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RESPONDING MAINTAINED UNDER INTERMITTENT SCHEDULES OF ELECTRIC-SHOCK PRESENTATION: "SAFETY" OR SCHEDULE EFFCTS?

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Four experiments were conducted in which lever pressing by squirrel monkeys was maintained under multiple, mixed, or chained schedules of electric-shock presentation. In the first two experiments, a multiple schedule was employed in which a fixed-interval schedule of shock presentation alternated with a signaled two-minute component. Initially, no events were scheduled during the two-minute component (a safety period). In the first experiment, the safety period was "degraded" by introducing and systematically increasing the frequency of periodic shocks presented during that component. In the second experiment, the proportion of overall safe time to unsafe time was decreased by decreasing the value of the fixed-interval schedule while holding constant shock frequency during the two-minute component. In the third experiment, the overall arrangement was changed from a multiple to a mixed schedule in an attempt to determine whether fixed-interval responding would be maintained when a single exteroceptive stimulus was associated with both components. In the fourth experiment, the overall arrangement was changed from a multiple to a chained schedule in an effort to determine whether fixed-interval responding would be maintained when its consequence was presentation of a signaled "unsafe" period. Fixed-interval responding was well maintained under all experimental conditions; the varied relationships obtained lend more support to conceptualizations of shock-maintained behavior as exemplifying schedule-controlled behavior than to suggestions that such behavior may be readily accounted for by "safety theory."

Key words: shock-maintained behavior, shock-elicited behavior, fixed-interval shock schedules, fixed-time shock schedules, chained schedules, safety, lever press, squirrel monkeys

Following initial experimental histories under schedules of food presentation, electric shock postponement, or electric shock termination, lever pressing in squirrel monkeys may be maintained under intermittent schedules of electric shock presentation (Bacotti, 1978; Barrett, 1975; Barrett & Glowa, 1977; Barrett & Spealman, 1978; Byrd, 1972; DeWeese, 1977; Kelleher & Morse, 1968, 1969; Malagodi, DeWeese, Webbe, & Palermo, 1973b; Malagodi, Gardner, & Palermo, 1978; McKearney, 1968, 1969, 1970, 1972a, 1974a, 1974c; Morse & Kelleher, 1970, 1977; Stretch, Orloff, & Dalrymple, 1968; Stretch, Orloff, & Gerber, 1970; Webbe, 1974). Maintenance of responding by shock presentation has been studied most extensively within the context of fixed-interval (FI) schedules under which a brief electric shock is produced by the first response occurring after a fixed period of time. Lever pressing may be maintained indefinitely under FI schedules of electric-shock presentation, with rates and patterns of positively accelerated responding being comparable to those characteristic of FI schedules of food or water presentation (cf. Branch & Gollub, 1974; Dews, 1978; Ferster & Skinner, 1957; Schneider, 1969).

Morse and Kelleher (1970, 1977) and others (e.g., Barrett & Spealman, 1978; Byrd, 1972; Kelleher & Morse, 1968; Malagodi et al., 1978; McKearney, 1968, 1969, 1970, 1972a, 1972b) have interpreted these results from a general viewpoint that characterizes schedules as "fundamental determinants of behavior." This view emphasizes the interactions among experimental histories, ongoing patterns of responding at the time at which an environmental event is introduced, and the schedule under which the event is introduced, as major determinants of whether presentation of a given stimulus will maintain responding—exemplifying the process of reinforcement; or

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suppress responding—exemplifying the process of punishment. Other theorists (Eubanks, Killeen, Hamilton, & Wald, 1975; Hendry, 1969; Melvin, 1971; Stretch, 1972) have interpreted these results in terms of the concept of "safety." This viewpoint focuses on the discriminative (informative, cue) properties of shock when presented on FI schedules as signaling a "safe period" during which no shocks are presented. It has been suggested that noxious electric shock may become positively reinforcing via this predictive relationship to an immediately forthcoming shock-free period (Hendry, 1969; Melvin, 1971; Stretch, 1972).

