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EFFECTS OF A CONDITIONED REINFORCER UPON ACCURACY OF MATCH-TO-SAMPLE BEHAVIOR IN PIGEONS[1]

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Three pigeons were trained to perform a two-key sequential match-to-sample task. During baseline conditions, food reinforcement was contingent upon the first match response to occur following 8-min periods, and orange illumination of both keys preceded the delivery of food by 0.5 sec. The baseline schedule of food reinforcement was in effect throughout the study. In some conditions, a 0.5-sec flash of orange keylight alone was presented contingent upon mismatch responses that followed variable time periods averaging 1 min. Rate of mismatch responses increased and accuracy of matching performances decreased as compared with baseline conditions. The ability of the 0.5-sec orange flash to reinforce mismatch responses was markedly reduced when it no longer immediately preceded the delivery of food.

Accuracy of match-to-sample behavior has been manipulated in several ways: by various schedules of primary reinforcement (Ferster, 1960; Nevin, Cumming, and Berryman, 1963); by periods of timeout from positive reinforcement that followed incorrect responses (Ferster and Appel, 1961; Zimmerman and Baydan, 1963; Zimmerman and Ferster, 1963); by periods of delay introduced between termination of the sample stimulus and presentation of the choice stimuli (Berryman, Cumming, and Nevin, 1963; Blough, 1959); and by requiring or not requiring a specific observing response to the sample stimulus before the choice stimuli were presented (Eckerman, Lanson, and Cumming, 1968).

In three of the above studies (Ferster, 1960; Zimmerman and Ferster, 1963; Ferster and Appel, 1961) each "match" response that did not produce food reinforcement was followed by a brief flash of a stimulus paired with food delivery (food-hopper light). Although the effect of these brief stimuli upon accuracy of match-to-sample behavior was not directly examined, a number of other studies have demonstrated the reinforcing function of brief stimuli paired with food. Findley and Brady (1965), Thomas and Stubbs (1966), Kelleher (1966), and de Lorge (1967) have reported control over rates and patterns of response in second-order schedules. Zimmerman (1963), Zimmerman and Hanford (1966), Randolph and Sewell (1965), and Zimmerman, Hanford, and Brown (1967) have shown the maintenance of behavior by brief stimuli paired with food in procedures with concurrent schedules.

Most research investigating the effects of brief stimuli paired with food has been confined to an investigation of its effects upon the rate and pattern of a simple response (*e.g.*, a key peck). An exception to this was a study by Zimmerman (1967) who showed the maintenance of mismatching behavior in a match-to-sample procedure by magazine stimuli associated with food delivery.

The purpose of the present study was to extend Zimmerman's results by showing the effect of a stimulus paired with food on accuracy of match-to-sample behavior. The match-to-sample procedure used was similar to one previously employed by Cohen (1969) and food reinforcement was presented according to a fixed-interval schedule. A fixed-interval schedule was used because it provided periods of time where behavior was maintained, but

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yet there was no contingent relationship between this behavior and food reinforcement (Ferster, 1960). The schedule of food reinforcement was held constant throughout all conditions of this study, while brief stimuli occasionally paired with food were made contingent upon different response groups (match responses or mismatch responses). The reinforcing effect of these brief stimuli was evaluated by the degree to which they increased rate and percentage of that response group upon which they were contingent.

METHOD

Subjects

Three adult male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights.

Apparatus

A sound-attenuating two-key pigeon chamber was used. The response keys were mounted on one wall of the chamber, 9.25 in. (23.5 cm) above the steel mesh floor. One key was on the vertical median line of the wall with the other key 3.5 in. (9 cm) to the right (center to center). The keys could be transilluminated by 7-w lamps of various colors. General illumination was provided by two 6-w white houselights located 3 in. (7.5 cm) from the floor and 4 in. (10 cm) on either side of the median line. The subjects had periodic access to mixed grain through a 2.3 in. (5.8 cm) diameter hole in the wall below the response keys. When grain was available, the food-hopper area was illuminated by a 7-w white lamp and the houselights were out. In addition, white noise was delivered through a speaker set behind the response wall of the chamber. A feedback relay attached to the back of the wall provided a discrete click with each peck on a functional key. Approximately 15 g of force (0.147 N) were required to operate the response keys.

