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INTERMITTENT PUNISHMENT OF S^{Δ} RESPONDING IN MATCHING TO SAMPLE[1]

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Incorrect matching responses of two pigeons on matching to sample were either continuously (CRF) or intermittently (FR) followed by a time out (TO). The matching accuracy was examined as a function of both TO duration and TO frequency (ratio size). With intermediate TO durations (10 sec, 1 min), accuracy increased as the frequency of TO increased. With an extremely short (1 sec) and an extremely long (10 min) TO duration, accuracy was poor over the entire range of frequencies.

In a previous study (Ferster and Appel, 1961), incorrect (S^{Δ}) responses in matching to sample were continuously followed by a time out (TO). The accuracy of matching was a function of the TO duration. When correct matching responses were reinforced with food on a VI 3 schedule, accuracy of matching was highest with TO durations of 10, 30, or 60 sec, but decreased at durations of either 1 sec or 120 sec. When correct matching responses were continuously reinforced, accuracy of matching was close to chance levels with all TO durations.

In this investigation, S^{Δ} responses were either continuously (CRF) or intermittently (ratio schedule) followed by a TO. The matching accuracy was examined as a function of both TO duration and ratio size.

METHOD

The two pigeons and the apparatus and general techniques used in this study were the same as those used in the previous study (Ferster and Appel, 1961).

Correct (S^{D}) matching responses were continuously reinforced with a 0.2-sec flash of the magazine lights, and were intermittently reinforced on a VI 3 schedule with 5-sec access to grain. A daily experimental session was terminated after a minimum of 8 hr or after a subject obtained 50 reinforcements, whichever occurred first. Incorrect (S^{Δ}) matching responses were followed by a TO of a given duration, either continuously (CRF schedule) or intermittently (FR schedule). The FR values were FR 50, FR 25, FR 12, FR 6, FR 4, or FR 2.

The general plan of the experiment was to use the performance under continuous punishment of S^{Δ} responses by TO as a base line from which to examine the effect of a given fixed ratio. Hence, each bird's performance was stabilized under the CRF punishment schedule before a shift to the next value of fixed ratio. Furthermore, a schedule was changed only after matching accuracy was stable (no consistent trend) for five successive daily sessions. After a series of schedules with a given TO duration was completed, the TO duration was altered, and again behavior was examined as a function of CRF and FR schedules. The TO duration for bird 84Y was decreased throughout the experiment. The order for bird 83Y was scrambled. Table 1 presents the order of experimental conditions for both animals throughout the experiment.

RESULTS

Figures 1 and 2 are overall summaries of the experiment, giving matching accuracy (indexed by the ratio of S^{Δ}/S^{D} responses), S^{D} rates, and S^{Δ} rates as a function of frequency of punishment (FR value). Every point in each function is the median value for the final five sessions on the given condition.

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Table 1
Order of Experimental Conditions

Bird	*Series*	*TO Duration*	*Experimental Conditions**
83Y	1	10 sec	CRF (10), FR 50 (11), CRF (7), FR 25 (9), CRF (5), FR 12 (16), CRF (6), FR 6 (10), CRF (12), FR 4 (10), CRF (8), FR 2 (12), CRF (7).
	2	10 sec (2nd Determination)	CRF (7)— (last in the above series), FR 25 (12), CRF (5), FR 6 (10), CRF (6), FR 50 (9).
	3	2 min	CRF (6), FR 2 (9), CRF (19), FR 4 (10), CRF (10), FR 6 (13), CRF (6), FR 12 (5), CRF (12), FR 25 (8), CRF (12), FR 50 (9).
	4	1 sec	CRF (9), FR 50 (16), CRF (10), FR 4 (6), CRF (6).
	5	1 min	CRF (6), FR 50 (8), CRF (5), FR 25 (7), CRF (7), FR 4 (6), CRF (9).
	6	10 min	CRF (17), FR 50 (6), CRF (11), FR 25 (7), CRF (9), FR Δ (6), CRF (7).
84Y	1	10 min	CRF (7), FR 50 (13), CRF (6), FR 25 (6), CRF (10), FR 12 (11), CRF (9), FR 6 (6), CRF (5), FR 4 (5), CRF (10), FR 2 (12), CRF (5).
	2	1 min	CRF (11), FR 50 (9), CRF (16), FR 25 (7), CRF (5), FR 12 (8), CRF (7), FR Δ (12), CRF (16), FR 4 (10), CRF (11), FR 2 (13), CRF (7).
	3	10 sec	CRF (10), FR 2 (6), CRF (5), FR 4 (7), CRF (7), FR 6 (11), CRF (8), FR 12 (11), CRF (9), FR 25 (12), CRF (13), FR 50 (10), CRF (7).
	4	1 sec	CRF (6), FR 50 (13), CRF (9), FR 25 (6), CRF (7), FR 12 (10), CRF (6), FR 6 (12), CRF (7), FR 4 (8), CRF (8), FR 2 (5), CRF (6).

