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FIXED-INTERVAL SCHEDULES OF ELECTRIC SHOCK PRESENTATION: EXTINCTION AND RECOVERY OF PERFORMANCE UNDER DIFFERENT SHOCK INTENSITIES AND FIXED-INTERVAL DURATIONS[1]

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In squirrel monkeys responding under a schedule in which responding postponed the delivery of electric shock, the presentation of *response-dependent shock* under a fixed-interval (FI) schedule increased the rate of responding. When the schedule of shock-postponement was eliminated, so that the only shocks delivered were those produced by responses under the FI schedule, a pattern of positively accelerated responding developed and was maintained over an extended period. When responses did not produce shocks (extinction), responding decreased. When shocks were again presented under the FI schedule, the previous pattern of responding quickly redeveloped. In general, response rates were directly related to the intensity of the shock presented, and inversely related to the duration of the fixed-interval. These results raise fundamental questions about the traditional classification of stimuli as reinforcers or punishers. The basic similarities among FI schedules of food presentation, shock termination, and shock presentation strengthen the conclusion that the schedule under which an event is presented and the characteristics of the behavior at the time the event is presented, are of overriding importance in determining the effect of that event on behavior.

In animals that have responded under schedules in which responding postpones the delivery of electric shock, the periodic delivery of response-independent shocks can maintain responding, even when the shock-postponement schedule is no longer in effect (Sidman, Herrnstein, and Conrad, 1957; Sidman, 1958; Kelleher, Riddle, and Cook, 1963; Waller and Waller, 1963). Recently it has been shown that a pattern of responding initially elicited by recurrently presented shock can be altered to a pattern of maximal responding just before each shock, and maintained under a fixed-interval schedule of shock-presentation (Morse, Mead, and Kelleher, 1967). In another experiment (Kelleher and Morse, 1968) a 10-min fixed-interval schedule of shock-presentation was arranged concurrently with a variable-interval 2-min schedule of food presentation in squirrel monkeys. In addition, *each* response produced a shock during the eleventh minute of each cycle (that is, for a 1-min period after delivery of shock under the FI schedule). After extended exposure to these concurrently arranged schedules, food presentations were eliminated, and a pattern of positively accelerated responding, characteristic of fixed-interval schedules, was maintained under the schedule of shock-presentation alone.

Previous experiments (McKearney, 1968) showed that, in monkeys previously trained to respond under a schedule of shock-postponement (Sidman, 1953), a pattern of positively accelerated responding can be engendered and maintained under a fixed-interval schedule of shock-presentation. The present paper amplifies and extends these findings, and reports the effects of eliminating scheduled shocks, and of varying shock intensity and parameter value of the fixed interval.

METHOD

Subjects and Apparatus

Three adult male squirrel monkeys (*Saimiri Sciureus*) were used. Two monkeys (S-65 and S-85) had been trained previously under various schedules of food presentation, but had no prior exposure to electric shock, and one (S-101) had been trained, several months previously, to terminate periodically presented

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electric shock. The monkeys were housed individually, and were handled according to the general procedures reported by Kelleher *et al.* (1963).

Experiments were conducted with individual monkeys seated in a restraining chair similar to that described by Hake and Azrin (1963). The monkey's tail was held motionless by a small stock, and electric shocks were delivered through brass electrodes which rested on a shaved portion of the tail. The shock was 650 v ac, 60 Hz, of 250-msec duration, delivered to the electrodes through variable series resistance. The response key (Lehigh Valley Electronics rat lever, LVE 1352) was mounted on a wall facing the monkey. Each depression of the response key with a force of approximately 20 g or more produced the audible click of a relay within the chamber, and was recorded as a response. The restraining chair was enclosed in a sound-attenuating chamber (Industrial Acoustics Co., AC-3). A 25-w overhead light illuminated the chamber during experimental sessions. Continuous white noise was present to mask extraneous sounds.

Data were recorded on digital counters, elapsed time meters, and cumulative response recorders. From the total number of responses occurring in each tenth of the fixed interval over the entire session, the percentage of the interval taken for the first quarter of the responses to occur was determined by linear interpolation. This quarter-life measure provides an index of the temporal patterning of responding which is relatively independent of response rate (Herrnstein and Morse, 1957; Gollub, 1964).

General Procedure

The experiments were divided into several phases. First, all monkeys were trained to respond under a continuous avoidance schedule (Sidman, 1953). Then, concurrently with the avoidance schedule, the first response occurring after 10 min was immediately followed by shock (10-min fixed-interval shock-presentation). After this, the avoidance schedule was eliminated, and the monkeys responded under the fixed-interval schedule alone; during this phase, the effects of the addition and subsequent deletion of a timeout period following shock were studied. In the fourth phase, scheduled shocks were omitted; initially the timeout period was still available, but later it also was eliminated. Phase 5 was concerned with the effects of varying shock intensities on performance under FI 10-min. In Phase 6, shocks were again eliminated, and in the last phase, performance under fixed intervals of 5, 3, and 1 min were studied. The various experimental phases are summarized in Table 1.

Table 1
Number of Sessions in Each Experimental Phase

Phases	*S-65*	*S-85*	*S-101*
1. avoidance	1-17	1-16	1-11
2. conc. avoid, FI 10-min	18-31	17-29	12-22
3. FI 10-min (with and without timeout)	32-101	30-101	23-82
4. extinction (with and without timeout)	102-152	102-136	83-121
5. FI 10-min (shock varied from 0.3-5.6 ma)	153-204	137-169*	122-184
6. extinction	205-211	204-221	185-189
7. FI 5-, 3-, and 1-min	212-290	222-284	190-265

*During sessions intervening between Phases 5 and 6 (Sessions 170-203), Monkey S-85 was subjected to several procedural variations which are described in the text.

