RESPONDING IN THE SQUIRREL MONKEY UNDER FIXED-RATIO SCHEDULES OF STIMULUS TERMINATION¹

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Key pressing was maintained under a fixed-ratio schedule in which electric shock was scheduled for delivery at a fixed time (t seconds) after each stimulus onset, and every n^{th} response terminated the stimulus and initiated a timeout from shock. Under this procedure, the higher the rate of responding, the briefer the duration of the stimulus presentation and the lower the frequency of shock delivery. The effects of several schedule parameters were studied to determine whether the maintenance of responding was dependent on an inverse relation between response rate and shock frequency. Shock rate and shock frequency were made independent of response rate by decreasing the value of t to 0.5 second and delivering shock only during the first presentation of the stimulus after a fixed time, including stimulus and timeout durations, had elapsed since the previous shock. The experiments showed that shock frequency and response rate are inversely related when t is of relatively long duration compared to the value of the fixed-ratio parameter, but that a decrease in shock rate or frequency due to a high rate of responding is not necessary for the maintenance of responding under a fixed-ratio schedule of stimulus termination.

Key words: fixed-ratio schedule, schedule of stimulus termination, fixed-ratio escape, schedule complex, response-independent electric shock, squirrel monkey

When electric shock is delivered intermittently in the presence of a distinctive stimulus and responses on a designated key can terminate the stimulus for a brief period of time, rates and patterns of responding characteristic of the schedule under which the stimulus is terminated can be maintained. Azrin, Holz, and Hake (1962), Azrin, Holz, Hake, and Aylton (1963), Kelleher and Morse (1964), and Morse and Kelleher (1966) described schedules under which responding in the squirrel monkey was maintained at a high rate when the n^{th} response terminated a stimulus associated with the delivery of response-independent electric shock and initiated a period free of shock (timeout). The pattern of responding in the presence of the shock stimulus was like the pattern maintained under a fixed-ratio (FR) schedule of food presentation. Following onset of the stimulus, there was a brief period of no responding; then, responding occurred at a high, steady rate until a response terminated the stimulus.

These studies showed that high response rates and FR patterns of responding can be maintained under an FR schedule of escape or stimulus termination, and also identified variables that can affect performance. Azrin *et al.* (1963) reported, for example, that response

rates decreased when shock was scheduled less than twice per hour. A major difficulty in interpreting the data on shock frequency in these experiments, however, is that shock frequency was modulated by response rate. In the Azrin *et al.* (1962) and Azrin *et al.* (1963) studies, electric shock was delivered at variable times after onset of the shock stimulus according to a tape timer that operated only during presentation of the stimulus. Although this procedure controlled the average number of shocks delivered during a given amount of time the stimulus was available to the subject, the duration of presentation of the stimulus and, consequently, the frequency of shock were a function of response rate. The higher the rate of responding, the briefer the duration of the stimulus presentation and the lower the frequency of shock delivery. Azrin *et al.* (1963) reported a 40% reduction in shock frequency for one monkey that responded at a mean rate of four responses per second. In the Kelleher

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and Morse (1964) and Morse and Kelleher (1966) studies, shock was scheduled for delivery at a fixed time after each onset of the stimulus. The time between stimulus onset and shock delivery was sufficiently long that responding at a high rate could terminate the stimulus before the delivery of shock, thus decreasing shock frequency. Therefore, a variable or event that affected response rate could also affect shock frequency under these procedures. To determine whether a decrease in shock frequency due to an increased response rate was necessary for the maintenance of responding under a schedule of stimulus termination, a procedure making shock rate and shock frequency independent of response rate was devised and studied. Responding was maintained by arranging for shock to occur during the first presentation of the stimulus after T min, including the stimulus and timeout durations, had elapsed since occurrence of the previous shock.

METHOD

Subjects

Two mature, female squirrel monkeys (*Saimiri sciureus*) were housed in individual cages where food and water were always available. The monkeys (SM-92 and SM-94) were handled according to the procedures described by Kelleher, Gill, Riddle, and Cook (1963).