*Number of sessions appears in parentheses.

Each column shows the functions between the matching performance and the schedule of TO for a different TO duration. Matching accuracy (top row) decreased with an increase in the FR value for all TO durations except 10 min. The S^{Δ} rates (bottom row, open circles) increased with an increase in the FR value for all TO durations, and S^{D} rates (bottom row, closed circles) decreased or did not change with an increase in the FR value for any TO duration except 10 min. The changes in relative rates of matching were most marked in the range of FR values between CRF and FR 4 or FR 6, and at the middle range of TO duration. The decrease in accuracy of matching with increasing FR values occurs largely as a result of increases in the rates of S^{Δ} responding. Figure 3 presents 1-hr segments of cumulative records of S^{D} and S^{Δ} responding taken from the final sessions of Bird 83Y in the TO 10-sec series. The records demonstrate the marked increase in S^{Δ} rate with an increase in FR value and the corresponding slight decrease in the S^{D} rate. These records correspond to the functions shown in the second column of Fig. 1 (first determination on TO 10 sec). With TO 10 min, the increase in the accuracy of matching that occurred with decreased frequency of TO was due to a corresponding increase in the rate of S^{D} responding.

The marked difference between the TO 10-min functions and all others suggested that the 10-min TO disrupted responding. To see the overall effect of the TO, Fig. 4 shows the total response rate ($S^{D} + S^{\Delta}$) for each animal as a function of TO frequency and across each TO duration. The total response rate decreased with a decrease in FR value (increase in frequency of TO) for Bird 84Y at all TO durations, but for Bird 83Y only when the TO duration was 1, 2, or 10 min.

Figure 5 presents a comparison of one of the results of this study with the VI 3 results of

