistent with the coding hypothesis, they did not provide direct evidence, since the existence of coding behavior was inferred rather than observed. Eckerman (1970), however, attempted to examine the hypothesis by providing the subjects with a source of sample-specific behavior that could serve the coding function. In that study, pigeons were required to respond to one location on a response strip in the presence of one sample, and to a second location in the presence of a second sample, so as to produce the comparison stimuli. In one of a series of experiments it was found that, after the two samples were replaced by white light, subjects continued to respond at above chance accuracy on the basis of stimuli associated with response location.

Although Eckerman demonstrated that location of responses had acquired control over comparison choice, it is not clear that coding behavior had therefore been observed. It may be that, in addition to the response-produced stimuli associated with topographically distinct responses, the location of those responses also represent a source of exteroceptive stimuli that could function as samples. That is, the exteroceptive stimulus "left" (right) rather than the behavioral stimulus "left response" (right response) may have been exercising instructional control. Thus, since the removal of sample colors may not have eliminated all sources of exteroceptive stimuli correlated with correct comparisons, there seems to be no

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way to determine whether comparison choice was under the control of exteroceptive stimuli, response-produced stimuli, or a compound of the two.

Because of the apparent confounding of exteroceptive and response-produced stimuli in situations where response location requirements are imposed, it seems important to examine the effects upon matching performances of other sources of response-produced stimuli. One such alternative source of response-produced stimuli is suggested by a series of fixed-ratio (FR) discrimination studies (Pliskoff and Goldiamond, 1966; Rilling, 1967, 1968; Rilling and McDiarmid, 1965). These procedures represent spatial conditional discrimination tasks in that the stimuli correlated with the completion of either a short or a long ratio instruct subjects as to whether a left- or a right-side key response is correct.

In the present study, the completion of either of two FRs was made available as a source of response-produced stimuli in zero-delay non-spatial matching procedures. Experimental conditions consisted of three groups of pigeons for which the samples were a compound of relevant exteroceptive and response-produced components, relevant exteroceptive and irrelevant response-produced components, or relevant response-produced and irrelevant exteroceptive components. Following acquisition, a second assessment of the effects of response-produced stimuli was made by placing all subjects on a transfer task in which samples were changed from colors to line orientations, while response-produced stimuli and comparisons remained unchanged.

METHOD

Subjects

Nine experimentally naive White Carneaux pigeons were maintained at $80 \pm 5\%$ of their free-feeding weight. Between sessions the subjects were individually housed in cages where water and grit were always available.

Apparatus

A cube-shaped conditioning chamber with 33-cm sides, containing a three-key stimulus panel, was enclosed in a sound attenuating chamber similar to that described by Weiss (1970). The 2.5-cm diameter response keys, mounted symmetrically about the vertical mid-

line, were 6.4 cm apart, center-to-center, and 24 cm above the floor. Industrial Electronics Engineers' display units transilluminated each key with appropriate stimuli. A rectangular aperture centered below the response keys permitted access to mixed grain and was illuminated by white light during reinforcement. General chamber illumination was provided by two 6-W bulbs mounted behind rectangular Plexiglas covers 2.5 cm from the top and 5 cm on either side of the vertical midline of the wall opposite the stimulus panel. Experimental contingencies were scheduled by BRS Foringer DigiBits, a tape reader, and electromechanical relays. Data were recorded by electromechanical counters.

Procedure

Preliminary training. Following key-peck shaping to a white center key, the subjects received one session during which each of 50 responses were reinforced by 3-sec access to food. During the next session, a response on the white center key turned this key off and transilluminated one of the two side keys with white light. The location of the transilluminated side key was mixed across trials, with each side presented 25 times. A response on the transilluminated side key produced reinforcement, while responses on the dark side and center key had no scheduled consequences. The following session required four responses on the center key before side key onset. At this point, reinforcement was changed from 3- to 2-sec access to grain. During the next 19 sessions, a mixed sequence of 8, 12, or 16 center-key responses were required before side key onset, with each response requirement occurring 17 times per session. Three subjects were then randomly assigned to each of three conditional discrimination acquisition groups.