Phases 1-3. All monkeys were first trained to press the key under a continuous avoidance schedule (Phase 1). Shocks (5.2 ma) were scheduled to occur every 10 sec, but each response postponed shock delivery for 30 sec. Sessions were usually 100 min long, and were conducted five days a week. After a number of sessions under the avoidance schedule, a 10-min fixed-interval (FI 10-min) schedule of shock-presentation was arranged concurrently with the avoidance schedule (Phase 2). Under the FI 10-min schedule, a shock was presented following the first response to occur after 10 min. In the third phase, the avoidance schedule was eliminated, and the FI 10-min was the only schedule in effect (Phase 3). At various times during Phase 3, a 30-sec timeout period followed each shock presentation; during the timeout period, the overhead light was off and responding had no scheduled consequences. A complete description of the procedures during Phases 1-3 was previously presented (McKearney, 1968).

Phase 4: elimination of scheduled shocks under FI 10-min. Beginning with Session 83

(S-101) or 102 (S-65 and S-85), shocks were eliminated. For the first four sessions, the 30-sec timeout was still available under the FI schedule, and was presented independently of responding if no response occurred within 2 min of the end of the 10-min FI. For the next 13 sessions, the 30-sec timeout was no longer presented independently of responding, but did follow the first response occurring after 10 min; for the remainder of the extinction sessions, the timeout period was eliminated.

Phase 5: reestablishment of responding under FI 10-min, with variations in shock intensity. After rates of responding had stabilized at low levels during Phase 4, shocks were again presented under the FI 10-min schedule. No timeout periods were presented. Shock intensity was either 0.3, 1.0, 3.0, or 5.6 ma, for varying numbers of sessions (see RESULTS). For all monkeys, the various shock intensities were given in ascending order.

During this phase, the shock intensity was increased to 10.0 ma for Monkey S-85. Responding was well maintained during the first session under this intensity, but during the second session the performance of this monkey was severely disrupted, and responding ceased over the next several sessions. Shock intensity was then reduced to 5.6 ma, and the schedule was modified in an attempt to restore responding. In the presence of a red stimulus light, shocks were scheduled to occur every 3 or 10 sec after the end of the 10-min FI. A response during this period produced a shock, and began a new fixed interval. After two sessions under this procedure, responding had recovered substantially, and the FI 10-min schedule, which was in effect before the disruption, was reinstated. Details of this modification are given in RESULTS.

Phases 6 and 7: extinction and development of performance under 5-, 3-, or 1-min fixed-interval schedules. After performance had stabilized under FI 10-min with 5.6-ma shock (Phase 5), shocks were again eliminated. During this phase (Phase 6), responding had no scheduled consequences. Following stabilization of rates of responding at low levels, shocks were again presented under varying parameter values of a fixed-interval schedule. Under the FI 10-min schedule in effect during previous phases, the overhead houselight was the only discriminative stimulus. In Phase 6, in addition to the overhead light, lumination from 6-w colored lights, mounted on the panel facing the monkey at approximately eye-level, served as discriminative stimuli. During FI 5-min, a green light was on, during FI 3-min an orange light, and during FI 1-min a white light. The number of sessions under each parameter value varied from monkey to monkey, and is given in RESULTS. Under FI 5-min and FI 3-min, the number of shocks delivered per session was kept constant; therefore, sessions varied in duration depending on the parameter value under study. For Monkeys S-85 and S-101, the number of shocks per session under FI 1-min was first 10 (as with other parameter values), and then 20 for the last five sessions. For Monkey S-65, the number of shocks per session was 20 for the entire time under FI 1-min.

RESULTS

Phases 1-3

Figure 1 summarizes rates of responding and quarter-life values for the three monkeys under the procedures of Phases 1-3. Under the continuous avoidance schedule, all monkeys developed a steady rate of responding characteristic of this schedule. When the FI 10-min schedule of shock presentation operated concurrently, there was no effect on the pattern of responding (quarter-life values were about 25%), but the rate of responding increased. After elimination of the avoidance schedule, the fixed-interval schedule of shock-presentation maintained a pattern of positively accelerated responding. When the 30-sec timeout was added, this pattern was accentuated (*i.e.*, quarter-life values increased), but subsequent removal and reinstatement of the timeout had no effect on the pattern that had developed. At the end of Phase 3, quarter-life values ranged from 66% to 70%. Figure 2 shows cumulative response records illustrating the terminal performance of the three monkeys under the 10-min FI schedule with timeout.

Phase 4

During the first four sessions after shock was eliminated (Fig. 3), the timeout was still available under the FI schedule, and was presented independently of responding if no response occurred within 2 min of the end of the