Scheduling was accomplished with standard electromechanical apparatus and data were collected on impulse counters and a cumulative recorder. A digital computer[2] was used for the data calculations.

[2]The authors extend their appreciation to the faculty and staff of the University of Kansas Computation Center for use of the GE-635 computer for data calculation.

Procedure

Matching behavior was periodically reinforced. At the beginning of each match-to-sample trial both keys were dark. A peck on the left key (sample key) illuminated that key with either a red or a green stimulus. This color was the sample stimulus for that trial. Subsequent pecks on the sample key while the right key was dark had no scheduled consequences. Pecks on the right key (comparison key) had scheduled consequences only when a sample stimulus illuminated the sample key. After the sample stimulus was on, the first peck on the comparison key (right key) illuminated that key with either red or green. Subsequent pecks on the comparison key resulted in a random alternation of red and green illumination on that key (an average of two pecks was required to change the color; the range was one to three pecks). At any time after both keys were illuminated, a peck on the sample key would complete the match-to-sample trial, causing both keys to go dark. If this sample-key peck occurred when both the sample and comparison keys were of the same color (red-red or green-green), a match response was recorded. If this sample-key peck occurred when the keys were illuminated with different colors (red-green or green-red), a mismatch response was recorded. With both keys again dark, a response on the sample key would illuminate it with red or green, thus providing the sample stimulus for the next trial. The sequence of sample stimuli (red or green) presented was random over trials, with the colors having an approximately equal probability of occurrence over a session.

Food reinforcement was 6-sec access to grain and was contingent upon the first match response (red-red or green-green) to occur after 8 min had elapsed since the last food reinforcement or from the beginning of the session (fixed-interval 8-min schedule of food reinforcement). The subjects had been exposed for approximatly six months to this basic fixed-interval 8-min schedule for match responses (FI 8-min) before the present study. During this time various manipulations concerning other problems were made. Throughout this period, each mismatch response was followed by a 20-sec timeout period during which the chamber was completely darkened and responses on all keys had no scheduled

Table 1

Outline of Experimental Conditions of the Match-to-Sample Study*

Conditions	Brief Stimulus Schedule	Response Required on Brief Stimulus Schedule	Stimulus Paired With FI Food	Number of Sessions Subjects 15	11	90
Baseline (base)	———	———	Orange	9	9	9
Match (mat)	VI 1-min	Match	Orange	9	9	9
Mismatch (mis)	VI 1-min	Mismatch	Orange	21	21	21
Baseline	———	———	Orange	22	22	26
Match	VI 1-min	Match	Orange	15	15	11
Mismatch	VI 1-min	Mismatch	Orange	15	15	15
Baseline	———	———	Orange	16	17	17
Mismatch (unpaired)	VI 1-min	Mismatch	Dark Key	37	16	20
Baseline (unpaired)	———	———	Dark Key	8	19	17
Mismatch (unpaired)	VI 1-min	Mismatch	Dark Key	18	13	8
Baseline	———	———	Orange	7	12	10
Mismatch	VI 1-min	Mismatch	Orange	46	25	34
Baseline	———	———	Orange	33	34	23
Mismatch	VI 1-min	Mismatch	Orange	28	18	36
Baseline	———	———	Orange	24	26	23
Mismatch	VI 1-min	Mismatch	Orange	30	8	10
Baseline	———	———	Orange	—	42	23
Mismatch	VI 1-min	Mismatch	Orange	—	12	20
Baseline	———	———	Orange	14	38	33
Mismatch (food, hopper flash, or mag. cycle)	VI 1-min	Mismatch	Orange	22	24	11
Baseline	———	———	Orange	13	8	7

*Under all conditions of the study food reinforcement was contingent upon a fixed interval 8-min schedule for match responses.

consequences. The timeout contingency was removed before the start of the present study.

