PUNISHMENT OF S^{Δ} RESPONDING IN MATCHING TO SAMPLE BY TIME OUT FROM POSITIVE REINFORCEMENT[1,2]

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A time out from positive reinforcement has been used as a mild punishment in the development of complex performances (Skinner, 1950). In matching to sample, for example, nonmatching responses are followed by a brief time out. The time out as an aversive stimulus presumably suppresses S^{Δ} responding.

In the experiment reported here, we studied the effectiveness of a time out used as punishment for S^{Δ} responses in matching to sample as a function of the duration of the time out. Matching to sample (Fig. 1) involves a chain of responses which consists of pecking the center key first and then the side key. Such a response sequence is reinforced when the bird responds to the side key whose color corresponds with that of the center key (S^{Δ}), and is unreinforced when the response is to the noncorresponding color. The matching performance consists of two such chains, one for each sample stimulus. The (aversive) stimulus used to punish is one in which none of the performances in this multiple schedule can be reinforced, that is, a time out or S^{Δ}, which already control a low or zero rate of responding. Many different combinations of schedules of reinforcement of punishment are possible: the time out could occur after every *n*th S^{Δ} response (FR) or contingent on the first S^{Δ} response after a period of *t* minutes elapses (FI). Parallel cases for all of the schedules of positive reinforcement could be constructed. We began by punishing each S^{Δ} response (CRF), since almost nothing is known of the effects of various schedules of punishment. In Experiment I, the matching to sample was reinforced continuously (CRF). In Experiment II, the matching to sample was reinforced as a variable-interval schedule. This schedule was used in order to provide a simple and easily interpreted base line from which to measure changes in the over-all rate of matching to sample (Ferster, 1960). The variable-interval schedule was also chosen as one which would produce a high rate of S^{Δ} responding, since the time out would presumably lower rather than increase the frequency of S^{Δ} responding.

METHOD

The subjects were two male, White Carneaux pigeons, naive at the start of the experiments. The apparatus and general technique have already been described in detail in a previous article (Ferster, 1960). Figure 1 illustrates the matching procedure.

Experiment I

The matching-to-sample performance was reinforced continuously. Each matching response to a side key produced a 4-second access to the food magazine. Responses to nonmatching side keys were all followed by a time out, which was varied from 0.5 to 600 seconds. The program of exposure to time outs of various duration (in seconds) was as follows: (the numbers in parentheses represent the number of experimental sessions the bird was exposed to the particular value of time out). For Bird 83Y the program was: 0.5 (16); 8 (11);

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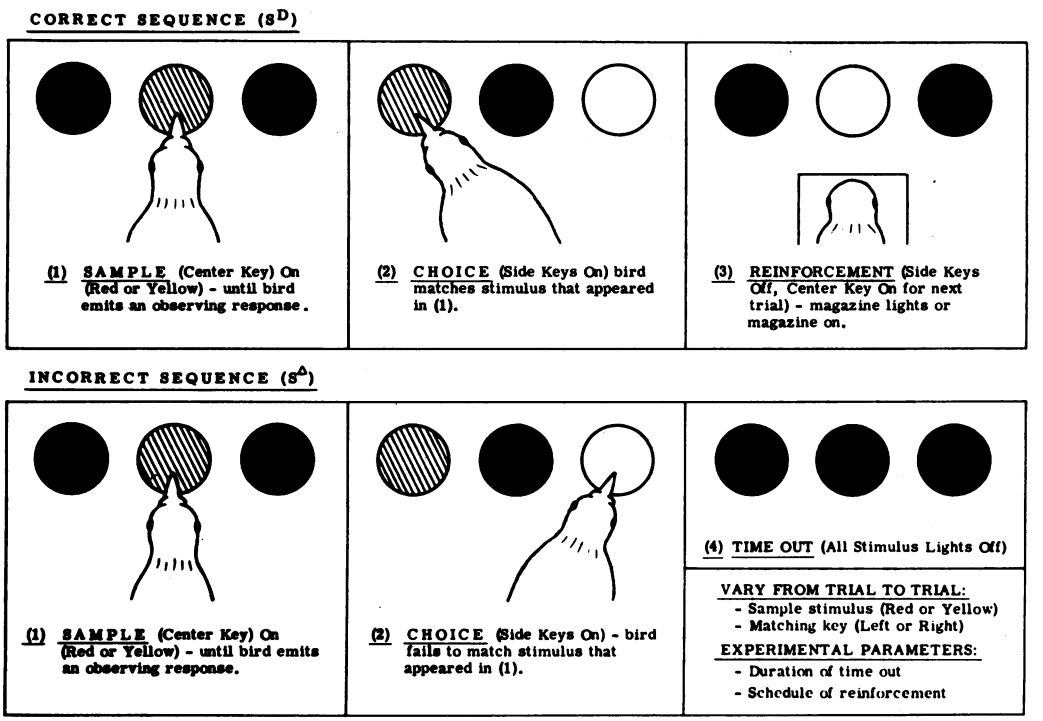

Figure 1. Schematic of the matching procedure.

15 (7); 60 (7); 300 (7); 600 (8); and 1 (5). For Bird 84Y it was: 0.5 (12); 8 (13); 15 (6); 60 (8); 300 (7); 600 (9); and 1 (5).