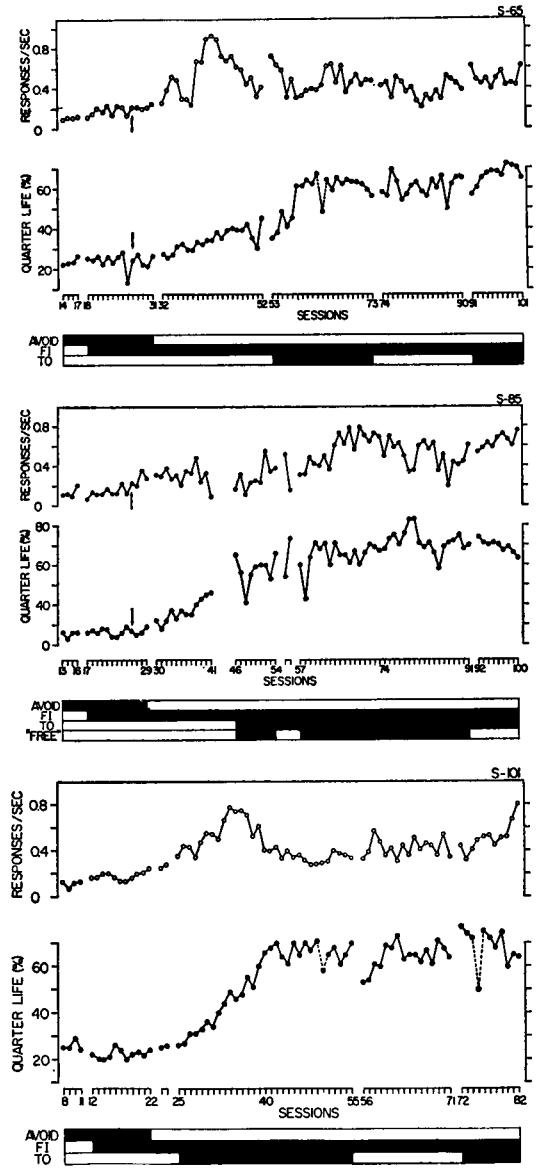


Fig. 1. Development of increased rates and a positively accelerated pattern of responding under a 10-min fixed-interval schedule of shock presentation. The solid black bars denote the procedures in effect during the various sessions. The mean number of shocks per session delivered under the avoidance schedule were 35.3, 12.0, and 8.4, respectively, for the last five sessions under simple avoidance, and the first and last five under the concurrent schedule. Note that when the avoidance schedule was eliminated, the rate of responding increased markedly but then decreased as positive curvature developed. Addition of the 30-sec timeout (TO) initially enhanced this curvature, but later deletion and reinstatement of timeout had no systematic effect. *Monkey S-65:* Before Session 27 (arrow), the shock delivered under the avoidance schedule was 5.2 ma, and the shock delivered under the FI 10-min schedule was 2.0 ma; in the sessions after the arrow, all shocks were 5.2 ma. For Session 56, the experimental chamber was moved to a new location, and the monkey was placed in the restraining chair in a slightly different way; for Session 63, the monkey's tail was improperly shaved. Both conditions resulted in slight disruptions of the behavior. *Monkey S-85:* Before Session 26 (arrow), the intensity of the shock under the avoidance schedule was 5.2 ma and that under the FI schedule was 2.0 ma; in Session 26 and thereafter, all shocks were 5.2 ma. During Sessions 42-45 (not shown) there was a disruption in performance and Monkey S-85 ceased responding for prolonged periods. Shock intensity was increased to 7.0 ma, and shocks were presented independently of responding if no response occurred within 1 min of the end of the FI 10-min; in addition, a 30-sec timeout period followed each shock. Under these conditions, the pattern of positively accelerated responding recovered (Sessions 46-54). In Session 55, shocks were no longer scheduled to occur independently of responding, and responding was well maintained. However, in Session 56, there were long pauses, and it was necessary to reinstate the response-independent shock procedure to maintain responding. Although response-independent shock was scheduled to occur in Sessions 57-91, few shocks were delivered under it (four in Session 57, two in 58, and one each in Sessions 61, 63, 74, 82, and 91). In Sessions 92-101, this contingency was eliminated, and responding was well maintained. *Monkey S-101:* The monkey escaped from restraint just before Session 50, and this resulted in a slight disruption of performance; the cause for the disruption during Session 75 is unknown. Note that Monkey S-101 was first studied for only two sessions (23-24) under FI 10-min without the 30-sec timeout.

interval. Under these conditions, rate of responding decreased abruptly for two monkeys (S-65 and S-101), but was relatively unchanged in the third (S-85); quarter-life values immediately decreased for all three monkeys, but positive curvature was still evident in the cumulative records (Fig. 4A). During the sessions when there was a possibility of response-independent presentation of the timeout, only in the case of Monkey S-101 was the timeout ever presented in this way (three times in Session 85 and two in Session 86). Over the course of the sessions in which timeout was still available under the FI schedule, but not independently of responding, rates of responding and quarter-life values decreased further for all monkeys (Fig. 4B).

When the timeout was eliminated, rates of responding fell to near zero levels, and quarter-life values varied about 25% (Fig. 4C).

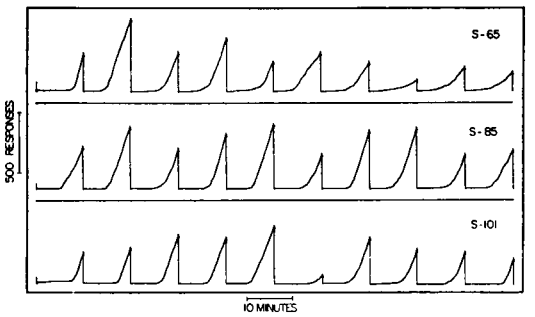


Fig. 2. Cumulative records of responding under 10-min fixed-interval schedule of electric shock presentation. Ordinate, cumulative number of responses; abscissa, time. The recording pen reset at shock presentation. A 30-sec timeout period followed each shock; the recorder was stopped during the timeout. Monkey S-65, Session 94; Monkey S-85, Session 97; Monkey S-101, Session 79.

Phase 5

The effects of reinstating scheduled shocks are summarized in the latter portions of Fig. 3. Cumulative records of terminal performances under each of the shock intensities are shown in panels D-G of Fig. 4.

At 0.3 ma, none of the monkeys responded appreciably (Fig. 4D). Quarter-life values, where rates of responding were sufficient to permit meaningful calculation, were approximately 25%; an exception to this was Monkey S-85 on the last day under the 0.3-ma shock (record D). In general, over the 1.0- to 5.6-ma shock range, rates of responding and quarter-life values increased and stabilized at values comparable to those obtained before extinction (Fig. 3).