Apparatus

The experiment was conducted in a ventilated chamber containing a Plexiglas restraining chair of the type described by Hake and Azrin (1963) and Kelleher and Morse (1964). When seated in the chair, the monkey faced an aluminum wall supporting a response key (Lehigh Valley Electronics, LVE #1352) and a stimulus panel (Industrial Electronic Engineers, Model 10256Q). The response key was 5 cm above the waist plate of the chair and 3 cm below the bottom of the stimulus panel; both the response key and the panel were equidistant from the sides of the chair. Each depression of the key with a force of at least 0.19 N registered a response and operated a feedback relay. A small stock held the monkey's tail motionless so that an electric current could be passed through two brass plates resting on a shaved area approximately 6 to 12 cm from the tip of the tail. Electrode paste (EKG Sol)

applied to the shaved area minimized changes in resistance between the monkey and a 650-V ac, 60-Hz shock source. A 25-W lamp (GE #101F), located on the ceiling to the rear of the monkey, illuminated the chamber. Continuous white noise and an exhaust fan masked extraneous sounds. Electromagnetic relay equipment in a remote room controlled events in the chamber.

Procedure

During daily sessions of 100 to 120 min, electric shock (200 msec, 6 mA) was delivered to the monkey's tail when both a red disk was present intermittently (940 msec on; 60 msec off) on the stimulus panel and the houselight was dimmed by the addition of a 600-ohm series resistor (shock stimulus). When a green disk was continuously present on the panel and the houselight was bright (series resistor omitted), shock was never delivered and responses (key presses) had no scheduled consequences (timeout). During initial training, shock was delivered every 15 sec, and the first response in the presence of the shock stimulus (red disk and dim houselight) terminated that stimulus and initiated a brief timeout (green disk and bright houselight). As rate of responding increased, duration of the timeout, number of responses required to terminate the shock stimulus, and time between shocks were increased. Before the present experiment, responding was maintained at various timeout durations and at various parameter values of the fixed-ratio schedule.

During the present experiment, shock was delivered according to two temporal parameters, T and t . First, shock could be delivered only during the first presentation of the stimulus after a fixed amount of session time (T min) had elapsed since the previous shock. Specifically, a clock began timing an interval (T min) at the beginning of the session, and ran continuously during presentation of the shock stimulus and timeout periods. When T min had elapsed, the clock arranged for a shock to be delivered to the monkey independently of responding during the next stimulus presentation. The clock timing interval T reset upon shock delivery and began timing another shock interval. Accordingly, when $T = 1$ min and timeout duration was 75 sec, shock could be delivered during each presentation of the stimulus, since the 75-sec timeout required

Table 1

Schedules under which shock was delivered and the shock stimulus was terminated, and the sessions each was studied for squirrel monkeys SM-92 and SM-94. The notation $T = 20$ min: $t = 1.0$ sec indicates that shock was delivered during the first presentation of the stimulus after 20 min had elapsed since the previous shock, and that 1.0 sec intervened between stimulus onset and shock delivery.

Variable	Schedule	Shock Interval		Sessions	
				SM-92	SM-94
FR size	FR 10	$T = 1$ min:	$t = 10.0$ sec	1- 13	1- 13
	FR 3	$T = 1$ min:	$t = 3.0$ sec	14- 26	14- 26
	FR 30	$T = 1$ min:	$t = 30.0$ sec	27- 34	27- 34
t^1	FR 30	$T = 20$ min:	$t = 1.0$ sec	35- 69	35- 69
		$T = 10$ min:	$t = 1.0$ sec	70- 74	70- 74
		$T = 10$ min:	$t = 0.5$ sec	75- 79	75- 79
		$T = 10$ min:	$t = 5.0$ sec	80- 84	80- 84
		$T = 1$ min:	$t = 30.0$ sec	85	—
		$T = 30$ min:	$t = 7.0$ sec	86- 98	—
		$T = 30$ min:	$t = 5.0$ sec	—	85- 98
		$T = 30$ min:	$t = 0.5$ sec	99-133	99-133
T^2	FR 30	$T = 1$ min:	$t = 20.0$ sec	134-142	134-142
		$T = 100$ min:	$t = 0.5$ sec	143-156	143-156
		$T = 30$ min:	$t = 0.5$ sec	157-174	157-174
		$T = 10$ min:	$t = 0.5$ sec	175-184	175-184
		$T = 3$ min:	$t = 0.5$ sec	185-194	185-194
		$T = 1$ min:	$t = 0.5$ sec	195-208	195-208
		$T = 3$ min:	$t = 0.5$ sec	209-214	209-214
		$T = 30$ min:	$t = 0.5$ sec	215-230	215-230

¹Time between stimulus onset and shock delivery.