The FI 8-min schedule of reinforcement for match responses provided the baseline performance from which the effects of the other stimulus conditions were evaluated. This schedule of food reinforcement for match responses remained constant under all conditions of the study. Each session terminated after 18 food reinforcements had been delivered on the FI 8-min schedule. In various portions of the study, a concurrent variable-interval 1-min schedule (VI 1-min) of brief stimulus presentation was also employed. The sequence of conditions is presented in Table 1 for each subject. In one concurrent schedule procedure (match condition) a brief stimulus (0.5-sec flash of orange illumination on the two keys) was presented contingent upon the first match response (red-red or green-green) to follow each of a number of varying intervals of time that averaged 1 min (Flesher and Hoffman, 1962). In another condition (mismatch condition), the brief orange flash was contingent upon mismatch responses (red-green or green-red) on the same VI 1-min schedule of stimulus presentation. In the conditions where the VI 1-min schedule of brief stimulus presentation was operative, the VI timer ran concurrently with the FI 8-min schedule of food except when the VI timer had primed and no response had been emitted that would produce the brief flash of orange light on the keys. During most conditions, the orange stimulus was also presented contiguously with food reinforcement. That is, 0.5 sec before food reinforcement, both keys were illuminated with orange light, which remained on throughout the food reinforcement. The only exceptions to this contiguous pairing of food and the orange stimulus occurred in the third and fourth exposures to the VI 1-min schedule for mismatch responses (*cf.* Table 1: mismatch [unpaired]) and the baseline condition between these two manipulations. In these unpaired mismatch conditions, the orange stimulus was aperiodically presented after mismatch responses, but was not presented before or during food reinforcement. No orange illumination occurred during the baseline conditions between these two unpaired mismatch conditions.

In an attempt to evaluate the reinforcing effects of other stimuli, each subject was exposed to a different stimulus on the VI 1-min schedule during the last mismatch condition.

Subject 15 was exposed to a mismatch condition in which food reinforcement was concurrently available on the VI 1-min schedule for mismatch responses, and the FI 8-min schedule for match responses. No orange stimulus was paired with the food produced on the VI schedule, although the orange stimulus remained paired with food produced on the FI schedule. To maintain Subject 15 at 80% of its free-feeding weight, a shorter duration of food presentation was used (2-sec access to grain) and sessions were terminated after the ninth FI food reinforcement. The 2-sec access was evaluated during the next-to-last baseline condition (Subject 15) and found to be comparable to 6-sec access in that similar response rates, patterns, and accuracies were produced by both durations of reinforcement. For Subject 11, a 0.5-sec hopper flash (hopper light illuminated, key and houselights out) was presented on the VI 1-min schedule for mismatch responses. For Subject 90, a 0.5-sec period of the magazine cycle (hopper light illuminated, key and houselights out, and the hopper raised) was presented on the VI 1-min schedule for mismatch responses. The orange illumination continued to precede and remain on throughout food reinforcement on the FI schedule during these conditions for all subjects.

All of the subjects were exposed to all conditions until the accuracy of match-to-sample performance (match responses/match + mismatch responses) showed no systematic trend for at least five consecutive days or until the trend was in the opposite direction from the accuracy expected under the next manipulation.