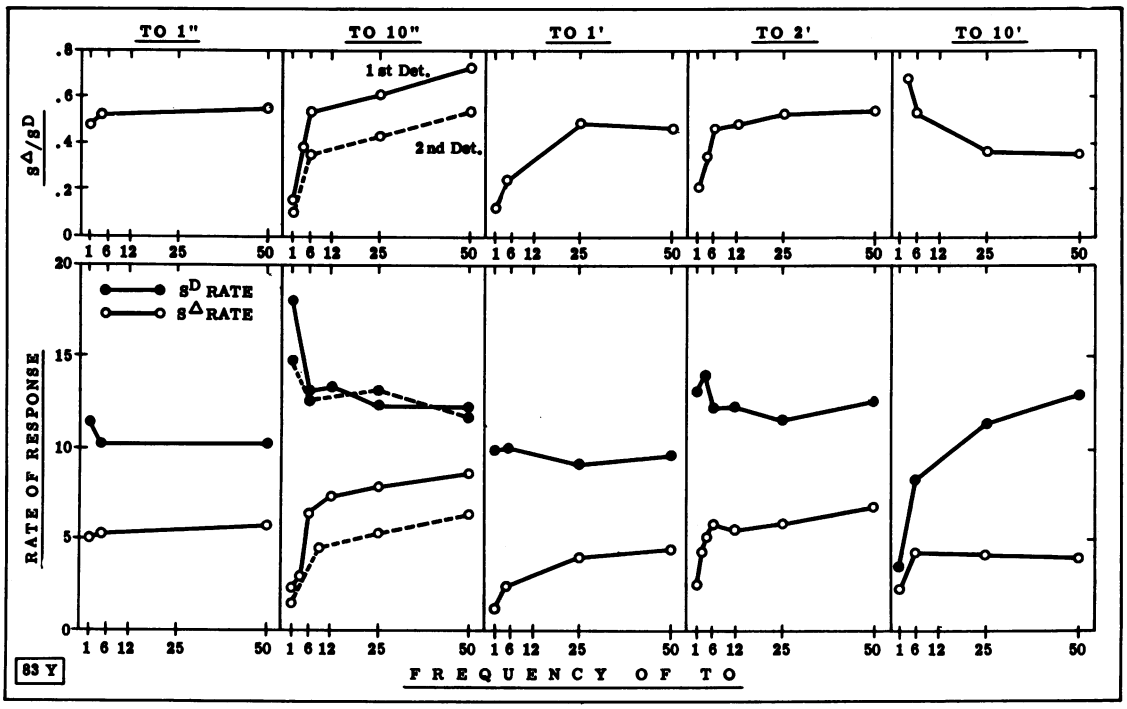

Fig. 1. Bird 83Y. Matching performance as a function of frequency of TO and of duration of TO (columns). Top row: Accuracy of matching. Bottom row: S^{D} rate (closed circles) and S^{Δ} rate (open circles). Dotted functions in second column are from the second determination (2nd Det.). Rate of response refers to number of responses per minute.

the earlier Ferster and Appel study. The median matching accuracy (S^{Δ}/S^{D}) value was plotted against the TO duration value. The schedule was always CRF punishment. Although the two sets of results were from two different experiments as much as two years apart, the functions are extremely similar. Matching accuracy was best at intermediate TO durations and worst at both short and long durations.

Changes in the duration of TO had an immediate effect on matching accuracy in several accidental probes when the TO was changed briefly. The results are shown in Table 2,

Table 2

Effect of Brief Changes in the TO Duration on Matching Accuracy

Bird	*Base line*	*Probe*	*Return to Base line*
83Y	CRF TO 10 sec .23	CRF TO 2 sec .35	CRF TO 10 sec .26
	CRF TO 2 min .32 .36	CRF TO 1 sec .15 .14	CRF TO 2 min .30 .19
	CRF TO 1 min .13	CRF TO 1 sec .48	CRF TO 1 min .18
84Y	CRF TO 10 min 1.27	CRF TO 10 sec .38	CRF TO 10 min .97
	FR 25 TO 1 min .93	FR 25 TO 10 sec .89	FR 25 TO 1 min .89

