ACQUISITION AND MAINTENANCE OF MATCHING WITHOUT A REQUIRED OBSERVING RESPONSE¹

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Two experiments demonstrated that matching-to-sample performance was improved when an explicit observing response was required to the sample stimulus. The first experiment demonstrated that fewer training sessions were required to establish matching with than matching without such a response. The second experiment demonstrated the dependence of established matching accuracy upon this observing response and the development in two of three subjects of a new overt observing response even when none was required by the experimenter.

The matching-to-sample procedure is a conditional discrimination procedure in which a standard (ST) or sample stimulus designates which of a number of comparison (CO) stimuli is correct (Cumming and Berryman, 1965). Analyses of behavior under this sort of conditional discrimination procedure have generally presumed the ST stimulus to exercise a logically and temporally different role than the CO stimuli. Skinner (1950) described matching-to-sample as "choosing red after being stimulated by red." Cumming and Berryman (1965) proposed that the ST exercises an "instructional" role controlling the strength of response to each of the CO stimuli. However, an alternative and more parsimonious analysis of matching-to-sample is available, and it seems worthwhile to eliminate this analysis before accepting the other. The terms of this alternative analysis become clearer once the apparatus employed in many matching-to-sample studies is described. Generally, matching-to-sample is studied in the laboratory using relatively few alternative stimuli (e.g., red, green, and blue lights for color matching). Often, a three-stimulus display is used, the center display presenting the ST and the two side displays presenting the COs. Given the few stimuli and the three-key display, it is possible that the entire three-

stimulus display might be acting as a unitary stimulus controlling the strengths of the responses "peck right" and "peck left" for a subject exhibiting high matching-to-sample accuracy. Depending upon the distance separating the three keys, a "unitary stimulus" analysis becomes possible: where keys are very close together, training to match-to-sample might merely be strengthening the response to the "larger" color, i.e., the side-key-center-key area that is of homogeneous color.

Although the unitary-stimulus analyses are more parsimonious than the instructional-stimulus analyses, they would be difficult to maintain if accuracy in matching-to-sample was shown to be dependent upon a separate observing response (Wyckoff, 1954) to the ST. In many matching-to-sample experiments such a separate response to the ST has been required (e.g., Riesen and Nissen, 1942; Ferster, 1960; Cumming and Berryman, 1965). In other experiments (Blough, 1959) the ST has appeared a short time before the COs, a practice which might be expected to maintain a separate ST observing response. The present experiments cast doubt upon the unitary-stimulus analysis by presenting two examples of the dependence of matching-to-sample accuracy upon the strength of an observing response to the ST.

METHOD

Subjects

Six male White Carneaux pigeons were maintained throughout the experiment at 80% of their free-feeding weights. Three

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(Birds 18, 19, and 20) were experimentally naive when the experiment began; Birds 36, 37, and 38 were well trained in the matching-to-sample procedure.

Apparatus

The apparatus was the same as that used in earlier studies (Cumming and Berryman, 1965) and consisted of a triangular cage with three pigeon keys and a grain magazine on one wall. Each key could be separately transilluminated by a red, green, or blue Christmas tree bulb. A mixture of 50% kaffir corn, 40% vetch, and 10% hemp seed was dispensed from the magazine.

Procedure I

The three experimentally naive birds were trained to peck each of the three keys when the keys were transilluminated with red, green, or blue Christmas tree lights. Approximately equal numbers of reinforcements were obtained for pecks on the right, center, and left keys and in the presence of each of the three hues. Birds were then placed on the matching-to-sample procedure. This procedure was very similar to that employed in many experiments in our laboratory (*vide* Cumming and Berryman, 1965). Birds were given daily (six days per week) 140-trial sessions whenever their weights did not differ from the 80% free-feeding value by more than ± 15 g. On each trial, the ST hue was presented on the center key. The two side keys presented CO stimuli. One of these stimuli matched the ST; the other was either of the two remaining colors. The stimulus order was arranged to equate the number of times the matching CO appeared on the left and right keys, the number of times a particular hue appeared as ST, and the number of times a hue appeared as the incorrect CO. A trial commenced with simultaneous onset of both ST and CO lights. Responses to the ST key were without effect, but the first response to one of the CO keys terminated the trial. If the response had been to the matching CO, reinforcement (3-sec access to grain) was given; if to the nonmatching CO, blackout (3-sec total darkness) was given. After reinforcement or blackout, a 25-sec intertrial interval (house-lights on, keys dark) preceded onset of the next trial in the sequence. No correction procedure was used, and thus the stimulus se-

quence was not determined by the bird's behavior. Birds were given 60 training sessions with this procedure.