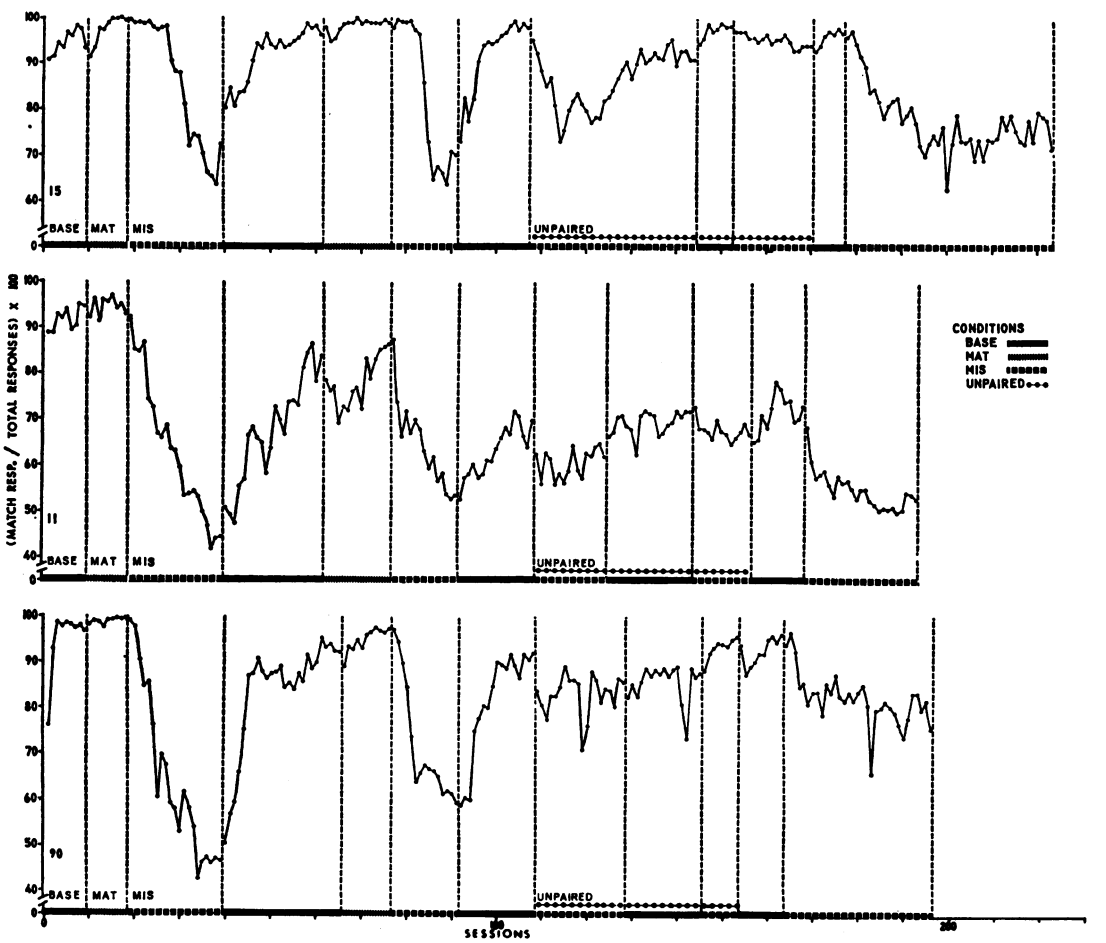

Fig. 1. Percentage of match responses for each session through the first 12 conditions of the study for each subject. The lines on the abscissa mark the various conditions.

RESULTS

Figure 1 shows the percentage of total responses that were match responses (match responses/match + mismatch responses) for each session through the first 12 conditions of the study for each subject. The baseline conditions (BASE) of FI 8-min reinforcement for match responses initially produced a high percentage of match responses for all subjects (all comparisons between conditions are based upon the last five sessions). When the VI 1-min schedule of orange flashes was concurrently scheduled for match responses (MAT condition), the percentage of match responses remained high. However, when the VI 1-min schedule of orange flashes was scheduled for mismatch responses (MIS condition), the percentage of match responses decreased (percentage of mismatch responses increased). A return to the baseline conditions produced approximately the same percentage of match responses as had the initial baseline condition for Subjects 15 and 90, but a somewhat lower percentage of match responses than had the initial baseline condition for Subject 11. A replication of the match condition (VI 1-min schedule of orange flashes for match responses) produced a slightly higher percentage of match responses for Subject 90 and little change from the immediately preceding baseline condition for Subjects 11 and 15. A replication of the mismatch condition (VI 1-min schedule of orange flashes for mismatch responses) produced a decreased percentage of match responses for all subjects.

Two replications of the VI 1-min schedule condition of orange flashes for mismatch responses were run when the orange stimulus was not paired with food reinforcement (UNPAIRED MIS condition: dotted chain on figure). The first unpaired mismatch conditions produced a slightly lower percentage of match responses relative to the immediately preceding baseline condition. The second produced a very small decrease in percentage of match