Experiment II

The variable-interval schedule had a mean value of 3 minutes (VI 3) and a range from successive responses reinforced to 6 minutes. Each reinforced matching sequence produced a 0.2-second exposure to the magazine stimuli. Food reinforcements consisted of a 4-second duration of the same stimuli while the food hopper was raised. Experiment II began immediately after the procedures described above in Experiment I. The birds were run on a VI 1 for five sessions before being reinforced on the VI 3 schedule. The time-out duration remained at 1 second during the development of a base-line variable-interval performance. The order of determination to the various values of time out, in seconds, was as follows. (The number of experimental sessions on each procedure is given in the parentheses.) For Bird 83Y, it was: 1 (9); 10 (23); 25 (4); 1 (8); 25 (20); 120 (7); 25 (7); 10 (8); 60 (6); 120 (4); 60 (16). For Bird 84Y, it was: 1 (6); 10 (17); 25 (12); 1 (8); 25 (6); 60 (6); 25 (8); 120 (7); 25 (6); 10 (7); 60 (5); 120 (5); 60 (6); and 10 (5). During a time out, cumulative recorders and the variable-interval programer stopped, the keys were disconnected, and all of the lights in the apparatus were turned out.

RESULTS

Experiment I: The Effect of Varied Durations of Time out on Matching to Sample Maintained on CRF

After 16 sessions of reinforcement on CRF, with S^{Δ} responses followed by a TO of 0.5 second, the duration of the time out was varied in the sequence mentioned above. Figures 2 and 3 summarize the effect of the various durations of time out on the number of S^{Δ} responses made during the CRF matching procedure. The curves connect the medians of the last five sessions on each time-out duration. The time out has little effect on the accuracy with which the bird matches except at TO 600 seconds, where the ratio of S^{Δ} to S^{D} responses reaches approximately 0.70 for Bird 83Y and 0.35 for Bird 84Y. The highest S^{Δ} levels occurred at TO 0.5 second. However, these may be due to incomplete exposure to the contingencies of the experiment, because the bird's first exposure to a time out was at this

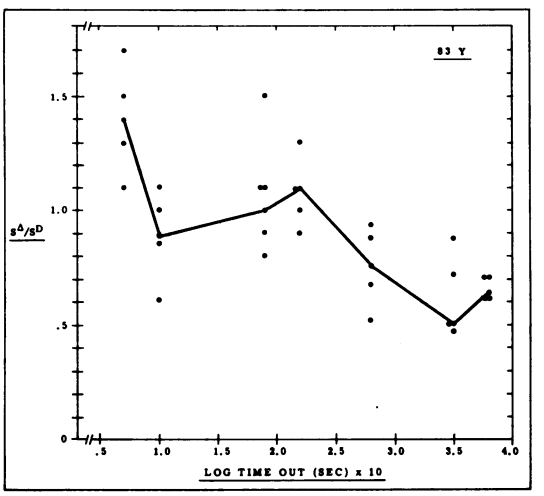

Figure 2. Bird 83Y. Relative amount of S^{Δ} responding as a function of the duration of the time out. Each point is the relative number of time outs during the final five sessions. The curve connects the median values.

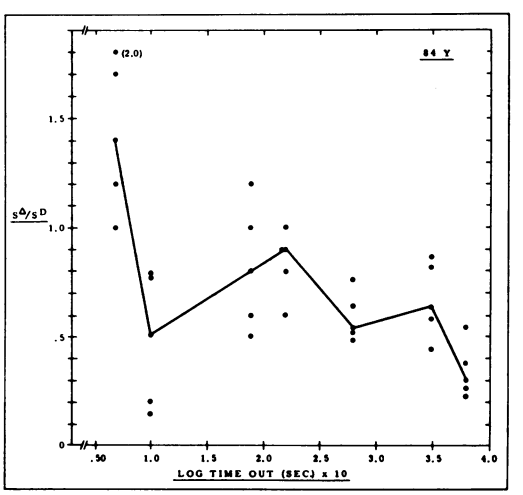

Figure 3. Bird 84Y. Relative amount of S^{Δ} responding as a function of the duration of the time out. Each point is the relative number of time outs during the final five sessions. The curve connects the median values.

value. The general level of S^{Δ} responding is of approximately the same order of magnitude as that under interval schedules of reinforcement without a time out (Ferster, 1960) except for the low S^{Δ} rate at TO 1 second for Bird 84Y. This low rate of S^{Δ} responding occurred after the exposure to TO 600 and may indicate a carryover from the effect of the larger time out.

Experiment II: The Effect of Varying Durations of Time Out on Matching to Sample Reinforced on VI 3

Figure 4 is a cumulative record of S^{D} responding during an entire experimental session. It shows the final performance for Bird 83Y on VI 3, with S^{Δ} responses followed by a time out at 1 second. This bird was previously reinforced on CRF, as described above in Experiment I, followed by five sessions on VI 1 and eight sessions on VI 3. The bird responds at an approximately constant rate of 20 matching sequences per minute, and the performance is sustained evenly except for slight pauses of approximately 10 seconds after reinforcement. The general effect of this schedule of reinforcement on the accuracy of the matching behavior (0.74 S^{Δ} response for each correct matching sequence) confirms the previous results reported with this schedule (Ferster, 1960). The range of S^{Δ}/S^{D} rates for the last 5 seconds on the VI 3 procedure was 0.74 to 1.02.

