SUPPRESSION OF A PERFORMANCE UNDER DIFFERENTIAL REINFORCEMENT OF LOW RATES BY A PRE-TIME-OUT STIMULUS

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The data most relevant to the aversive properties of the time out are from chaining and schedule-preference experiments. Presumably, a time out from a preferred schedule of reinforcement might be more aversive than a time out from a less preferred schedule of reinforcement. Published experiments already have shown a wide disparity with which schedules of reinforcement are preferred. Findley (1958) and Herrnstein and Morse (1955) showed that they could sustain a performance whose reinforcement was the change from one schedule of reinforcement (less preferred) to another (more preferred). A similar preference is shown in chaining experiments where stimuli correlated with various schedules of reinforcement maintain different rates of responding on identical first numbers of the chains (Ferster & Skinner, 1957). Herrnstein (1955) varied the frequency of reinforcement in a variable-interval base line, and recorded increased relative rates of responding in the pre-time-out stimulus when frequency of reinforcement of the variable-interval schedule was decreased. Herrnstein interpreted the increased pre-time-out responding as evidence that the stimulus correlated with the low-frequency, variable-interval schedule of reinforcement became aversive instead of positively reinforcing, and hence the time out from this schedule became positively reinforcing. Ferster (1958) found that animals would stop responding toward the end of a pre-time-out stimulus and avoid a time out if a limited-hold procedure was used in respect to the time-out contingency. The time out from this variable-interval schedule of reinforcement also appeared to be aversive in a two-key experiment where a response on one key could prevent the schedule from terminating. It was possible to sustain avoidance responding whose rate was a function of the interval by which the avoidance response postponed the time out. The suppression of the responding during the pre-time-out stimulus as well as the successful avoidance on a second key of the time out questions Herrnstein's interpretation of positive reinforcement by the time out. The present experiment was an attempt to make the base line schedule of reinforcement less and less favorable by decreasing the mean value of the variable-interval schedule and adding successively longer DRL contingencies to see whether at extreme values these schedules are preferred over time outs. Both of these schedule factors would tend to make the schedule of reinforcement less preferred, as would be judged from chaining experiments (Ferster & Skinner, 1957) and preference experiments (Herrnstein & Morse, 1955). If the time out continued to be aversive regardless of how unfavorable or less favorable the schedule of reinforcement became, we would expect that the subjects would stop responding during the limited-hold part of the pre-time-out stimulus, so that no time outs would occur.

METHOD

The subjects of the experiment were two male monkeys, Maccaca Mullatta, weighing 5.3 and 6.3 kilograms, respectively, at the start of the experiment. Monkey M2 was underweight for its size, even at free feeding; it never responded at normal rates, even under the most severe levels of deprivation.

Reinforcement consisted of a 10-second access to a dipper containing 4 cubic centimeters of a liquid homogenate of Purina monkey chow, peanut oil, banana flakes, and water. Monkey M2 was run at 75–80%, and Monkey M3 at 70–75%, of free-feeding body weight. After each experimental session, they were fed a supplement of vitamins and enough Purina monkey chow to bring their weights to free-feeding values. The experimental session was 6–8 hours or 60 reinforcements, whichever occurred first.

Apparatus

The experimental space consisted of a refrigerator case on its side. All of the working components of the apparatus were mounted on a vertical panel which divided the inside of the refrigerator case. The animal's space was 16 by 24 inches and 19 inches high. The key was a Switchcraft Lev-R action switch, 7.5 inches from the floor and adjusted to 20 grams. Pressing the key broke a normally closed contact and produced an audible click. Stimuli were colored lights behind a translucent plexiglas panel on which the key was mounted. An overhead light illuminated the entire compartment. The magazine cup entered the cage through a 1-inch hole in a ledge on the front panel 4 inches to the right of the key and 4 inches from the floor. The motor driving the magazine produced a distinctive sound. During time outs, all of the lights in the box, cumulative recorders, and the click feedback on the key were disconnected.

Experimental Procedure

A stable performance was developed on a 6-minute, variable-interval schedule of reinforcement after continuous reinforcement. A pre-time-out stimulus (red light) then appeared every 18 minutes. During the first 45 seconds of the pre-time-out stimulus, responses could still be reinforced on the VI 6 schedule of reinforcement. However, any responses occurring during the 45th to 50th seconds produced a 60-minute time out, and could not be reinforced (fixed-interval, limited-hold reinforcement by the time out). A reinforcement that was programmed during the pre-time-out stimulus but not yet delivered was not available after a time out. The pre-time-out stimulus terminated without a time out if no response occurred during the 45th to 50th seconds. The experiment began after a final performance developed under the pre-time-out procedure: 9 sessions of variable-interval reinforcement; 47 sessions during which the duration of the pre-time-out stimulus was increased slowly from 4 seconds to 50 seconds; and 10 sessions at the final value. The procedure in the pre-time-out stimulus and the duration of the time out were kept constant throughout the experiment, while the size of the DRL and the mean of the variable-interval schedule of reinforcement were varied. The exact program of the experimental procedures is given in the body of Fig. 3 and 4.