The present experiments studied responding maintained by presentation of noxious electric shock under conditions in which each response-dependent shock was followed by either a safe period (timeout) or an unsafe period (a period during which inescapable and unavoidable shocks were repeatedly presented). In the first two experiments, a multiple schedule was employed in which, in the presence of one discriminative stimulus, electric shock was presented on an FI schedule. This FI component alternated with a second 2-min component that was associated with a second exteroceptive stimulus; initially, no events were scheduled during the 2-min component. In the first experiment, periodic response-independent shock was introduced during the 2-min component and the relation between responding in the FI component and the frequency of shocks presented during the 2-min component was examined. In the second experiment, shock frequency during the 2-min component was held constant and the effects of decreasing the parameter value of the FI schedule were examined. In the third experiment, the effects of eliminating the association of different discriminative stimuli with the two components were assessed by changing the overall schedule from multiple to mixed. In the fourth experiment, a chained schedule was employed to determine whether responding would be maintained when the immediate consequence of FI responding was not presentation of electric shock, but presentation of a signaled unsafe period.

EXPERIMENT I

In general, the concepts of "safety" and "safety signals" refer to periods of time during which no noxious or aversive events are presented and to exteroceptive stimuli (e.g., lights, tones, food, or shock) that reliably predict that state of affairs (cf. Azrin, Holz, Hake, & Ayllon, 1963; Badia, Harsh, Coker, & Abbott, 1976; Seligman, 1968; Seligman, Maier, & Solomon, 1971). Safe periods thus may be conceptualized as occupying one end of a continuum in which maximum safety is defined as a zero frequency of aversive events per unit of time. The other end of this continuum may be conceptualized as being occupied by periods of aversiveness or "unsafe periods," in which the degree of aversiveness is directly related to the frequency or intensity of aversive events or to the duration of the period during which they occur.

As noted above, several theorists have interpreted the phenomenon of responding maintained by intermittent presentations of noxious electric shock (shock-maintained behavior) in terms of the general concept of safety. Melvin (1971) and Stretch (1972) have suggested that responding may be maintained under FI schedules of electric-shock presentation because shock presentation is usually followed by either formal timeouts or simply the beginning of the next fixed interval. In both cases, the postshock periods meet the criteria according to which safe periods are formally defined. Hendry (1969) has suggested that electric shock becomes a conditioned positive reinforcer because of its informative and associative relation to either of these safe periods. Eubanks et al. (1975), in interpreting their failure to maintain responding under variable-interval (VI) schedules of electric-shock presentation, have suggested that a postshock safe period may be necessary for the chronic maintenance of behavior by shock presentation.

If safety interpretations of shock-maintained behavior are basically valid, several sources of evidence suggest that such responding should decrease in frequency, and perhaps cease altogether, under conditions in which the postshock period is changed from one of safety to one of increasing aversiveness. These sources include studies that have shown direct relations between rate of escape responding and duration of the safe period (e.g., Azrin et al., 1963; Dinsmoor, 1962), those that have found decreases in rate of avoidance responding with increases in rate of postresponse shocks or with decreases in delay to shock presentation (e.g., Herrnstein, 1969; Herrnstein & Hineline, 1966; Hineline, 1970), and studies of "preference for signaled shock" that have related rate of switching into signaled shock conditions to duration of safe periods and to probability of shock presentation during those periods (e.g., Badia et al., 1976; Harsh & Badia, 1976).

The first experiment examined the effects of degrading an initial safety period by introducing, and subsequently increasing the frequency of, unavoidable, inescapable electric shocks during that period.

METHOD

Subjects

Three adult male squirrel monkeys (*Saimiri sciureus*) served. SM-37N and SM-215 were experimentally naive. SM-43 had served in a previous experiment involving schedules of electric shock presentation (Malagodi et al., 1978). Food and water were continuously available in their individual home cages.