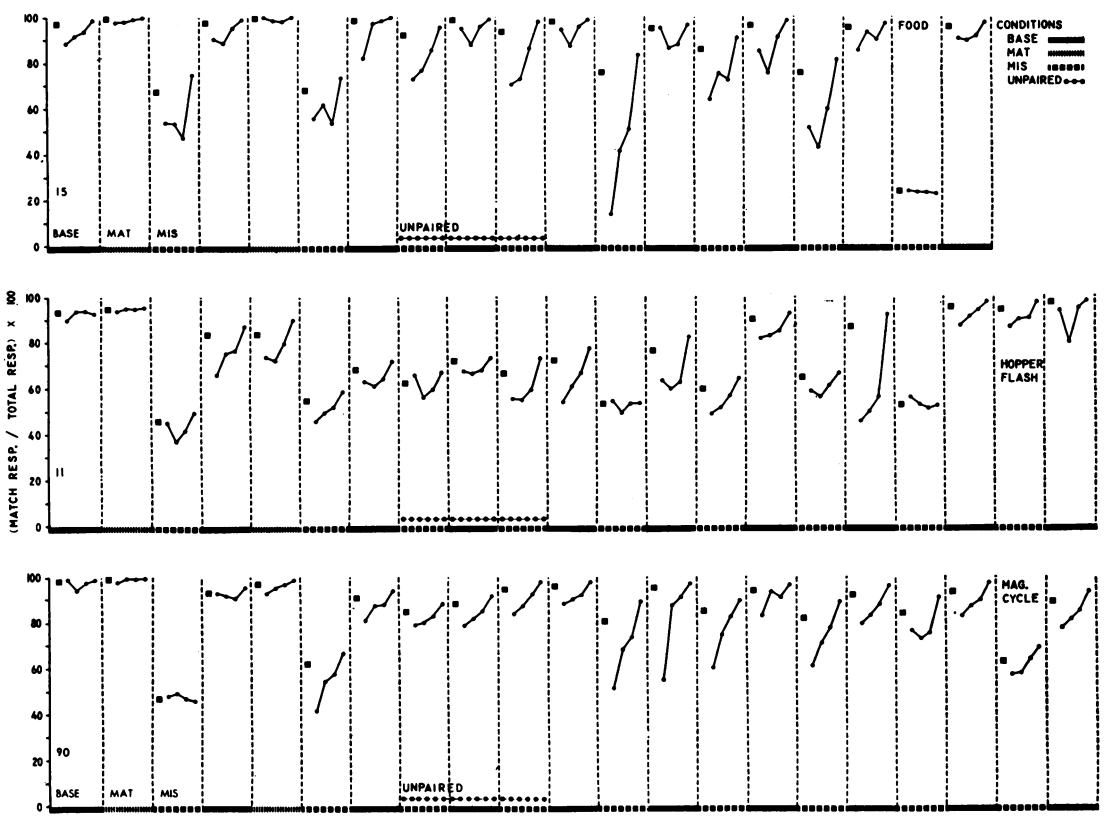

Fig. 2. Percentage of match responses averaged over the last five days of each condition (squares) and the percentage of match responses within successive 2-min quarters of all 8-min inter-reinforcement intervals during the last five days of each condition (connected circles). The lines on the abscissa mark the various conditions.

responses for Subjects 15 and 11, and a slight increase in the percentage of match responses for Subject 90.

When the orange stimulus was again paired with food reinforcement, the mismatch condition produced a substantial decrease in the percentage of match responses relative to the immediately preceding baseline condition.

Figure 2 is a graph of summary data for all subjects under all conditions. This figure is a plot of the percentage of match responses averaged over the last five days of each condition (squares) and the percentage of match responses within each 2-min quarter of all 8-min inter-reinforcement intervals during the last five days of each condition (connected circles). In all cases for all subjects when an orange stimulus was intermittently paired with the food, the VI 1-min schedule of orange flashes for mismatch responses (mismatch condition) produced a decrease in percentage of match responses relative to the immediately preceding baseline condition. However, the effects of this mismatch condition for Subject 90 were somewhat less for the last four replications than for the first two replications.

The last mismatch condition (Fig. 2) for Subject 15 shows those same measures when 2 sec of food reinforcement was arranged concurrently on the VI schedule for mismatch responses and the FI schedule for match responses (FOOD condition: last mismatch condition). For this subject, the magnitude of the change in accuracy from baseline under this condition was substantially greater than any of the changes in accuracy produced by the orange flash when arranged on the VI 1-min schedule for mismatch responses. The 0.5-sec hopper flash, when arranged on the VI 1-min schedule for Subject 11 (HOPPER FLASH condition: last mismatch condition), had no durable effect upon accuracy. For Subject 90, a 0.5-sec presentation of the magazine cycle for mismatch responses produced a substantial decrease in accuracy (MAGAZINE CYCLE condition: last mismatch condition). This decrease was greater than that produced by any of the last four mismatch conditions in which the orange stimulus (occasionally paired with food) was presented contingent upon mismatch responses.