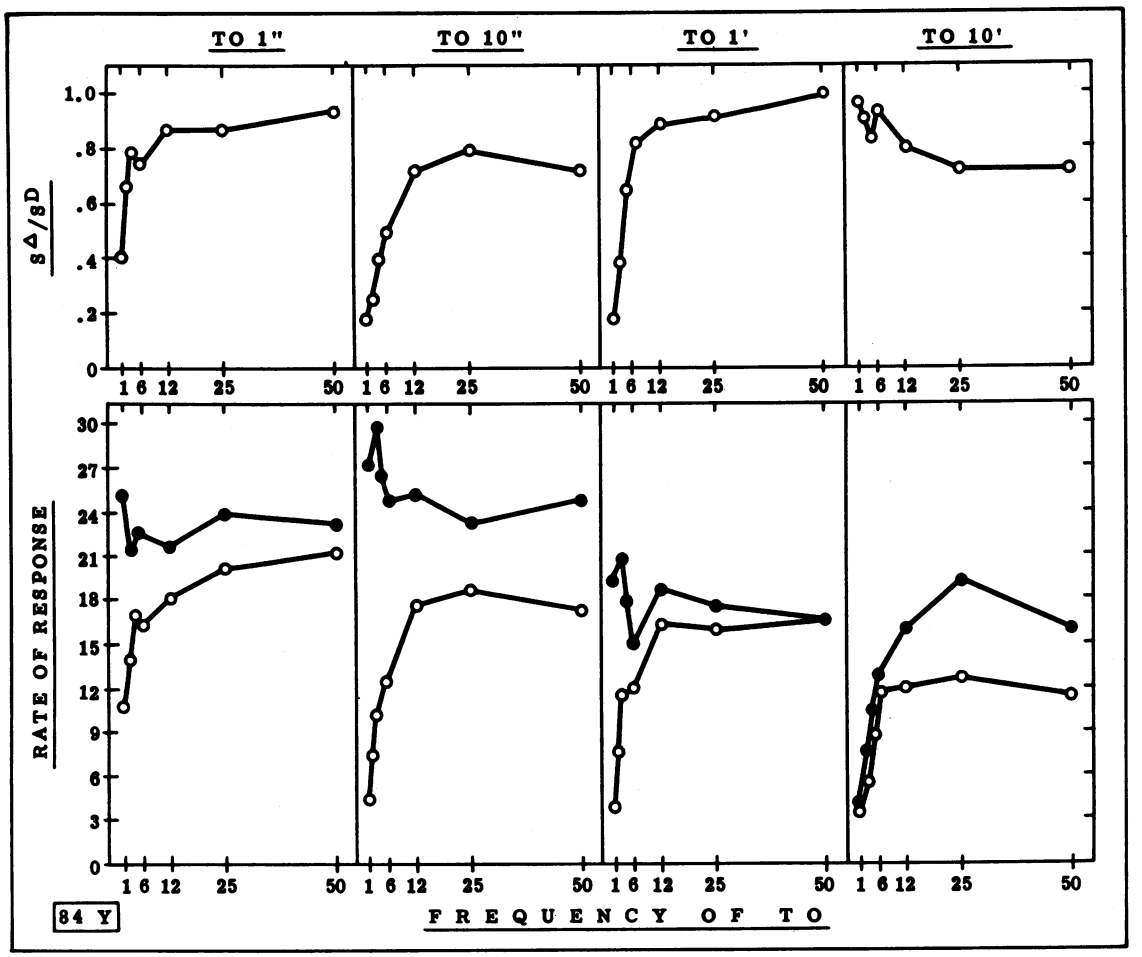

Fig. 2. Bird 84Y. Matching performance as a function of frequency of TO and of duration of TO (columns). Top row: Accuracy of matching. Bottom row: S^{D} rate (closed circles) and S^{Δ} rate (open circles). Rate of response refers to number of responses per minute.

which contains the matching accuracy before, during, and after the changed TO duration. In every case, the accuracy of matching changed in accordance with the general result reported in Fig. 5, and the original level of matching accuracy recovered as soon as the original duration was restored.

When the TO was discontinued briefly, the S^{Δ} rates of responding increased immediately, demonstrating that the effect of punishment was temporary. Figure 6 presents cumulative records of S^{D} and S^{Δ} responding for Bird 83Y during two sessions in which the schedule of TO was changed from FR 25 (first session) to FR ∞ to CRF (FR 1) (second session). After brief exposure to CRF (FR 1) in the second session, the schedule was coincidentally changed to FR ∞ (no TO) for approximately 45 min. The schedule was then returned to CRF. The rate of S^{Δ} responding increased almost immediately following the last TO in the second segment of the record. When the CRF procedure was reinstated in the third segment, the S^{D} rate fell to a level typically observed in the CRF condition. The S^{D} rate increased only slightly without TO, and was little affected by the return to the TO procedure. Figure 7 presents similar results for Bird 84Y; *i.e.*, the same kind of procedural change occurred when this bird was being stabilized on CRF punishment with TO 1 min.

Table 3 reveals the immediate sensitivity of the behavior to a punishment schedule in general. The values of the matching accuracy index on the final day of a given con-