Disruption and recovery of performance of Monkey S-85. After completion of the sessions under the 5.6-ma shock, shock intensity was increased to 10.0 ma for Monkey S-85. Performance was well maintained during the first session under the 10.0-ma shock (Fig. 5A). During the latter part of the second session, however, the performance of Monkey S-85 was disrupted (at *a* in Fig. 5B), and responding ceased. The next session was relatively normal (Fig. 5C), but in the following session (Fig. 5D), responding ceased after three fixed-interval cycles had been completed. During the next four sessions (not shown), various changes in procedure were made in an unsuccessful attempt to restore responding. In Sessions 174 and 175, shocks were presented independently

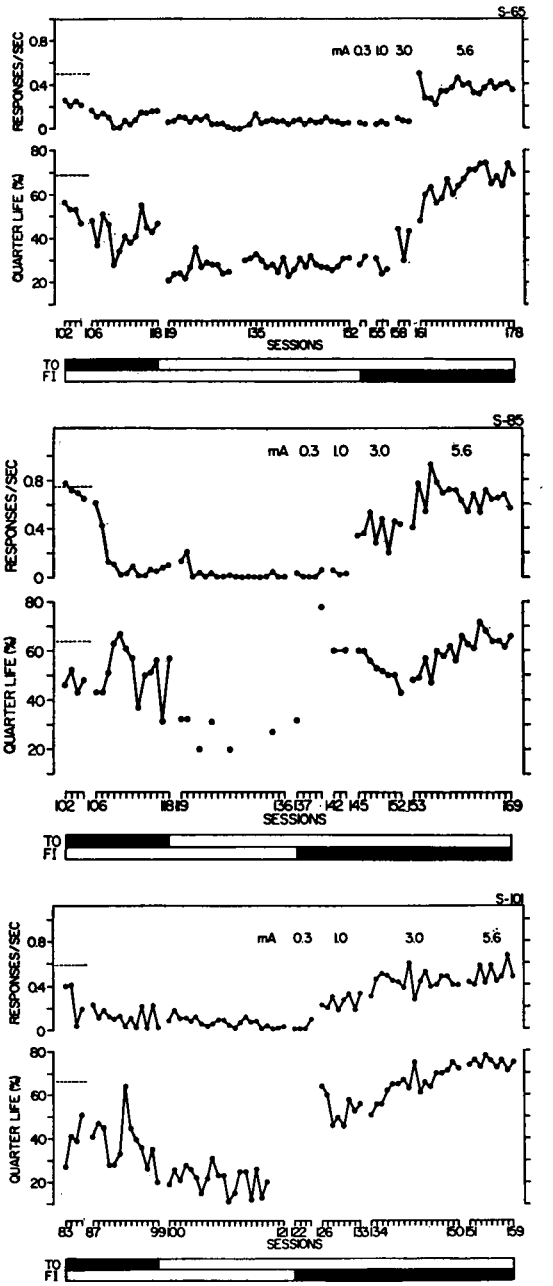
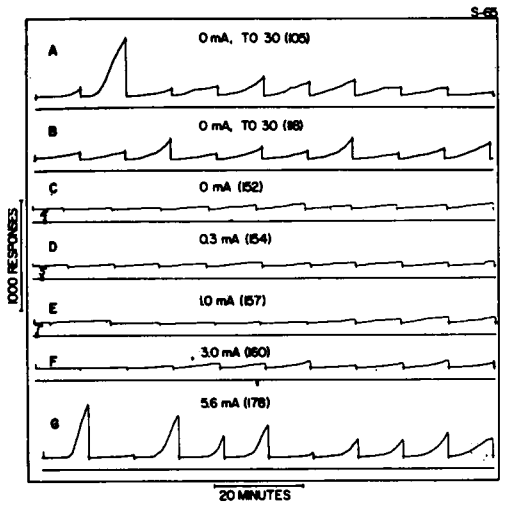
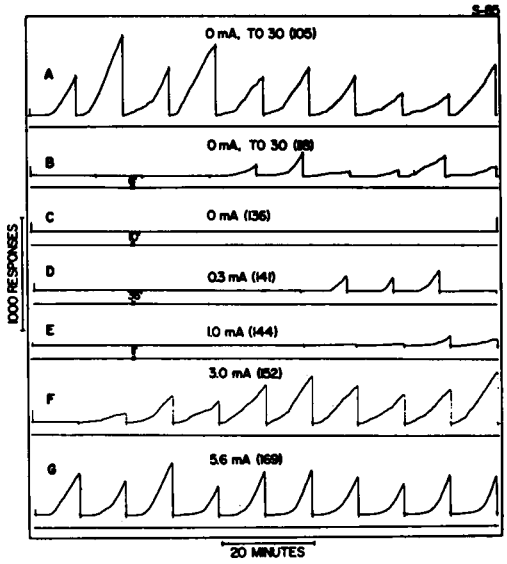


Fig. 3. Decreases in response rate and quarter-life after elimination of scheduled shocks (extinction), and redevelopment of responding under various shock intensities. The solid black bars denote the procedures in effect during the various sessions. The horizontal dashed lines at the left represent the mean rates of responding and mean quarter-life values for the last five sessions under FI 10-min. Quarter-life points were not plotted for certain sessions in which response rate was near zero.





