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SCHEDULES USING NOXIOUS STIMULI. I. MULTIPLE FIXED-RATIO AND FIXED-INTERVAL TERMINATION OF SCHEDULE COMPLEXES[1]

W. H. MORSE AND R. T. KELLEHER

HARVARD MEDICAL SCHOOL

The termination of a schedule complex, comprising a stimulus in the presence of which brief presentations of electric shocks are scheduled, is a reinforcer. Conditions were studied under which schedule-controlled patterns of responding characteristic of fixed-interval, fixed-ratio, and multiple fixed-interval fixed-ratio schedules can be maintained in the squirrel monkey by terminating a schedule complex. The schedule of shock presentation was a critical determinant of the patterns of responding, especially under fixed-interval schedules of termination. The rates and patterns of responding under various schedules of termination of schedule complexes were generally akin to those maintained under comparable schedules of food presentation. The findings suggest a general similarity in the dynamic aspects of performances under schedules of schedule-complex termination and comparable schedules of food presentation. The schedule of reinforcement is more important than the nature of the reinforcer in the control of behavior.

The increased occurrence of responses similar to one that immediately preceded some event identifies that event as a reinforcer; following such responses in time with a reinforcer is reinforcement. In comparing different types of reinforcers, it is useful to go beyond this basic criterion for identifying reinforcers. Presenting reinforcers according to a consistent schedule leads to a reproducible temporal pattern of responding which gives more information on the dynamic properties of reinforcers than does a mere increase in frequency of responding. The development of comparable schedule-controlled patterns of responding maintained by different types of events is powerful evidence favoring the equivalence of these events as reinforcers. This paper deals with conditions under which patterns of responding characteristic of fixed-ratio and fixed-interval schedules can be maintained by terminating a complex of events comprising a visual stimulus and an associated schedule of brief presentations of electric shock (schedule complex).

Numerous studies of schedule-controlled behavior maintained by stimulus termination (sometimes called escape behavior) have been reported. These studies may be grouped in three categories according to the types of events scheduled to be terminated. Responding terminates for some duration: (1) a continuously-presented noxious stimulus; (2) a schedule complex; (3) a schedule complex programmed concurrently with another schedule of reinforcement.

(1) Intermittent termination of a continuously presented noxious stimulus was first studied by Keller (1941) and later by Kaplan (1952, 1956). In Kaplan's classic experiments on fixed-ratio schedules in the rat, responding terminated a continuously-presented light of high intensity. Kaplan found that there was a period of no responding at the beginning of each fixed ratio (initial pause) followed by an abrupt shift to a high rate of responding which was maintained until the fixed ratio was completed (terminal rate). As the fixed-ratio response requirement was increased from 5 to 30 responses, the initial pause lengthened. Kaplan (1956, p. 54) noted: "When escape behavior is maintained by fixed-ratio schedules of reinforcement, the temporal properties of its emission are similar to those of fixed-ratio re-

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sponding under positive reinforcement." More recently, Winograd (1965) obtained qualitatively similar results with fixed-ratio schedules of termination of continuously presented electric shock. Martin and Heckel (1965) reported that a wheel-turning response similar to that previously described by Verhave, Owen, and Robbins (1957) facilitated acquisition of fixed-ratio escape performance in the rat. Although Hendry and Hendry (1963) did not maintain characteristic fixed-ratio responding by terminating a rapidly pulsating electric shock, their results are not comparable with those discussed above because of several procedural differences (see Winograd, 1965).

Fixed-interval schedules of light termination in the rat were studied by Kaplan (1952). As the fixed-interval duration was increased from 0.2 to 5 min, rates of responding decreased sharply from about 25 responses per min to an asymptote at about 10 responses per min. Kaplan noted that the cumulative response records under these fixed-interval schedules of light termination were "essentially linear in form"; however, under fixed-interval schedules of food presentation responding usually increases during the interval.

Cook and Catania (1964) have briefly described a fixed-interval schedule of shock termination in the squirrel monkey under which responding did increase during the interval; however, differences in species, in type of noxious stimulus, and in other schedule parameters make it difficult to compare directly their findings with those of Kaplan. Variable-interval schedules of termination of continuously-presented noise (Barry and Harrison, 1957) or electric shock (Dinsmoor and Winograd, 1958) have been shown to maintain steady rates of responding.

(2) The maintenance of behavior by the termination of stimuli associated with intermittent schedules of brief presentation of noxious stimuli was first reported by Dinsmoor (1962). The term schedule-complex termination is used here to describe this general procedure. Dinsmoor (1962) reported that a variable-interval schedule of termination of a stimulus associated with occasional electric shock maintained relatively low rates of responding; a period of no responding at the beginning of each session was followed by responding that increased to a steady rate of about 0.1 responses per sec. Recently, Azrin, Holz, and Hake (1962) and Azrin, Holz, Hake, and Ayllon (1963) studied fixed-ratio termination of a schedule-complex in the squirrel monkey. A variation of the fixed-ratio procedure reported in the present experiments has also been reported by Finocchio (1962). In the experiments by Azrin *et al.* (1962), when the fixed-ratio response requirement was 75 or less, average rates of responding were about 4 per sec. As the response requirement was increased to a maximum of 300, the initial pause lengthened, but terminal response rates did not change. Azrin *et al.* (1962) concluded that the patterns of responding maintained under fixed-ratio termination of a schedule complex appeared to be similar to those maintained under fixed-ratio presentation of food.

(3) Numerous procedures have been studied which involve termination of schedule complexes programmed concurrently with other events. For example, Verhave (1959, 1962) and Sidman (1962) reported that responding was maintained on one response key when it produced "time out from an avoidance schedule" programmed on another response key. Hearst and Sidman (1961) and Hearst (1963) reported experiments in which responding was maintained by terminating a stimulus associated with the scheduled presentation of both food and electric shock. Azrin, Hake, Holz, and Hutchinson (1965) reported that responding was maintained on one response key when it eliminated response-produced electric shocks programmed concurrently with a variable-interval schedule of food presentation on another response key. Responding may also be maintained or enhanced by termination of components of food presentation schedules (for example, Azrin, 1961; Ferster, 1958; Findley, 1958, 1962; Herrnstein, 1955; Kelleher, Riddle, and Cook, 1962; Thompson, 1964; Zimmerman and Ferster, 1964).

The present experiments investigated performances maintained under various fixed-interval, fixed-ratio, and multiple fixed-interval fixed-ratio schedules of termination of a stimulus associated with intermittent electric shocks. Because performances under fixed-interval termination of a schedule complex have not been reported previously, the present experiments were particularly concerned with the conditions necessary to produce characteristic fixed-interval performance. Initial results indicated that both rates and patterns of responding under multiple fixed-interval fixed-ratio schedules of termination can be similar to responding engendered by comparable schedules of presentation of food. Subsequent experiments, which studied monkeys with different experimental histories under different combinations of fixed-ratio and fixed-interval schedules and different schedule parameters, confirmed the initial findings and extended the conditions under which characteristic fixed-interval performances developed.

EXPERIMENT I

Development of FI Curvature under Multiple FR FI

Subjects. Three mature, male squirrel monkeys (*Saimiri sciureus*) were used (S-7, S-24, and S-26). All had been previously trained under various schedules of food presentation and shock termination in conventional experimental chambers. In this and subsequent experiments, the monkeys were generally handled according to the procedures described by Kelleher, Gill, Riddle, and Cook (1963) except that the leash was sometimes removed during initial training sessions. Subjects had free access to food and water in their living cages.

Apparatus. A restraining chair similar to the one described by Hake and Azrin (1963) was used. A picture of it has been published elsewhere (Kelleher and Morse, 1964). Each monkey was restrained in the seated position by a waist lock, its tail held motionless by a small stock. Electric current could be delivered through the tail by two hinged brass plates that rested lightly on a shaved portion of the tail. A noncorrosive electrode paste (EKG Sol) insured a low resistance electrical contact between the plates and the tail. The electric shock was 110 v ac, 60 cps, delivered to the plates through a series resistor. The response key (Lehigh Valley Electronics rat lever, LVE 1352) was mounted on the right side of a metal wall facing the monkey. When the key was pressed with a force of 22 g or more, a response was recorded. Each response produced the audible click of a relay. Just above the key was a stimulus panel which could be transilluminated by lights and patterns (Industrial Electronics Engineers, One Plane Digital Display Unit, Model No. 10256Q). The entire chair unit was enclosed in a ventilated refrigerator shell. General illumination could be provided by an overhead light (25-w GE type 101F bulb). Continuous white noise was used to mask extraneous sounds.

Procedure. Subjects were trained to press the key to terminate a stimulus associated with intermittent shock deliveries; they were then studied under various schedules and parameter values to determine optimum conditions for maintaining behavior in the restraining chair. These data are not reported.

The present experiment studied multiple fixed-ratio fixed-interval schedule-complex termination. In the presence of a pattern of horizontal bars on the stimulus panel, shocks were never delivered, and responding had no programmed consequences (time out). In the presence of a red stimulus, shocks were scheduled to occur at 20-sec intervals; the 20th response terminated the red stimulus and produced a 30-sec time out (FR 20). The concurrent presence of the red light and shock schedule constitutes the FR schedule complex. In the presence of a white stimulus (white light and general illumination) shocks were scheduled to occur at regular intervals starting after 10 min; the first response after 10 min terminated the white stimulus and produced a 30-sec time out (FI 10 min). The concurrent presence of the white stimulus and shock schedule constitutes the FI schedule complex. When the shock schedule is synchronized with the schedule of stimulus termination in this manner, the time (t) between the end of the fixed interval and the first scheduled shock is an important parameter. In this experiment, subsequent shocks during FI schedule complexes were scheduled to occur at intervals of the same duration as t.

During the first 26 sessions, t was varied unsystematically between 10 sec and 3 sec; during the next 30 sessions, t was 1 sec. Shocks were delivered through a 10,000 ohm resistor; the current through the tail was about 6.2 ma for each monkey during shock delivery. Initially, shock duration was 150 msec. Fixed-ratio and fixed-interval components alternated throughout each session. Each session terminated when 60 schedule components had been completed.

Beginning with the 57th session, a multiple FR 30 FI 10-min schedule was in effect. Shocks were scheduled to occur every 30 sec in FR 30 components; t remained 1 sec in FI 10-min components. Shock duration was decreased to 50 msec; time-out periods were increased to 2.5 min; and each session terminated after 20 schedule components had been completed. During these sessions, drugs were occasionally administered; some of these data have been reported elsewhere (Kelleher and Morse, 1964). There was no indication that effects obtained in drug sessions affected later performance.

Average fixed-interval and fixed-ratio rates of responding for each session were computed in responses per second from digital counters and elapsed time meters. From the total number of responses recorded in each tenth of the fixed-interval duration over the entire session, the average time taken for the first quarter of the responses in the fixed interval to occur was computed by linear interpolation. This estimated quarter-life value provides an indication of the temporal patterning of fixed-interval responding which is relatively independent of fixed-interval rates of responding (Herrnstein and Morse, 1957; Gollub, 1964). For convenience in comparing data from fixed intervals of different durations, the average quarter life is expressed as a percentage of the duration of the interval (Gollub, 1964). Responding was also recorded on cumulative response recorders.

Results. When *t* was decreased from 10 sec to 3 sec under the multiple FR 20 FI 10-min schedule, rates of responding in FI 10-min components remained lower than in FR 20 components; however, responding tended to occur at a constant rate throughout FI 10-min components. During the 26th session (*t* 3 sec), response rates ranged from 1.8 to 2.1 responses per sec in FR 20 and from 0.4 to 0.8 responses per sec in FI 10 min; quarter-life values ranged from 25% to 36%. In the next session similar performances were maintained with *t* 1 sec (Fig. 1). Response rates ranged from 1.6 to 2.5 responses per sec in FR 20 and from 0.2 to 0.6 responses per sec in FI 10 min. The average quarter lives were 28% for S-7, 25% for S-24, and 39% for S-26. With further exposure to the multiple FR 20 FI 10-min (*t* 1 sec) schedule, all subjects developed positively accelerated responding in FI 10 min.

The terminal performance, after 30 sessions with *t* 1 sec, is shown in Fig. 2. Average response rates ranged from 1.7 to 3.1 responses per sec in FR 20 and from 0.5 to 1.3 responses per sec in FI 10 min; quarter-life values ranged 40% to 64%.