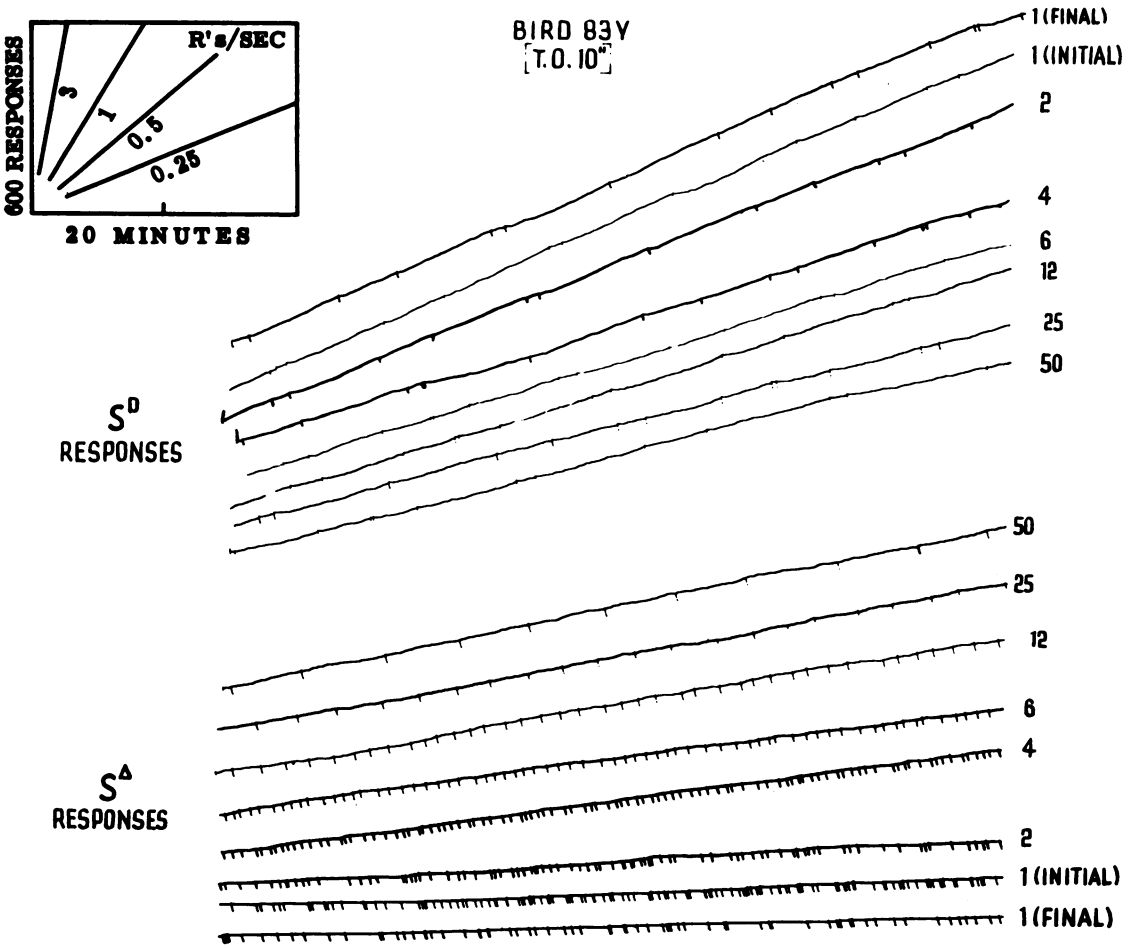

Fig. 3. Bird 83Y. Cumulative records of S^D (top segments) and S^Δ (bottom segments) responding from final performances on the various FR schedules of punishment with a 10-sec TO.

Table 3

Final and Transition Values of S^Δ/S^D

Transition From	*TO 1 sec*	*TO 10 sec*	*TO 1 min*	*TO 2 min*	*TO 10 min*	*TO 1 sec*	*TO 10 sec*	*TO 1 min*	*TO 10 min*
CRF to FR 50	.55 to .56	.24 to .57	.11 to .36	.24 to .39	.56 to .36	.32 to .46	.13 to .52	.22 to .69	.89 to .89
CRF to FR 25		.14 to .39	.09 to .54	.27 to .39	.58 to .37	.38 to .60	.20 to .78	.22 to .70	.61 to .82
CRF to FR 12		.15 to .43		.15 to .38		.35 to .66	.19 to .38	.15 to .69	.82 to .69
CRF to FR 6		.13 to .46		.18 to .27	.61 to .50	.41 to .82	.14 to .25	.17 to .53	.99 to .76
CRF to FR 4	.40 to .51	.12 to .21	.10 to .20	.18 to .22		.41 to .66	.19 to .29	.18 to .47	.85 to .85
CRF to FR 2		.09 to .11		.12 to .18		.45 to .52	.16 to .21	.16 to .28	1.25 to .89
FR 50 to CRF	.55 to .50	.79 to .33	.46 to .11		.31 to .17	.92 to .65	.72 to .23	.91 to .28	.71 to .79
FR 25 to CRF		.61 to .21	.49 to .11	.49 to .16	.43 to .41	.86 to .58	.79 to .27	.89 to .20	.72 to .78
FR 12 to CRF		.57 to .19		.47 to .17		.87 to .57	.72 to .33	.88 to .29	.76 to .83
FR 6 to CRF		.51 to .26		.46 to .21	.54 to .51	.74 to .50	.53 to .39	.82 to .55	.85 to 1.02
FR 4 to CRF	.59 to .53	.39 to .17	.23 to .13	.44 to .23		.76 to .60	.42 to .30	.58 to .47	.84 to .80
FR 2 to CRF		.18 to .10		.32 to .23		.66 to .50	.26 to .22	.37 to .31	.81 to 1.00