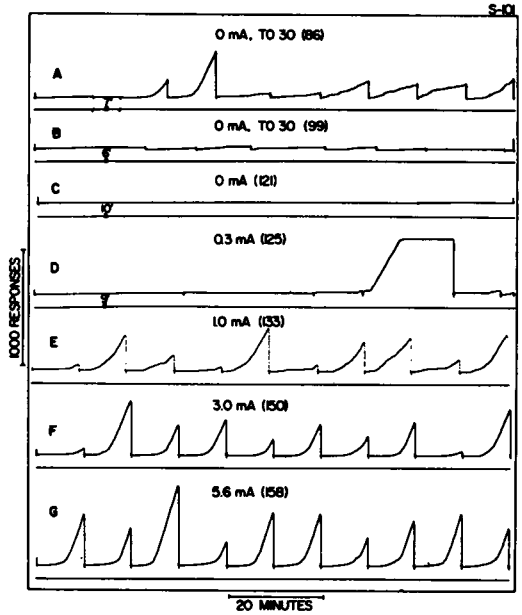


Fig. 4. Cumulative response records during various stages of extinction, and during redevelopment of responding under various shock intensities. *Monkey S-65:* A: Session 105, last session in which 30-sec timeout could be presented independently of responding; B: Session 118, last session in which 30-sec timeout was available under the FI 10-min; C: Session 152, last extinction session; D: Session 154, last session under FI 10-min, 0.3 ma; E: Session 157, last session under FI 10-min, 1.0 ma; F: Session 160, last session under FI 10-min, 3.0 ma; G: Session 178, eighteenth session under FI 10-min, 5.6 ma. Portions of records C, D, and E, during which there was no responding, have been eliminated; the numbers designate the number of minutes removed. *Monkey S-85:* A: Session 105, last session which 30-sec timeout could be presented independently of responding; B: Session 118, last session in which 30-sec timeout was available under FI 10-min; C: Session 136, last extinction session; D: Session 141, last session under FI 10-min, 0.3 ma; E: Session 144, last session under FI 10-min, 1.0 ma; F: Session 152, last session under FI 10-min, 3.0 ma; G: Session 169, seventeenth session under FI 10-min, 5.6 ma. As for Monkey S-65, portions of records B, C, D, and E, during which there was no responding, were eliminated. *Monkey S-101:* A: Session 86, last session in which 30-sec timeout could be presented independently of responding (indicated by marks on the event record); B: Session 99, last session in which 30-sec timeout was available under FI 10-min; C: Session 121, last extinction session; D: Session 125, last session under FI 10-min, 0.3 ma; E: Session 133, last session under FI 10-min, 1.0 ma; F: Session 150, last session under FI 10-min, 3.0 ma; G: Session 158, eighth session under FI 10-min, 5.6 ma. As for the other monkeys, portions of records A, B, C, and D in which there was no responding have been removed.

of responding if no response occurred within 2-min of the end of the FI. In Session 176, a 30-sec timeout after each shock was also scheduled. None of these changes noticeably increased responding. In Session 178, the FI schedule was modified as follows: in the presence of a red stimulus light, 5.6-ma shocks were scheduled to occur every 3 sec after the end of the 10-min FI. A response during this period terminated the condition, produced a

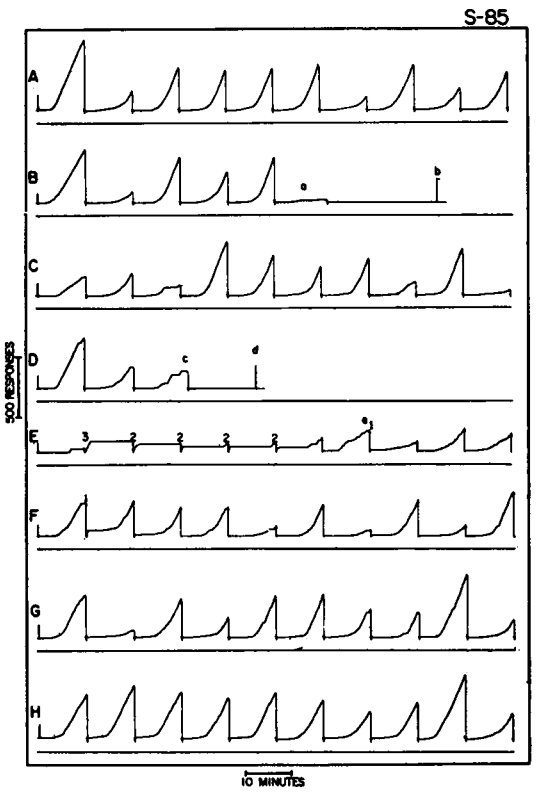


Fig. 5. Disruption and recovery of performance under FI 10-min schedule of shock presentation in Monkey S-85. A: Session 170, FI 10-min, 10.0 ma; B: Session 171, FI 10-min, 10.0 ma; disruption occurred at *a*, and session was terminated at *b;* C: Session 172, FI 10-min, 10.0 ma; D: Session 173, FI 10-min, 10.0 ma; shock reduced to 5.6 ma at *c*, session terminated at *d;* E: Session 178, modified FI schedule (see text); numbers refer to number of extra shocks delivered; shock-shock interval increased from 3 sec to 10 sec at *e;* F: Session 179, modified FI schedule; 10-sec shock-shock interval; one extra shock delivered at end of first interval only; G: Session 180, FI 10-min, 5.6 ma; H: Session 184, FI 10-min, 5.6 ma.

single 5.6-ma shock, and began a new fixed interval. Figure 5E shows the performance during the first session (178) under this modified schedule. For the first several cycles, responding was largely confined to the beginning and the end of each interval. In the sixth and seventh cycles of this session, and in subsequent cycles, responding in the early parts of the interval diminished, and a pattern of positively accelerated responding developed. After the sixth cycle, the shock-shock interval was increased to 10 sec. Note that during the last three cycles of Session 178, no shocks other than those following a response under the FI schedule were delivered. The same modified schedule was in effect during the subsequent session (179). In this case (Fig. 5F), the only "extra" shock delivered was at the end of the first FI; during succeeding intervals, a pattern of positively accelerated responding was well maintained. In the next session (180), and in subsequent sessions, the 10-min FI schedule (5.6-ma shock), identical to that in effect before the disruption in performance, successfully maintained responding that, in both rate and pattern, was indistinguishable from that obtained before the disruption (Fig. 5G and 5H).

Phases 6 and 7

Beginning with Session 185 (S-101), 204 (S-85), or 205 (S-65), shocks were again omitted from the 10-min FI schedule; responding had no scheduled consequences. Rates of responding gradually declined to near-zero, and quarter-life values abruptly decreased to about 25% for all monkeys. The initial portion of Fig. 6 summarizes the effects on rate and quarter-life for Monkey S-85.

The effects of reinstating shock under a 5-min fixed-interval schedule were immediate; rates of responding increased sharply, and quarter-life values rose to approximately 60 to 65% (Fig. 6). Subsequently, in the presence of different colored stimulus lights, shocks were presented under FI 3-min and FI 1-min schedules. The number of sessions and the average rates of responding and quarter-life values under each of the fixed-interval parameters are summarized in Table 2.