Apparatus

A Plexiglas chair, similar to the one described by Hake and Azrin (1963), was enclosed within a ventilated, sound attenuating chamber similar to that described by Weiss (1970). Each monkey was restrained in the seated position by a waist lock, with its tail held motionless in a small stock. A BRS-Foringer (model SG-901) constant-current ac shock generator delivered electric shock of 100-msec duration and 6-mA intensity (300 V, 60 Hz, through a series resistance of 50-K ohms) to two hinged brass plates that rested on a shaved portion of the tail. Electrode paste (Grass EC-2) ensured low resistance between the tail and brass plates. The lever (Lehigh Valley #1352) was mounted on the left side of the front wall, 6.0 cm above the waist plate. Lever presses with a downward force greater than .2 N registered as responses and briefly operated a feedback relay. Illumination was provided by two pairs of 7-W 115 V ac houselights (yellow or blue) located at the top of the front wall. White noise was continuously present in the experimental chamber. Electromechanical programming and recording equipment was located in an adjoining room.

Procedure

Preliminary procedures. With Monkeys SM-37N and SM-215, lever pressing was established following the general procedures described by McKearney (1968). In the presence of yellow houselights, an avoidance schedule was in effect: shocks were delivered every 5 sec in the absence of responding, and each response postponed scheduled shocks for 20 sec (Sidman, 1953). For Monkey SM-37N, sessions lasted 100 min with the yellow houselights continuously illuminated. For Monkey SM-215, each 6 min of yellow houselight illumination alternated with 2 min of blue houselight illumination. In the presence of blue houselights, no shocks were scheduled and responses had no programmed consequences (extinction; EXT). Sessions terminated after the sixteenth 2-min EXT component.

After 16 sessions with Monkey SM-37N, a 6-min fixed-interval schedule of electric-shock presentation (FI 6-min) was added to the avoidance schedule. Under this conjoint schedule of shock postponement and shock presentation, lever presses continued to postpone shocks scheduled according to the avoidance component, and the first response after each 6 min resulted in immediate shock presentation. Sessions terminated after the 16th response-produced shock. After 42 sessions of alternating avoidance and EXT components with Monkey SM-215, the FI 6-min schedule was conjointly added to the avoidance schedule in the presence of the yellow houselights. The blue houselights continued to accompany the 2-min EXT components which now followed each response-produced FI shock. Sessions terminated after the 16th 2-min EXT component.

Experimental procedures. After 15 and 24 sessions under the conjoint conditions for Monkeys SM-37N and SM-215, respectively, the avoidance schedule was removed. Thus, the experimental condition for Monkey SM-215 now consisted of a two-component multiple schedule with an FI 6-min schedule of electric-shock presentation as one component in the presence of yellow houselights, and EXT for 2 min as the other component in the presence of blue houselights. Monkey SM-37N was exposed to the same experimental condition by introducing the 2-min EXT component at this time. Monkey SM-43 had been responding under an FI 6-min schedule of electric shock presentation at the end of a previous experiment (Malagodi et al., 1978), and was exposed immediately to the same multiple schedule conditions as Monkeys SM-37N and SM-215. For all monkeys, components changed from FI 6-min to EXT immediately after each shock presented under the FI schedule, and from EXT to FI 6-min after 2 min in the presence of the blue lights.

After responding had stabilized in both components, electric shock was introduced during the 2-min component on a response-independent fixed-time (FT) schedule. Initially, the schedule was FT 2-min; one shock was presented, independently of responding, at the end of each 2-min component. The FT schedule was then geometrically decreased in successive experimental phases, increasing the number of shocks periodically delivered during each presentation of the 2-min component to 2, 4, 8, 16, 32, and 64. Thus, for example, under the highest parameter value studied (64 shocks) a shock was delivered every 1.9 sec during each 2-min presentation of the blue light. Each experimental phase remained in effect until responding in the FI 6-min component was clearly stable.

The order of experimental conditions and the number of sessions under each are shown in Table 1 (Because of renal failure, Monkey SM-43 was removed from the experiment after the phase at 4 shocks per 2-min component).

Sessions terminated after the 16th 2-min component, and were usually conducted six days per week.