RESULTS

Figures 1 and 2 show M2 and M3's final performance on VI 6 with the pre-aversive stimulus, confirming the results of earlier experiments on chimpanzees with the same procedure (Ferster, 1958). The pre-time-out stimulus either suppresses responding completely (Chimpanzee No. 67 and Monkey M2) or it suppresses responding only at the end of the pre-time-out stimulus where time outs may occur (Chimpanzee No. 97 and Monkey M3). Records A and B of the figures give the first and last 2 hours of the session, and Record C contains enlarged excerpts in the immediate vicinity of the pre-aversive stimulus from the middle part of the session for M2. The oblique marks indicate the start and end of the pre-time-out periods; reinforcements are not shown. The variable-interval base line is rough, with many sudden changes in rate and frequent pausing; the rate is moderate over-all, approxi-

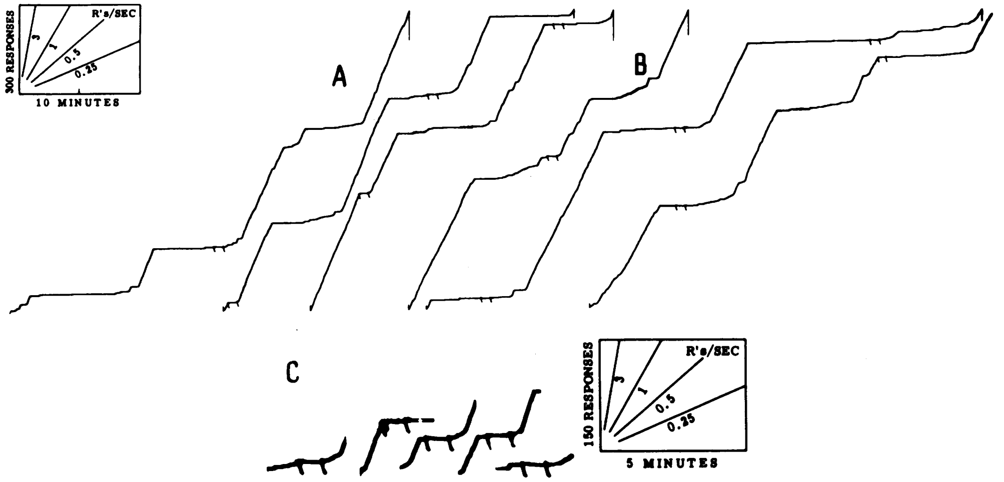

Figure 1. Monkey M2: final effect of the pre-aversive stimulus. Records A and B contain the first and last part of the experimental session. The middle part of the session is represented by the enlarged segments in Record C.

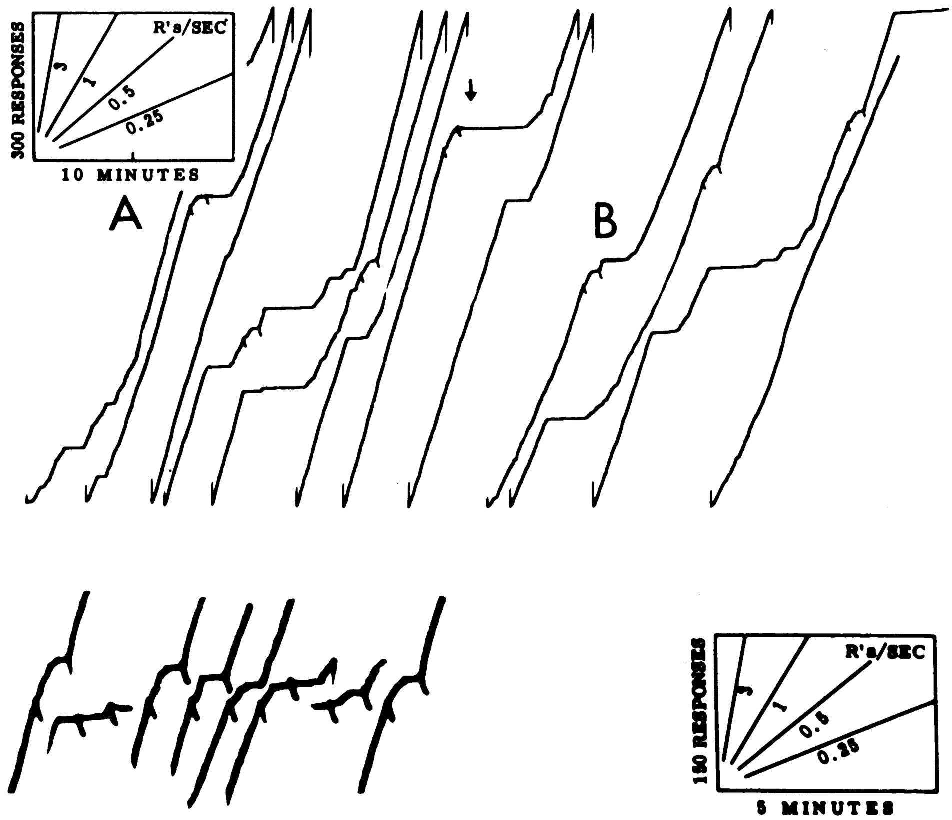

Figure 2. Monkey M3: final effect of the pre-aversive stimulus. Records A and B contain the first and last part of the experimental session. The middle part of the session is represented by the enlarged segments.