For all monkeys, rates of responding increased as the duration of the fixed-interval was shortened; during this time, quarter-life values did not vary systematically, and were always close to 60%. Representative cumulative records of responding at each parameter are shown in Fig. 7. The relationship between fixed-interval duration and resultant rate of responding was an inverse linear one when the rate was plotted against the logarithm of the fixed-interval duration (Fig. 8).

DISCUSSION

In monkeys that have previously responded under schedules in which responding postpones the delivery of shock, the presentation of response-dependent electric shock under a fixed-interval schedule can enhance respond-

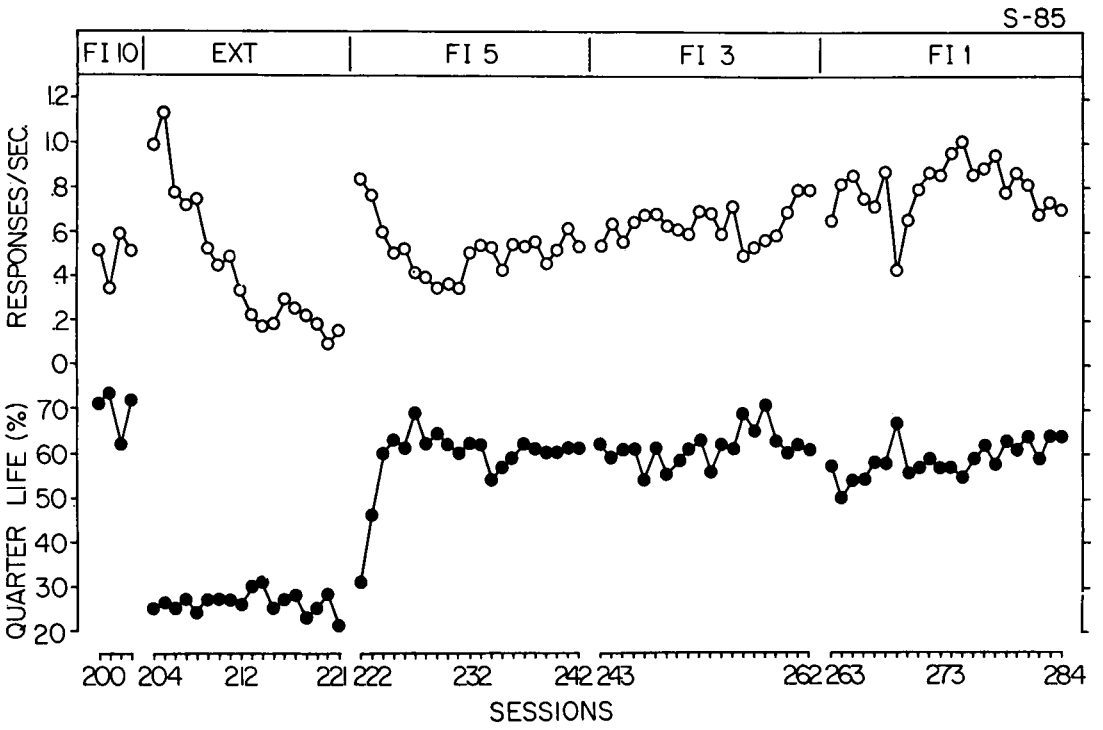


Fig. 6. Decreases in response rate and quarter-life after elimination of scheduled shocks (extinction), and redevelopment of responding under FI 1-min, 3-min, and 5-min (Monkey S-85).

ing, and lead to the development and maintenance of a pattern of positively accelerated responding. When shocks no longer followed responses (extinction), responding decreased (Phases 4 and 6). When shocks were again presented under the fixed-interval schedule, both rate and pattern of responding quickly recovered (Phases 5 and 7). In general, rates of responding were directly related to the intensity of the electric shock presented (Phase 5), and inversely related to the parameter value of the fixed interval (Phase 7).

Under a fixed-interval schedule of electric shock presentation, a shock is presented following the first response to occur after a fixed period of time has elapsed; responses during this fixed period have no scheduled consequences. Such a schedule is formally analogous to fixed-interval schedules under which food, water, or other stimuli are presented. The pattern of positively accelerated responding engendered under a fixed-interval schedule of shock presentation is similar in every respect to that engendered under fixed-interval schedules of food or water presentation (Skinner, 1938; Ferster and Skinner, 1957), or under fixed-interval schedules of termination of stimuli associated with the delivery of electric shock (Morse and Kelleher, 1966).

When food is no longer presented under a schedule of food presentation, or when shocks are no longer delivered under schedules of stimulus-shock termination, responding decreases (Skinner, 1938; Morse and Kelleher, 1966); similarly, the present experiments have shown that responding decreases when shocks are eliminated under fixed-interval schedules of shock presentation. Rates of responding under schedules of food presentation have been reported to be directly related to the amount or concentration of the food presented (Stebbins, Mead, and Martin, 1959; Shettleworth and Nevin, 1965), and rates of responding under schedules in which responding terminates electric shock are directly related to the intensity of the shock (Dinsmoor and Winograd, 1958; Winograd, 1965). The rates of responding under the fixed-interval schedules of shock presentation studied here were also directly related to the shock intensity. Under fixed-interval schedules of food presentation, response rate is inversely related to the duration

Table 2

Rates of responding and quarter-life values under several parameters of fixed-interval schedules of electric shock presentation.