Procedure II

The three birds used in Procedure II had been given previous experience in conditional discrimination problems. Their original training had involved an "insoluble" problem in which the same three colors (red, green, and blue) appeared behind the same configuration of three keys (left, center, and right as described above under Procedure I). A trial in this original training had commenced with onset of the center (ST) key light (red, green, or blue). A peck on this key illuminated the side (CO) keys and left the ST still illuminated. The color of one CO matched the ST. The other CO was either of the other colors. A peck on either CO extinguished all keys, produced either reinforcement (3-sec access to grain) or blackout (3-sec total darkness) and a 25-sec intertrial interval (house-light on, keys dark). In this "insoluble" problem, reinforcement was randomly assigned to matching or nonmatching CO on a particular trial with an equal number of reinforcements in a session assigned to right and left keys. Subsequent to this original training, these birds were given training in matching-to-sample and oddity-from-sample according to procedures described by Cumming and Berryman (1965). Extensive training in matching-to-sample immediately preceded Procedure II. During Procedure II, the following sequence of changes was made in the basic matching-to-sample procedure. (1) *No ST response (NSTR)*. For 20 sessions the requirement of a peck to the ST key was lifted. A trial commenced with onset of all three keys simultaneously, and a peck to the center key had no effect. This stage thus used a procedure identical to that of Procedure I. (2) *DRO 10-sec*. The next 30 sessions employed a procedure in which center-key pecks during the intertrial interval delayed the onset of the trial. The minimum intertrial interval was still 25 sec but the trial was not initiated until there had been at least 10 sec of no ST-key responding (DRO 10-sec). (3) *STR*. A recovery stage was given in the next eight sessions. Again a trial commenced with onset of ST only, and a response to it was required in order to illuminate the COs. The

DRO 10-sec was discontinued. (4) *Cancel (C)*. For three sessions, any center-key response during a trial cancelled the trial. All three stimuli were presented simultaneously. Pecking on the ST key during the intertrial interval produced no delay as it had in the DRO procedure; but pecking the ST key once the stimuli were illuminated cancelled the trial: the lights were extinguished, a 25-sec intertrial interval was programmed, and the same stimulus configuration was presented on the next trial. (5) *STR*. Two recovery sessions with procedure identical to that in (3) above concluded the experiment. Special note should be made of an event which took place midway through the NSTR plus DRO phase (phase 2 above). After Session 38 for S36, Session 39 for S37, and Session 34 for S38, the experimental chamber was completely cleaned and refurbished. This procedure involved washing all parts of the chamber and repainting areas which had been scraped or spotted. Some of these scraped and spotted areas surrounded the response keys. The cage cleaning did not greatly alter the appearance of the stimuli themselves, but it did serve to alter the background against which they appeared.

RESULTS AND DISCUSSION

Procedure I

Accuracy of matching-to-sample is plotted as a function of sessions in Fig. 1 for birds given Procedure I training (Birds 18, 19, and 20) and for birds from a previous experiment (Cumming and Berryman, 1965, p. 292).

The first and last 10 trials of each 140-trial session were deleted from the analysis. For both sets of birds the data shown thus represent the number of correct matches out of 120 trials. Chance accuracy was 60 correct in both experiments. Procedure I differed from the procedure of the previous experiment in only two ways: (1) the ST and CO stimuli were presented simultaneously in Procedure I, whereas the ST onset preceded CO onset in the prior experiment, and, (2) a peck on the ST key was required in the prior experiment in order to illuminate the COs. No such peck was required in Procedure I. Acquisition of matching accuracy in the previous experiment required between four and six sessions. Acquisition functions such as those presented in the right-hand panel of Fig. 1 have been obtained in our laboratory for a great many experiments involving color

Fig. 1. Acquisition of matching-to-sample accuracy with and without a required response to the standard stimulus. Functions are presented in open circles for Birds 18 (solid function), 19 (dashed), and 20 (dashed and dotted) and in filled circles for Birds 72 (solid function), 73 (dashed), and 74 (dashed and dotted). These last three functions were obtained in a previous experiment (Cumming and Berryman, 1965).

matching-to-sample training where an observing response is required to the ST color before presenting the CO's color. Acquisition of matching accuracy required over 40 sessions for two birds of Procedure I and over 20 sessions for the remaining bird. No responding was observed on the ST key during ST presentation.