The experiments were continued with the changed parameters described above (see Procedure). Figure 3 shows representative performances for each monkey under multiple FR 30 FI 10 min (*t* 1 sec). Response rates ranged from 2.5 to 2.7 responses per sec in FR 30 and from 0.7 to 1.4 responses per sec in FI 10 min; average quarter lives ranged from 54% to 60%. Performances at these parameter values were maintained in these subjects for extended periods of time. Monkey S-24 died with a respiratory infection after about seven months. Monkeys S-7 and S-26 were maintained for about 10 months at these parameter values until the procedure was modified as described in Exp II. Over this entire period, characteristic fixed-ratio and fixed-interval patterns of responding, such as shown in Fig. 3, were maintained by multiple FR FI schedule-complex termination.

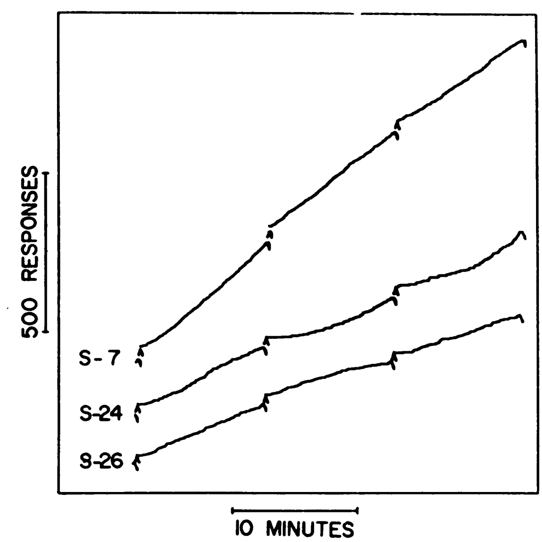

Fig. 1. Sample cumulative response records for three monkeys from the first session under the multiple FR 20 FI 10-min (*t* 1 sec) schedule of termination of a schedule complex. At the beginning of each record, the FR 20 schedule was in effect in the presence of a red stimulus. The 20th response terminated the red stimulus and produced the pattern of horizontal bars for a 30-sec time-out period during which the paper feed stopped and the recording pen was displaced downward. Responses during time-out periods appear as vertical displacements of the record. Following the time-out period that terminated FR 20, the FI 10-min (*t* 1 sec) schedule was in effect in the presence of a white stimulus. The next downward stroke of the pen indicates that the first response after 10 min terminated the white stimulus and produced the pattern of horizontal bars for another 30-sec time-out period. This cycle was repeated throughout each session. Note the slow, steady rates of responding in FI 10 components.

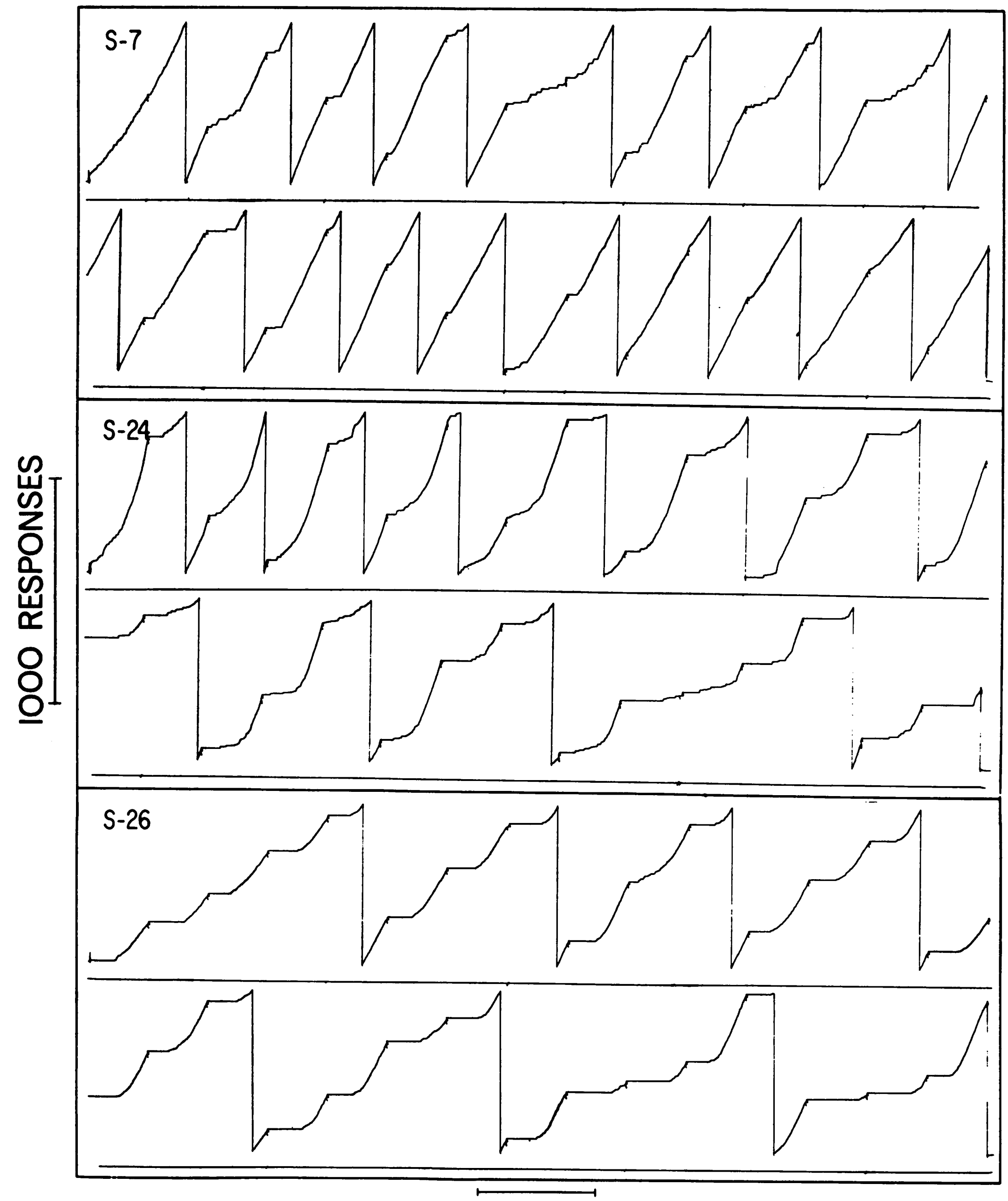

Fig. 2. Cumulative records showing later performances of each monkey under the multiple FR 20 FI 10-min (*t* 1 sec) schedule. The upper and lower records in each frame are continuous, showing performance over an entire experimental session for each monkey. The short downward strokes of the recording pen indicate 30-sec time-out periods in which the paper feed stopped. The recording pen reset to the bottom of the record when 1100 responses had cumulated and at the end of each session. Short downward strokes of the event pen indicate shock deliveries. Fixed-ratio and fixed-interval components alternated. Note the positively accelerated patterns of responding in FI 10-min components; these were less pronounced for S-7.

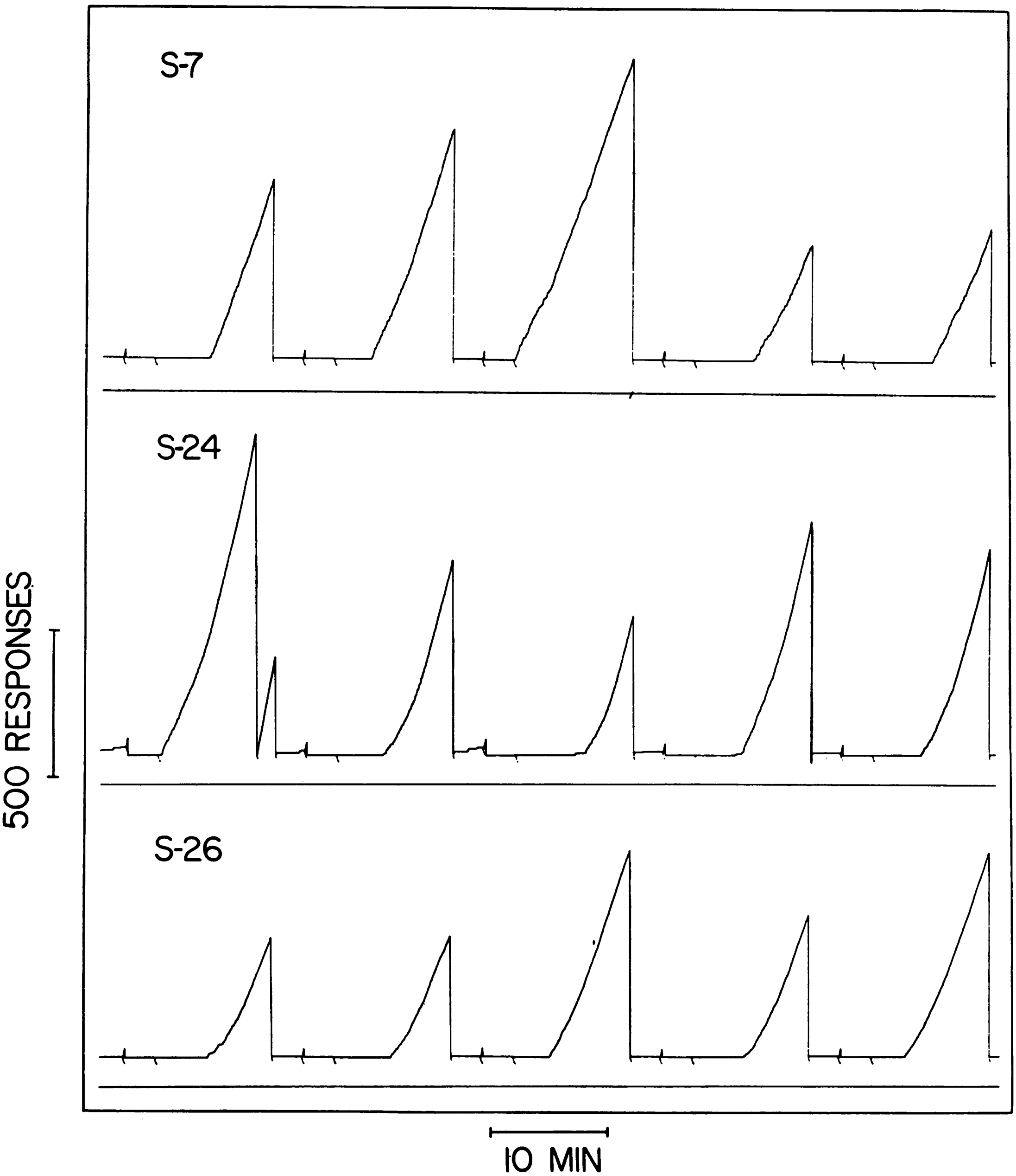

Fig. 3. Stable performances for each monkey under the multiple FR 30 FI 10-min (*t* 1 sec) schedule. Downward strokes on the event record indicate shock deliveries; similar strokes on the cumulative record indicate the beginning of a fixed-ratio or fixed-interval component. The recording pen reset to the bottom of the record when a response terminated the white or red stimulus light or when 1100 responses had cumulated. The recorder continued to run during time-out periods. Responding in FR 30 components occurred at high, steady rates (about 2.5 responses per sec) while responding in FI 10 min was usually positively accelerated.

EXPERIMENT II

Omission of Scheduled Shocks under Multiple FR FI

This experiment studied the effects of eliminating the shock schedule components of the two schedule complexes.

Subjects and apparatus. The subjects were two male squirrel monkeys from Exp I (Monkeys S-7 and S-26), and the apparatus was the same.

Procedure. The procedure was the same as at the end of Exp I. A multiple FR 30 FI 10-min (*t* 1 sec) schedule was used; time-out periods were 2.5 min; and each session ended after the 20th time out. In the present experiment, which immediately followed Exp I, all electric shocks in both FR 30 and FI 10-min components were omitted for 18 sessions. If the monkey did not terminate a component by responding, the component automatically terminated after four shocks would have occurred under multiple FR 30 FI 10 min (*t* 1 sec); that is, FR 30 components terminated after 120 sec, FI 10-min components after 10 min and 4 sec.