Results

Baseline. The cumulative records in Figures 1A and 2A show baseline responding for Monkeys SM-37N and SM-215 when no shocks were presented in the 2-min component (EXT). Responding in the FI 6-min component typically consisted of a pause at the beginning of each interval followed by either a steady rate of responding or positively accelerated responding that terminated with shock presentation. Rates of responding during the FI component for Monkeys SM-37N and SM-215 were 15.7 and 30.1 responses per min, respectively. The only responses in the 2-min components were a few that occurred immediately after component onset (i.e., after the shock delivered at the end of the preceding FI component). Cumulative records for Monkey SM-43 showed patterns of responding similar to those for the other two monkeys.

Responding in the FI component. Positively accelerated responding was maintained in the FI component during all phases of Experiment I. Rate of responding during the FI 6-min component decreased with all monkeys when shock was first introduced during the 2-min component (Figures 1B and 2B; Table 2), but was not systematically related to subsequent increases in shock frequency. For example, with Monkey SM-37N, response rate progressively decreased to as low as 5.5 re-

Table 1

Summary of Procedures and Numbers of Sessions Under Each for Experiment I

Shocks per 2-min component	*Monkey SM-37N*		*Monkey SM-215*		*Monkey SM-43*	
	Order	*Sessions*	*Order*	*Sessions*	*Order*	*Sessions*
0	1	52	1	102	1	42
	8	32	9	30		
1			2	42	2	85
2	2	31	3	31	3	38
			10	20		
4	3	20	4	71	4	102
8	4	32	5	36		
			11	33		
16	5	28	6	55		
			8	42		
			12	50		
32	6	65	7	77		
			13	26		
64	7	41				