Figures 5 and 6 summarize the main effect of the duration of time outs on the accuracy with which the bird matches. Each duration of time out was determined at least twice, and separate curves are presented for each determination. Third and fourth determinations are presented in Table 1. The curves connect the medians of the last five sessions of each time-out duration. Time outs between 10 and 60 seconds produce a maximum increase in the accuracy of matching over the performance at TO 1 second. At TO 120 seconds, however, the performance is disrupted and the level of S^{Δ} responding increases to values of the order of those obtained at TO 1 second. The curves representing second determinations fall below the curves of the first determinations. Therefore, the continuous exposure to the matching procedure during the various time-out durations has generally improved the accuracy of matching. The form of the curve remains similar, however.

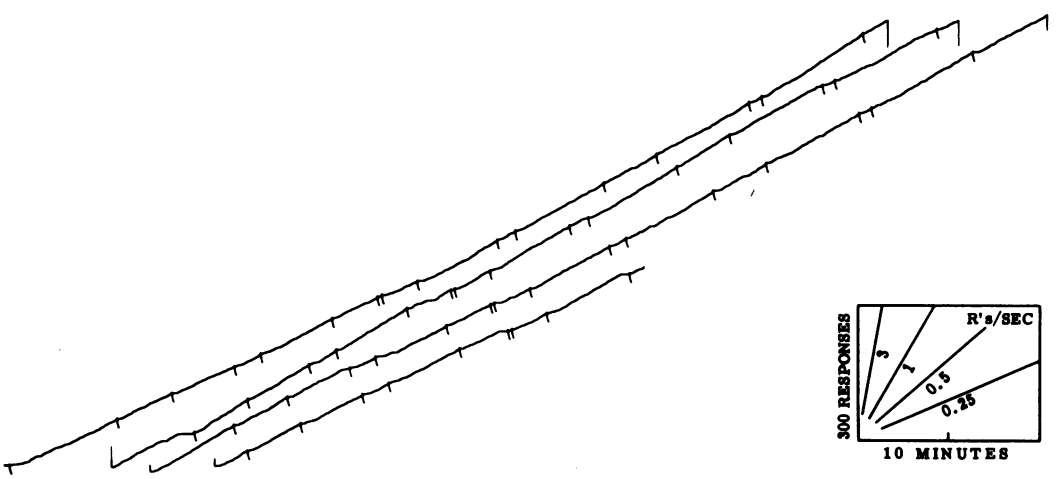

Figure 4. Bird 83Y. Cumulative record of an entire experimental session showing a stable performance on VI 3 with a 1-second time out after S^{Δ} responses.

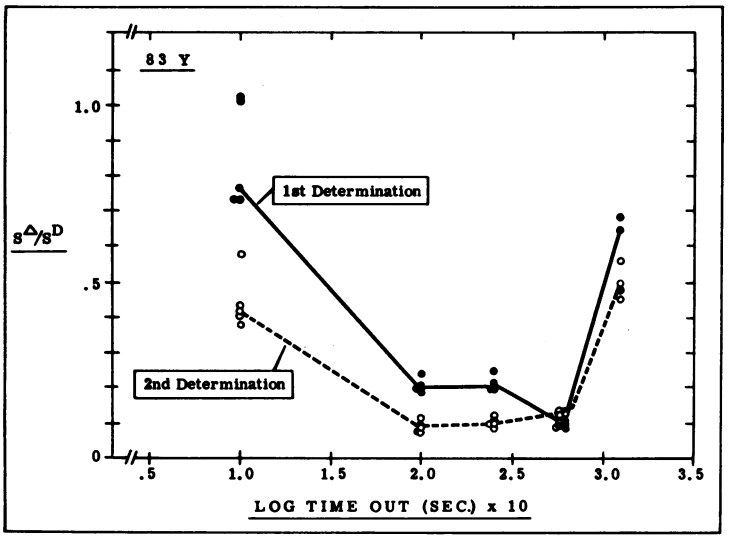

Figure 5. Bird 83Y. Accuracy of matching on VI 3 as a function of the duration of the time out. The two curves give data for two separate determinations. Each point gives the relative number of time outs for each of the last five sessions at each value of time out. The lines connect the median values.

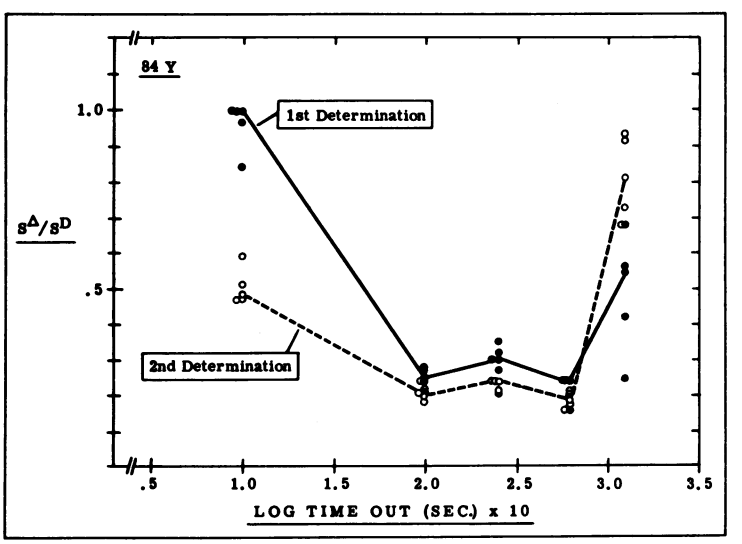

Figure 6. Bird 84Y. Accuracy of matching on VI 3 as a function of the duration of the time out. The two curves give data for two separate determinations. Each point gives the relative number of time outs for each of the last five sessions at each value of the time out. The lines connect the median values.