Results. When scheduled shocks were omitted, average rates of responding in FI 10-min components decreased and average quarter-life values increased for both monkeys (Fig. 4 and 5). The increase in quarter-life values reflects the tendency for long initial pauses under fixed-interval schedules to be related to decreased average rate of responding, suggesting that under some conditions increasing *t* might generate a fixed-interval performance with a longer pause at the beginning of the interval. Average rates of responding in FR 30 components were little changed for Monkey S-7 (Fig. 4B) but did eventually decrease to low values for Monkey S-26 (Fig. 5B). When scheduled shocks were again delivered, rates of responding increased in both FR 30 and FI 10-min components, and the average value of the quarter life decreased (Fig. 4C and Fig. 5C). Although only seven sessions are shown in Fig. 4C and 5C, characteristic fixed-ratio and fixed-interval performances were maintained for several additional months after Exp II.

The cumulative response records in Fig. 6 and 7 show changes in patterns of responding that occurred when shocks were omitted. Responding in many FI 10-min components decreased to near zero, while relatively high rates of responding were maintained in FR 30 com-

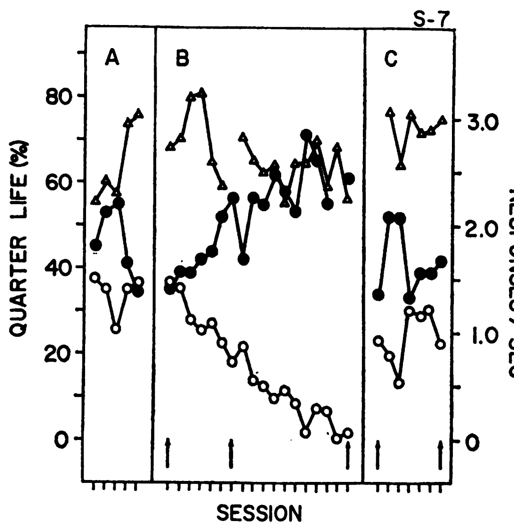

Fig. 4. Rates of responding and quarter-life values under multiple FR 30 FI 10 min when all shocks were omitted (Monkey S-7). Triangles: responses per sec in FR 30; open circles: responses per sec in FI 10 min; closed circles: quarter life. A: multiple FR 30 FI 10 min (*t* 1 sec); B: no shocks delivered but responding still produced time-out periods according to multiple FR 30 FI 10 min; C: multiple FR 30 FI 10 min (*t* 1 sec). Arrows indicate sessions for which cumulative response records are shown in Fig. 6.

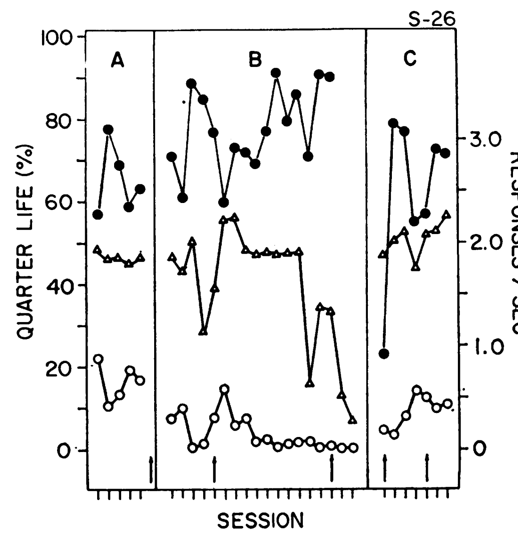

Fig. 5. Rates of responding and quarter-life values under multiple FR 30 FI 10 min when all shocks were omitted (Monkey S-26). Triangles: responses per sec in FR 30; open circles: responses per sec in FI 10 min; closed circles: quarter life. A: multiple FR 30 FI 10 min (*t* 1 sec); B: no shocks delivered but responding still produced time-out periods according to multiple FR 30 FI 10 min; C: multiple FR 30 FI 10 min (*t* 1 sec). Arrows indicate sessions for which cumulative response records are shown in Fig. 7.

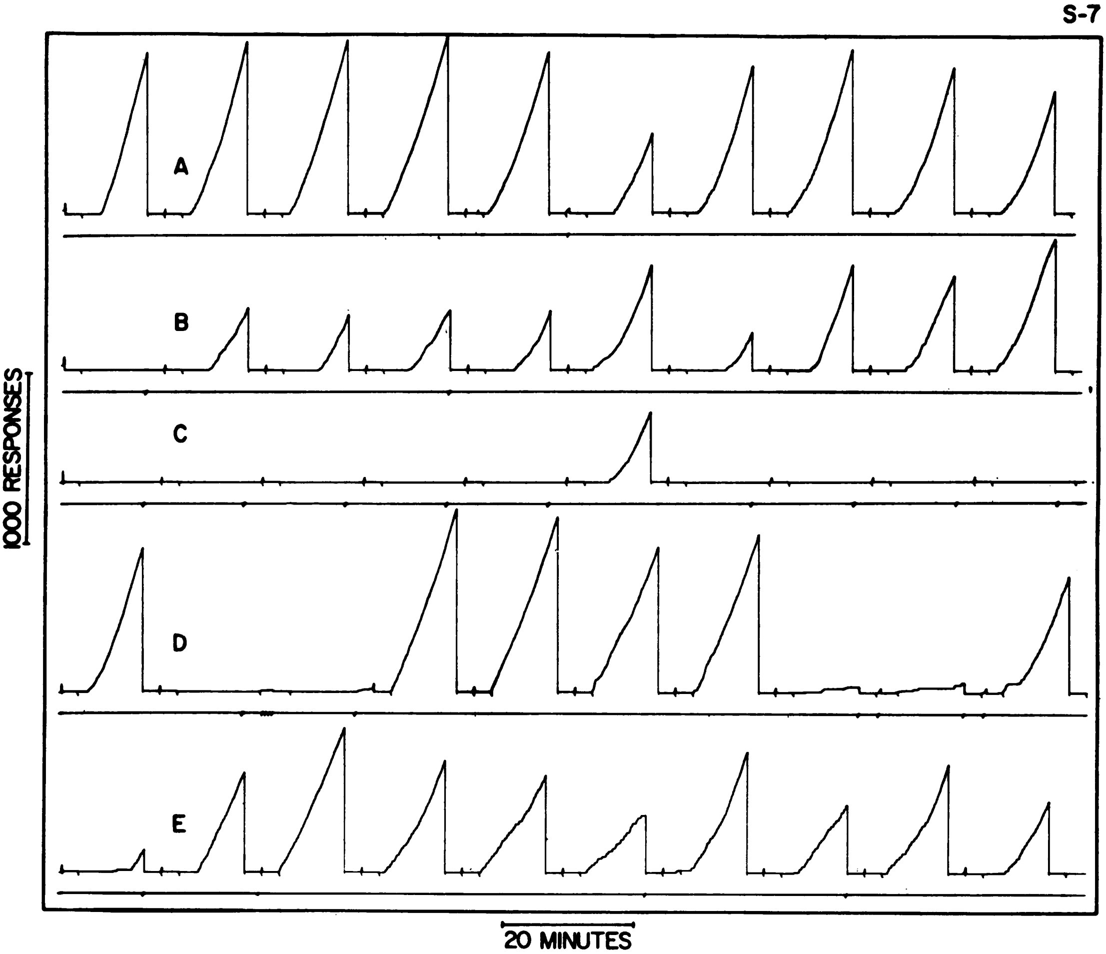

Fig. 6. Effects of omitting all scheduled shocks on performance under multiple FR 30 FI 10 min (Monkey S-7). Short diagonal strokes on the cumulative records indicate the beginning of FR 30 or FI 10-min components. The recording pen reset to the bottom of the record at the termination of each schedule component. A: representative performance under multiple FR 30 FI 10 min (*t* 1 sec); short diagonal strokes on the event record indicate shock deliveries; B: seventh session in which no shocks were delivered; short diagonal strokes on the event record indicate instances in which shocks would have been delivered under multiple FR 30 FI 10 min (*t* 1 sec); C: 18th session in which no shocks were delivered; first session (D) and seventh session (E) with scheduled shocks again presented.

ponents. For both monkeys there were many instances in which a characteristic fixed-interval pattern occurred following intervals earlier in the session in which no responding occurred. For example, in Fig. 6 the initial fixed-interval component in Frame B was terminated automatically; all subsequent components were terminated by responding. In Frame C, only the sixth fixed-interval component was terminated by responding. Additional examples can be seen in Fig. 7, Frames B and C.

When shocks were delivered again after 18 sessions without shock, the performance of S-7 was initially disrupted. The first shock was delivered at the end of the second fixed-interval component in Frame D of Fig. 6; the following fixed-ratio component was terminated automatically after four shocks had been delivered. In many subsequent fixed-interval components responding occurred throughout the interval; in the ninth and tenth fixed-ratio components, a shock was delivered before the animal terminated the component. This disruption in fixed-ratio performance by shock delivery appeared to result from the introduction of shocks after 18 sessions in which no shocks occurred; in contrast, the infrequent occurrence of sched-

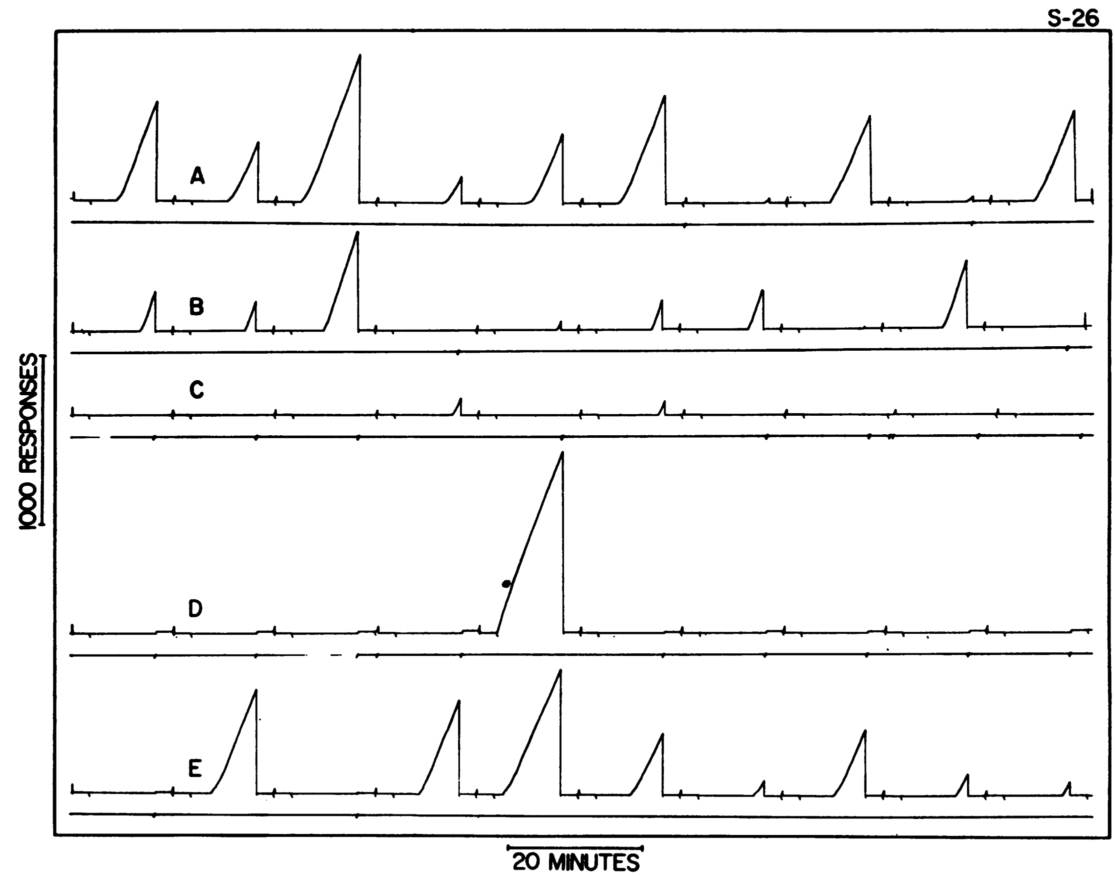

Fig. 7. Effects of omitting all scheduled shocks on performance under multiple FR 30 FI 10 min (Monkey S-26). Short diagonal strokes on the cumulative record indicate the beginning of FR 30 or FI 10-min components. The recording pen reset to the bottom of the record at the termination of each schedule component. A: representative performance under multiple FR 30 FI 10 min (*t* 1 sec); short diagonal strokes on the event record indicate shock deliveries; B: fifth session in which no shocks were delivered; short diagonal strokes on the event record indicate instances in which shocks would have been delivered under multiple FR 30 FI 10 min (*t* 1 sec). C: 16th session in which no shocks were delivered; first session (D) and fifth session (E) with scheduled shocks again presented.

uled shocks may increase fixed-ratio rates of responding (see Exp V).