Figure 1 demonstrates the facilitation of matching acquisition when the procedure incorporates a temporal sequencing of ST and COs and/or a requirement for a response to the ST. The facilitation may be a result of either (1) a strong observing response to the ST or (2) an increased likelihood for the development of a mediating response to the ST (Cumming, Berryman, and Cohen, 1965; Berryman, Cumming, Cohen, and Johnson, 1965). The reader is referred to the noted articles for a distinction between observing and mediating responses. These data do not differentiate between these two sources of added control.

Procedure II

The results of Procedure II are presented in Fig. 2. This figure shows accuracy of matching for the three pigeons over the course of the experiment. The ordinate again plots the number of correct matches out of the 120 recorded trials per session. Chance performance was again 60 trials correct.

Since the performance of the three birds differed somewhat in the effect of the experimental manipulations, data are discussed individually for them.

Subject 36. The effect of eliminating the standard response requirement decreased this bird's matching accuracy to approximately 75%. Early in the first 20 days, center-key responding stopped. Thus, introduction of the DRO had no effect. The two low-accuracy sessions during the DRO phase followed a cage cleaning. Recovery of accuracy was good after the standard response requirement was reinstated. The cancel procedure (C) again eliminated center-key pecking and dropped the accuracy to 75%. No consistent description of the bird's behavior as to color or position preference has been found. The stability of the accuracy around 75% suggests, however, that some consistent mode of responding was being exhibited. Analysis of sequential response patterns was impossible on the

collected data. The effect on this bird may be summarized by saying that when the center-key response was weakened, matching accuracy dropped from near 100% to 75% and was maintained there.

Subject 37. This subject was not affected by the mere elimination of the center-key response requirement. It retained a "superstitious" chain of center-key responding during the intertrial interval, and responding extended into the time when all three key-lights were on. Responding on the dark ST key during the intertrial interval has been frequently observed. Presumably the responding is maintained by the adventitious reinforcement of ST presentation at the end of the intertrial interval. Introduction of the DRO weakened this superstitious chain and initially dropped accuracy to chance. On the day of the cage cleaning, however, the DRO contingency was accidentally lifted for this subject. Accuracy rose and the center-key response again appeared. The following day the DRO was reinstated. The superstitious chain of center-key pecks during the intertrial interval again dropped out, but the bird continued to peck at the center key after the three key-lights were lit. The bird did this on every trial, waiting until the three lights came on and then pecking, usually more than once, on the center key. Accuracy remained at a high level until the cancel procedure eliminated this superstitious response chain. The presence of higher matching accuracy when a response to the ST key was strong suggests that all of the maintenance of the intertrial ST responding during the NSTR and NSTR plus DRO stages may not have been adventitious. Under the cancel procedure accuracy again dropped to chance. This bird's chance performance was characterized by a complete position preference. Thus, when the center-key response in the presence of the standard hue was at low strength, matching accuracy dropped to chance levels. When this response to the standard was fortuitously strengthened, it retained strength over long periods without an explicitly programmed contingency.

Subject 38. The elimination of the standard response requirement dropped Subject 38 to about 90% correct. A superstitious chain of pecks during the intertrial interval and extending into the trial was also observed. Introduction of the DRO had the

Fig. 2. Accuracy of matching-to-sample is traced across the six experimental procedures explained in the text. The session labeled A followed a cage cleaning.

expected effect of dropping accuracy by weakening this chain. Even though explicit center-key pecking dropped to zero, observation revealed that the DRO and subsequently the cancel procedure did not eliminate pecking around the center key at the time the standard was turned on. This subject was observed to remain near the center key, pecking above and just short of it during the intertrial interval and usually for a second or two after the three keys were illuminated. The two low days again followed the cage cleaning. The DRO contingency was not accidentally removed for Subject 38 at this time. Again a return to a high level of accuracy was observed when an explicit peck was required; the cancel procedure decreased accuracy to about what it had been under DRO. The results with this subject may be summarized as follows: accuracy on the matching task was retained at 98% when a strong chain of explicit center-key pecks occurred in the presence of the standard stimulus; when no explicit response was required on the center key, a chain of pecking around the center key at the time of its onset was noted and accuracy of between 70 and 95% was observed.