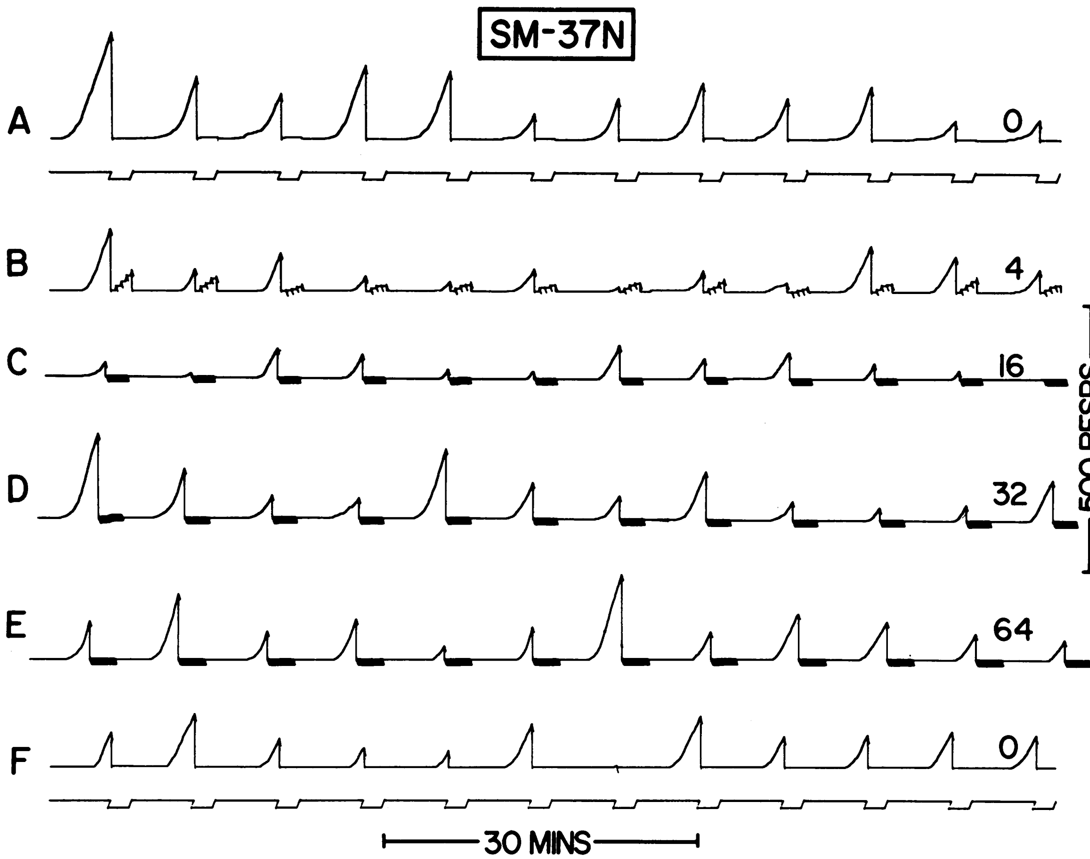

Fig. 1. Portions of cumulative records for Monkey SM-37N from Experiment I. The number above the right side of each record indicates the number of shocks per 2-min component; the first two and last two repetitions of the multiple schedule have been omitted from each record. Diagonal marks of the response pen indicate shock presentations. Resets of the response pen indicate component changes. In records A and F the event pen is displaced downward during the 2-min extinction (0 shocks) components. Records are from the session with the median FI 6-min response rate of the last 15 sessions under each condition.

sponses per min at a value of 8 shocks and subsequently increased to as high as 11.6 responses per min at 32 shocks (Figure 1B through 1E; Table 2). Removal of shock presentation from the 2-min component, following exposure to 64 shocks, resulted in no change in FI response rate (Figure 1F; Table 2).

Contrasting results were obtained with Monkey SM-215 during the first series of increases in the number of FT shocks. Response rate during the FI component increased to 20.4, 27.1, and 52.9 responses per min at 4, 8, and 16 shocks, respectively (Figure 2C through 2E; Table 2). Although response rate decreased to 38.3 responses per min when the number of shocks was further increased to 32, that rate remained above baseline levels (30.1 responses per min) (Figure 2F, 2A; Table 2). Peak rate of responding was recaptured during the second exposure to 16 shocks, and responding returned to baseline levels following the return to EXT during the 2-min component (Table 2). During the second series of increases in the number of FT shocks, changes in FI response rate more closely resembled those obtained for the first monkey (Figure 3; Table 2).

Although there was a slight reduction in FI response rate when shock was introduced during the 2-min component with Monkey SM-43, responding recovered to baseline levels at values of 2 and 4 shocks per component presentation (Table 2).