mately 0.5 response per second. All reinforcements are followed by a pause of about 60 seconds, probably because of competing magazine behavior. The pre-aversive stimulus completely suppresses the VI base-line performance. Monkey M3 (Fig. 2) responds faster than M2 at an over-all rate of about 1 response per second. Records A and B contain the first and last parts of a daily session, and the remaining middle part of the sessions is represented by the enlarged segments at the bottom of the figure excerpted in the region of the pre-time-out stimulus. As with M2, there are many pauses and sudden rate changes in the variable-interval base line. This monkey responds substantially early in the pre-time-out stimulus, and stops responding before the final 5 seconds, when responses produce time outs. Sometimes, the rate of responding during the initial part of the pre-time-out stimulus continues at the prevailing base-line rate; at other times, there is a shift to a slightly lower rate of responding. This animal occasionally continued to respond in the pre-time-out stimulus, thereby producing a time out, as, for example, at the arrow in Record A.

Figure 3 contains an over-all summary of the experiment for M2. The 75 sessions of the experiment are on the abscissa, and each point is an average value for the session. The upper curves give the over-all rate of responding and the rate during the pre-time-out stimulus. The bottom curve gives the pre-time-out rate relative to the over-all rate, and the bars give

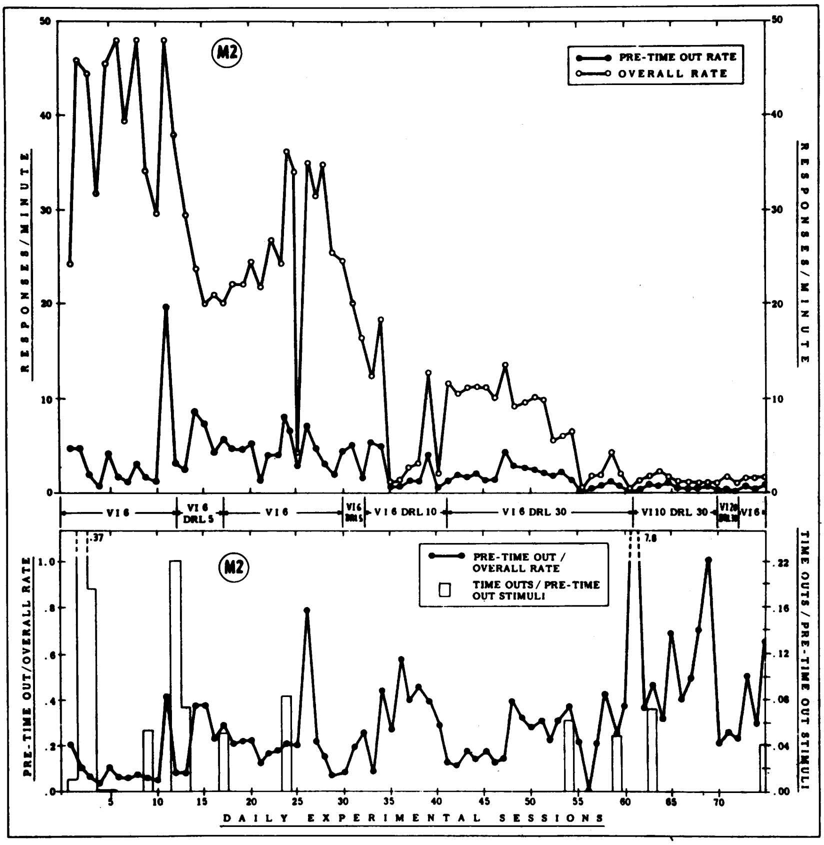

Figure 3. Monkey M2: summary graph of mean daily rates of responding and rates of responding in the pre-time-out stimulus. Each point is the mean of the daily session. The bars give the frequency of time outs.

the number of time outs in each session. The panel dividing the upper and lower graph gives the procedures in each session. The over-all rate of responding (upper curve) shows the characteristic decline produced by the DRL contingency and the decreased variable-interval schedule. There is also a corresponding decrease in the pre-time-out rate of responding. The relative rate of responding in the pre-time-out stimulus, however, increases markedly, especially during the final procedure on VI 10 DRL 30. Here, the pre-time-out rate is 40 to 80% of the over-all rate of responding as compared with much lower prevailing rates elsewhere, especially in the absence of the DRL. One exception occurs on the 26th session, when the over-all rate of responding was atypically low. In spite of the increased relative rate of responding in the pre-time-out stimulus, however, no change in the number of time outs occurs.

Figure 4 shows a similar result for M3, except that the pre-time-out rate of responding is even more resistant to the DRL reinforcement. During the period of the VI 6 DRL 30 reinforcement, the absolute value of the pre-time-out rate of responding ranged predominantly from 30 to 60% of the over-all rate of responding as compared with values of less than 10%. elsewhere. As with the other animal, the number of time outs did not increase, in spite of the marked rate increase in the pre-time-out stimulus.