²Time between successive shocks.

that more than 1 min would elapse between successive stimulus presentations. When $T = 30$ min, at least 30 min of session time elapsed between successive shock deliveries. In addition to the temporal parameter T , if shock was to be delivered during a given stimulus presentation, the second parameter specified that the shock would be delivered precisely t sec after stimulus onset. If the stimulus was terminated before t sec had elapsed, the shock was not delivered during that stimulus presentation.

FR size. The first part of the experiment was conducted to determine the effect of changes in the fixed-ratio (FR) parameter value when shock was scheduled during each stimulus presentation ($T = 1$ min), and the relation between mean response rate and probability of shock delivery was held constant. The time (t sec) between stimulus onset and shock delivery covaried with the FR value, so that the response-rate requirement to terminate the stimulus in less than t sec was constant (1.0 response per second) at all FR values studied. Initially, the schedule was FR 10 and t was 10 sec. After 13 sessions, the parameters were changed to FR 3 and 3 sec. Later (Sessions 27 to 34), the sched-

ule was FR 30 and t was 30 sec. Timeout duration was always 75 sec.

Time (t) between stimulus onset and shock delivery. During the remainder of the experiment, the FR value was 30 responses and changes in the values of t and T were studied to determine effects on rates and patterns of responding. During Sessions 35 to 69 (Table 1), the time T between consecutive shock deliveries was 20 min; intervals of 10 or 30 min were studied during Sessions 70 to 133. The parameter t was 1.0 sec during Sessions 35 to 74 and either 0.5, 5.0, or 7.0 sec during Sessions 75 to 133. Various values of the temporal parameters (T and t) were studied in an attempt to determine the effect of each parameter on the maintenance of FR rates and patterns of responding.

Time (T) between successive shocks. Once data had been obtained indicating parameter values at which FR responding could be maintained under this procedure, an attempt was made to determine the limits of T under which responding could be maintained. The time T between successive shock deliveries was varied systematically between 1 and 100 min, while

the time t between onset of the shock stimulus and delivery of the shock remained 0.5 sec. Since the interval T was timed from the beginning of the session, shock was always delivered at the end of the session when T was 100 min. When T was 1 min, shock was delivered during each stimulus presentation. All procedures are summarized in Table 1. Each procedure remained in effect until inspection of the cumulative records and mean response rates indicated little change during four successive sessions.

RESULTS

FR size. When the n^{th} response terminated a stimulus in the presence of which brief electric shock was scheduled for delivery t sec after each stimulus onset ($T = 1$ min) and a 75-sec timeout followed each termination of the stimulus, high rates of responding were maintained in the presence of the stimulus. At the three FR values studied, onset of the stimulus was followed by a very brief period of no responding; then, responding occurred at a steady rate that persisted until termination of the stimulus (Figure 1). There was seldom any responding during timeout periods. Mean response rates in the presence of the stimulus were highest when shock was delivered 30 sec (t) after stimulus onset and the thirtieth response terminated the stimulus; rates were lowest when shock was delivered 3 sec (t) after stimulus onset and the third response terminated the stimulus (Figure 2). This monotonic relation between response rate and FR value was obtained even though the response-rate requirement was constant for the three sets of values, *i.e.*, a mean rate in excess of 1.0 response per second was adequate to terminate the stimulus before t sec had elapsed and shock was delivered. In spite of this constant relation between shock probability and response rate, responding increased from approximately 2.0 responses per second during the last four sessions under FR 3 to 3.5 (SM-92) and 5.0 (SM-94) responses per second under FR 30. Moreover, shock frequency did not remain constant and independent of FR value and response rate. Shock averaged 0.54 per session under FR 3, 0.43 per session under FR 10, and 0.13 per session under FR 30. These data suggest, therefore, that shock frequency and response rate are inversely related when t is of relatively

long duration compared to the size of the FR schedule.

