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MATCHING-TO-SAMPLE ACCURACY ON FIXED-RATIO SCHEDULES

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Pigeons performing on a matching-to-sample procedure were exposed to six fixed-ratio (FR) schedules (FR 1, 5, 10, 20, 40, and 60) of food reinforcement for correct matching responses. During both a correction and a noncorrection procedure without an intertrial interval (ITI), matching accuracy was lower on FR 1 and FR 60 than at intermediate ratios. With the FR 1 schedule, both a 5-sec and a 25-sec ITI resulted in higher matching accuracy than without an ITI; accuracy, with an ITI, was fairly constant for ratios of 1 to 20 but declined at higher ratios. The results suggest that the presence or absence of an ITI in matching to sample may account for inconsistencies obtained in earlier studies of the relationship of matching accuracy to ratio size.

Key words: matching to sample, matching accuracy, intertrial interval, fixed-ratio schedule, correction procedure, noncorrection procedure, pigeons

Matching to sample is a procedure in which an organism is required to respond correctly to stimuli that correspond in some fashion to a sample stimulus. Such matching responses can be maintained by intermittent schedules of reinforcement (Skinner, 1950), and the reinforcement schedule has been demonstrated to affect both rate and accuracy of performance (i.e., Boren & Gollub, 1972; Clark & Sherman, 1970; Ferster, 1960; Nelson, 1978; Nevin, Cumming, & Berryman, 1963). Several studies have examined the maintenance of matching to sample on fixed-ratio (FR) schedules in which every *n*th correct matching response is reinforced (Ferster, 1960; Mintz, Mourer, & Weinberg, 1966; Nevin et al., 1963). Accuracy of matching has been related to the size of the FR schedule; however, there are at least two inconsistent sets of data specifying the function relating accuracy to FR size. Ferster (1960), studying ratios of FR 1 to FR 95, found that matching accuracy was lowest on FR 1 and increased with ratio size from FR 1 to intermediate ratios (FR 15-FR 20). Nevin et al. (1963), studying ratios of FR 1 to FR 10, found that matching accuracy was highest on FR 1 and somewhat lower with higher ratios. It is not obvious why these sets of data differ, particularly for the FR 1 conditions; however, there are a number of procedural differences between the two studies (see Nevin et al., 1963, for a complete listing of procedural differences). Two of the possible important differences in procedure are that Nevin et al. used an intertrial interval and Ferster did not, and that Ferster used a correction procedure and Nevin et al. used a noncorrection procedure. These two procedural differences were directly manipulated in the present study, which examined matching accuracy as a function of ratio size.

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METHOD

Subjects

Two adult White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Both subjects were experimentally naive before exposure to the matching-to-sample procedure. Water and grit were available continuously in the home cages.

Apparatus

The experimental space was a chamber similar to that described by Ferster and Skinner (1957, p. 14), with a response panel containing three response keys for use with rear-projection systems (Ferster, Holtzman, & Leckrone, 1962). The keys could be operated by a force of .15 N or more. Two houselights were located in the upper two corners of the response panel. Masking noise was continuously provided to the chamber by a white-noise generator. The chamber was located in a darkened room that also attenuated most extraneous sounds. Scheduling was accomplished automatically by electronic circuits located in a separate control room. Data were recorded on counters and cumulative recorders.

Procedure

A small white square and a large white square projected on the response keys from the rear were the two sample stimuli used throughout the study. A session began with either the small or large square randomly projected on the center response key. When a subject responded on the center key, the sample was removed from that key and the small and large squares were projected on the two side keys. This is a zero delay match with a single observing response as described by Berryman, Cumming, and Nevin (1963). The two stimuli randomly appeared on each of the left and right response keys. A response on the side key on which the stimulus corresponded to the center key stimulus (a matching response) produced .3 sec of the magazine light, and the stimuli on the two side keys went off. The grain magazine did not operate. Following a correct matching response, one of the two sample stimuli was randomly projected on the center key. If the subject responded on the nonmatching key, all of the lights in the chamber were turned off (blackout) for 1 sec. Following an incorrect match, the same sample stimulus was projected on the center key (correction procedure). Initially, every fifth correct match produced a 4-sec operation of the grain feeder (FR 5). The grain was illuminated during the 4-sec cycle by the feeder light, and the houselight was turned off.