Details of a final performance of M3 on the VI 6 DRL 5 procedure are shown in the cumulative curves of Fig. 5. The first part of the experimental session is shown in the top part of the figure, and the remainder of the session is represented by enlarged excerpts in the vicinity of the pre-time-out stimulus. The pen marker on the cumulative recorder is deflected both by the pre-time-out stimulus and reinforcements. As the over-all rate of responding falls with the exposure to the DRL, the initial rate of responding during the pre-time-out stimulus frequently exceeds the prevailing rate, as, for example, the 4th, 5th, 6th, and 7th enlarged segments. Of the 22 pre-time-out stimuli occurring during this session, five terminated with a time out because responding occurred during the last 5-second period. Two of the pre-time-out stimuli ending in a time out are shown in the upper part of the figure at the arrows. During the 22 pre-time-out periods, 608 responses were emitted. Figure 6 shows M3's performance on the VI 6 DRL 30 procedure just before the pre-time-out rate of responding reached its lowest values (three sessions preceding the VI 10 procedure). The records have been arranged to emphasize the performance in the pre-time-out stimuli by placing the segments with the pre-time-out stimuli in line. Except for brief periods, responding is at a very low constant rate of the order of a few responses per minute. Substantial responding occurs during the pre-time-out stimulus, however, with frequent segments beginning with rates of the order of 60 responses per minute. The rate of responding typically falls off toward the end of the pre-time-out, so that time outs seldom occur. During the 27 pre-time-out stimuli in the session, 523 responses and 4 time outs (at the arrows) occurred. A reinforcement occurs during the pre-time-out stimulus in the 6th segment of the 2nd column. Figure 7 shows the final DRL 30 performance for M3, 3 sessions after Fig. 6. By this time, responding in the pre-time-out stimulus has fallen to rates comparable with the over-all rate. Only 121 responses and 3 time outs (at the arrows) occurred during the 23 pre-time-out stimuli programmed during the session. A reinforcement occurred during the second pre-time-out stimulus. Substantial rates of responding still occurred during occasional pre-time-out periods, however, as, for example, two of the pre-time-out periods ending in time out. The final performance on VI 20 DRL 30 is shown in Fig. 8. The rate of responding during the pre-time-out stimulus falls to the lowest recorded values of the experiment, with 36 responses occurring during the 35 pre-time-out periods of the session. Three time outs oc-