Time (t) between stimulus onset and shock delivery. When the delivery of shock 30 sec after stimulus onset was omitted after Session 34 and, instead, shock was delivered 1.0 sec (t) after stimulus onset during the first stimulus presentation after 20 min (T) had elapsed (Sessions 35 to 69), response rates in the presence of the stimulus and during timeout increased. During the second to fourth sessions with $T = 20$ min and $t = 1.0$ sec (see Table 1), response rates during the shock stimulus reached a maximum of 4.17 (SM-92) and 6.55 (SM-94) responses per second, and rates during the timeout increased to 0.44 (SM-92) and 0.25 (SM-94) response per second. Response rates then decreased during the next several sessions and eventually became stable at a lower level. During the last four sessions (Sessions 66 to 69), mean rates of 1.94 (SM-92) and 2.61 (SM-94) responses per second were maintained in the presence of the shock stimulus, even though a high rate of responding could not result in a decrease in the frequency of shock delivery. Responding during the timeout periods persisted during the 35 sessions that this procedure was in effect (Sessions 35 to 69, Table 1), and during the last four sessions averaged 0.09 (SM-92) and 0.02 (SM-94) responses per second. Moreover, response rate during timeout periods was positively accelerated, *i.e.*, a period of no responding at the beginning of the timeout was followed by a gradual increase in responding that persisted until the end of the timeout period. Responses during successive 15-sec periods of the 75-sec timeout were recorded separately, and quarter life, the point in the timeout at which the first one-fourth of the timeout responses had occurred, was determined via linear interpolation. Quarter life (Gollub, 1964; Herrnstein and Morse, 1957) had a mean value of 78% (SM-92) and 50% (SM-94) during the last four sessions (Sessions 66 to 69). Cumulative records showing performance under this procedure comprise Figure 3. Typically, shock delivery occurred during the brief period of no responding following onset of the shock stimulus, and a high rate of responding was initiated after the shock. Consequently, shock delivery seldom occurred during responding.

When the time (T) between consecutive shock deliveries was decreased to 10 min but

Fig. 1. Effect of changes in FR parameter value on performance of SM-92 under a fixed-ratio schedule of stimulus termination. Cumulative records show performance when: (top) electric shock was delivered 3 sec after onset of the stimulus ($t = 3$ sec) and the third response terminated the stimulus; (middle) $t = 10$ sec and the tenth response terminated the stimulus; and (bottom) $t = 30$ sec and the thirtieth response terminated the stimulus. Onset and termination of the shock stimulus are indicated by diagonal marks of the response pen.

the time (t) between onset of the shock stimulus and delivery of shock remained 1.0 sec (Sessions 70 to 74), performance changed little for either monkey. Except for a decrease in response rate during timeout periods, rates and patterns of responding were similar to those maintained when T was 20 min. When T was 10 min but t was decreased to 0.5 sec (Sessions 75 to 79), performance in the presence of the shock stimulus and during the timeout periods changed little. During the last four sessions, mean response rates in the presence of the shock stimulus were approximately 1.46 (SM-92) and 2.43 (SM-94) responses per second, and patterns of positively accelerated responding occurred occasionally during timeout periods.

Increasing t to 5.0 sec during Sessions 80 to 84 enhanced responding in the presence of the shock stimulus by SM-94. Response rate for this monkey increased enough initially (4.63 responses per second) that shock typically occurred near the end of the ratio run when t was 5.0 sec, and occasionally, 30 responses were emitted before 5 sec had elapsed. The resultant effect was an increase in response rate and a decrease in the frequency of shock delivery when t was 5.0 sec (Figure 4). For SM-92, however, mean response rate in the presence of the shock stimulus became more variable and response patterns were less uniform when the time (t) between onset of the stimulus and delivery of shock was increased to 5.0 sec (Sessions

Fig. 2. Effect of changes in parameter value of a fixed-ratio schedule of stimulus termination on mean response rates of squirrel monkeys SM-92 (unfilled circles) and SM-94 (filled circles). Each data point is the mean response rate, and the vertical line the range of rates, in the presence of the stimulus during the last four sessions each parameter value was in effect. The schedules are described in Figure 1.