Acquisition training. All trials began with the presentation of white light on the center, or sample key. The first sample response changed the color to either red or green. For Group 1 (Birds 10, 14, and 18) on sample-red trials, seven additional responses were required before the sample key extinguished and the two side, or comparison, keys were transilluminated with red on one side and green on the other. On sample-green trials, 15 additional responses were required. The two response requirements will be referred to as FR 8 and FR 16, respectively. A response to the comparison

that matched the color of the sample was reinforced, while errors produced a 2-sec timeout. No intertrial interval preceded the next sample presentation. During each 72-trial session, red and green samples were presented equally often in a mixed sequence. Also mixed was the location (right or left) of red and green comparison stimuli. Group 2 (Birds 19, 21, and 22) differed from Group 1 only in that the sample-key response requirement (FR 8 and FR 16) was mixed across trials independently of the sample colors. For Group 3 (Birds 7, 8, and 16), reinforcement was contingent upon the choice of a red comparison following FR 8 and a green comparison following FR 16, with the sample-key colors mixed across trials without regard to the relevant FR schedules. Acquisition training terminated after 60 sessions.

Transfer training. On the day following the end of acquisition training, all subjects were placed on the transfer task. For all groups, on trials during which a red sample had previously been presented, a horizontal black line on a white background now appeared. Similarly, on former green sample trials, a vertical black line on a white background was presented. Thus, for Groups 1 and 2 a red comparison was correct on sample-horizontal trials and a green comparison was correct on sample-vertical trials. For Group 3, the two line orientation stimuli were irrelevant to the matching task. Transfer training terminated after 35 sessions.

RESULTS

Acquisition Training

As shown in Figure 1, all subjects started matching at or near chance (50%) accuracy, with no systematic differences between groups in terms of the number of chance sessions preceding the point at which above chance matching started. Given that above chance matching had started, Group 1 subjects, for which the FRs were sample-specific, approached an asymptotic level of accuracy more rapidly than did Group 2 subjects, for which the FRs were mixed. For example, following the first session of above 60% accuracy, each Group 1 subject required two sessions between 60% and 90% before reaching the first session of above 90%, while Group 2 Subjects 19, 21, and 22 required 3, 5, and 12 sessions, respectively.

The mean matching accuracy across the last

Fig. 1. Acquisition accuracy as a function of sessions for individual subjects in each treatment group.

five sessions for Group 1 Subjects 10, 14, and 18 was 99.4%, 100%, and 99.7% respectively, while the accuracy for Group 2 Subjects 19, 21, and 22 was 97.4%, 99.2%, and 93.9%, respectively. These results indicate that the asymptotic accuracy of Group 1 was significantly higher than for Group 2 ($p < 0.05$, Mann-Whitney U test). As compared with Groups 1 and 2, the rate of acquisition of Group 3 subjects, for which completion of FR 8 and FR 16 served as the only source of sample stimuli, was slow and irregular. From this group, only Subject 16 appears to have reached an asymptotic level of matching accuracy (90.8%) during the last five acquisition sessions.

During acquisition training, any given level of non-perfect matching accuracy could be achieved in a number of ways; that is, errors could be randomly distributed or they could, in some way, be systematically related to the comparison stimuli. Such systematic choice be-

haviors, or preferences, may consist of responding predominantly either to comparisons of one color regardless of side, or to right or left comparisons regardless of color. In Figure 2, position and color preferences are shown as a function of sessions for individual subjects, with chance preference set at 0%. A break in preference functions after Session 1 indicates that the omitted sessions differed from Session 1 by less than 5%. Where preference functions were terminated before Session 60, the index for the excluded sessions does not exceed 20%.