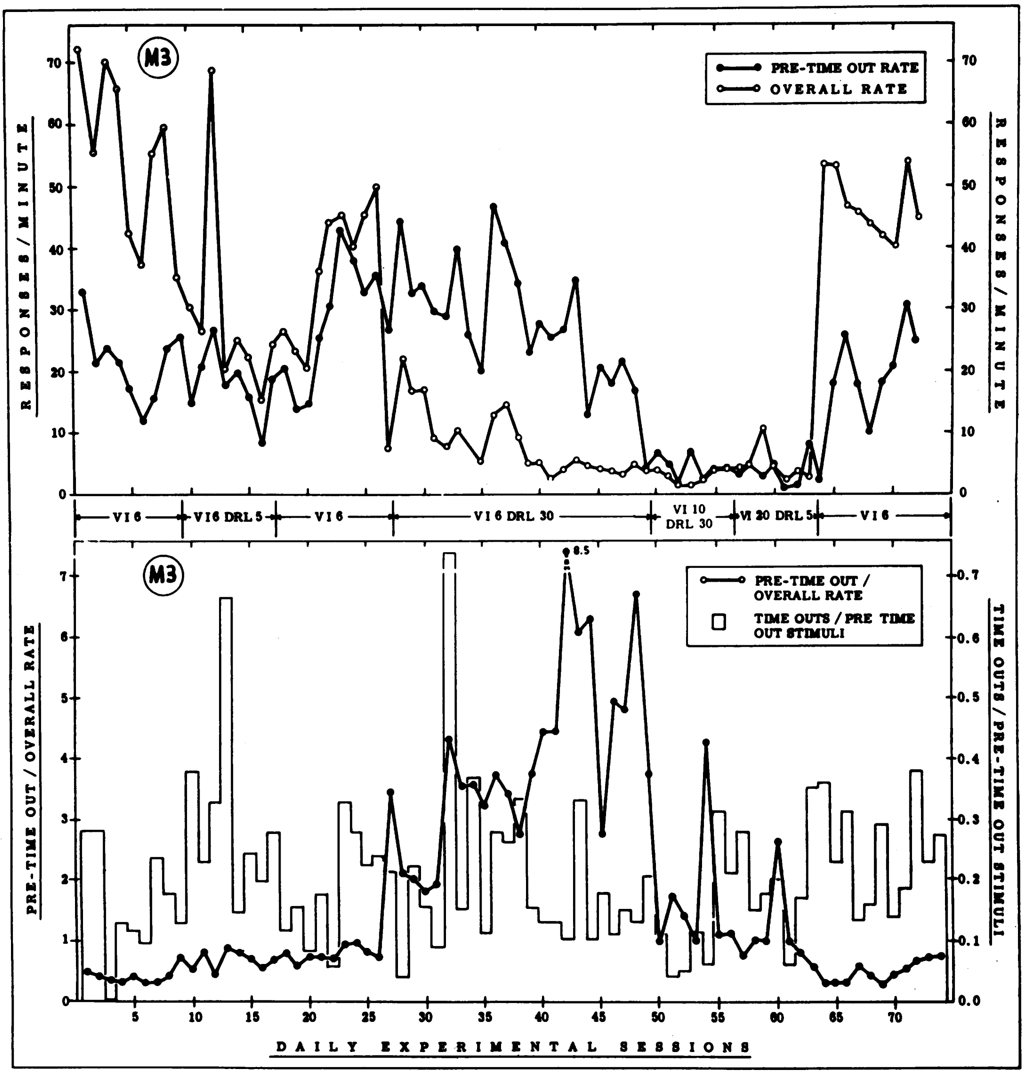

Figure 4. Monkey M3: summary graph of mean daily rates of responding and rates of responding in the pre-time-out stimulus. Each point is the mean of the daily session. The bars give the frequency of time outs.

curred (at the arrows). Figure 9 contains a performance from the second session, after the return to the original VI 6 schedule of reinforcement. When the DRL contingency was removed and the VI 6 schedule restored, the rate of responding increased rapidly. The performance in Fig. 9 is similar to the control performance recorded at the start of the experiment. The pre-time-out rate returns to the original values, but the over-all rate of responding is somewhat lower than in the control sessions. Most of the pre-time-out segments show the typical negatively accelerated curve. Responding generally ceases before the final 5 seconds of the pre-time-out period, when responses might produce time outs.

Figure 10 shows details of M2's performance during the VI 6 DRL 30 reinforcement period. Records A-1 and A-2 contain the beginning and end of the 4th session, before the

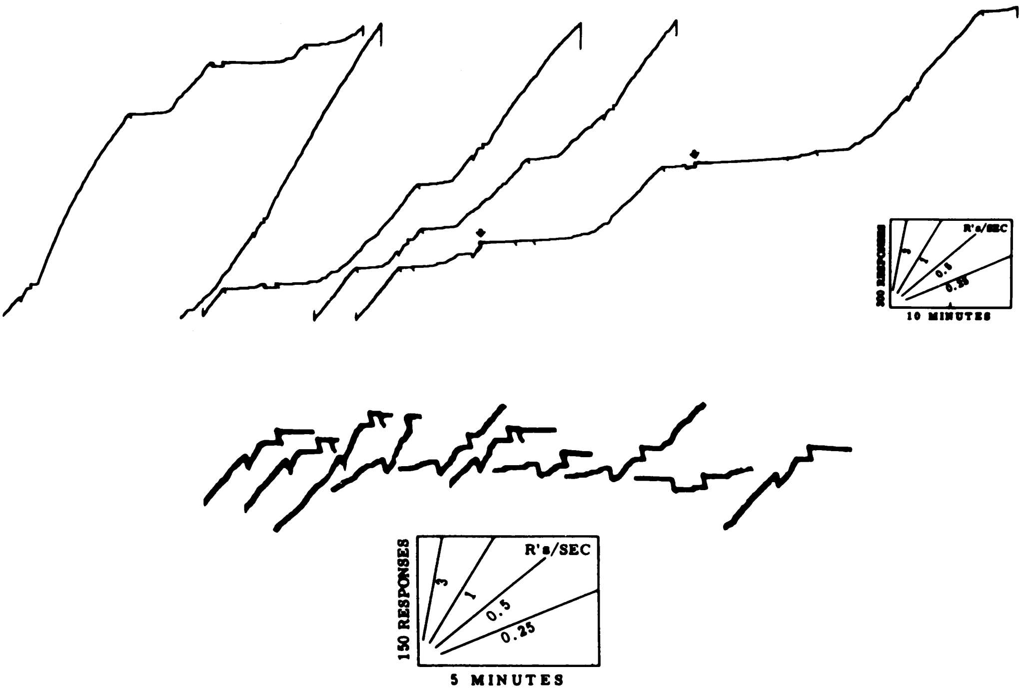

Figure 5. Monkey M3: final performance on VI 6 DRL 5. The top part of the figure contains the first part of the session, while the remainder of the session is shown in the bottom of the figure by the enlarged segments in the vicinity of the pre-time-out stimulus.