80 to 84). Response rate by SM-92 did not show the initial increase observed in SM-94 and, consequently, performance of SM-92 was characterized by the delivery of shock after responding had begun and before one-half to two-thirds of the ratio run had been completed. The occurrence of shock earlier in the ratio run was due partly to the initially lower response rate (approximately 1.4 responses per second) in this monkey (Figure 4). As a result, responding by SM-92 became irregular and inconsistent after a shock, then finally ceased during Session 84 and the session was terminated early. In neither monkey were patterns of positively accelerated responding observed during timeout periods when t was 5.0 sec.

To regenerate and recover responding in SM-92, the schedule was changed at the beginning of Session 85 so that shock would be scheduled for delivery during each stimulus presentation ($T = 1$ min) and t had a value of 30 sec, i.e., the schedule was identical to the one in effect during Sessions 27 to 34 (see Table 1). Responding by SM-92 increased and returned to a high rate during Session 85, and

at the end of the session performance was similar to that shown in Figure 1 (bottom). During Sessions 86 to 98, t was changed to 7.0 sec to determine whether shock occurring nearer the end of the ratio run for SM-92 would have an effect similar to the enhancing effect observed for SM-94 during Sessions 80 to 84. An increased rate of responding in the presence of the shock stimulus was engendered in SM-92 at $t = 7.0$ sec and performance was very similar to the performance of SM-94 when T was 10 min and t was 5.0 sec (Figure 4). The higher response rate by SM-92 plus the longer t (7.0 sec) resulted in the delivery of shock nearer the end of the ratio run. Moreover, the monkey occasionally emitted 30 responses before 7.0 sec had elapsed. The overall effect was an increase in response rate and a decrease in shock frequency due to the occasional completion of the ratio run before 7.0 sec had elapsed.

Since responding had been maintained at a relatively high rate by SM-94 when T was 10 min and t was 0.5 sec (Sessions 75 to 79) and increases in the value of t had resulted in a monotonic increase in mean response rate by this monkey (Figure 4), the value of T was increased to 30 min during Sessions 85 to 98 to determine whether a substantial change in shock frequency under the T - t schedule would also affect response rate. Subsequently, a high rate of responding in the presence of the shock stimulus was maintained during Sessions 85 to 98 by SM-94 and the stimulus was occasionally terminated before enough time ($t = 5.0$ sec) had elapsed for shock to be delivered. Moreover, mean response rate when T was 30 min (5.3 responses per second) was near the rate maintained when T was 10 min (5.0 responses per second) (Figure 4). Thus, increasing T , the time between successive shocks, had little effect on performance by SM-94 when t was 5.0 sec.

Figure 4 summarizes the effect of t duration on mean response rate during the stimulus for the two monkeys and shows that variability in rate was least when t was 0.5 sec and increased as t increased in value. The figure also shows that response rates of the two monkeys were similar when t was of brief duration or when t was of long duration, i.e., when shock delivery occurred immediately after stimulus onset or when it occurred near the end of the ratio run. In the case of the latter, comparable rates and patterns were obtained when t was 5.0 sec and

Fig. 3. Changes in performance under an FR 30 schedule of stimulus termination when electric shock was delivered 1.0 sec (t) after stimulus onset during the first presentation of the stimulus after 20 min (T) had elapsed. Cumulative records show performance during the first and subsequent sessions after the schedule of shock delivery was changed. Shock delivery is indicated by a diagonal mark of the event pen. The response pen reset after 1100 responses.

T was 10 or 30 min for SM-94, and when t was 7.0 sec and T was 30 min for SM-92. At these relatively long durations of t , each subject occasionally emitted 30 responses in less than time t and, consequently, the interval between successive shocks was altered by response rate.

To confirm the results obtained during Sessions 35 to 79, that responding could be maintained under the T - t schedule when response rate did not affect shock frequency, t was decreased to 0.5 sec and T was set at 30 min during Sessions 99 to 133. A value of 0.5 sec was chosen for t because session-to-session variability in response rate was minimal at this value (Figure 4). During the 35 sessions that t was 0.5 sec and T was 30 min, a high response rate persisted for both monkeys and performance in the presence of the stimulus was similar to that shown in Figure 1 (bottom). In addition,

response rate during timeout periods increased and patterns of positively accelerated responding were again observed. During the last four sessions (Sessions 130 to 133), mean quarter life during timeout was approximately 84% (SM-92) and 54% (SM-94); response rate in the presence of the shock stimulus was 4.60 and 3.03 responses per second, respectively. Moreover, session-to-session variability in mean response rate in the presence of the stimulus decreased to less than 0.3 response per second for each subject.