As shown, Group 1 and Group 2 subjects initially exhibited a marked color preference. For each subject, this preference was for red comparisons. Color preference was maintained until the start of above chance matching, at which point the red preference declined sharply along with the temporary development of lesser degrees of position preference. For all

Group 3 subjects, the start of acquisition was accompanied by a change from color to a position preference, which declined as accuracy increased.

In addition to accuracy and preference data, a third performance index was the mean lapsed time between the first and last response in each of the two FRs emitted on the sample key, or FR latency. Figure 3 shows that the change from preliminary training to matching lengthened latencies of all FRs emitted on a green key (*i.e.*, the same color as the non-preferred comparison). When the FRs were emitted on a red sample, no systematic changes were found in latencies from preliminary training to matching. For Groups 1 and 2, the FR latencies on the green samples decreased as preference for red comparisons decreased. Group 3 subjects exhibited marked latency differences as a function of sample color only during the first several acquisition sessions.

Fig. 2. Color and position preference as a function of sessions for individual subjects. See text for additional details.

Fig. 3. Mean lapsed time between the first and last response in fixed ratios per session for individual subjects. Unconnected data points to the extreme left of each panel represents the mean time-to-complete FR 8 (circle), FR 12 (square), and FR 16 (triangle) across the last five pretraining sessions.

Transfer Training

Figure 4 presents the accuracy per session for individual subjects during transfer training. As shown, the change from red and green sample stimuli to horizontal and vertical line orientations resulted in an immediate decrement in accuracy. All Group 1 subjects rapidly regained asymptotic accuracy, having exceeded 90% by the tenth session, while Group 2 Subjects 19 and 21 exceeded 90% in Sessions 33 and 19, respectively.

For Group 3 subjects, the change from irrelevant sample color to irrelevant sample line orientations also disrupted accuracy, even though the relevant FR schedules were not changed. Subject 16, which had attained a relatively high level of accuracy during the initial

acquisition task, rapidly regained this accuracy level. In contrast, Subjects 7 and 8, which had not attained asymptotic levels of accuracy during acquisition, increased in accuracy at a slow and irregular rate.

Initial exposure to the transfer procedure also resulted in a return to pronounced choice preferences, but these typically were dissimilar to those found during acquisition training. Subjects 10, 14, 19, and 22 exhibited green preferences, and Subjects 8 and 21 preferred right comparisons. The remaining subjects (7, 16, and 18) were not readily classifiable as to one predominant type of preference. Fixed-ratio latencies also increased in Sessions 1 or 2 of the transfer procedure, but by the third session, all FR latencies were at or lower than that found during the final acquisition session.

Fig. 4. Transfer accuracy as a function of sessions for individual subjects in each treatment group.

DISCUSSION

The present results demonstrated that the stimuli correlated with the completion of ei-

ther of two FRs may come to exert instructional control in conditional discrimination tasks. Control over choice by prior behavior has also been found in FR discrimination studies in which pigeons reported which of two FRs had just been completed by emitting a response to either a right or a left side key (*e.g.*, Pliskoff and Goldiamond, 1966; Rilling and McDiarmid, 1965). The present Group 3 results, however, extend these findings to a situation in which a discrimination must be based on the stimuli presented on the comparison keys regardless of side (non-spatial choice), rather than upon comparison key location (spatial choice). Such non-spatial FR discrimination tasks have been found to control lower accuracy when compared with spatial FR discrimination procedures (Lydersen, Perkins, and Chairez, 1973).

Control over choice by response-produced stimuli apparently has also occurred in delayed matching-to-sample tasks (Blough, 1959; Perkins, 1970; Perkins, Lydersen, and Beaman, 1973). Blough (1959), for example, reported that pigeons performed with higher accuracy when sample-specific delay behaviors were emitted than when differential delay behaviors were not observed.