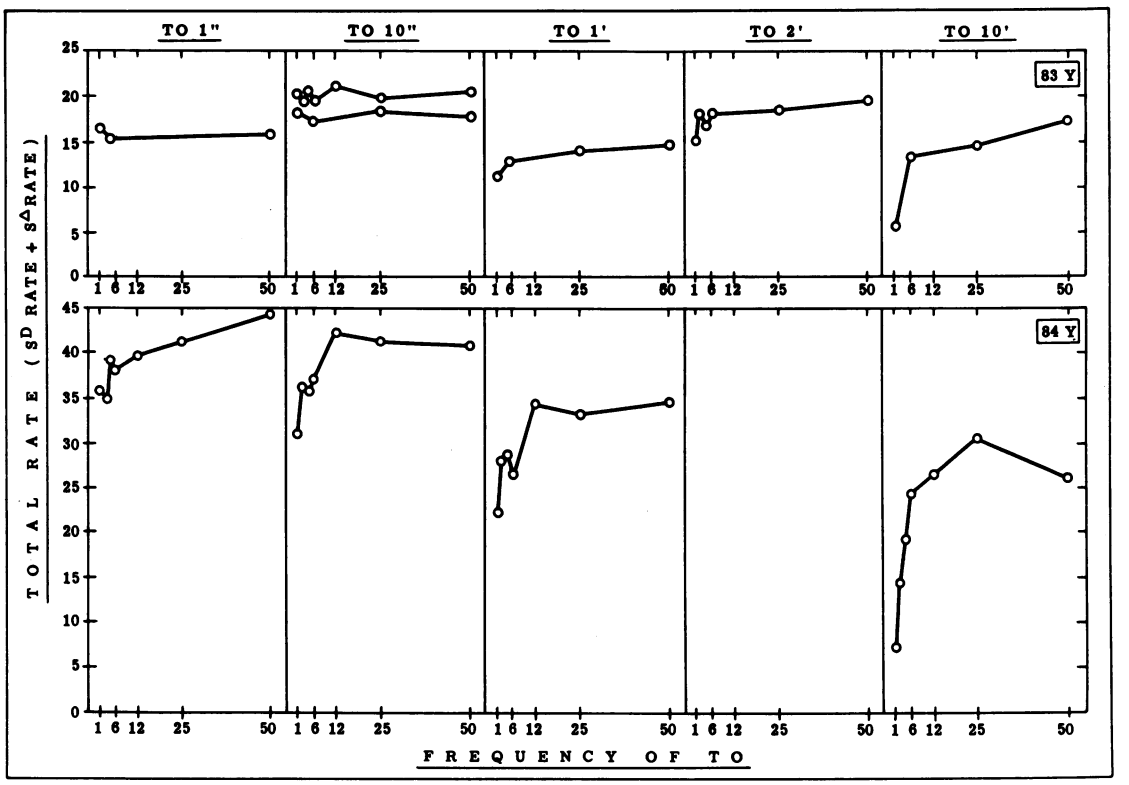

Fig. 4. Birds 83Y (top) and 84Y (bottom). Total response rates (S^D rate plus S^Δ rate) as a function of frequency of TO and of duration of TO (columns).

dition and the initial day of the following condition are tabulated for both birds. For all TO durations except the 10-min duration, accuracy immediately decreased when a bird was moved from a CRF schedule to an FR schedule, and it immediately improved when the program change was in the opposite direction. The magnitude of the change was roughly a function of the FR value. (The larger the FR, the greater the change in matching accuracy.) In the TO 10-min series, such immediate changes were less predictable.