DRL 30 has had its final effect. The over-all rate of responding, in bursts of 10–15 responses separated by brief pauses, falls markedly during this session, reaching the low, steady rates of responding shown in Record A-2. Little responding occurs during the pre-time-out stimulus here as elsewhere during the experiment with this animal. Responses in the pre-time-out

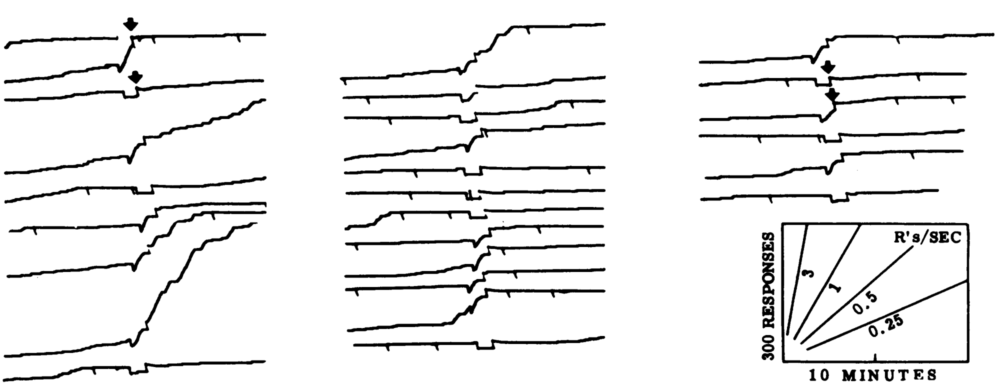

Figure 6. Monkey M3: a performance from a daily session just before the DRL 30 had its final effect. The cumulative curves are arranged to emphasize the performance in the pre-time-out stimulus. Each segment is a continuation of the previous one.

stimulus occur only in the first few seconds. The arrows in the figure indicate reinforcement occurring during the early part of the pre-time-out period. The performance shown in Record B occurs when the over-all rate of responding falls markedly after 20 sessions on the VI 6 DRL 30 procedure. Responding is still in small bursts, but the lengths of the runs are considerably reduced. No time outs occurred during either of these sessions.

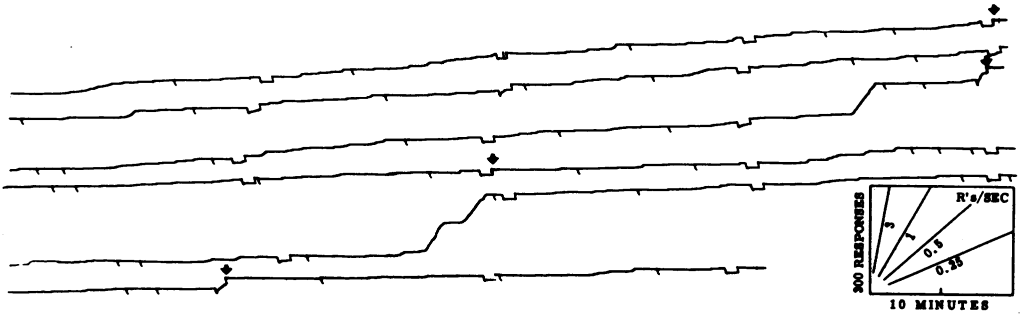

Figure 7. Monkey M3: an entire experimental session showing the final performance on VI 6 DRL 30.

DISCUSSION

The major finding of the experiment was that (1) the time out remained an aversive stimulus even under infrequent reinforcement with large DRL's; and (2) there is no evidence for any decrease in aversive properties of the pre-time-out stimulus as the DRL was increased and the frequency of reinforcement decreased. Both animals showed increases in the relative rate of responding in the pre-time-out stimulus; but this rate was not related to the number of time outs. Even when the absolute magnitude of the pre-time-out rate remained high, responding ceased during the last part of the pre-time-out stimulus when responses might pro-

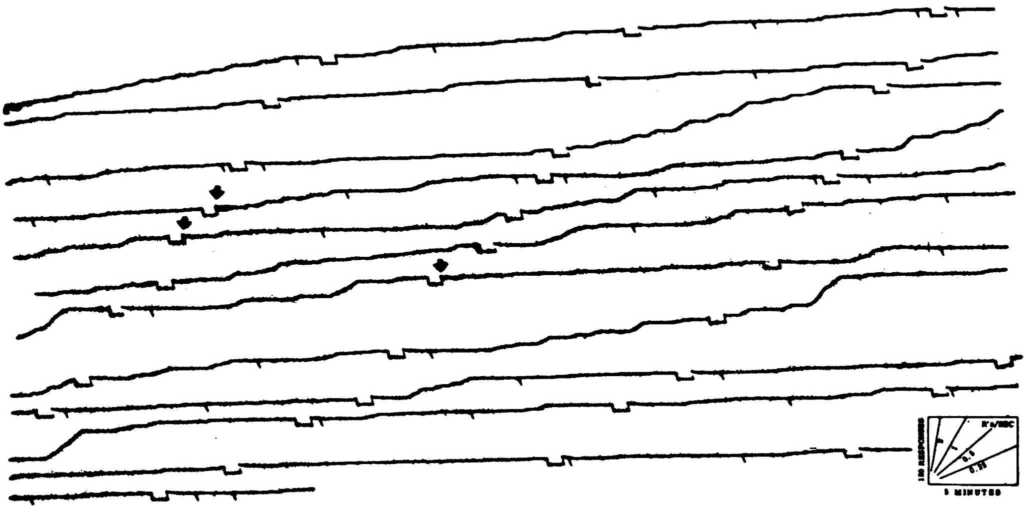

Figure 8. Monkey M3: an entire experimental session showing the final performance on VI 20 DRL 30.