Figures 7 and 8 are over-all summaries of the experiment, comparable with Fig. 5 and 6, giving S^{D} and S^{Δ} rates of responding at the various durations of time out. The accuracy at which the bird matches the sample could result from either a decline in the level of S^{Δ} responding, an increase in the rate of S^{D} responding, or a combined decrease in the former and increase in the latter. Both figures show that the increase in matching accuracy pro-

Table 1

Third and Fourth Determinations of the Matching Accuracy at Various Durations of Time Out

Bird	Determination	Time Out (Seconds)	Median	Range
83Y	3	25	0.08	0.07–0.09
84Y	3	10	0.21	0.19–0.24
84Y	3	25	0.18	0.18–0.21
84Y	3	60	0.39	0.33–0.51
84Y	4	25	0.16	0.16–0.30
84Y	4	60	0.28	0.25–0.31

duced by the time out is due to both a decrease in S^{Δ} responding as well as an increase in the rate of S^{D} responding compared with the rates at TO 1 second. However, the large disruption in the accuracy of matching is due to the large fall in the S^{D} rate of responding rather than the increase in the amount of S^{Δ} responding. With S^{Δ} responses followed by TO 120 seconds, the over-all rate of matching to sample declines drastically below any of the values recorded at other durations of time out.

Figure 9 illustrates the initial effect of the exposure to TO 10 seconds before the subjects had been exposed to time outs other than 1 second. The 10-second time out continues to affect the performance for over 20 experimental sessions: the rate of S^{D} responding increases almost continuously, along with a corresponding (but briefer) decrease in the rate of S^{Δ} responding. The cumulative curves (reading from the bottom up) give 30-minute segments

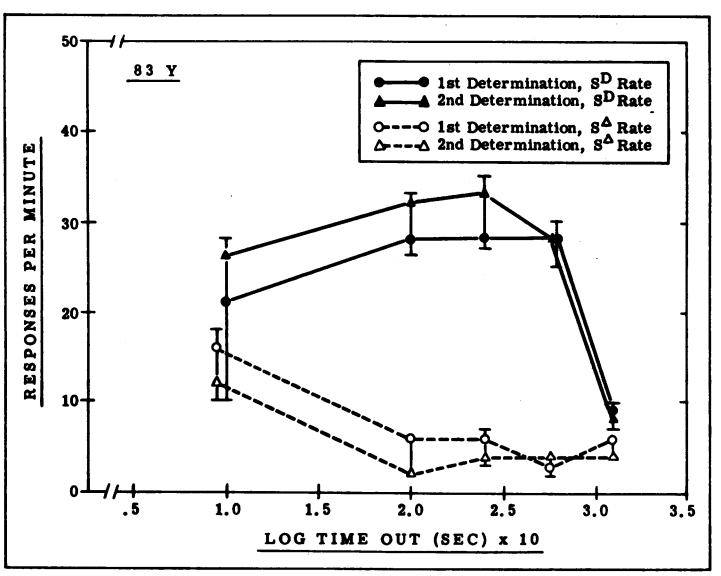

Figure 7. Bird 83Y. Median and range of rate of S^{D} and S^{Δ} responding as a function of the duration of the time out. The two curves give the first and second determinations.

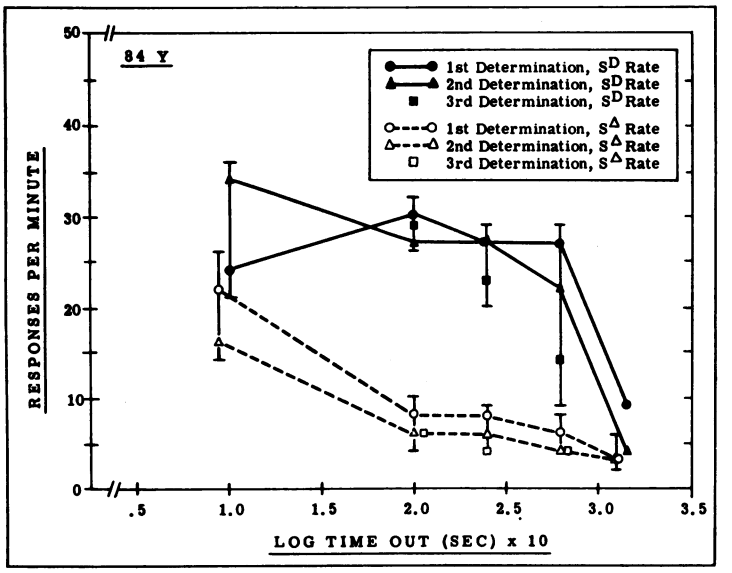

Figure 8. Bird 84Y. Median and range of rate of S^D and S^{Δ} responding as a function of the duration of the time out. The two curves give the first and second determinations. Three of the points were determined a third time, as indicated.

from the middle of every other experimental sessions represented in the graphic insert. In general, the performance remains stable and typical of the base-line variable-interval performance. The initial effect of the TO 10 seconds is a marked decline in the rate of S^D responding, as in a 120-second time out.