The results of Exp I and II show that multiple schedules of schedule-complex termination can engender steady-state patterns of responding comparable to those obtained with multiple schedules of food presentation. When the parameter value of t in the fixed-interval schedule complex was made 1 sec, fixed-interval performance developed, was maintained for many months, changed when all shocks were omitted, and redeveloped when scheduled shocks were reinstated. These findings support the view that the schedule of shock delivery (and the parameter value of t) was important in developing characteristic fixed-interval performance. Because of the varied and extensive experimental histories of the subjects, further experiments on the role of t were continued with an untrained monkey.

EXPERIMENT III

Initial Development of Multiple FR FI in a Monkey with No Previous Training

Subject and apparatus. The subject was a female squirrel monkey (Monkey S-23). The apparatus was the same as that used in the preceding experiments.

Procedure. In Sessions 1-6, shocks were delivered through a 10,000 ohm resistor; the current through the tail was 6.2 ma during shock delivery. In subsequent sessions shocks were delivered through a 4050 ohm resistor; the current was 8.6 ma during shock delivery.

During Session 1, only FR was in effect in the presence of a red stimulus light, each time out was 30 sec, and session duration was about 1 hr. At the beginning, the schedule was FR 1 with shocks scheduled to occur every 5 sec. After about 40 min, the FR parameter value was gradually increased during the remainder of the session to FR 10 with shocks scheduled to occur every 10 sec.

In all subsequent sessions, FR and FI components alternated, and each time out was 60 sec. If the monkey did not terminate a component by responding, the component automatically terminated after four shocks had been delivered. Each session ended when 20 schedule components had been terminated. In Sessions 2-6, the fixed-interval component was FI 1 min (*t* 5 sec); in Sessions 7 and 8, it was FI 2 min (*t* 5 sec). In Sessions 2-4 the fixed-ratio component was still FR 10; in subsequent sessions it was FR 30. In Sessions 9-83 the schedule was multiple FR 30 FI 5 min; the value of *t* varied during these sessions (Table 1).

Under FR 30, shocks were scheduled to occur every 30 sec in the presence of a red stimulus light; the 30th response terminated the red stimulus and produced a 60-sec time out in the presence of a pattern of horizontal bars. Under FI 5 min the first response after 5 min in the presence of the white stimulus light terminated the component and produced a 60-sec time out. When *t* was 1, 5, or 15 sec, shocks were scheduled to occur every *t* sec after the 5-min interval had elapsed. When *t* was 0 sec, the first shock at the end of each 5-min interval was inevitable; subsequent shocks were scheduled to occur at 1-sec intervals.

Results. Figure 8 shows the initial conditioning of key-pressing for Monkey S-23. When the monkey was placed in the chair before the experiment, its general activity resulted in several operations of the key, producing the vertical line at *a* in Fig. 8A. The first seven presentations of the schedule complex were terminated by a response after three to five shocks had been delivered. In these segments, termination of the schedule complex is shown approximately by cessation of the downward displacements of the event marker indicating shock deliveries. At *b*, *c*, and *d* the termination of the schedule complex was followed immediately by additional responses during the time out. Beginning after *c*, a response sometimes terminated the schedule complex after a single shock delivery; beginning after *e*, a response sometimes terminated the schedule complex before a shock was delivered. In the latter part of the session the schedule parameters were changed as the rate of responding increased. Figure 8B shows the terminal part of the second session under a multiple FR 10 FI 1-min (*t* 5 sec) schedule. The rate of responding tended to be higher at the start of the fixed-

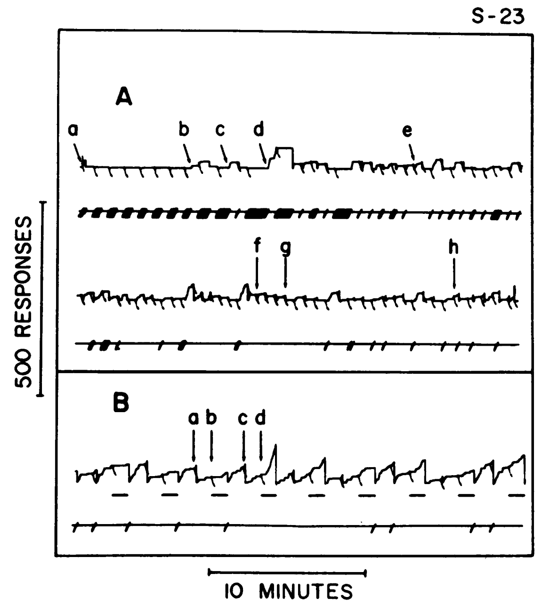

Fig. 8. Initial conditioning for Monkey S-23. The records in Frame A show the complete first session. The recorder ran continuously. At the start of the session, an FR 1 schedule terminated the red light and shock schedule. Shocks were scheduled to occur every 5 sec; time-out periods were 30 sec. Shock deliveries are indicated as a downward displacement of the event record. The onset of the red light is indicated as a downward displacement of the cumulative records. The cumulative record was reset at the termination of the red light; this cannot be seen at low FR values except when responding occurred during time out. See text for explanations of responding at a, b, c, d, and e. Beginning at f, the schedule of termination was FR 2 with shocks scheduled every 10 sec; beginning at g, the schedule of termination was FR 5 with shocks scheduled every 10 sec; beginning at h, the schedule of termination was FR 10 with shocks scheduled every 10 sec. Frame B shows performance in the terminal part of the second session in which the schedule was multiple FR 10 (red light) FI 1 min (*t* 5 sec) (white light); the time out was 60 sec; shocks were scheduled every 10 sec in the presence of the red light. Fixed-interval components are indicated by horizontal bars under the cumulative record.

ratio schedule complex (for example, *a* and *c*) than at the start of the fixed-interval schedule complex (*b* and *d*). The rate of responding during time-out periods was highest following components in which shocks were delivered. Beyond establishing conditions sufficient to develop schedule-controlled patterns of responding, no attempt was made to analyze the dynamic relations existing during initial conditioning.

The effects of decreasing t. The first two columns of Table 1 indicate the sessions in which different values of *t* were in effect under the multiple FR 30 FI 5-min schedule. The patterns of responding that developed at each value of *t* and during transitions from one value of *t* to another are shown in Fig. 9 and 10. At *t* 15 sec rates of responding of about 1.0 response per sec quickly developed in FR 30 components, while low steady rates of about 0.1 responses per sec developed in fixed-interval components (Fig. 9A). After *t* was decreased to 5 sec, rates of responding in fixed-interval components increased to about 0.2 responses per sec, and slight fixed-interval curvature developed (Fig. 9B and 9C). The quarter-life values increased from 27% at *t* 15 sec to 35% at *t* 5 sec (Table 1). When *t* was decreased to 1 sec, rates of responding in FI components abruptly increased (Fig. 9D); in subsequent sessions at *t* 1 sec, fixed-interval rates of responding were about 1 per sec and the pattern of responding was positively accelerated (Fig. 9E and 9F). Wtih further exposure to *t* 1 sec, the rate of responding and quarter-life value increased in FI components and the number of shocks delivered decreased.

When *t* was further decreased to 0 sec, fixed-interval rates of responding initially increased (Fig. 10A) and then decreased (Fig. 10B); the curvature in fixed-interval components gradually increased to a quarter-life value of 68% (Table 1). When *t* was increased to 1 sec again, the fixed-interval pattern of responding was little changed from what it had been at *t* 0 sec (Fig. 10C and 10D).

Quantitative data on the final performances at each value of *t* are presented in Table 1 and summarized in Fig. 11. The quarter-life value increased as *t* was decreased; it remained relatively high at *t* 1 sec when this point was redetermined. Rates of responding in both components increased as the value of *t* in fixed-interval components was decreased from 15 sec to 1 sec; rates in both components decreased when the value of *t* was 0 sec. The high rates of responding initially obtained at *t* 1 sec were not recovered when this point was redetermined after exposure to *t* 0 sec.

The results of Exp III indicate the multiple fixed-ratio fixed-interval performances maintained by schedule-complex termination can be developed in a previously untrained squirrel monkey; thus, the findings in Exp I did not depend on the extensive histories of the subjects. Further, the development of positively accelerated responding in fixed-interval components developed only as the value of *t* was decreased. This confirms the observation in Exp I that the development of fixed-interval

Table 1

Medians and ranges of various measures of performance under multiple FR 30 FI 5 min (Monkey S-23). These data were computed from the last five sessions at each value of *t*.

Sessions	*t* (sec)	*Quarter Life (%)*	*Responses/Sec* FI 5	FR 30	*Shocks/Session* FI 5	FR 30
9-20	15	27	0.11	1.03	2	5
		(18-30)	(0.07-0.14)	(0.67-1.11)	(1-3)	(2-8)
21-29	5	35	0.22	0.92	4	8
		(30-39)	(0.12-0.28)	(0.80-1.04)	(2-5)	(2-10)
30-60	1	46	1.10	1.80	1	0
		(38-47)	(1.10-1.30)	(1.70-1.80)	(0-1)	(0-0)
61-74*	0	68	0.50	1.40	11	1
		(56-72)	(0.50-0.70)	(1.30-1.50)	(10-11)	(0-1)
75-83	1	59	0.60	1.20	4	1
		(51-72)	(0.30-0.80)	(1.20-1.50)	(2-5)	(1-2)

*In Sessions 63-65, *t* was 1 sec. Note that when *t* was zero, the minimum number of shocks per session in FI 5 min was 10.