	Monkey S-65			*Monkey S-85*			*Monkey S-101*		
	No.[a]	*Rate*	*Q*[d]	*No.*	*Rate*	*Q*	*No.*	*Rate*	*Q*
FI 10-min	44[b]	0.399 (0.082)[c]	62.8 (5.5)	24	0.488 (0.079)	71.4 (6.9)	34	0.792 (0.040)	59.6 (6.1)
FI 5-min	52	0.664 (0.056)	60.8 (0.5)	21	0.533 (0.050)	60.6 (2.0)	32	1.069 (0.082)	64.8 (2.6)
FI 3-min	17	0.870 (0.095)	57.0 (3.9)	20	0.681 (0.035)	63.4 (7.1)	20	1.330 (0.071)	59.0 (4.1)
FI 1 (10 cycles)	—	—	—	17	0.896 (0.077)	60.2 (1.7)	17	1.687 (0.126)	58.8 (1.8)
FI 1 (20 cycles)	10	0.739 (0.140)	62.4 (2.8)	5	0.758 (0.067)	62.4 (2.1)	5	1.528 (0.157)	60.6 (2.1)

[a]no. = number sessions under particular schedule parameter.
[b]number of sessions under FI 10-min is the number under the 5.6-ma shock.
[c]response rate in responses per second (mean of last five sessions). Standard deviations in parentheses.
[d]Q = quarter-life in per cent (mean of last five sessions). Standard deviations in parentheses.

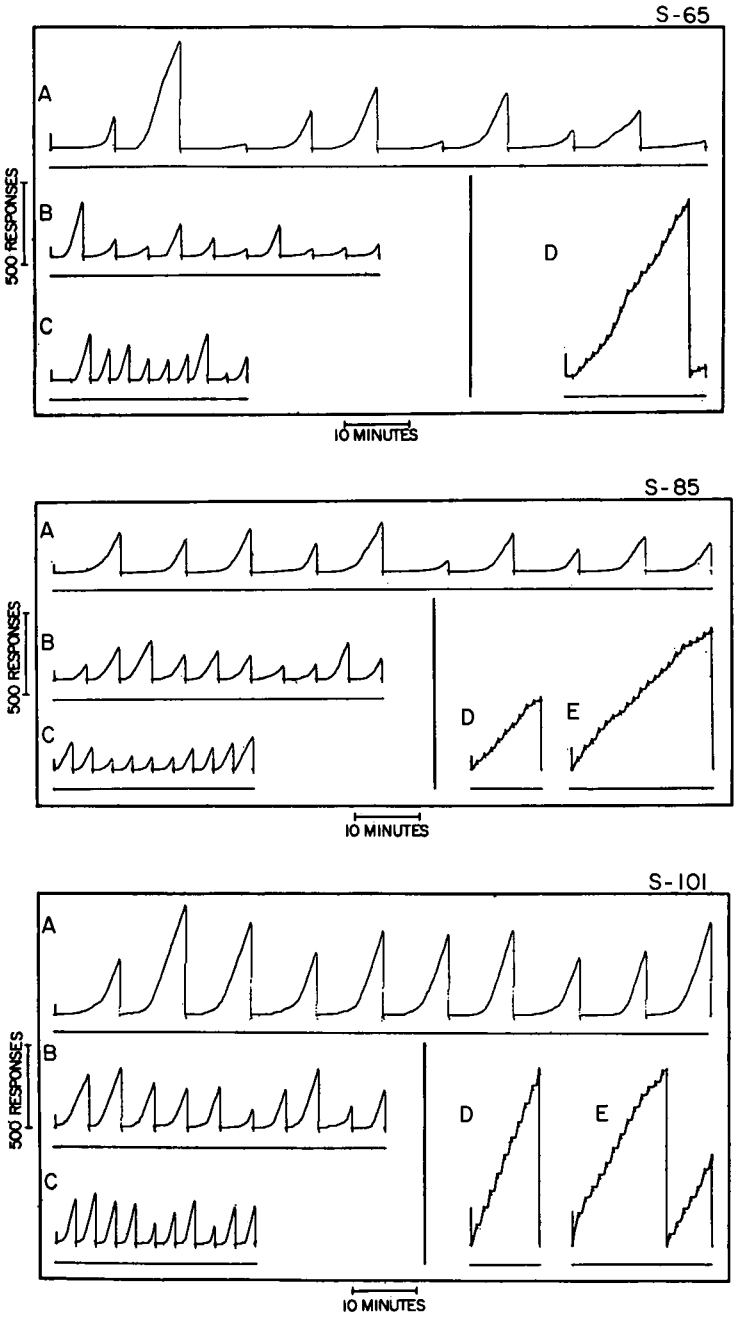


Fig. 7. Cumulative records of responding under several parameter values of FI schedules of shock presentation. The recording pen reset to the baseline after each shock, except under FI 1-min. *Monkey S-65:* A: Session 204, FI 10-min, 5.6 ma; B: Session 216, fifth session under FI 5-min, 5.6 ma; C: Session 268, fifth session under FI 3-min, 5.6 ma; D: Session 286, fifth session under FI 1-min, 5.6 ma (20 cycles per session). *Monkey S-85:* A: Session 201, FI 10-min, 5.6 ma; B: Session 226, fifth session under FI 5-min, 5.6 ma; C: Session 247, fifth session FI 3-min, 5.6 ma; D: Session 268, fifth session under FI 1-min, 5.6 ma (10 cycles per session); E: Session 286, fifth session under FI 1-min, 5.6 ma (20 cycles per session). *Monkey S-101:* A: Session 184, FI 10-min, 5.6 ma; B: Session 195, fifth day under FI 5-min, 5.6 ma; C: Session 227, fifth day under FI 3-min, 5.6 ma; D: Session 248, fifth day under FI 1-min, 5.6 ma (10 cycles per session); E: Session 264, fifth day under FI 1-min, 5.6 ma (20 cycles per session).