Time T between successive shocks. The amount of timeout responding observed when T was 30 min was greater than that observed when T was 20 min (Sessions 35 to 69) or 10 min (Sessions 70 to 84). This difference raised the possibility that timeout responding was a function of the value of T . To determine whether there was an orderly relation between

Fig. 4. Effect of time (t) between onset of the shock stimulus and delivery of an electric shock on mean rates of responding by two monkeys. Shock was delivered independently of responding during the first presentation of the stimulus after T min had elapsed since the previous shock. Each data point is the mean rate, and the vertical line the range of rates, in the presence of the stimulus during the last four sessions. SM-92 ceased responding during the fifth session when t was 5.0 sec; however, the unfilled circle at 5.0 sec was based on the same number of sessions (4) as the other data points. The two filled circles at 5.0 sec (SM-94) were obtained when T was 10 min (left) or 30 min (right); the unfilled circle (SM-92) at 7.0 sec was obtained when T was 30 min. For all other data points, T was 10 min (see Table 1 and text).

timeout responding and T , and to determine the range of T values under which responding could be maintained, the schedule was first changed back to the schedule of shock delivery studied during Sessions 1 to 34, to minimize order effects that might be carried over from the immediately preceding sessions. Then, during the remainder of the experiment (Sessions 143 to 230), the value of T was varied systematically between 1 and 100 min while t remained constant at 0.5 sec.

When shock was scheduled for delivery 20 sec (t) after each onset of the stimulus during Sessions 134 to 142, response rates during timeout periods decreased markedly and approached zero. Steady responding at a high rate was maintained in the presence of the shock stimulus, however, even though shock was infrequent during the nine sessions. Response rates were sufficiently high that the stimulus was

usually terminated before 20 sec elapsed and shock was delivered. The patterns of responding maintained during Sessions 134 to 142 were nearly identical to those maintained during Sessions 27 to 34 when t was 30 sec and T was 1 min (Figure 1, bottom).

Mean response rates in the presence of the shock stimulus changed little when, during the remainder of the experiment (Sessions 143 to 230), shock was delivered 0.5 sec after stimulus onset ($t = 0.5$ sec) and T was varied between 1 and 100 min (Figure 5). Except for SM-92 at $T = 100$ min, responding during the shock stimulus was maintained by both monkeys at mean rates of 2.5 to 3.5 responses per second. Whether shock was delivered 0.5 sec (t) after each onset of the stimulus ($T = 1$ min; Sessions 195 to 208) or 0.5 sec (t) after the last stimulus onset of a session ($T = 100$ min; Sessions 143 to 156), performance was composed of a very brief pause (period of no responding) immediately after stimulus onset, followed by responding at a relatively high rate until stimulus termination (Figure 6).

In contrast to the consistent, stable rates and patterns of responding maintained in the presence of the shock stimulus, responding during timeout periods was a function of the time between successive shock deliveries. Response rate and quarter life during timeout increased to a maximum when shock was delivered during the first stimulus presentation after 30 min (T), and were lowest when the minimum interval between successive shocks (T) was 1 min. The pattern of positively accelerated responding engendered during timeout periods was similar to the pattern of responding typically maintained under fixed-interval schedules (Figure 6).

DISCUSSION

The present report describes a procedure, designated a T - t schedule, under which rates and patterns of responding characteristic of fixed-ratio schedules can be maintained in the squirrel monkey when responding results in no change in the rate or frequency of shock delivery. Shock frequency was made independent of response rate by delivering an electric shock at a fixed, brief time (t sec) after stimulus onset during the first presentation of the shock stimulus after a fixed period of time T min) had elapsed since the previous shock. Re-