Each daily experimental session terminated after 50 4-sec presentations of mixed grain reinforcements or 3 hr, whichever occurred first. Each session was preceded and followed by a blackout condition (variable in duration), during which all lights in the experimental chamber were off and responses had no scheduled consequences.

The subjects, while performing on the matching-to-sample procedure, were exposed to four different experimental conditions. The first condition was the correction procedure described above in which the sample presented on the center key changed only following a correct match. The second and third conditions were also correction procedures with the addition of an intertrial interval (ITI). A 5-sec and then a 25-sec ITI separated each grain reinforcement, feederlight presentation, or blackout from the projection of the next stimulus presentation on the center key. During the ITI the houselight was on and the keys were dark. Responses had no programmed consequences during the interval. The fourth condition was a noncorrection procedure, with no ITI, in which the sample presented on the center key changed randomly following either a correct or an incorrect match.

Table 1

Sequence and Number of Sessions on Each Schedule

Procedure	*Fixed Ratio (FR)*	*No. Sessions*	
		Subject 1	*Subject 2*
Correction with no ITI	5	16	14
	20	20	20
	10	15	14
	1	12	12
	40	25	25
	60	20	21
Correction plus 5-sec ITI	1	10	12
	5	21	16
	20	34	23
	10	21	22
	40	19	16
	60	18	25
Correction plus 25-sec ITI	5	21	19
	10	11	11
	1	11	10
	20	14	12
	40	10	14
	60	5	5
Noncorrection with no ITI	5	15	13
	20	22	18
	1	25	23
	10	13	14
	60	16	15
	40	10	11

Under each of the above four conditions, the subjects were exposed to six different FR schedules of correct matches (FR 1, 5, 10, 20, 40, and 60). Incorrect matches (errors) had no effect in advancing a ratio towards its completion. The correction procedure was studied first, then the 5-sec ITI was introduced into the program and studied, followed by the 25-sec ITI. The noncorrection condition was studied last. The sequence and number of sessions on each condition are given in Table 1 for the two subjects. The subjects were exposed to a particular ratio schedule until daily matching accuracies showed no systematic trends over five consecutive sessions.

RESULTS

Matching accuracy in terms of percent correct for all of the conditions studied is summarized for the two subjects in Figure 1. The columns in this figure are the medians of the last five sessions on each condition. Vertical lines through the medians indicate the range of accuracies for the last five sessions.

The main finding of this study concerns the FR 1 condition (four columns on the far left of Figure 1). When an ITI was introduced into the correction procedure (columns 2 and 3), matching accuracy was higher under the FR 1 condition than without an ITI (column 1). There was no consistent difference between the 5-sec and the 25-sec ITI in terms of increasing the level of accuracy. Under the FR 1 condition the noncorrection procedure (column 4) produced no difference in matching from the correction procedure without an ITI.

In the absence of an ITI, accuracies of both the correction and noncorrection procedures were higher for FR 5, FR 10, and FR 20 than for FR 1. Within a given FR condition in this range, there were no consistent differences as a function of correction or ITI. At FR 40 Bird 2 demonstrated a decline in accuracies in all four conditions. Both birds at FR 60 showed lower accuracies with 0- and 5-sec ITIs than were obtained for those conditions at lower ratios (an exception was Bird 2 with a 5-sec ITI). The 25-sec ITI condition could not maintain responding on FR 60 for either subject. The relationship between accuracy and FR size appeared similar for both the correction and the noncorrection procedures without an ITI: accuracy generally increased from FR 1 to intermediate FRs and then declined with further increase in FR size. Accuracy tended to be fairly constant with 5- and 25-sec ITIs from FR 1 through intermediate FRs and then declined with further increase in FR size.

Patterns of responding appeared similar to those maintained by FR schedules for less complex responses, and the patterns generally were similar for the four experimental conditions across the various FR sizes. To illustrate terminal performances on each of the FRs, Figure 2 shows cumulative records of entire sessions of Bird 1 on the correction procedure with no ITI. Cumulative correct matches appear as the top records in the figure with the cumulative error record for the same session displayed below. Responding was generally well maintained up to FR 40. Much of the difference in overall performance was due to the preratio pauses which increased with ratio size. Performances consisted of a pause in responding followed by a rather steady running rate until reinforcement. The strained performance on the FR 60 schedule, as evidenced by the extreme pausing shown in the bottom of Figure 2, also was typical of FR schedules in that once responding began it was usually maintained until reinforcement. Close examination of the cumulative records indicated a distinctive pattern of error responding throughout a ratio. Errors tended to occur at the beginning of responding following the preratio pause and persisted throughout much of the ratio run. Near the end of the ratio, error responses often declined as the terminal correct matching rate increased. These error patterns may be seen most clearly in the records for FR 20 and FR 40.