Figure 10 shows a second transition from TO 1 second to a larger time out (25 seconds). Here, the time out reduces the rate of S^{Δ} responding almost immediately as compared with the gradual decline in S^{Δ} responding during the first transition (Fig. 9). The rate of S^D responding also falls during the first session, but the order of magnitude of the fall is not so great as that which occurred previously. The recovery in rate of S^D responding is also more rapid than that occurring in Fig. 9: normal values appear by the sixth session. During 83Y's first exposure to TO 10 seconds the rate of S^D responding increased continuously for over 20 sessions.

The transition back to TO 1 from TO 25 occurs rapidly. Figure 11 shows the cumulative records of the transition following the sessions described in Fig. 10. The final performance at TO 25 is shown in the curve marked S^{Δ} (TO 25) and S^D (TO 25). During the next session, shown in S^{Δ} (TO 1) and S^D (TO 1), the duration of the time out was decreased to 1 second (at the arrow) after approximately 30 minutes. The rate of S^D responding did not change, but that of S^{Δ} responding increased slowly and continuously, reaching a maximum about 60 minutes after the time out had been reduced to 1 second.

Figure 12 shows in more detail the results of the 120-second time out and the return to a smaller-duration time out. The first exposure to TO 120 in the left panel of the figure occurs after a performance had been developed with TO 25. Except for the very first session for Bird 84Y, the longer time out does not affect the bird's performance immediately. By the second and third days, however, the rate of S^D responding falls sharply, reaching the lowest values at around the fifth to seventh experimental session. The rate of S^{Δ} responding is only

slightly affected. The return to TO 25 on the eighth session is given by the individual points (Day 8 on the abscissa). The performance immediately returns to the previously recorded values at TO 20 seconds. Also, the median range for the next five sessions (shown at the extreme right of the graph) show that it is subsequently stable on TO 25. The second transition to TO 120 seconds occurred after the previous exposure to TO 60. The result is similar to the first transition except that it is more rapid. The recovery of the performance after the return of TO 60, however, occurs much more slowly and is not complete even during the

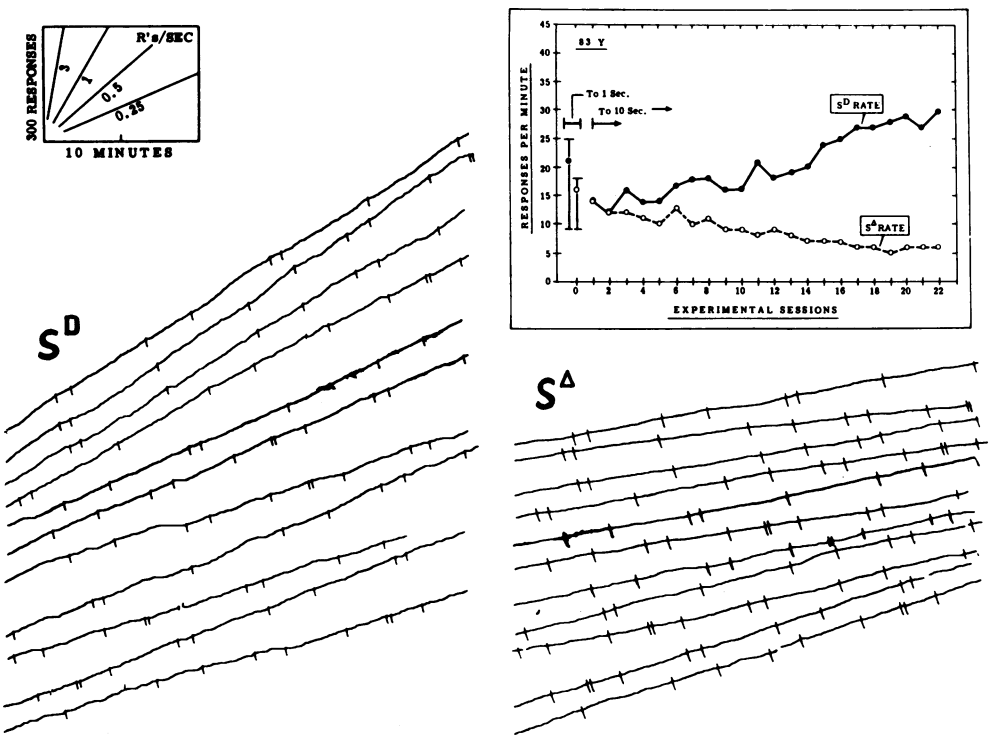

Figure 9. First effect of TO 10 after a stable performance on TO 1. The cumulative curves contain 30-minute segments from the middle of alternate daily experimental sessions. The curves are arranged in order from bottom to top. The average daily S^D and S^Δ rates of responding are given in the insert for the first 22 sessions of the TO 10 procedure. The first values on the graph give the median and range of the final five sessions on TO 1 just before TO 10.

next five sessions on the smaller value of time out. Both birds subsequently recovered the previous TO 60 values with further exposure to this value of time out. Bird 84Y again showed a greater sensitivity to the time out: the initial effect of the larger time out; the rate at which the final performance on the longer time out developed; and the rate of recovery from the long time out.