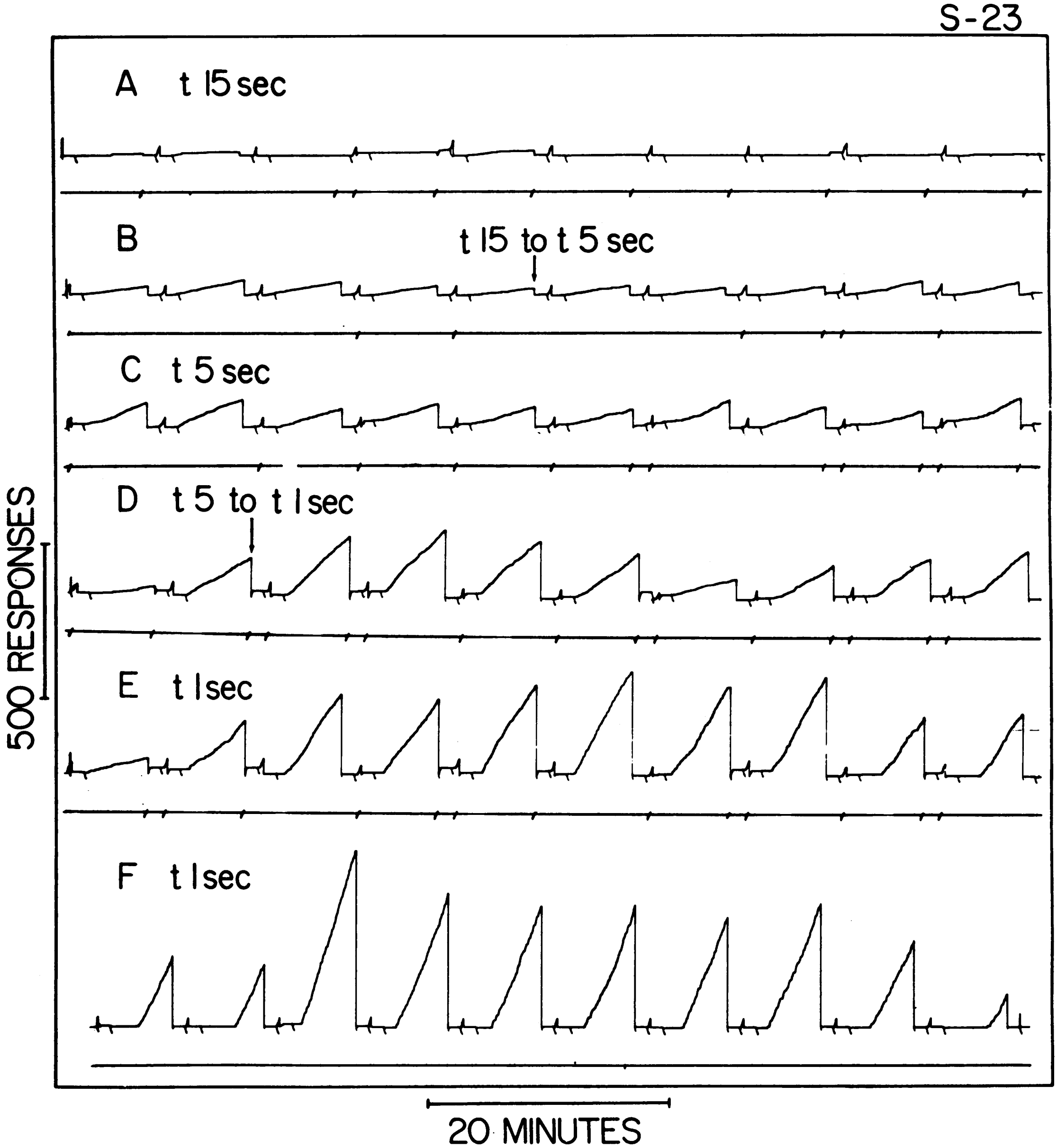

Fig. 9. Performance under multiple FR 30 FI 5 min with *t* 15 sec and the transition to *t* 5 sec (Monkey S-23). Short downward strokes on the event record indicate shock deliveries; strokes on the cumulative record indicate the beginning of FR 30 or FI 10-min components. The recording pen made a short downward stroke or reset to the bottom of the record at the termination of each schedule component.

A: Session 9, first complete session under multiple FR 30 FI 5 min (*t* 15 sec). Rate of responding was high in FR 30 components, but near zero in FI 5 components.

B: Session 20, final performance at *t* 15 sec and transition to *t* 5 sec (at the arrow). Initially, the performance was little changed.

C: Session 28, final performance at *t* 5 sec. There is only slight indication of fixed-interval curvature.

D: Session 29, transition from *t* 5 sec to *t* 1 sec (at the arrow). Rates of responding are increased in FI components under *t* 1 sec.

E: Session 34, development of performance under *t* 1 sec (quarter life, 37%; FI rate, 0.7 responses per sec; FR rate, 0.8 responses per sec).

F: Session 60, final performance under *t* 1 sec (quarter life, 47%; FI rate, 1.1 responses per sec; FR rate, 1.8 responses per sec).

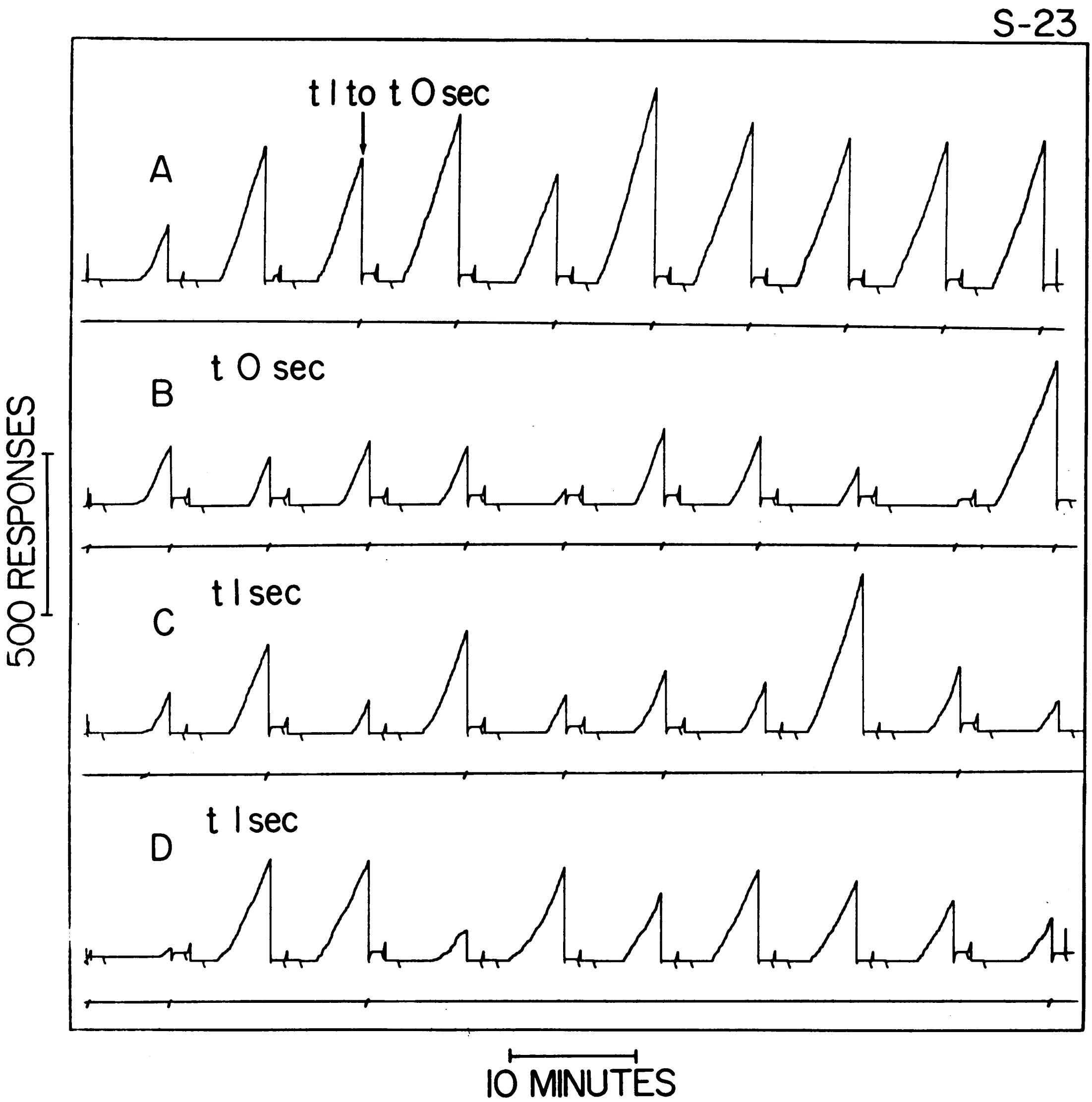

Fig. 10. Performance under multiple FR 30 FI 5 min under *t* 1 sec and *t* 0 sec (Monkey S-23). Short diagonal strokes on the event record indicate shock deliveries; similar strokes on the cumulative record indicate the beginning of FR 30 or FI 5-min components (Monkey S-23). The recording pen reset to the bottom of the record at the termination of each schedule component.

A: Session 61, transition from *t* 1 sec to *t* 0 sec (at the arrow). The FI rate initially increases when the shock is made inevitable.

B: Session 74, final performance at *t* 0 sec (quarter life, 68%; FI rate, 0.5 responses per sec; FR rate, 1.3 responses per sec).

C: Session 75, first session at *t* 1 sec after *t* 0 sec (quarter life, 65%; FI rate, 0.6 responses per sec; FR rate, 1.4 responses per sec).

D: Session 83, final performance at *t* 1 sec (quarter life, 55%; FI rate, 0.7 responses per sec; FR rate, 1.5 responses per sec).

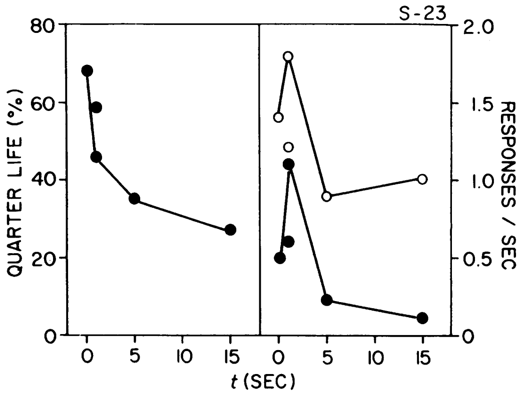

Fig. 11. Median rates of responding (right frame) and quarter life (left frame) at various values of *t* (Monkey S-23). Open circles: FR 30; closed circles: FI 5 min. The connected points were determined in succession from right to left. The unconnected points at *t* 1 sec were determined after the points at *t* 0 sec.

curvature was functionally related to the shock schedule (*t*) during the fixed-interval component of the multiple schedule. To determine the possible inductive influence of the fixed-ratio component of the multiple schedule on the development of the fixed-interval performance, the fixed ratio was omitted in Exp IV.

EXPERIMENT IV

Performance under FI at Different Values of t

Subject and apparatus. A male squirrel monkey with previous training under various schedules of food presentation and shock termination in a conventional experimental chamber was used (Monkey S-16). This monkey had not been used in any experiment for about one year before the present experiment. The apparatus was the same as in Exp I.

Procedure. Shocks of 50 msec duration were delivered through a 4050 ohm resistor; the current through the tail was about 8.6 ma during shock delivery. At the start of the first session FR 10 was in effect in the presence of a red stimulus light, shocks were scheduled to occur every 15 sec and time-out periods were 60 sec. Responding developed rapidly, and after the 20th time out the schedule was changed to FI 5 min (*t* 15 sec) in the presence of a white light; the session ended after the 40th time out. In all subsequent sessions, only the FI 5-min schedule was in effect, and each session ended after the 20th time out. The value of *t* was 15 sec in Sessions 1-15, 5 sec in Sessions 16-24, and 1 sec in Sessions 25-34. Subsequent shocks were scheduled to occur at intervals of the same duration as *t*. After five shocks, the schedule complex terminated automatically and a time-out period occurred. The experiment was stopped after Session 34 because the monkey became sick.

Results. Decreasing the value of *t* generally increased average rates of responding and produced positively accelerated responding within fixed-interval components (Fig. 12 and 13). After Session 4 at *t* 15 sec, responding was relatively steady with a quarter-life value of about 25% and an average rate of about 0.1 responses per sec (Fig. 12A and 13A). When *t* was decreased to 5 sec, the cumulative records showed some instances of positively accelerated responding (Fig. 12B and 12C); there was a slight increase in quarter-life value and average rate of responding (Fig. 13B). When *t* was further decreased to 1 sec, average rates of responding became generally higher and more variable; quarter-life values rapidly increased to about 50% (Fig. 13C). The patterns of acceleration in responding shown in Fig. 12D and 12E suggest that a steady-state performance had not been reached when the experiment was terminated.

The results of Exp IV, using a fixed-interval schedule complex, confirm the major finding of Exp I and III that the development of a positively accelerated pattern of fixed-interval responding depends upon the parameter value of the shock schedule in the fixed-interval schedule complex. In Exp V, an inductive effect within the multiple fixed-ratio fixed-interval schedule complex was explicitly studied; the initial development of responding under the fixed-interval component of the multiple schedule was studied in a monkey previously trained under a fixed-ratio schedule complex.