The plot of the percentage of match responses within each 2-min quarter of the FI 8-min schedule (connected circles of Fig. 2) shows that accuracy often increased from the first quarter to the fourth quarter within the 8-min inter-reinforcement interval (a scalloping of accuracy). However, there are a number of exceptions to this general trend, particularly during the early manipulations for each subject. It may also be seen from Fig. 2 that the lowest percentage of match responses was typically obtained in the early quarters of the 8-min intervals under the mismatch conditions.

Figure 3 shows the mean rates of response averaged over the last five days for all baseline, match, mismatch, and unpaired mismatch conditions (excluding the last two baseline conditions for each subject). The three bars show the mean session rates for total responses (match + mismatch responses), match responses, and mismatch responses. The connected diamonds in the figure show mean rates of total responses within successive 2-min quarters, the connected squares show rates of match responses within successive 2-min quarters, and the connected circles show rates of mismatch responses with successive 2-min quarters.

The bar graphs in Fig. 3 show that total rates of match-to-sample responses (first bar) increased slightly during the match and mismatch conditions as compared to the baseline condition for each subject. The rate of match responses (second bar) increased during the match condition and decreased during the mismatch condition for each subject. In contrast, the rate of mismatch responses (third bar) showed little change during the match condition when compared to the rate under the baseline condition for each subject, but increased during the mismatch condition.

The rates of response (bar graphs) under the unpaired mismatch condition are similar to the baseline rates for Subjects 15 and 90. Although Subject 11 emitted a similar total rate of match-to-sample responses (first bar) under the unpaired mismatch condition and the baseline condition, there was a higher rate of mismatch responses (third bar) under the unpaired mismatch condition than under the baseline condition. However, the rate of mismatch responses under the unpaired mismatch condition was substantially lower than the mismatch response rate under the mismatch condition when the stimulus was occasionally paired with food.