Figures 13 and 14 give details of the performance during the decline in S^D responding resulting from punishment by the long time out. Record A (S^D) and Record A (S^Δ) show the cumulative curves corresponding with initial effects of TO 20 already described in the left-hand panel of Fig. 12. Each daily session is represented by a 20-minute segment taken

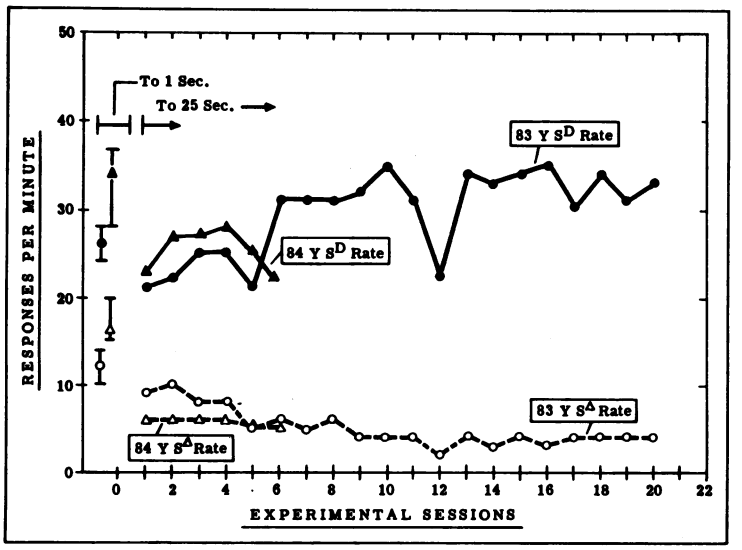

Figure 10. Second transition from TO 1 to a substantial time out. Each point is the median rate of responding for the daily experimental session. The initial points give the median and range of the mean rates of responding for the final five sessions on TO 1 before TO 25.

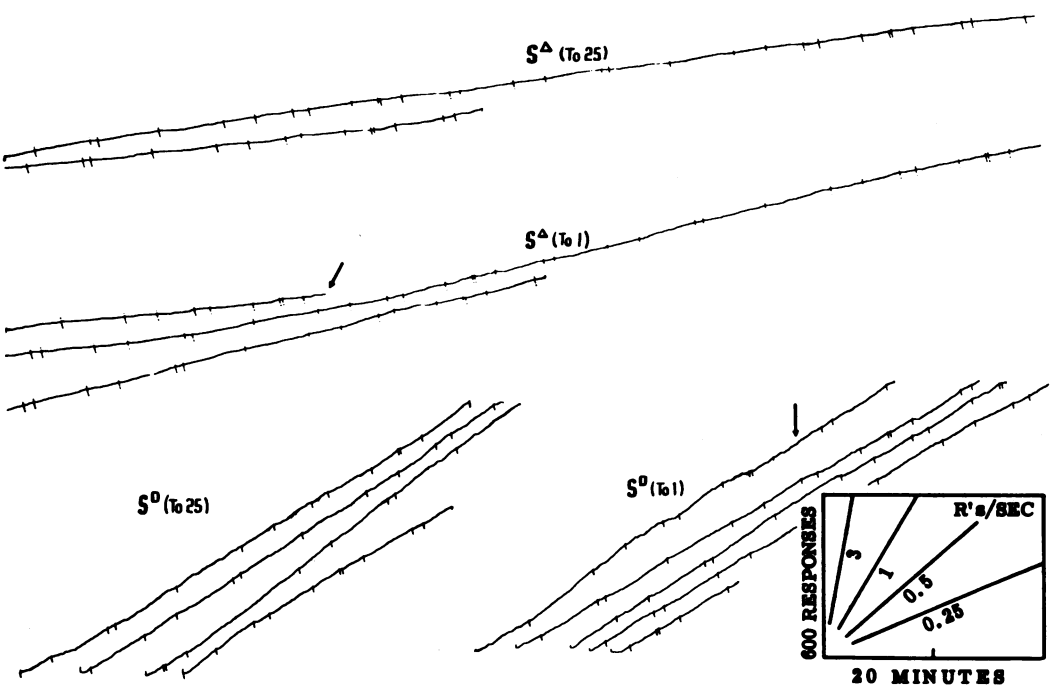

Figure 11. Transition from TO 25 to TO 1 showing an increased rate of S^{Δ} responding. The final S^{Δ} performance (complete experimental session on TO 25) is given by the S^{Δ} (TO 25) curve. The corresponding S^{D} performance is given by the S^{D} (TO 25) curve. After 30 minutes on the following session, the TO was decreased to 1 second (at the arrow).