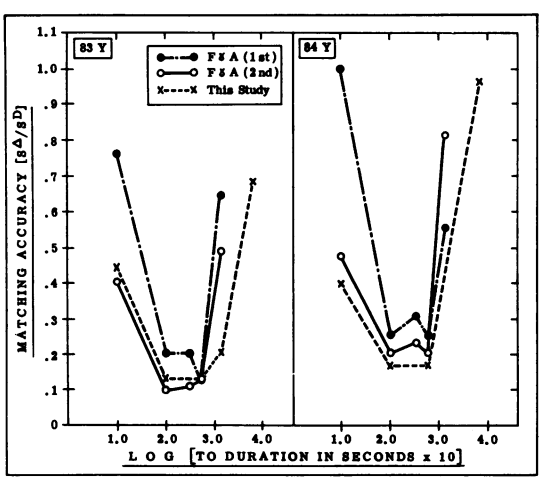

Fig. 5. Birds 83Y (left) and 84Y (right). Accuracy of matching as a function of TO duration. Solid lines are from the results of Ferster and Appel (two separate determinations). Dashed lines are from the present study.

Table 4 shows that changes in the schedule of the TO in several accidental probes also produced immediate changes in the accuracy of the matching performance. The numbers in the center column are the matching accuracy on sessions when the schedule of punishment was accidentally changed for a brief period. Increased frequencies of TO increased the accuracy of matching, and *vice versa*.

DISCUSSION

When S^Δ responses in matching to sample were followed by TO, the accuracy of match-

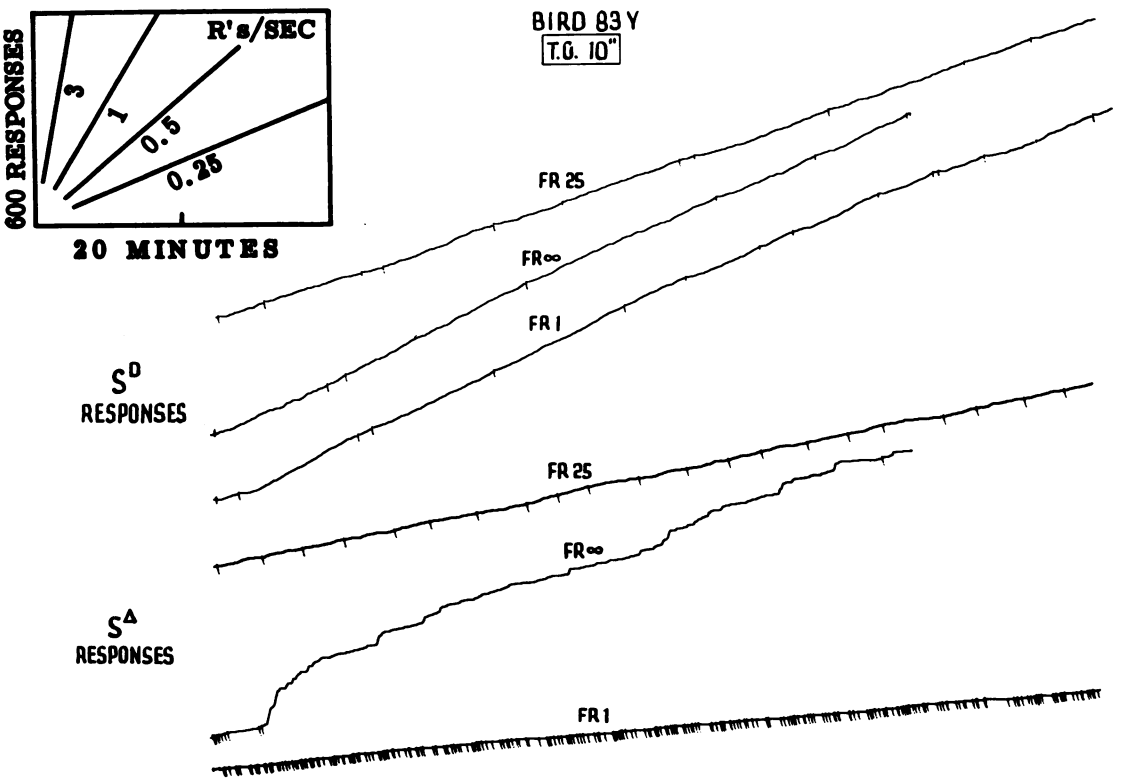

Fig. 6. Bird 83Y. Cumulative records of S^D (top segments) and S^Δ (bottom segments) responding on an FR 25, TO 10-sec schedule, an FR ∞ schedule, and a CRF, TO 10-sec schedule.