DISCUSSION

The present study indicates that the ITI may be an important variable that accounts for the two general sets of conflicting data concerning matching accuracy under FR 1. If no ITI is used, results are like those showing low matching accuracies under FR 1 (Ferster, 1960; Ferster & Appel, 1961; Holt & Shafer, 1973; Zimmerman & Ferster, 1963). If an ITI is used, the results are more like

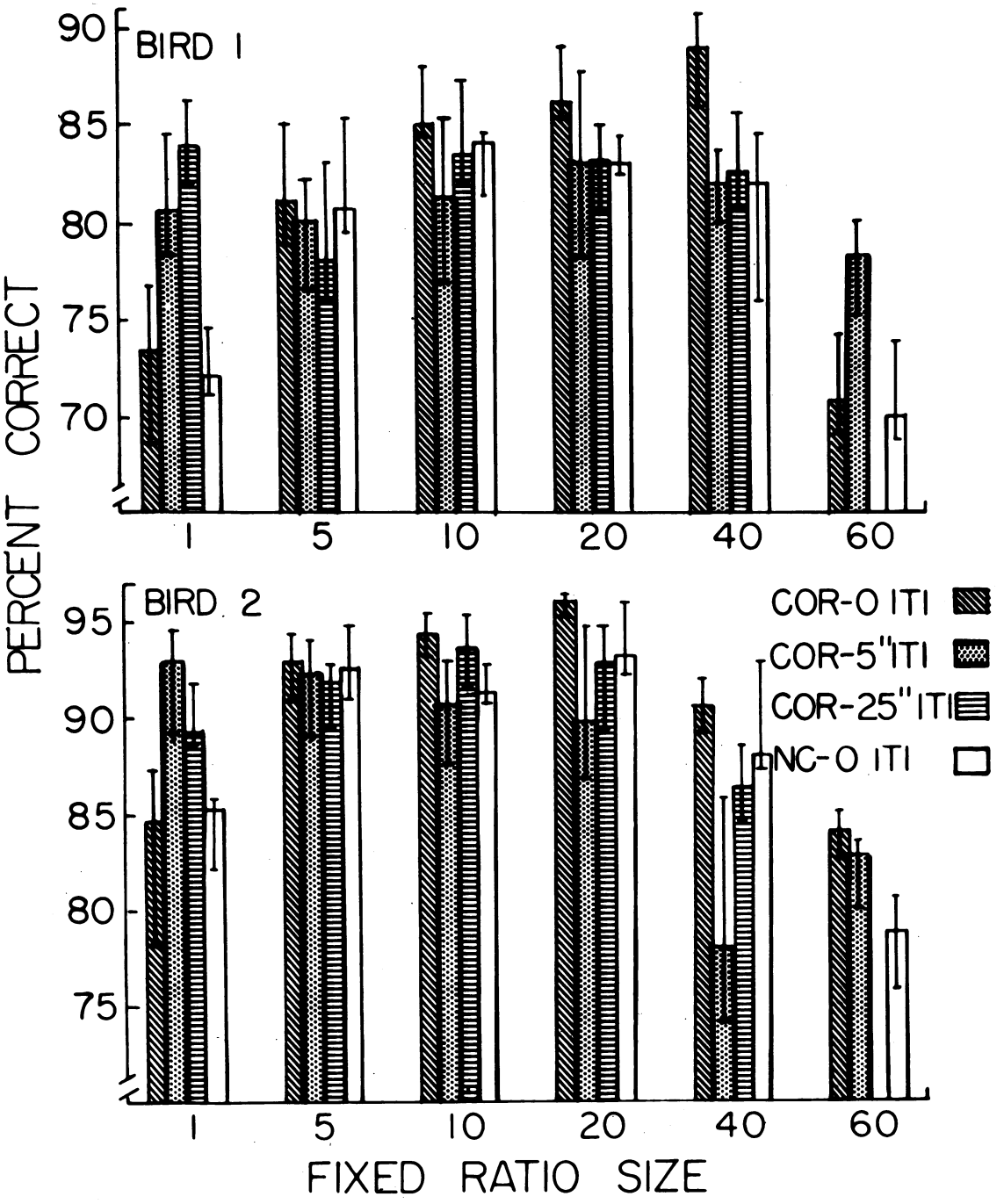

Fig. 1. Effects of fixed-ratio size on matching-to-sample accuracy (percent correct) of two pigeons for a correction procedure with no ITI, a correction procedure with a 5-sec ITI, a correction procedure with a 25-sec ITI, and a noncorrection procedure with no ITI. Each column represents the median of the last five sessions at each condition and vertical lines through the medians indicate ranges.

studies showing higher accuracies under FR 1 (Berryman et al., 1963; Cumming & Berryman, 1961; Nevin et al., 1963).

Without an ITI the lowest accuracy of matching occurred on FR 1 and FR 60 and high accuracies were maintained with inter-