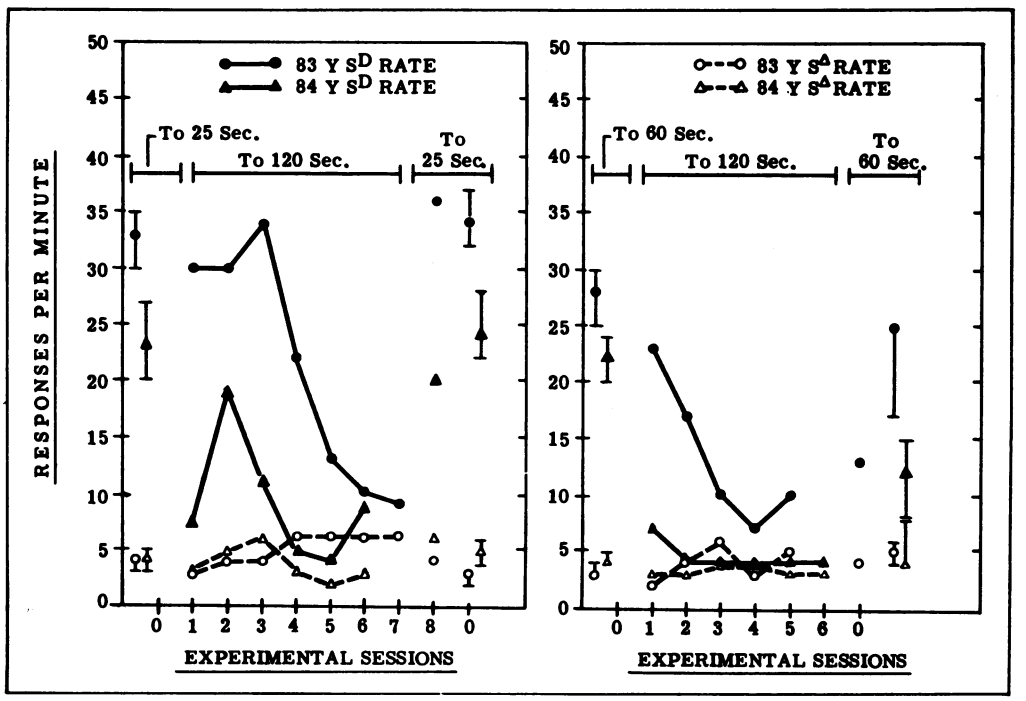

Figure 12. The disruptive effect of TO 120 seconds. The left-hand panel shows the transition from TO 25 seconds to 120 seconds, and the return to TO 25 seconds. The first points give the median and range of the final performance on TO 25 seconds (last five sessions). The eighth experimental session is the first performance on TO 25, and the final point is the median and range of the next five experimental sessions on TO 25. The right-hand panel gives the second exposure to TO 120 seconds (after 60 seconds). The initial values give the median and range of the final five sessions on TO 60. The sixth experimental session gives the first exposure to TO 60 after 120, and the final points give the median and range of the next five sessions on TO 60.

from the middle of the session. As the over-all rate of responding falls with further exposure to TO 120, the performance becomes irregular, with frequent pauses and bursts of responding. The level of S^Δ responding changes little except in Curves 5 to 8, where the rate increases. The recovery of the performance after the return to TO 25 is shown in Record B, where the duration of the time out is reduced at the arrow. The rate of S^D responding increases immediately, so that the final TO 25 performance is received at once. Figure 14 shows cumulative records of the first effect of TO 120 on Bird 84Y, whose S^D performance was disrupted by the very first experience with the long time out. Record A (S^D) and Record A (S^Δ) show the final VI 3 performance with S^Δ response followed by TO 25. The TO 120 punishment at the start of the following session, Record B (S^D) and Record B (S^Δ), immediately lowers the rate of S^D responding; and after 15 recorded minutes, the performance deteriorates even further. Except for a slight increase during the first 15 minutes, the S^Δ level of responding is not affected.

DISCUSSION

The effect of the time out when used as a punishment for S^Δ responding depended upon the base-line schedule of positive reinforcement. Under the punishment procedures, fewer

S^{Δ} responses occurred when matching was reinforced on VI 3 than on CRF. The differential effectiveness of the time out occurred even though both the CRF and VI 3 schedules produced approximately the same levels of S^{Δ} responding with brief time outs.

When matching was continuously reinforced, even when the punishment duration was 10 minutes, the pigeons' matching accuracy was not so great as when other schedules of reinforcement (e.g., fixed ratio) and brief time outs were used.

When the base-line performance was maintained on a VI 3 schedule of reinforcement, brief durations of time out were effective in producing accurate matching. A 10-second time out reduced the relative S^{Δ} levels of responding to approximately 0.20 compared with an S^{Δ} level in the range of 0.70 to 1.00 with TO 1 second. This confirms the finding that the base-line schedule of positive reinforcement is a major factor in the accuracy at which the bird matches the sample.

When the matching was maintained on the variable-interval schedule, the longer durations of time out had major effects on S^{D} responding. The disruptive effect of the TO 120 punishment is probably on the birds' over-all disposition to respond. The levels of S^{Δ} responding were already low. However, time outs in the range of 10 to 60 seconds differentially lower the S^{Δ} level of responding without major effects on the over-all rate. Even larger time outs (600 seconds) did not reduce the rate of pecking when the matching behavior was maintained on continuous reinforcement. Furthermore, the accuracy of the performance on CRF matching even increased over the levels recorded at shorter time outs. This is in contrast with the severe declines in the over-all rate of responding and accuracy of matching produced by TO 120 seconds on the VI 3 base line. This result may be related to general higher sensitivity of intermittently reinforced behavior to many independent variables compared with continuous reinforcement or small fixed ratios.