The present data also indicate that, once above chance performance occurred, asymptotic matching accuracy was reached more rapidly when sample-specific FRs were scheduled (Group 1) than when the FRs were mixed across samples (Group 2). That the FRs functioned as effective samples for Group 1 subjects is further suggested by the results of the transfer task, which Group 1 subjects clearly acquired more rapidly than did subjects in Group 2. These results are consistent with those reported in a series of experiments by Eckerman (1970) in which presentation of comparison stimuli was contingent upon the emission of a response to a sample-specific location on a horizontal response strip. In that study, it was found that the greater the distance between the two required sample-specific response locations, the more rapid the acquisition and the higher the asymptotic level of matching accuracy. Further, when the two sample colors were subsequently replaced by white light, subjects continued to respond at above chance accuracy with only response location available as a source of instructional control. The accuracy level controlled by re-

sponse location alone was, however, somewhat lower than when sample colors were correlated with response location.

It would appear that sample-specific responding facilitates conditional discrimination performances in situations where the stimuli produced by sample-specific behaviors are sufficient to control above chance accuracy in the absence of correlated exteroceptive samples. Because behavior has been shown to exert stimulus control in much the same way as do exteroceptive stimuli, it would seem appropriate to consider exteroceptive and response-produced stimuli as separate sample components in situations where both are correlated with correct comparisons. Both the present results and those of Eckerman (1970) suggest that sample stimuli consisting of a compound of exteroceptive and response-produced components were more effective than when either component was available as the only source of instructional control.

This analysis of the data differs from the response coding interpretation. The coding hypothesis presently under consideration asserts that, in the accurately performing subject, behaviors emitted in the presence of sample stimuli have become specific to each sample. It is further asserted that stimuli produced by sample-specific responding exercise control over comparison choice, while exteroceptive samples exercise control over the emission of coding behavior. In terms of the present data, when FR 8 was scheduled only in the presence of red samples and FR 16 only in the presence of green samples (Group 1), the response-produced stimuli associated with the completion of each FR were available as codes. If the FRs indeed were serving a coding function then the matching acquisition of Group 1 subjects should be similar to that of Group 3 subjects, for which FR 8 and FR 16 were the only sources of sample stimuli. This similarity is required because, according to the coding hypothesis, accuracy for both groups should be a direct function of response-produced stimuli. The considerable difference between Group 1 and Group 3 acquisition appears, therefore, to be inconsistent with the coding hypothesis.

This conclusion must remain speculative, however, since for Group 1 subjects the two FRs were scheduled in the presence of different discriminative stimuli (*i.e.*, multiple FR 8 FR 16), while for Group 3 subjects the two

FRs were presented according to a mixed schedule. Thus, to the extent that the multiple FR 8 FR 16 performance differed from the mixed FR 8 FR 16 performance, the response-produced stimuli correlated with the respective schedules might also be expected to differ. It may be, therefore, that a direct comparison of the performances of Groups 1 and 3 in terms of the coding hypothesis is not appropriate.

The results of the present study also indicate that acquisition typically follows a period of chance matching accuracy that is characterized by the systematic choice of comparisons on the basis of color or location (*e.g.*, Berryman *et al.*, 1965; Cumming and Berryman, 1965; Cumming *et al.*, 1965). Although stereotyped preacquisition performances may influence both the rate of acquisition and asymptotic accuracy levels, there exists no clear explanation as to why this occurs (*e.g.*, Eckerman, 1970). The present FR latency results suggest, however, that once comparison preference has developed, the non-preferred comparisons possess what may be conceptualized as functionally aversive properties. For example, during Group 2 chance accuracy sessions, the time-to-complete an FR on a sample key presenting the same color as the non-preferred comparison was longer than when the sample was the same color as the preferred comparison. If the non-preferred color is considered as a discriminative stimulus indicating the non-availability of reinforcement, and as such represents a functionally aversive stimulus, it seems possible to consider the longer FR time-to-complete as an index of aversiveness associated with the non-preferred color.

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