EXPERIMENT V

Transition from FR to Multiple FR FI and Further Evaluation of the Parameter t

The purpose of this experiment was to study the development of the fixed-interval performance in a monkey trained to respond with a high rate under a fixed-ratio schedule complex. In the course of developing the fixed-ratio performance, observations were made of the lasting effects on fixed-ratio rate of increasing the

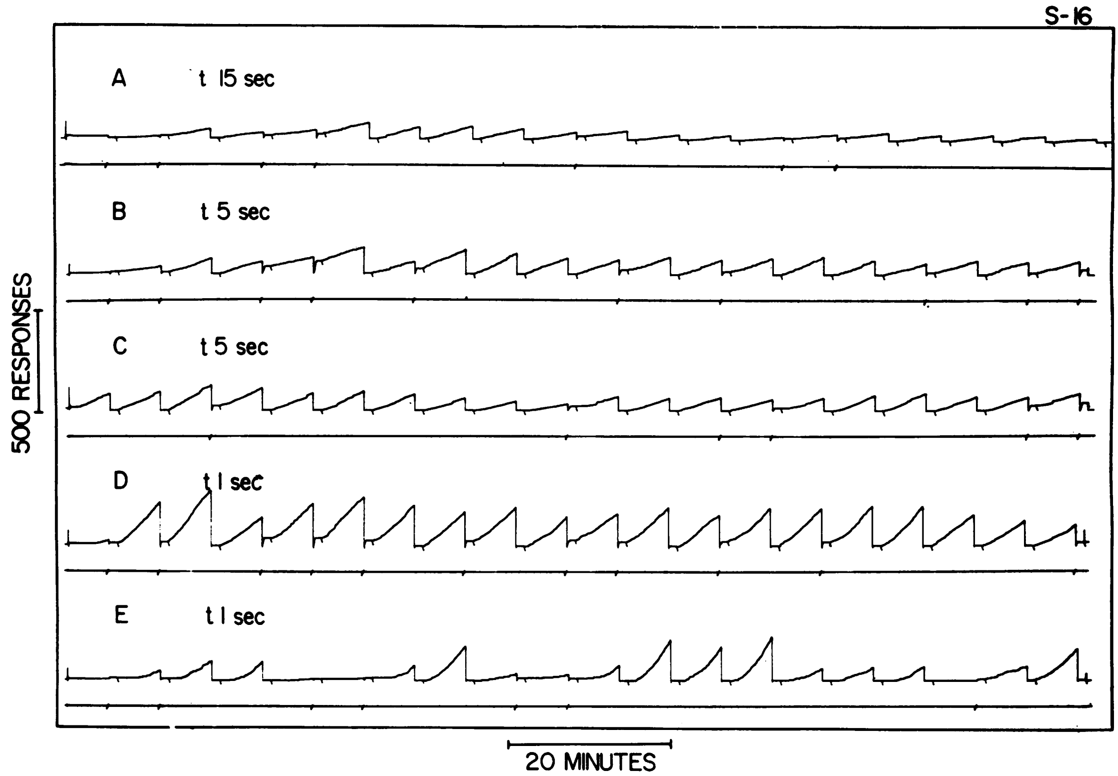

Fig. 12. Performance under FI 5 min at different values of *t* (Monkey S-16). Short diagonal strokes on the event record indicate shock deliveries; similar strokes on the cumulative record indicate the termination of each time out. The recording pen reset to the bottom of the record at the termination of each FI 5 min. A: Session 15, final performance under *t* 15 sec; B: Session 16, first session under *t* 5 sec; C: Session 24, final performance under *t* 5 sec; D: Session 25, first session under *t* 1 sec; E: Session 33, final performance under *t* 1 sec. Responding usually occurred at the beginning of time-out periods following a shock delivery. As *t* was decreased, responding in FI 5 min became more positively accelerated.

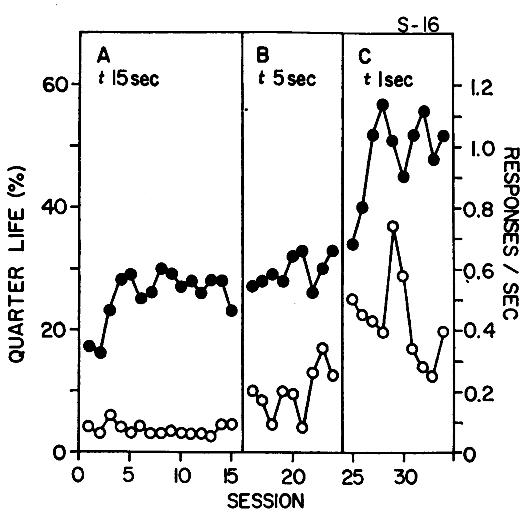

Fig. 13. Average rate of responding and average quarter life in each session under FI 5 min at different values of *t* (Monkey S-16). Open circles: responses per sec; closed circles: quarter life. Note the rapid increase in quarter-life values after the transition to *t* 1 sec.

frequency of scheduled shocks for a brief period of time. While performance in the fixed-interval component of the multiple schedule was developing, the effects of briefly decreasing the value of *t* from 1 sec to 0 sec were studied.

Subject and apparatus. A male squirrel monkey with no previous training (Monkey S-40) was studied in the same apparatus used in the preceding experiments.

Procedure. Shocks of 50 msec duration were delivered through a 10,000 ohm resistor; the current through the tail was about 6.2 ma during shock delivery. Because responding was unusually slow to develop in this monkey, there were 25 sessions of preliminary training in which schedules of termination, schedules of shock delivery, and time-out durations were frequently changed. (The schedules of termination ranged from FR 1 to FR 30 and from FI 15 sec to FI 2 min. During fixed-ratio components, shocks were scheduled to occur at frequencies ranging from 1 per sec to 1 per 15 sec; during fixed-interval components, *t* ranged from 1 sec to 5 sec. Time-out durations ranged from 1 to 150 sec.) During the last five sessions of preliminary training, only fixed-ratio schedules were in effect in the presence of a red light; the schedule value was gradually increased from FR 5 to FR 30 with shocks scheduled to occur every 30 sec; time-out periods were 60 sec. Performance under the FR 30 schedule complex was studied for 131 sessions (Sessions 1-131). Each session ended after the 20th time out. In Sessions 69 and 70, however, shock frequency was varied, and the sessions were longer.

In 60 subsequent sessions, the schedule was multiple FR 30 FI 10-min with a 2.5 min time out. The discriminative stimuli and the alternation of schedule components were the same as in Exp I. In Sessions 1-34 and 43-44 under the multiple schedule, *t* was 1 sec; in Session 35, *t* was 0.25 sec; in Sessions 36-42 and in Sessions 45-60, *t* was 0 sec. If the monkey did not respond after the inevitable shock at *t* 0 sec, subsequent shocks occurred at 1-sec intervals; after five shocks, the component automatically terminated.

Results

Relation of fixed-ratio to frequency of scheduled shocks. Under FR 30, with shocks scheduled every 30 sec, the two-valued pattern of responding characteristic of fixed ratio developed. Pauses at the start of each FR 30 component were followed by an abrupt shift to a rapid rate of responding (Fig. 14A). The initial pauses ranged up to 30 sec; the infrequently occurring shocks always were immediately followed by a high rate of responding. In Sessions 65-69, the median of average rates of responding was 1.6 responses per sec (range 1.5-1.8); the median number of shocks per session was 2 (range 0-3).

Increasing the frequency of scheduled shocks decreased the initial pauses and increased average rates of responding (Fig. 14B and 14C). In the segments in which shocks were scheduled every 10 sec, at least one shock occurred in each FR component, usually while the monkey was responding. After the two sessions with higher shock rates (Fig. 14B and 14C), rates of responding under FR 30 remained relatively high in subsequent sessions with shocks scheduled every 30 sec (Fig. 14D). The average rate of responding did not fall below 2.0 responses per sec until Session 88, and a scheduled shock did not occur until Session 90. Although average rates decreased slightly over the remainder of the experiment, they remained generally higher than they had been before Session 69 (Fig. 14D). In Sessions 127-131, the median of average rates of responding was 1.7 (range 1.6-2.0); no shocks occurred in any of these sessions.

Introduction of the multiple schedule. The first five daily sessions under multiple FR 30 FI 10 min (*t* 1 sec) are shown in Fig. 15. During these sessions, the median of the average rates of responding in the FR component was 1.8 (range 1.6-2.5). The transition had little effect on responding in the FR components. The many instances of negatively accelerated responding at the beginning of fixed-interval components suggest an inductive effect from the FR component. Sustained responding at a

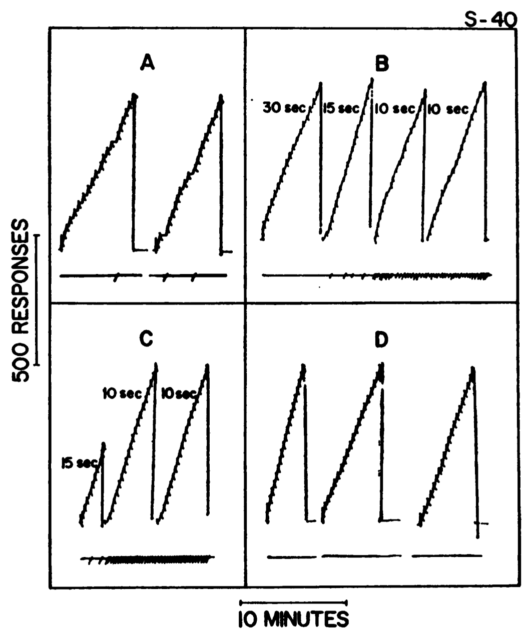

Fig. 14. Effect of increasing scheduled frequencies of shock on performance under FR 30 (Monkey S-40). A: Sessions 61 and 65, shocks scheduled every 30 sec. B: Session 69, shocks scheduled every 30 sec in the first segment, every 15 sec in the second segment, and every 10 sec in the third and fourth segments. C: Session 70, shocks scheduled every 15 sec in the first segment and every 10 sec in the second and third segments. D: Sessions 75, 113, and 124, shocks scheduled every 30 sec. When the shock frequency was increased, rate of responding tended to increase (Sessions 69 and 70); in subsequent sessions, response rates were higher than they had been before Session 69.

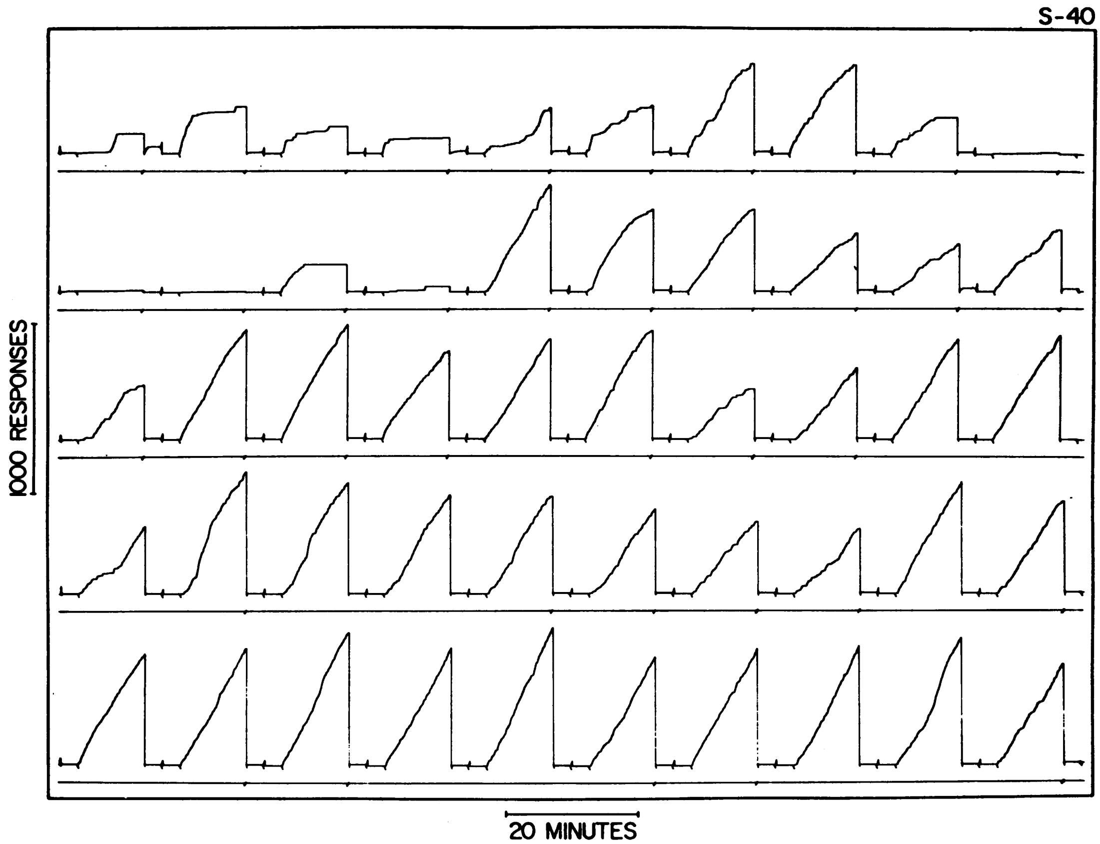

Fig. 15. Initial performance under multiple FR 30 FI 10 min (t 1 sec) following extended training under FR 30 (Monkey S-40). Short diagonal strokes on the event record indicate shock deliveries; similar strokes on the cumulative record indicate the beginning of FR 30 or FI 10 min components. The recording pen reset to the bottom of the record at the termination of each component. The first five sessions are presented in order from top to bottom. In these sessions the average rates (responses per sec) in the FR components were 2.5, 1.9, 1.9, 1.7, and 1.6; in the FI components the rates were 0.42, 0.47, 0.89, 0.96, and 1.18.

rate of about 1 response per sec was maintained throughout the fixed-interval component after the second session; the quarter-life values for Sessions 3-5 were 25%, 29%, and 28%. Over the next 10 sessions the quarter-life values increased to a stable level of about 35%-40%. Figure 16A and 16B show the performance under multiple FR 30 FI 10 min (t 1 sec) on Sessions 22 and 34. Some positive acceleration in responding can be seen in fixed-interval components following the high initial rate that persists in many intervals.