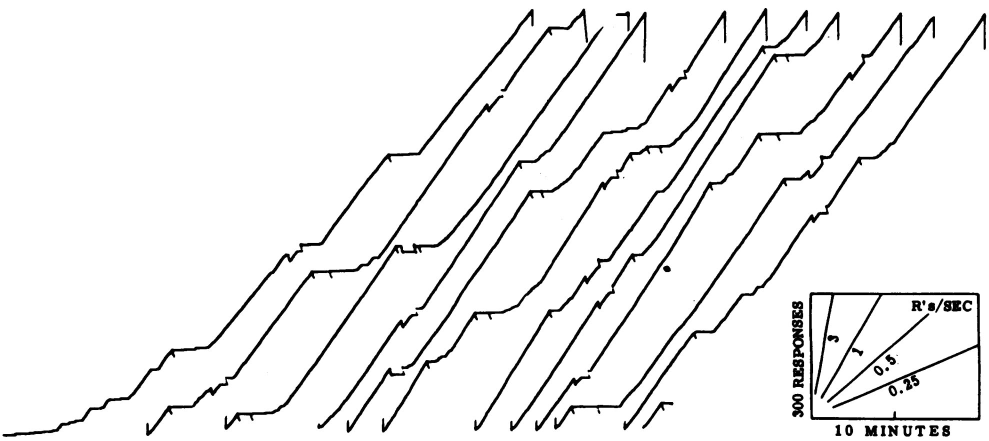

Figure 9. Monkey M3: the second session on VI 6 after discontinuing the DRL procedure.

duce time outs. All of the schedules of reinforcement used in this experiment were sufficiently reinforcing so that their discontinuation was aversive as measured by the effect of a pre-time-out stimulus. No explicit measurement was made, however, of the order of magnitude of reinforcement potentially available by a stimulus correlated with a schedule of positive reinforcement. Presumably, increasing the mean of the VI schedule from 6 to 20 minutes

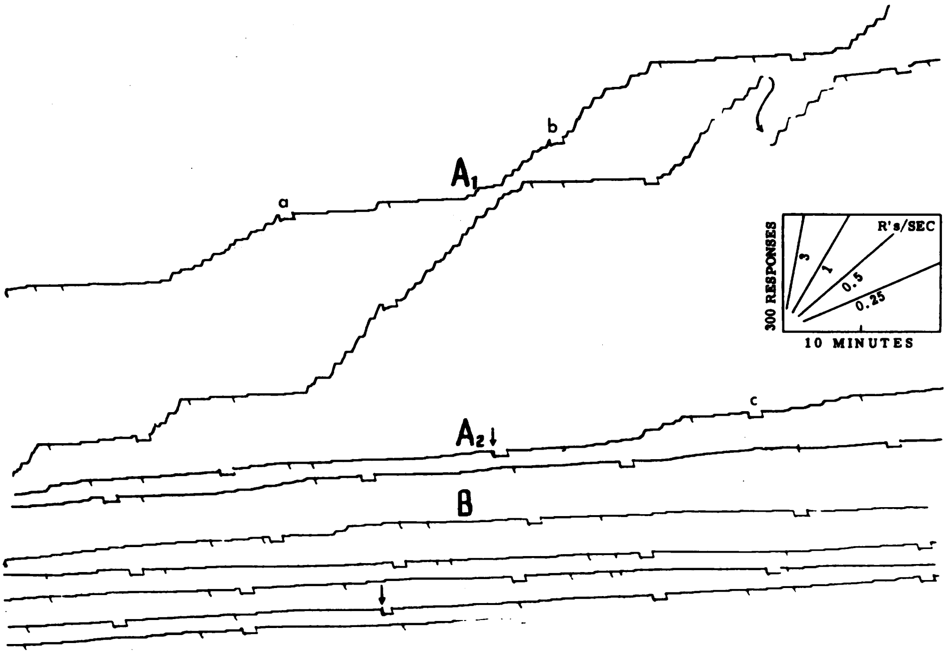

Figure 10. Monkey M2: cumulative curves of the performance on VI 6 DRL 30. Records A-1 and A-2 show six portions from the beginning and end of the fourth session, before the DRL has its final effect. Record B shows an entire session, illustrating the final effect of the DRL 30 contingency.