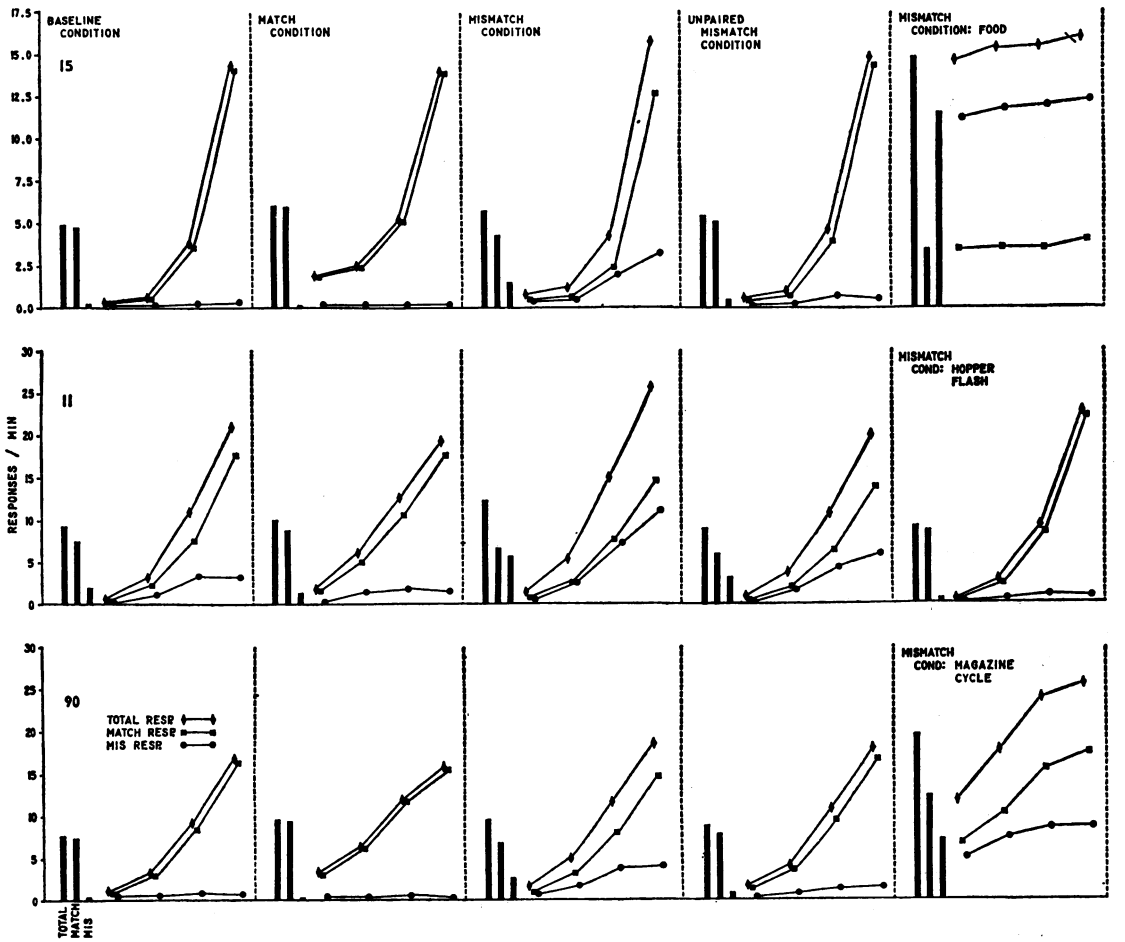

Fig. 3. Mean rates of response averaged over the last five days for all baseline, match, mismatch, and unpaired mismatch conditions. The three bars show mean rates for total responses (match + mismatch responses), match responses, and mismatch responses. The connected diamonds show mean rates of total responses within successive 2-min quarters of the 8-min intervals, the connected squares show mean rates of match responses within successive 2-min quarters, and the connected dots show mean rates of mismatch responses within successive 2-min quarters.

Figure 3 also shows the effects of the other three stimuli (arranged on the VI 1-min schedule for mismatch responses) on response rates. The stimuli were: 2 sec of food reinforcement, 0.5-sec hopper flash, and a 0.5-sec magazine cycle scheduled for Subjects 15, 11, and 90, respectively. The rate of total responses (first bar) and mismatch responses (third bar) increased for Subjects 15 and 90 over their baseline conditions. The hopper flash, for Subject 11, did not increase the rate of mismatch responses as the orange stimulus flash did under the mismatch conditions.

The response rate for each quarter of the FI schedule (Fig. 3: connected diamonds) showed that the rate of total match-to-sample responses increased over successive 2-min intervals under all conditions. The quarter rates of match responses (connected squares) showed analogous patterns, whereas mismatch responses (connected circles) showed a similar pattern only for Subjects 15 and 11 under the mismatch conditions and Subject 11 under the unpaired mismatch condition.

As may also be seen in Fig. 3, the increase in match responses under the match condition as compared to the baseline condition (connected squares) is attributable to increased rates of match responses within the first three quarters of the 8-min interval. The rate of

match responses in the last quarter of the 8-min interval during the match condition was approximately the same (Subjects 15 and 11) or slightly lower (Subject 90) than during the baseline condition. Increases in the rate of mismatch responses during the mismatch condition as compared to the baseline condition is attributable to increased rates of mismatch responses in all quarters of the 8-min interval for all subjects.

When exposed to other stimuli (2 sec of food reinforcement, Subject 15; 0.5-sec hopper flash, Subject 11; and 0.5-sec magazine cycle, Subject 90), Subjects 11 and 90 generally showed an increased response rate over successive 2-min intervals for total responses and match responses, whereas Subject 15 showed more constant response rates across all quarters of the 8-min intervals.

An examination of the frequency of food reinforcement of the FI schedule for the various conditions of the study for each subject revealed no systematic differences in the frequency of food reinforcement among conditions or subjects. The frequency of FI food reinforcement for each subject averaged (last five days of conditions) between 0.125 and 0.127 reinforcements per minute under all conditions.

The match-to-sample response employed in the study required a minimum of one comparison-key peck per trial. However, if high matching performances were to be maintained, a minimum average of two pecks on the comparison key per trial was required. Averaged over the last five days of each condition, there was little difference in the number of pecks to the comparison key per match-to-sample response between match and baseline conditions (Subject 15, 3.19 *vs.* 3.25; Subject 11, 1.75 *vs.* 1.74; Subject 90, 2.47 *vs.* 2.50). However, the mean number of pecks on the comparison key per match-to-sample response was lower under the mismatch conditions than under the baseline conditions (Subject 15, 2.39 *vs.* 3.25; Subject 11, 1.25 *vs.* 1.74; Subject 90, 2.11 *vs.* 2.50). The mismatch conditions in which the stimulus was not paired with food resulted in a lower number of pecks on the comparison key per match-to-sample response than did the baseline conditions (Subject 15, 3.06 *vs.* 3.25; Subject 11, 1.51 *vs.* 1.74; Subject 90, 2.17 *vs.* 2.50), but not as few as the mismatch conditions with the paired stimulus.