Effects of decreasing t to 0 sec. The effects of changes in t on fixed-interval patterns of responding are shown in Fig. 16 and 17, and effects on average rates of responding in each component and average quarter life are shown in Fig. 18. Fig. 16 shows the initial effect of decreasing the value of t to 0.25 sec (at the arrow in Fig. 16C) and then to 0 sec (at the arrow in Fig. 16D). Decreasing t to 0.25 sec had no immediate effect. At the end of the session in which t was decreased to 0 sec, the high rate at the beginning of fixed-interval components was less evident (Fig. 16D).

Positively accelerated responding in FI 10-min components developed when a shock at the end of each component was inevitable (t 0 sec) (Fig. 17A and 18C). After seven sessions with t 0 sec, quarter-life values had increased to about 60%. When t was subsequently increased to 1 sec for two sessions, the patterns of responding became similar to those previously obtained at this value, and the quarter-life values decreased to about 40% (Fig. 17B and 18D). Note the initial high rates of responding in the last three FI components in Fig. 17B. This recoverability of the pattern of

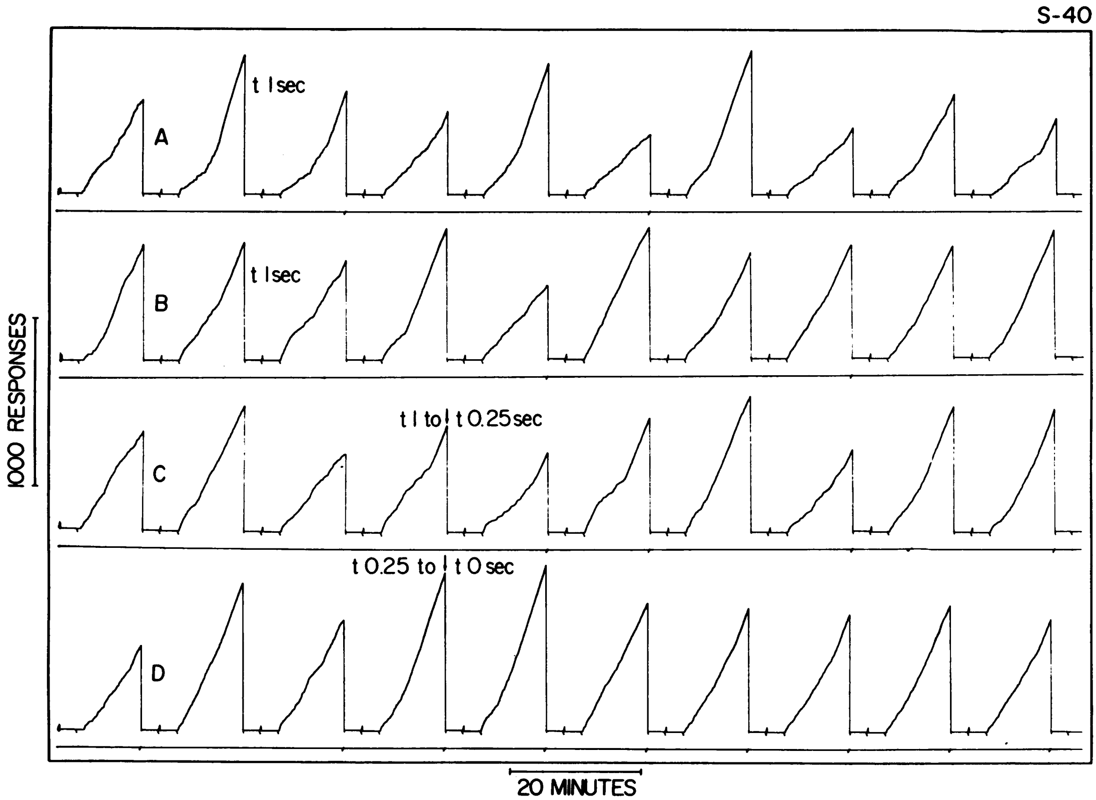

Fig. 16. Performance under multiple FR 30 FI 10 min (*t* 1 sec) and showing transitions to *t* 0.25 sec and *t* 0 sec (Monkey S-40). Short diagonal strokes on the event record indicate shock deliveries; similar strokes on the cumulative record indicate the beginning of FR 30 or FI 10-min components. The recording pen reset to the bottom of the record at the termination of each component. A: Session 22, *t* 1 sec; B: Session 34, *t* 1 sec; C: Session 35, *t* 1 sec was changed to *t* 0.25 sec at the arrow; D: Session 36, *t* 0.25 sec was changed to *t* 0 sec at the arrow. There are few instances of clear positively accelerated responding in FI components; responding was often negatively accelerated at the start of FI components.

responding at *t* 1 sec after a week's exposure to *t* 0 sec contrasts with the results of Exp III (see Table 1). When shocks were again inevitable (*t* 0 sec), positively accelerated responding in FI components redeveloped, and the quarter-life values increased to over 60% (Fig. 17C, 17D, and 18E). Although a shock inevitably occurred at the end of each FI 10-min component with *t* 0 sec, responding was well maintained for the more than six months this procedure was in effect after the present experiment.

EXPERIMENT VI

Multiple FI (Food Presentation) FI (Schedule-Complex Termination)

The purpose of this experiment was to develop characteristic fixed-interval patterns of responding under multiple fixed-interval schedules comprising food presentation and schedule-complex termination.

Subjects. Two male squirrel monkeys with no previous training (Monkeys S-48 and S-50) were maintained at 80% of their free-feeding weights.

Apparatus. The apparatus was similar to that described in Exp I. The metal wall contained a recessed area directly in front of the monkey. A solenoid-operated dipper could provide access to liquid food through a hole in the bottom of the recessed area. During food delivery the recessed area was illuminated by two 6-w bulbs.

Procedure. The monkeys were trained initially under a schedule of termination of a schedule complex. The source of electric shock was 600 v ac, 60 cps. Shocks of 50 msec duration were delivered through a 40,000 ohm series resistor; the current through the monkey's tail was about 12 ma during each shock delivery. Shocks were scheduled to occur periodi-

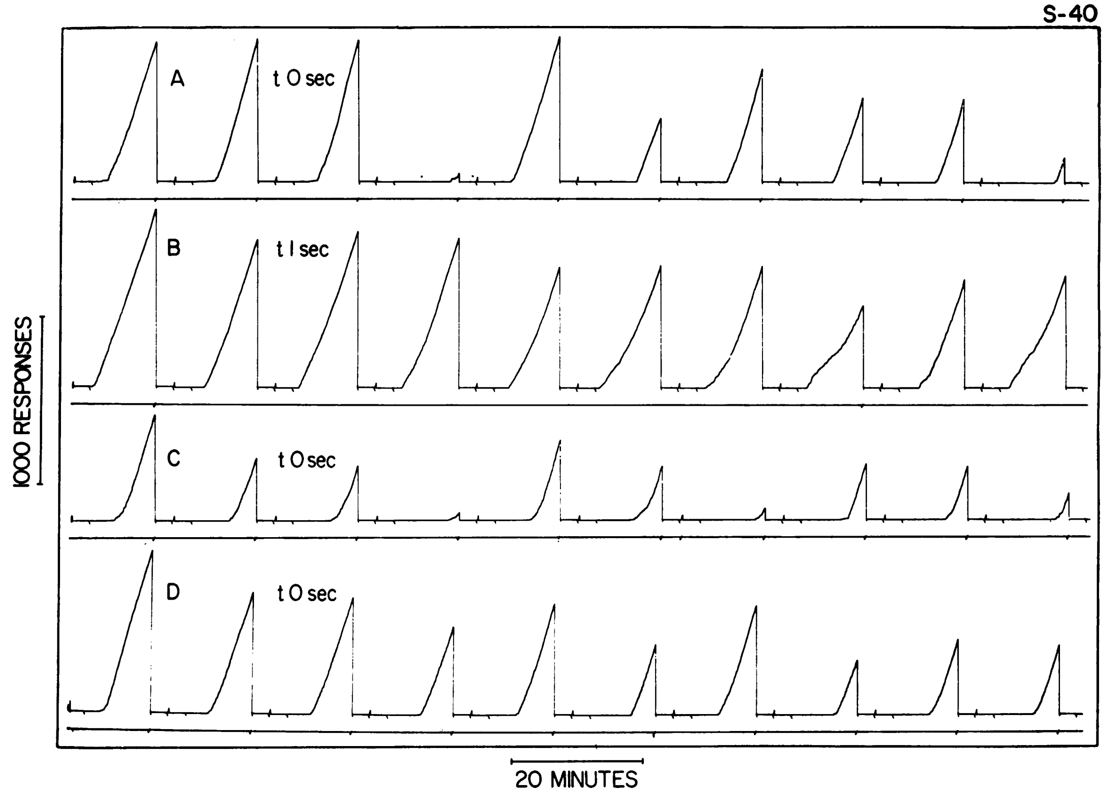

Fig. 17. Performance under multiple FR 30 FI 10 min (t 0 sec) and showing transitions to and from t 1 sec (Monkey S-40). Short diagonal strokes on the event record indicate shock deliveries; similar strokes on the cumulative record indicate the beginning of FR or FI components. The recording pen reset to the bottom of the record at the termination of each component. A: Session 42, t 0 sec; B: Session 44, t 1 sec; C: Session 50, t 0 sec; D: Session 60, t 0 sec. Note that the positively accelerated pattern of responding is less marked at t 1 sec (B) than at t 0 sec (A, C, D).

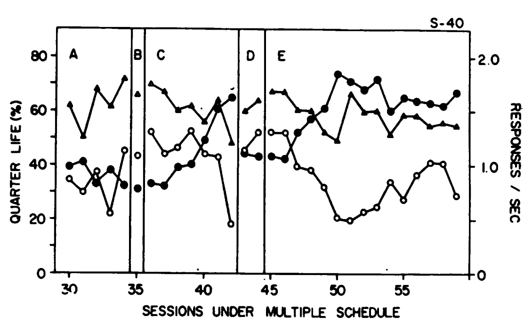

Fig. 18. Rates of responding and quarter life at different values of t (Monkey S-40). Triangles: responses per sec in FR 30; open circles: responses per sec in FI 10 min; closed circles: quarter life. A: t 1 sec; B: t 0.25 sec; C: t 0 sec; D: t 1 sec; E: t 0 sec. Relatively high rates of responding in FR components are maintained at all values of t. In FI components, rate of responding decreased and quarter life increased markedly at t 0 sec.

cally in the presence of the white stimulus; responses terminated the white stimulus and produced a 1-min period of time out (dark experimental chamber). When some responding had developed under this schedule of termination, the monkeys were trained to respond under a schedule of food presentation. Responding in the presence of a red stimulus light produced access to 0.25 ml of liquid food (Ellison and Riddle, 1961) for 3 sec. Each food delivery was followed by a 1-min time out.

Data obtained during training are not reported because procedures and schedule parameters were changed frequently and unsystematically. By the 20th daily session, responding was well maintained on both an FI 5-min schedule of termination of a schedule complex and an FI 5-min schedule of presentation of food. Sessions 20-40 each comprised 30 FI 5-

min components; the schedule of termination of the complex was in effect for the first half of the session, with the schedule of food presentation in effect for the second half. In the attempt to develop rates and patterns of responding that would be comparable under both FI 5-min schedules, the duration of t under the FI 5-min schedule of termination was frequently changed and eventually maintained at 3 sec. After Session 40 the type of schedule in effect was changed after every five components.