Fig. 5. Effect of changes in the frequency of shock delivered independently of responding on mean response rates maintained under an FR 30 schedule of stimulus termination. Electric shock was delivered 0.5 sec (t) after stimulus onset during the first presentation of the stimulus after T min had elapsed since the previous shock. T was either 1, 3, 10, 30, or 100 min. Each data point for 1, 10, and 100 min is the mean rate, and the vertical line the range of rates, in the presence of the stimulus during the last four sessions. Each data point for 3 and 30 min is the mean rate, and the vertical lines the range of rates, resulting from the two occasions each of these interval durations was studied. The two data points nearest the Y-axis (20 sec) show mean response rates during Sessions 134 to 142 when t was 20 sec and shock was scheduled during each stimulus presentation ($T = 1$ min).

sponding in Monkeys SM-94 and SM-92 was maintained for 45 (Sessions 35 to 79) and 35 (Sessions 99 to 133) consecutive sessions when shock was scheduled in this manner. The persistence of fixed-ratio rates and patterns of responding during these sessions indicated that the performance was not transitory.

Manipulation of the value assigned to the temporal parameter t showed that independence of response rate and shock frequency was obtained only when t was relatively brief. At a duration of 0.5 or 1.0 sec, shock was delivered immediately after stimulus onset and usually before the first response of the fixed ratio. Variation in response rate had little or no effect on shock frequency, and responding at a high rate only increased the immediacy of the stimulus termination and the next presentation of the stimulus. When t was 5.0 (SM-94) or 7.0 (SM-92) sec in duration, fixed-ratio patterns of responding were also maintained, but response rates were high enough that the shock stimulus was occasionally terminated before t sec had elapsed. Termination of the stimulus in less than t sec had the effect of increasing

the interval between successive shocks and, therefore, shock frequency and response rate were not independent at the longer durations of t . When a t duration intermediate between 1.0 and 7.0 sec was studied, shock frequently occurred during the first 15 to 20 responses of the FR 30 schedule for one monkey (SM-92). The delivery of shock this early in the ratio run apparently had a suppressive effect, because responding became variable and inconsistent, and then ceased. These data suggest that FR responding in the presence of the shock stimulus can be maintained when t is either brief or relatively long in duration, but that response rate and shock frequency are independent only when t is brief.

Systematic variation of the value of T , the time between successive shocks, showed this parameter to have little effect on responding in the presence of the shock stimulus, even though T varied 100-fold from 1 to 100 min. The value of T did have an effect on responding during timeout periods, however. Responding during timeout seldom occurred when T was 1 min, but as T increased in value, time-

Fig. 6. Effect of changes in the frequency of shock delivered independently of responding on performance of SM-94. Cumulative records show performance when shock was delivered 0.5 sec (t) after stimulus onset during the first presentation of the stimulus after a fixed period of time (T) had elapsed since the previous shock. The minimum time (T) between successive shocks was 1, 3, 10, 30, or 100 min. The thirtieth response in the presence of the stimulus terminated the stimulus and initiated a 75-sec timeout. Recording as in Figure 3.

out responding also increased. Responding during timeout reached its maximum when T was 30 min, and then decreased when T was 100 min. An interesting aspect of the performance was the distribution of responses during the timeout period. The characteristic pattern was a positive acceleration in rate during the timeout, a pattern characteristic of a fixed-interval schedule (Dews, 1970; Gollub, 1964; Herrnstein and Morse, 1957). Typically, the monkey would gradually increase its rate of responding during the timeout and, upon presentation of the shock stimulus, cease responding. After a brief pause or period of no responding, there was an abrupt transition to

a high rate of responding characteristic of a fixed-ratio schedule. The patterns of responding were similar to those described by Marr (1969) under CHAIN FI-FR schedules of food delivery in the pigeon. Unfortunately, the present experiment provided little information on the basis for the increased timeout responding under the T - t schedule or why timeout responding should vary systematically with the value of T .

The absence of a systematic change in mean rate of responding in the presence of the stimulus when T varied between 1 and 100 min is consistent with the data reported by Azrin *et al.* (1963). In that study, shock was delivered

at variable times during presentation of the shock stimulus, and the mean shock rate varied from one shock per 2 min to one shock per 360 min. Rates and patterns of responding characteristic of an FR schedule were maintained when the shock rate was as low as one per 30 min, and response rates changed little as shock rate increased to a maximum of one per 2 min. The range of values of T studied in the present experiment thus overlaps with the range of average values scheduled in the Azrin *et al.* (1963) study. One major difference between the Azrin *et al.* study and the present procedure, of course, is that the shock timer ran only during the stimulus presentations in the former study but ran continuously during stimulus presentations and timeout periods in the present work. In addition, the present experiment shows that responding can be maintained under a T - t schedule when shock is delivered as infrequently as once per 100 min and shock frequency is independent of response rate (Figure 6). When shock was scheduled for delivery less than once every 30 min in the Azrin *et al.* (1963) study, periods of no responding began to occur.