GENERAL DISCUSSION

Two examples have been presented in which a requirement of a response to ST and/or a temporal ordering of ST-CO presentation has led to increased accuracy in matching-to-sample. In Procedure I, this effect was observed in a comparison of acquisition times for birds having and not having an ST observing-response requirement. In Procedure II, this effect was observed as a long-term decrement in performance when no observable pecking response to the ST was at high strength. Five points will be brought up in discussion of these results. (1) The results of both procedures contradict predictions based on a simple unitary-stimulus analysis of the matching performance as outlined in the introduction. The ST stimulus seems to exercise some function which it performs more readily when an ST observing response is required. (2) The recovery of accuracy during Procedure II, when a peck or a peck-like response to the ST was reacquired (S37, 38), is of special interest. These data suggest that an overt response to ST was important in

some way other than merely inserting a temporal delay between ST and COs, for the topography of the response seemed critical. Both observing responses which were reacquired involved pecking activity around the ST key closely following ST onset. The reason for this topographical dependence might be simply that the pigeon does not observe efficiently unless it pecks. Such an analysis would be contradicted by the data of Procedure I, since no key-pecking responding was observed on the ST key and yet the matching performance was eventually acquired. The ST was influencing the performance of these birds, and yet they did not peck at the ST. Another suggestion regarding the dependence of accuracy on the topography of the ST observing response comes from a mediational (or "coding") analysis of conditional discrimination performance (Cumming *et al.*, 1965; Berryman *et al.*, 1965). The coding analysis suggests that birds develop an ST-specific coding response which has stimulus properties much as the ST stimulus itself. Other predictions based on this coding analysis have obtained support elsewhere (Cohen, 1967; Eckerman, 1966). (3) The cancel procedure was terminated after only three sessions since it exactly replicated those sessions of the NSTR and NSTR plus DRO phases where no observed response to the ST stimulus took place. It did not add to the central observation of Procedure II that matching-to-sample accuracy had become dependent upon the ST key-peck response. We suggest that continued exposure to the cancel procedure would promote the development of some non-key-peck observing response to the standard. (4) It might be suggested that a schedule-of-reinforcement effect was acting to amplify the differences obtained in the present Procedure II study. That is, if it is assumed that a decrease in reinforcement frequency tends to decrease matching accuracy, and if the effect of removing the ST observing-response requirement is assumed merely to disrupt initial performance, then the effect of this initial disruption might be to decrease the frequency of reinforcement. This decrease would in turn tend to slow recovery of accuracy. The main assumption of this analysis of Procedure II is that a decrease of reinforcement frequency will act to decrease matching accuracy. Although fixed-ratio schedules with procedures very

similar to that of the present study have been found to decrease overall accuracy, variable-ratio schedules have not (Cumming and Berryman, 1965). Since the obtained reinforcements were not distributed in a fixed pattern across trials, the schedule-of-reinforcement interpretation of Procedure II is suspect. If later evidence supports such an interpretation, however, the number correct and hence the number of reinforcements can be determined from Fig. 2. (5) With the results of Procedure II and those of the earlier studies (Cumming and Berryman, 1965) two cells of a 2×2 contingency table are complete. Acquisition of matching-to-sample performance has been observed when ST and CO stimuli are temporally separated and an ST observing response is required; and acquisition has been observed where ST and CO stimuli are presented simultaneously and no ST observing response is required. Two other procedures are possible: temporal separation without an observing response and an observing response without temporal separation. Results from these other procedures would be of interest. It should be noted, however, that an effective temporal sequencing of ST and CO stimuli might be obtained even when all three stimuli are presented simultaneously. Similarly, an observing response ("orienting reflex") might be conditioned to the ST if ST onset preceded CO onset even though no such observing response was required. Interpretation of the results from the other two possible procedures might thus be complex.

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