Results. The rates and patterns of responding maintained under the FI 5-min termination of a schedule complex were generally comparable to those maintained under the FI 5-min schedule of presentation of food. The upper cumulative response records for each monkey (Fig. 19A and 19C) show performances when the type of schedule in effect was changed in the middle of the session; the lower records show performances when the type of schedule changed after every five schedule components (Fig. 19B and 19D). The results show that performances can be developed under multiple FI 5-min schedules of food presentation and schedule-complex termination in individual monkeys.

DISCUSSION

The present results suggest that the schedule of reinforcement is more important in the control of behavior than is the nature of the reinforcer. Fixed-ratio and fixed-interval termination of schedule complexes can engender the characteristic patterns of responding usually obtained using these schedules with food presentation. Further, patterns of responding maintained by termination of schedule complexes can be controlled by discriminative stimuli in multiple schedules. The present results support previous reports that under a variety of experimental conditions schedules of termination of stimuli produce patterns of responding comparable to those produced by schedules of presentation of stimuli.

The general similarity of patterns of responding under fixed-ratio and fixed-interval termination of schedule complexes to patterns under fixed-ratio and fixed-interval schedules of presentation confirms that presentation of

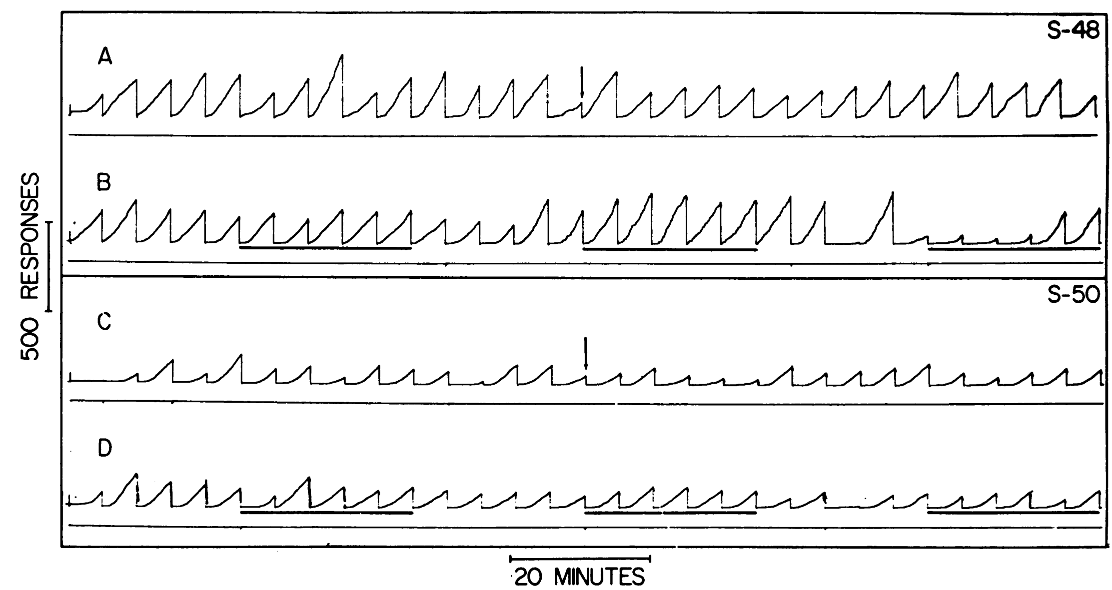

Fig. 19. Performance under multiple schedules of reinforcement in individual squirrel monkeys; multiple FI 5 min (food presentation) FI 5 min (schedule-complex termination). In the presence of a red light, the first response after 5 min terminated the light and was followed by food delivery; in the presence of a white light, the first response after 5 min terminated the shock schedule complex. Shock deliveries are indicated by short diagonal strokes on the event record (t 3 sec); food deliveries are indicated by short diagonal strokes on the cumulative record. The recording pen reset to the bottom of the record at the end of each FI 5-min component. The recorder did not run during the time out that followed each FI. In Frames A (Session 36) and C (Session 40), arrows indicate where the schedules alternated in the middle of the session. In Frames B (Session 49) and D (Session 44), horizontal bars under the cumulative record indicate the FI 5-min components reinforced by food presentation.

certain kinds of stimuli and termination of certain kinds of stimuli have similar reinforcing effects upon behavior (Keller and Schoenfeld, 1950, pp. 61-62; Skinner, 1953, p. 73). Reinforcers are always empirically defined; the further qualification of reinforcers as positive or negative is superfluous because it merely indicates whether the reinforcer is presented or terminated. Distinctions lacking empirical significance cause trouble. Until there is experimental evidence to support the distinction (see below, *Comparisons between reinforcers*), theoretical speculations on the nature of the differences between positive and negative reinforcers are not only gratuitous, but tend to obscure the sole defining characteristic of a reinforcer—that it can strengthen and shape behavior.

The role of the shock-schedule component of the schedule complex. The schedule of shock delivery under a schedule complex is an important controlling variable. With fixed-ratio schedule complexes, different schedules of shock presentation appear to be effective in generating fixed-ratio patterns. Azrin *et al.* (1962) and Azrin *et al.* (1963) studied fixed-ratio schedules of termination of a stimulus associated with the intermittent delivery of brief electric shocks at variable time intervals. The frequency of scheduled shocks during the schedule complex was independent of responding; responding terminated the complex for specified durations. Azrin *et al.* (1963) varied the frequency of shocks from one per 6 hr to 30 per hr; over the range from 2 per hr to 30 per hr, rates of responding on FR 25 were little affected. Responding was not disrupted when shocks occurred while the squirrel monkey was responding at a high rate. Azrin *et al.* (1963) found that relations between responses and shock deliveries were less important than relations between responses and termination of the stimulus associated with shocks under their fixed-ratio procedure.

In the present experiments, unlike those of Azrin *et al.* (1963), the frequency of shocks in the presence of the schedule complex was inversely related to the rate of responding. Since the delivery of shocks occurred at fixed time periods following the onset of the schedule complex, shocks never occurred if the average rate of responding was above some minimum value. We intended that this inverse relation between rate of responding and shock frequency would facilitate acquisition of responding, but we have no evidence that it did. The shock schedule used produced characteristic fixed-ratio patterns of responding, but the maintained rates of responding under fixed ratio were lower than those reported by Azrin *et al.* (1963). The fixed inverse relation between rate of responding and the rate of shocks on fixed ratio was probably detrimental to the continued maintenance of high rates on fixed ratio because the rate of responding increased when the frequency of scheduled shocks was increased (see Fig. 14, Exp V).

The schedule of shock presentation is critical in developing performances under fixed-interval schedule complexes. We were not able to produce characteristic fixed-interval patterns under a fixed-interval schedule complex with variable intermittent presentations of brief electric shock throughout the interval, but fixed-interval patterns did emerge when the train of shocks came shortly after the end of the interval. The delivery of brief shocks during the interval might be expected to modulate fixed-interval responding as other stimuli do (Dews, 1962). Perhaps the occurrence of shocks after the end of the interval was partly effective because it preserved homogeneity of stimuli during the interval. But this particular shock schedule had the disadvantage that there was an inverse relation between terminal rate of responding and shock frequency. At high values of t, when many intervals terminated without a shock presentation, a characteristic positively accelerated pattern of fixed-interval responding failed to develop. Both regular exposure to shocks and homogeneity of stimuli during the interval were insured by making the value of t shorter and shorter, down to an inevitable occurrence of a brief shock at the termination of each fixed-interval.

The effectiveness of inevitable shock in maintaining characteristic patterns of responding under the fixed interval schedule may be viewed from another angle. Azrin *et al.* (1962) emphasized the need for the terminal change in stimulus to be especially pronounced under their fixed-ratio procedure. In general, effective reinforcers tend to be salient stimuli that are presented suddenly and briefly. Perhaps the saliency of the fixed-interval schedule-complex termination in the present experiment was enhanced by the brief electric shock at the end of each interval.

Metastability. In studying conditions necessary for maintaining patterns of responding under fixed-ratio and fixed-interval schedule complexes it was essential to consider the history of the subject and the stability of the performance over long periods of time. Under both fixed ratio and fixed interval, it appeared that the schedule of shock presentation necessary to develop characteristic performances was more critical than the schedule of shock presentation needed to maintain them. Two different patterns of responding maintained under the same schedule parameters, one before and one after an intervening treatment, have been called metastable (Staddon, 1965). Instances of such metastability occurred when the value of *t* was decreased and then increased in Exp III, and when the shock rate during the FR component was increased and then decreased in Exp V. We are not certain whether the instances of metastable performances observed in the present experiments resulted primarily from the particular parameter values employed, or whether metastability is a common property of performances under schedule-complex termination.

Stimulus control. In the present experiments, characteristic fixed-ratio and fixed-interval patterns of responding maintained by termination of schedule complexes were brought under multiple stimulus control that was maintained throughout these experiments. Responding sometimes occurred during the time out, especially after a component in which shock had been presented. As with other multiple schedules, there were both transitory and stable interactions between the two components, but after the schedule performances had developed there was little evidence of responding appropriate to one component occurring during the other component. The development of multiple schedule control may appear to be inconsistent with the widely-held assumption that stimulus control does not develop as well under conditions involving noxious stimuli as under conditions involving food presentation. This assumption appears to be based upon such findings as the relatively flat stimulus generalization gradients following training under continuous avoidance schedules and the difficulty in establishing stimulus control in avoidance experiments (Appel, 1960; Hearst, 1960, 1963; Sidman, 1961). It must be understood that continuous avoidance is a schedule with unique properties; results pertaining to continuous avoidance do not necessarily apply generally to schedules involving the termination of noxious stimuli.

Comparisons between reinforcers that are presented and terminated. The similarity in performances in the fixed-interval components of the multiple schedule comprising food presentation and schedule-complex termination (Exp VI) further supports previous drug results (Kelleher and Morse, 1964) in indicating a general similarity in the dynamic aspects of performances under multiple schedules of presentation or termination. It is clear that different kinds of events will function as reinforcers and can be scheduled to produce characteristic patterns of responding. Nevertheless the sorts of comparisons between reinforcers described in Exp VI can be misleading, and must be carefully analyzed. Because of the power of schedules of reinforcement, the similar scheduling of different kinds of events can result in similar performances. Similar performances imply that the schedule of reinforcement is an overpowering controlling variable; similar performances do not necessarily demonstrate the functional identity of unlike events. Just how similar performances will be depends not only on the parameter values of the schedules but also upon other experimental conditions. As yet, we do not know the range of parameter values over which schedule performances maintained by presentation and termination of reinforcers will remain similar. If the conditions under which reinforcers can be used are more critical for one general type (presentation or termination) than for the other, this would provide an empirical difference between reinforcers that are presented and terminated.

Different kinds of events such as presentation of food and termination of electric shocks are alike only in that they are both reinforcers. Reinforcing stimuli also have other stimulus functions. For example, when food is reinforcing it is also satiating and is often discriminative. Noxious stimuli that reinforce by their termination often elicit behavior, and because they may be presented for long durations, they are likely to acquire discriminative control over responding. If the stimulus functions other than reinforcement are more pronounced for reinforcers that are terminated than for reinforcers that are presented, this would provide another empirical difference between types of reinforcers.

We have studied schedule-complex termination using the same methods of analysis previously used in studying reinforcers such as food (Skinner, 1938). Having established that termination of a schedule complex is an effective reinforcer, we are exploring the schedule conditions under which such a reinforcer can be used. We have not yet attempted to relate this work to any existing theoretical formulation of aversive control of behavior (for example, Anger, 1963; Azrin *et al.*, 1963; Dinsmoor, 1954, 1955; Miller, 1950; Mowrer, 1960; Schoenfeld, 1950; Skinner, 1953), nor have we attempted to hypothesize concerning the nature of the reinforcing stimuli or the intervening processes that support behavior maintained by schedule-complex termination. We believe that analysis of why schedule-complex termination is reinforcing will be less fruitful for understanding the dynamic nature of reinforcement than studying the ways in which schedule [illegible]lexes can be scheduled.

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