ing was a function of both the duration of TO and of the frequency of such presentations. At intermediate values of TO duration, accuracy improved markedly as the frequency of TO increased; the best matching behavior in the entire experiment occurred when every S^Δ response was followed by a TO of intermediate duration. At the shortest TO duration (1 sec), matching accuracy was poor over the entire frequency range but did improve somewhat (especially for Bird 84Y) with an increase in the frequency of TO. At the longest TO duration (10 min), accuracy of matching was poor over the entire frequency

Table 4

Effect of Brief Changes in the TO Frequency on Matching Accuracy

Bird	*Base line*	*Probe*	*Return to Base line*
83Y	FR 50 TO 10 sec .51	CRF TO 10 sec .18	FR 50 TO 10 sec .54
	CRF TO 1 min .18	FR 50 TO 1 min .47	CRF TO 1 min .15
84Y	CRF TO 1 min .25	FR 2 TO 1 min .53	CRF TO 1 min .23
	FR 6 TO 1 sec .74	CRF TO 1 min .46	FR 6 TO 1 sec .66
	CRF TO 1 min .23 .22	FR ∞ TO 1 min .95 .97	CRF TO 1 min .31 .17

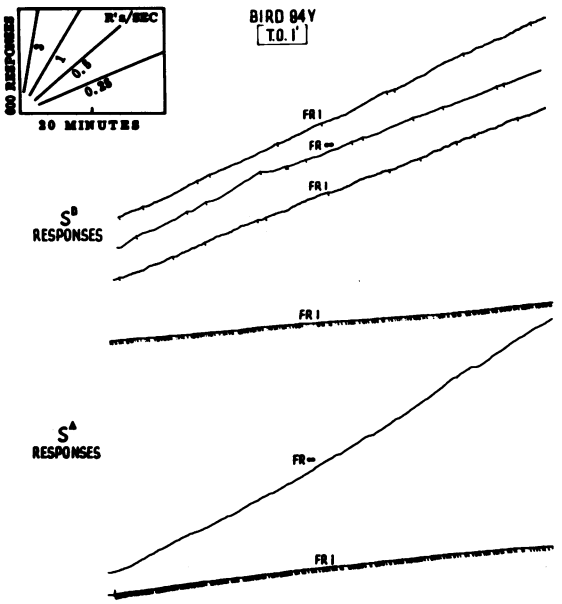

Fig. 7. Bird 84Y. Cumulative records of S^D (top segments) and S^Δ (bottom segments) responding on a CRF, TO 1-min schedule, an FR ∞ schedule, and a CRF, TO 1-min schedule.

range, but improved somewhat (especially for Bird 83Y) with a decrease in frequency of TO. High rates of S^Δ responses account for the poor matching at the short TO duration and at low frequencies of TO. Low rates of S^D responding causes the poor matching at the long TO duration. Some of these results confirmed earlier results of Ferster and Appel, who studied only CRF punishment schedules.

The low total rate of responding recorded with both subjects under CRF punishment with TO 10 min, suggested that TO suppressed behavior. For Bird 84Y, the total rate decreased both with an increase in TO frequency and TO duration (Fig. 4). For Bird 83Y, the total rate decreased with an increase in TO frequency when the TO duration was 1 min, 2 min, or 10 min. However, the total rate of responding was not a simple function of TO duration for this bird, even though the lowest total rates also occurred at the TO 10 min condition. One reason for the difference in these results for the two birds might be that the order of TO durations for Bird 84Y was decreased throughout the experiment, whereas the order for Bird 83Y was scrambled. (See Table 1.)

The sensitivity of the behavior to the independent variables examined was demonstrated by the rapid change in matching accuracy that followed a change in punishment. (See Tables 2, 3, and 4.)

The order of presentation of the FR values in a given series was usually from FR 50 through FR 2. However, when this order was different (Bird 83Y, TO 10 sec, second determination; Bird 83Y, TO 2 min; Bird 84Y, TO 10 sec), little difference was observed in the functions.

The shape of the functions may have been influenced by the use of the CRF procedure as a baseline for evaluating FR schedules. However, the CRF values throughout a given series were reliable and were not consistently affected by the prior FR condition.

REFERENCE

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