The effect of interval and ratio schedules of reinforcement on the accuracy of a matching

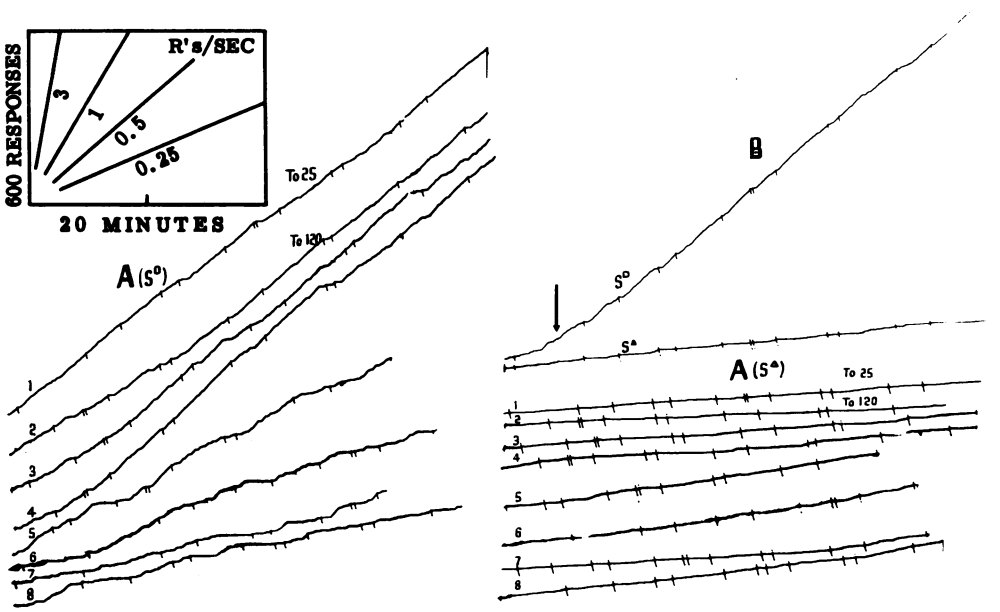

Figure 13. Bird 83Y. Cumulative curves showing the gradual disruptive effect of TO 120.

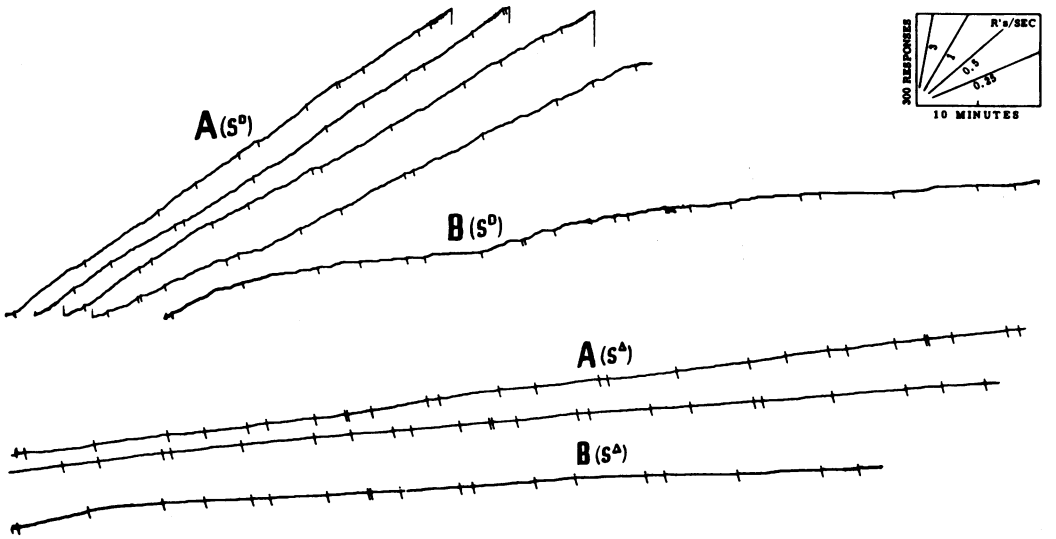

Figure 14. Bird 84Y. Cumulative curves showing the disruptive effects of TO 120. Record A shows the final performance on TO 25; Record B shows the first session on TO 120.

performance were correlated with the frequency of reinforcement under different S^{Δ} levels of responding (Ferster, 1960). Responding in S^{Δ} decreased the frequency of reinforcement in fixed-ratio schedules (high accuracy) but not in the fixed-interval schedules (low accuracy). A comparison of the VI 3 with the CRF results suggests that the over-all frequency of reinforcement resulting from the time-out procedures only partially determines the accuracy of the matching performance. The over-all frequency of reinforcement on CRF TO 10 is only one-half the frequency of reinforcement on VI 3 TO 2 and 25 per cent of the frequency of reinforcement on VI 3 TO 10, while the level of accuracy is much higher in the latter cases.

REFERENCES

Ferster, C. B. Intermittent reinforcement of matching to sample. *J. exp. anal. Behav.*, 1960, **3**, 259–272.
Skinner, B. F. Are theories of learning necessary? *Psychol. Rev.*, 1950, **57**, 193–216.

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