and the DRL to 30 seconds, reduces the reinforcing effects of a VI schedule of reinforcement; but the dimensions and order of magnitudes of reinforcing effect can not be specified in advance of direct measurement. It may be possible that the failure to show any change in the aversive properties of the withdrawal of the DRL and reduced frequency of the reinforcement schedules may occur because the main changes in reinforcing effects occur at frequencies of reinforcement less than 6 minutes, and thereafter more infrequent reinforcement does not materially lessen the reinforcing effects of the schedule. Chaining experiments are needed to relate how the reinforcing effect of a stimulus correlated with a schedule of reinforcement changes with different values of the schedule and different schedules. The rate of responding on a prior member of the chain would indicate how reinforcing the schedules of reinforcement were during the latter members of the chain. Such chaining experiments could provide independent evidence for how reinforcing a particular schedule of reinforcement might be.[1] At the same time, time outs from the more reinforcing schedules would be expected to be the most aversive. The measurement of the aversiveness of a time out, however, awaits development of technique of aversive control by time outs. At the present time, it may sometimes be difficult to determine when the lack of sensitivity of aversive control is due to an ineffective change in the range of the base-line schedule or to an insensitive technique of aversive control. It might be the case, for example, that rates of responding on a first member of a chain would not differ when the second member is reinforced on a VI 6 as compared with a VI 6 DRL 30, or even on a VI 6 as compared with VI 20 DRL 30; or that the main changes in responding on the first member of the chain occur as the frequency of reinforcement goes from very low means to VI 6.

In this experiment, the frequencies of reinforcement at which the pre-time-out stimulus continues to suppress the monkeys' behavior were at least as low as the lowest frequencies used by Herrnstein (1955). In Herrnstein's experiment the rate of responding during a pre-time-out stimulus increased as the mean of the variable-interval schedule increased. Herrnstein concluded that the pre-time-out rate increased because the time out from the low reinforcement-frequency schedules became positively reinforcing instead of aversive. This experiment differs from Herrnstein's in the species used. Furthermore, in this experiment the time out is on a limited-hold schedule, whereas in Herrnstein's experiment each pre-time-out period inevitably ended in a time out. Possibly, the increased pre-time-out rate in Herrnstein's experiment represents interactions between the schedule of reinforcement and the time out in regard to the specific inter-response time–reinforcement–time-out relationship (Ferster, 1955). Monkey M3's sustained responding at the start of the pre-time-out period may be related to the effect of the time out reported by Herrnstein.

The resistance of responding in the pre-time-out stimulus to the DRL contingency in the present experiment is indirect evidence for a secondary effect of a time out. Such increases in rate of responding have been observed elsewhere (Ferster, 1958) as explicit effects of a time out and in experiments on stimulus control where periods of reinforcement and nonreinforcement alternate (e.g., Ferster & Skinner, 1957, p. 526). Hanson's experiment (1959) on stimulus generalization shows a similar effect of interpolated periods of extinction on rate of responding in the reinforced stimulus. Where the wavelengths of S^D and S^Δ stimuli were sufficiently displaced, animals reinforced without interpolated extinction periods responded, on the average, approximately 60% slower than animals with a history of discrimination training. Monkey M3's highest rates of responding occurred in the first part of the

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[1] More accurately, the stimulus correlated with a schedule of reinforcement is more or less reinforcing.

pre-time-out stimulus, particularly when the over-all rate was low under the DRL reinforcement. The low pre-time-out rate of M2, which did not respond substantially in the pre-time-out stimulus at any time during the experiment, may be related to the low rate of responding of this animal in general, and its greater sensitivity to the time out. Monkey M2's performance is generally similar to that of Chimpanzee No. 67 (Ferster, 1958), whose pre-time-out responding was low but which also showed strong aversive control by time outs in avoidance and punishment experiments. The sensory superstition, reported by Morse and Skinner (1957), may be a large factor in the kind of control exerted by a pre-time-out stimulus. The accidental reinforcements occurring in the pre-time-out stimulus produce larger rate changes than the time out. In the case of M2 and M3, however, the change from higher to lower rates of responding in the pre-time-out stimulus is evidence that the time out is the major factor in the control of the pre-time-out rate.

SUMMARY AND CONCLUSIONS

The suppressive effect of a pre-time-out stimulus on a variable-interval base line was measured as a function of reinforcement on a VI DRL 5 to 30 seconds and a reduction in the frequency of reinforcement from VI 6 to VI 20. The monkey could avoid time outs by not responding during the last part of the pre-time-out period. Both subjects continued to avoid time outs throughout the experiment, giving no evidence that the time out became less aversive as the schedule of reinforcement was made less favorable.

REFERENCES

Ferster, C. B. Control of behavior in chimpanzees and pigeons by time out from positive reinforcement. Psychol. Monogr. 1958, **72**, No. 14 (Whole No. 461).

Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement.* New York: Appleton-Century-Crofts, 1957.

Findley, J. An intermediate restraining device for working with monkeys. *J. exp. anal. Behav.*, 1959, **2**, 121-125.

Hanson, H. M. Effects of discrimination training on stimulus generalization. *J. exp. Psychol.*, 1959, **58**, 321-334.

Herrnstein, R. J. Behavioral consequence of removal of a discriminative stimulus associated with variable-interval reinforcement. Unpublished doctoral thesis, Harvard Univer., 1955.

Herrnstein, R. J., and Morse, W. H. A technique for studying the preferability of schedules of intermittent reinforcement. Paper read at Eastern Psychol Ass., Philadelphia, April, 1955.

Morse, W. H., and Skinner, B. F. A second type of superstition in the pigeon. *Amer. J. Psychol.*, 1957, **70**, 308-310.

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