In their initial paper describing an FR escape schedule, Azrin *et al.* (1962) reported the effects of varying the FR parameter value from 25 to 350 responses (Figure 2, Azrin *et al.*, 1962). However, they did not describe performance at FR values below 25 responses. Sessions 1 to 34 of the present experiment complement the Azrin *et al.* (1962) study and show that mean response rates in the presence of the stimulus decrease at FR values less than 25 or 30. Moreover, the function relating response rate to FR value in the present experiment was similar to the function reported by Boren (1961) for FR responding maintained by food delivery. Response rates were highest when the schedule was FR 30, lower under FR 10, and lowest under FR 3. Response rate increased as FR value increased, even though the shock parameter used with each FR value in this experiment was chosen so as to impose the same minimum response rate at all FR values. A mean response rate just in excess of 1.0 response per second was adequate to terminate the stimulus and avoid shock under any of the three FR values studied. Therefore, the increase in response rate obtained was apparently due to the FR schedule parameter and not to a change in the frequency of shock delivery.

To have changed the FR value without also changing the shock parameter would have confounded the effect of FR value by imposing different requirements on the response rate necessary to terminate the stimulus without a shock. In spite of these efforts, the procedure in effect during Sessions 1 to 34 did not maintain an independence between response rate and shock frequency.

Azrin *et al.* (1963) suggested "the intriguing possibility that operant responses might be maintained by an apparent period of safety even when no shock reduction is permitted. Such a procedure would constitute an instance of pure conditioned reinforcement uncontaminated by changes of the frequency of shock presentation" (page 455). The present procedure arranged the frequency of shock delivery to be independent of response rate and, therefore, the criteria of Azrin *et al.* for "an instance of pure conditioned reinforcement" would appear to be met. When shock was delivered 0.5 or 1.0 sec (t) after stimulus onset during the first presentation of the stimulus after a fixed period of time (T) had elapsed since the previous shock, shock frequency was relatively constant as long as response rate was greater than zero. Since the monkeys did not cease responding at these values of t , shock frequency was invariant and responding was "maintained by an apparent period of safety even when no shock reduction" resulted (Azrin *et al.*, 1963, page 455). Under the T - t schedule, responding not only terminated the shock stimulus and produced a timeout, it also ensured that the shock stimulus would be presented again, and if time T had elapsed, a shock would be delivered immediately after onset of the stimulus. Rates and patterns of responding characteristic of an FR schedule were maintained, even though responding did not alter the rate or frequency of shock presentation or result in a delay in shock delivery. Hineline (1970) reported the maintenance of responding in the rat when shock frequency was relatively constant but, unlike the present procedure, responses delayed the delivery of shock.

The format used for scheduling shock delivery in the present experiment need not be restricted to those instances where $T = x$ min, i.e., shock is delivered during the first stimulus presentation after x min have elapsed. Theoretically, shock could be delivered during every N th presentation of the stimulus where $N > 1$.

Moreover, the number of stimulus presentations between successive shock deliveries could vary around a mean value and shock would be delivered during the N^{th} presentation of the stimulus on the average. The similarity of this format for specifying shock delivery to second-order fixed-ratio and variable-ratio schedules (Kelleher, 1966) is apparent. Each presentation of the shock stimulus can be regarded as a single event and shock can be scheduled according to N presentations of the stimulus. Of course, shock can also be scheduled for delivery on the basis of time. Shock can occur during the first presentation of the stimulus after a fixed period of time, T min, has elapsed (as in the present experiment) or during the first stimulus presentation after a variable amount of time has elapsed. It would appear possible to extend this format for arranging shock delivery to schedules other than those described here. Arranging the delivery of shock in this way should allow more precise control and specification of the schedule of shock delivery, and emphasize the similarities between schedules of escape or stimulus termination and schedules under which reinforcers other than shock are presented.

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