DISCUSSION

Throughout the study, match responses produced food reinforcement on a FI 8-min schedule. During most conditions an orange stimulus preceded the delivery of food by 0.5 sec (paired with food). When 0.5-sec orange stimulus flashes were contingent upon mismatch responses on a VI 1-min schedule (mismatch condition), the rate of mismatch responses increased as compared with the condition in which the stimulus was presented, only paired with the FI food reinforcement (baseline condition). This increase in rate of mismatch responses was reflected by a decrease in accuracy (percentage of match responses) of match-to-sample behavior. Correlated with the increase in mismatch responses was a decrease in the number of pecks on the comparison key (right key) per match-to-sample response as compared with baseline conditions. When orange flashes were presented contingent upon match responses on a VI 1-min schedule (match condition), the rate of match responses increased slightly as compared with the baseline condition, but little change in accuracy was noted. Perhaps the failure to obtain changes in accuracy during match conditions was due to the high accuracy produced by the FI 8-min schedule of food reinforcement under the baseline condition.

Since the power of the stimulus flash to reinforce mismatch responses was markedly reduced when the stimulus no longer was paired with FI food reinforcement (unpaired mismatch condition), it appears that the reinforcing function of the stimulus flash was dependent upon its occasional pairing with food, and, therefore, it was a conditioned reinforcer.

The present results are consistent with those of de Lorge (1967), who found that the reinforcing effectiveness of a brief stimulus paired with food was reduced when that stimulus was no longer paired with food. The results are also consistent with those of Kelleher (1966) and Zimmerman and Hanford (1966), who found that stimuli paired with food reinforcement were more effective in controlling rates and/or patterns of response than stimuli never paired with food reinforcement. Since these studies employed a simple key-pecking response, the present results extend the findings to the more complex behavior of match-to-sample.

Zimmerman (1967) reported the use of a brief magazine stimulus to control rate of match-to-sample behavior in a situation where food was delivered only after periods of nonkey pecking. The present results show control over rate and accuracy of match-to-sample behavior in a situation where food was contingent upon match responses.

The effectiveness of the orange stimulus flash in reinforcing mismatching behavior was compared to the effectiveness of 2 sec of food reinforcement (Subject 15), 0.5-sec hopper flash (Subject 11), and a 0.5-sec magazine cycle (Subject 90). A comparison of the magnitude of change in accuracy between the last mismatch conditions (following the unpairing conditions) for Subjects 15 and 90, reveals that the orange flash was not as effective as 2-sec access to food or the 0.5-sec magazine cycle. Visual observation of sessions indicated that Subject 90 occasionally obtained grain on the 0.5-sec magazine cycle. On the basis of the results with Subject 11, the orange flash appeared far more effective than the 0.5-sec hopper flash. However, since only one comparison condition was employed with each subject, these conclusions can only be tentative.

The increased rate of response over successive 2-min quarters of the 8-min intervals for total responses, during most conditions of the study, approximated scalloped patterns of responding typical of FI schedules of food reinforcement involving a simple key-peck response (Ferster and Skinner, 1957). Scalloped patterns of match-to-sample behavior under FI schedules have previously been reported by Ferster (1960). In the present study, it was also found in many conditions that the proportion of match responses increased over successive quarters of 8-min intervals. Thus, accuracy was typically higher near the end of the FI interval than at the beginning. This increased percentage of match responses as a function of time would be predicted by the concomitant increased probability of reinforcement (food) for a response of that response group (match responses) under the FI schedule and provides a partial replication of the changes in accuracy that occurred over successive quarters reported by Ferster (1960).

The high accuracy of the match-to-sample behavior that often occurred under the baseline FI 8-min schedule of food reinforcement is somewhat discrepant from data that Ferster (1960) reported from two pigeons on an FI 10-min schedule. However, the present match-to-sample procedure was considerably different than that employed by Ferster, so it is difficult to make direct comparisons. In addition, the present subjects had been run for approximately six months on the FI 8-min schedule for matching before the beginning of this study. This schedule history may have contributed to the high accuracy levels of the baseline conditions.

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