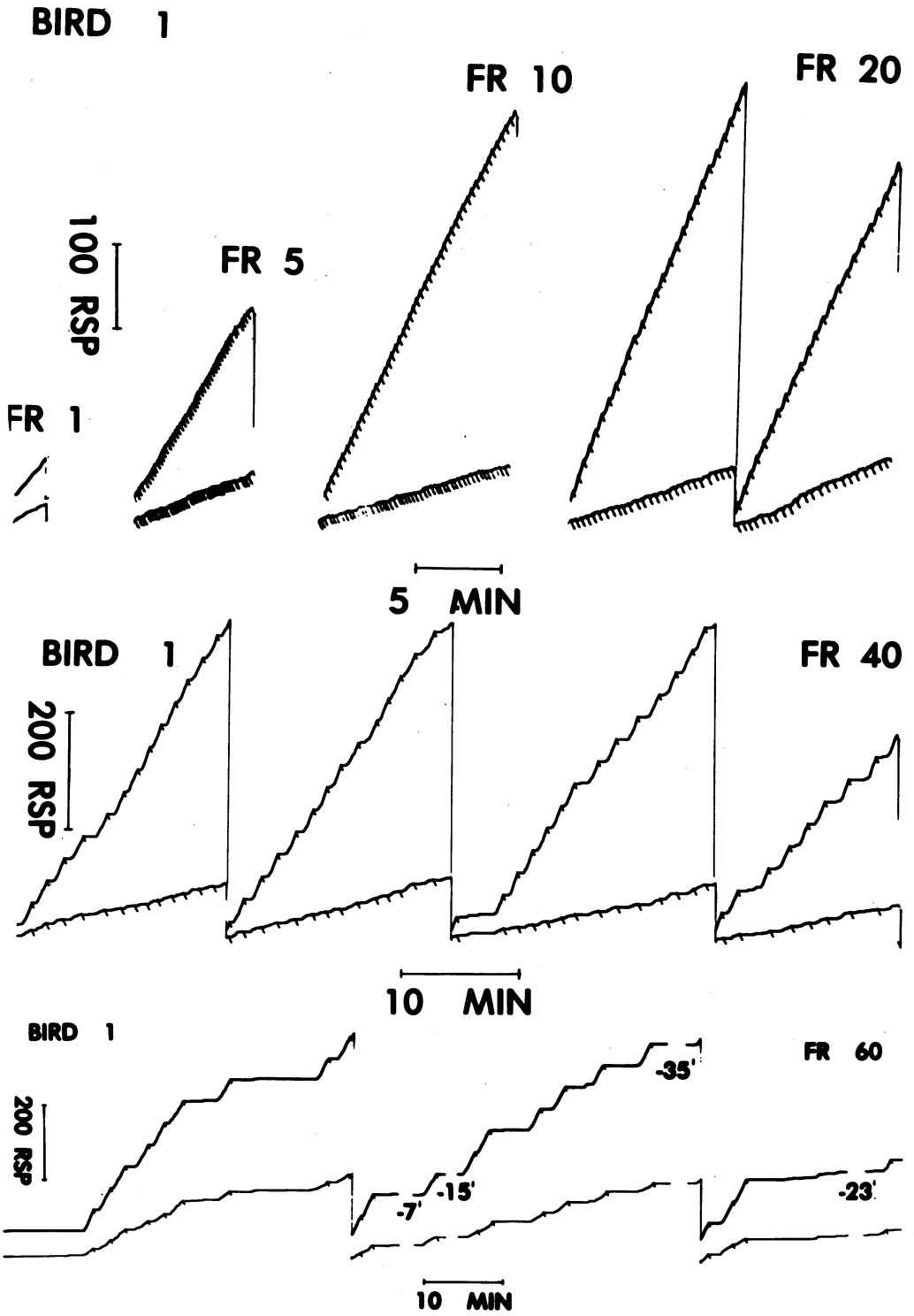

Fig. 2. Cumulative response records of Bird 1 showing terminal performances for entire sessions on FR 1, FR 5, FR 10, FR 20, FR 40, and FR 60. The top record for each pair is cumulated correct matches and the bottom record is cumulated errors. A downward deflection of the response pen indicates reinforcement (no deflections appear on the FR 1 records). Portions of the FR 60 records where no responding occurred have been deleted as indicated.

mediate FRs. The lower matching accuracy under the FR 1 condition without an ITI is consistent with the function reported by Ferster (1960). However, the accuracy levels in the present study for FR 1 (68 to 87 percent correct) are higher than those obtained by Ferster for FR 1 (50 percent correct). This discrepancy may result because the birds in the present study were well trained with an extended history of matching on different FRs before the FR 1 condition was examined. By comparison, Ferster investigated FR 1 as the initial condition so that the accuracy level at FR 1 may have been confounded with the order of exposure to the schedules. Also, a decline in matching accuracy at the highest ratio (FR 60) investigated in the present study was consistent with the decline in accuracy at the highest ratios (FR 60-FR 95) reported by Ferster for his only subject exposed to higher ratios.

When an ITI was introduced into the correction procedure, accuracies generally were higher on FR 1 than without the ITI. The levels of accuracy with an ITI were fairly constant from FR 1 through FR 20 for Bird 2 and from FR 1 through FR 40 for Bird 1. Using a two-key matching procedure, Sherman (footnote in Carter & Werner, 1978, p. 580) showed that a relationship similar to that reported by Ferster in which accuracy was lowest for short ratios and higher for larger ratios was changed when an ITI was employed such that accuracy was inversely related to FR size. Holt and Shafer (1973) also found that ITI durations of 1 to 60 sec produced higher accuracies than no ITI in matching to sample maintained on FR 1. They found no consistent differences among the ITI durations in terms of