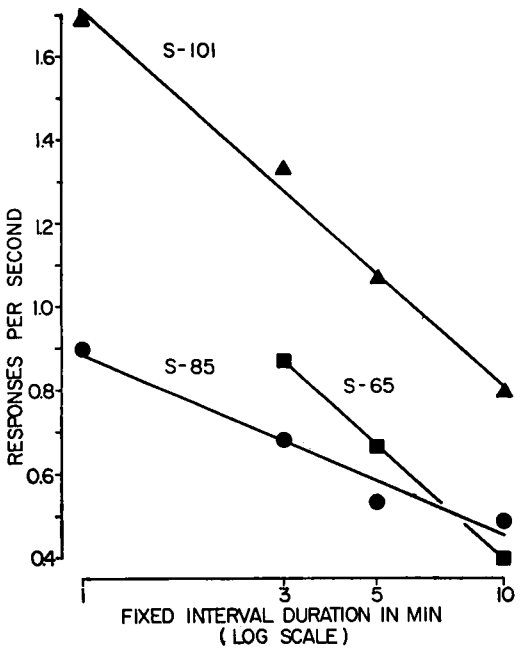


Fig. 8. Response rate as a function of fixed-interval duration. Ordinate, responses per second during the FI; abscissa, duration of FI (log scale). For FI 1-min, only the data from the sessions in which 10 shocks were delivered are plotted. Each point is the mean of the last five sessions under each parameter. Lines were fitted by the method of least-squares.

of the fixed interval (Skinner, 1938; Wilson, 1954; Ferster and Skinner, 1957); in the present experiments, over a 1- to 10-min range of FI durations, response rates were an inverse linear function of the logarithm of the fixed-interval duration. Thus, there appear to be no important differences among performances engendered under fixed-interval schedules of food presentation, shock termination, or shock presentation in the characteristic pattern of positively accelerated responding engendered, in the effects of elimination, reinstatement, and variations in intensity of the reinforcing stimulus, and in the effects of variations in parameter value of the fixed-interval schedule. This basic similarity strengthens and emphasizes previous conclusions (Kelleher and Morse, 1964; Morse and Kelleher, 1966; McKearney, 1968; Kelleher and Morse, 1968) that the schedule under which an event is presented, rather than the nature of that event, can be the most important determinant of the effects that event will have on behavior.

If the frequency of responding increases when the presentation of an event is made dependent upon a response, that event is called a reinforcer (Skinner, 1938). Distinctions are often drawn between stimuli which maintain responses preceding their termination or postponement ("negative" reinforcers), and those maintaining responding preceding their presentation ("positive" reinforcers) (Keller and Schoenfeld, 1950; Reynolds, 1968). That such distinctions are frequently arbitrary and without empirical significance is demonstrated by the fact that, in the present experiments, electric shock first maintained responding that postponed it (Phases 1 and 2) and later maintained responding that led to its presentation (Phases 3-7). Thus, the electric shock met the defining criteria for both "types" of reinforcers.

To expect that any environmental event will have invariant effects is unreasonable; yet, for traditional behavior theories such invariance has usually been a tacit assumption. For a properly deprived animal, stimuli such as food or water are assumed to be inherently "positive", in the sense that the animal will work "for" them, and stimuli such as electric shock are thought to be invariably "negative" stimuli which animals will avoid or escape; exceptions are usually described as "paradoxical". However, there is evidence that a given stimulus can have different and even opposite effects in the same organism at the same time. For example, in the present experiments, electric shocks of the same intensity that functioned to maintain responses that postponed them later functioned to maintain responding preceding their presentation. Kelleher and Morse (1968) have recently shown that, in monkeys responding under a two-component FI 10-min, FR 1 schedule of electric-shock presentation, the presentation of electric shock maintained responding during the FI component, but suppressed responding during the FR 1 component. Clearly, the manner in which a stimulus is scheduled can be a more crucial determinant of its effects than any inherent qualities of that stimulus.

The development and maintenance of characteristic patterns of positively accelerated responding under fixed-interval schedules of shock presentation clearly depends also on the characteristics of the behavior existing at the time the schedule of shock presentation is imposed. It is equally clear, however, that no one particular reinforcement history or pattern of

ongoing behavior is critical for the development of this behavior. For example, Morse *et al.* (1967) have shown that a pattern of responding (leash pulling in monkeys) initially elicited by delivery of electric shock can be altered to a pattern of maximal responding immediately before each shock, and then maintained under a fixed-interval schedule of shock presentation. In other experiments, monkeys responding under fixed-interval schedules of stimulus-shock termination or under interlocking shock-postponement schedules (in which successive responses postpone shocks for decreasing durations) have been maintained under fixed-interval schedules of electric shock presentation (Morse and Kelleher, 1969). In the latter experiments the subjects had previous experience in terminating or postponing electric shocks, but additional experiments (Kelleher and Morse, 1968) have shown that such experience is not necessary. After extended exposure to a concurrent variable-interval 2-min schedule of food presentation and two-component FI 10-min FR 1 schedule of shock presentation in squirrel monkeys, a pattern of positively accelerated responding developed and was maintained for extended periods under the fixed-interval schedule of shock presentation alone.

Complex interactions between ongoing behavior and the effects of new schedule conditions, and the general dependence of present and future behavior on past behavior are not peculiar to experiments involving the presentation of electric shock or similar events. For example, the effects of adventitiously presented reinforcers (Morse and Skinner, 1957; Herrnstein and Morse, 1957; Zeiler, 1968), of withholding the presentation of scheduled reinforcers (Ferster and Skinner, 1957), and of presenting stimuli correlated with periods of non-reinforcement (Ferster, 1958) are among the many interventions whose effects have been shown to depend upon the characteristics of behavior upon which they are imposed.

The direction and degree of the effects which environmental consequences have on a particular behavior depend importantly on the rate of occurrence, patterning in time, and physical topography of that behavior; these, and other aspects of behavior, are critically determined by the organism's history of reinforcement. The effects that a given stimulus will have when imposed upon a pre-existing sequence of behavior depend, as well, upon the schedule under which *it* is presented. The net effect, therefore, is the result of an interaction between the effects of the reinforcement schedules controlling the existing behavior, itself complexly determined, and the schedule under which the new event is presented.

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