accuracy. Nevin et al. (1963) found little difference in matching accuracy between a 1-sec or 25-sec ITI. There also were no consistent differences between the 5- and 25-sec ITI in the present study. It appears that the presence or absence of an ITI is more important in affecting matching performance than the particular duration of the interval.

The matching-to-sample FR schedules maintained performances similar to those maintained with less complex responses. The smaller ratios produced well-maintained responding. As the size of the FRs increased, a FR pattern of responding developed. There was pausing after a reinforcement followed by responding at the terminal FR rate. The largest ratios produced extreme pausing and strained responding. These findings are in accord with previous studies (Ferster, 1960; Nevin et al., 1963). The distribution of errors within a ratio showed that errors tended to occur at the beginning of ratio responding and to decline near the end of the ratio. This pattern of errors within ratios also appears similar to previous findings (Mintz et al., 1966; Nevin et al., 1963).

It was supposed that whether or not a correction procedure was used would influence accuracy levels on matching to sample (cf. Nevin et al., 1963). The noncorrection procedure, however, does not appear to produce results that differ from the correction procedure with the well-maintained matching behavior observed in the present study.

The results do not directly indicate why the ITI increased the matching accuracy under FR 1 or small fixed ratios. Two possibilities seem appropriate. One is that the ITI may affect FR 1 or low ratio-maintained matching performance in the same way that timeout affects them (Ferster & Appel, 1961) and may be related to changes in the overall reinforcement frequency. The other possibility is that the ITI may interfere with superstitious chaining of responses or delay of reinforcement effects occurring in the FR 1 situation (cf. Boren, 1969). A detailed and sequential analysis of correct matching and error responses similar to that conducted by Boren may clarify such effects.

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