Responding in the 2-min component. Positively accelerated responding between FT

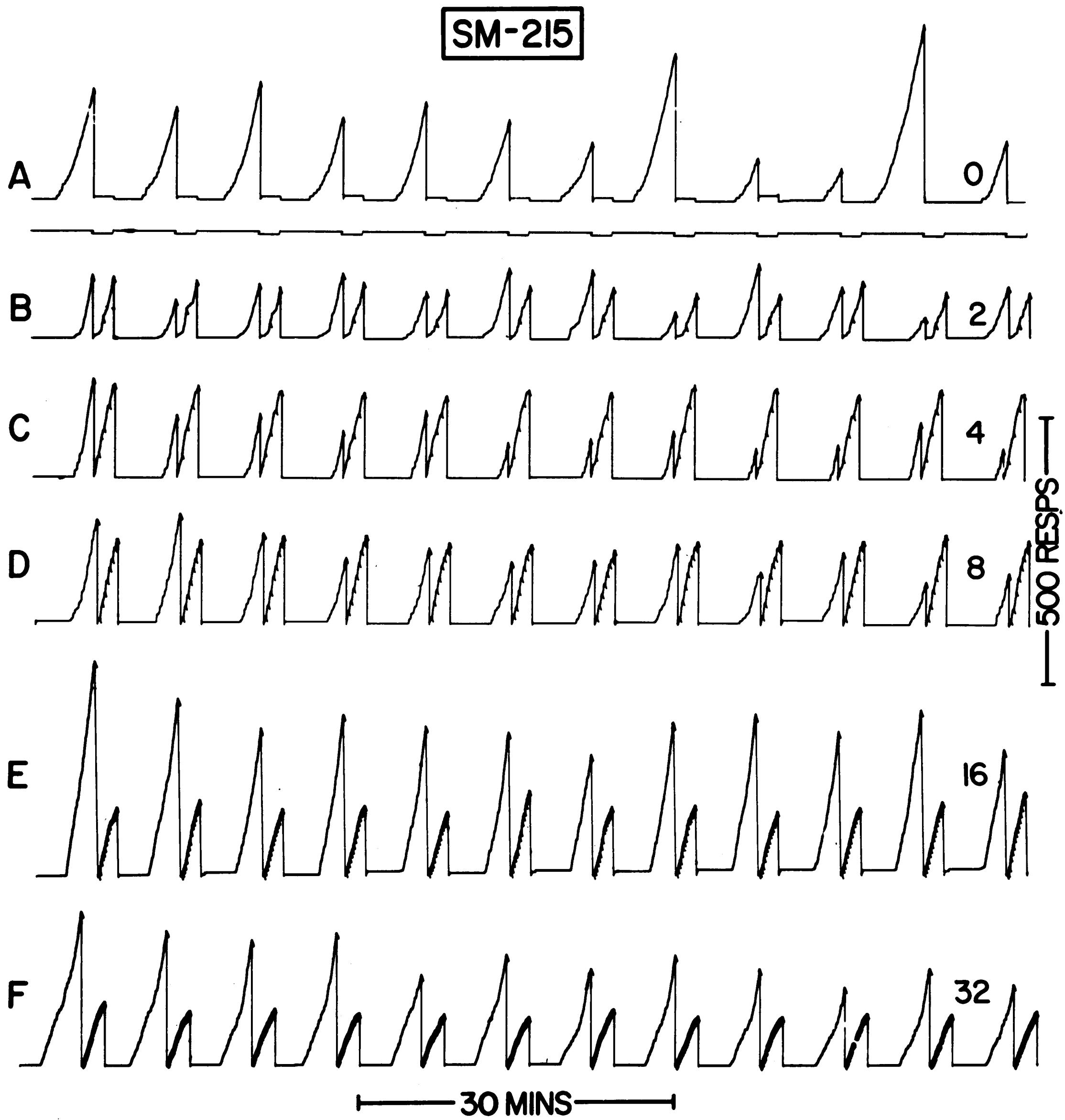

Fig. 2. Portions of cumulative records for Monkey SM-215 from the first series of increases in the number of shocks per 2-min component during Experiment I. Recording, display, and selection conventions are the same as in Figure 1.

shocks was maintained with all monkeys when the number of shocks per 2-min component was relatively low. Figures 1B and 2B show these patterns at four shocks with Monkey SM-37N and at two shocks with Monkey SM-215. Similar patterns of responding had been generated during the preceding values of shock presentation (see Table 2 for rates of responding). With Monkey SM-37N, rate of responding decreased markedly to approximately two responses per min when the number of FT shocks was increased to eight and then 16 (Figure 1C; Table 2). As response rates decreased, the temporal patterning of responding changed from positive acceleration between successive shocks (Figure 1B) to either negative acceleration, or restriction of responding to the beginning of each 2-min component (Figure 1B through 1E).

The results with Monkey SM-215 were simi-

Table 2

Median response rates from the last 15 sessions of each condition for both components of the multiple schedule. Ranges are given in parentheses.

Shocks Per 2-min	Monkey SM-37N		Monkey SM-215		Monkey SM-43	
component	FI	FT	FI	FT	FI	FT
0	15.7 (12.0-19.0)	0.8 (0.5-1.4)	30.1 (21.7-39.4)	3.4 (2.6-3.9)	18.6 (16.8-20.0)	0.6 (0.3-1.1)
	10.8 (6.7-13.0)	0.1 (0.0-0.3)	30.0 (23.8-40.1)	2.3 (1.6-10.6)		
1			17.5 (14.7-22.7)	31.2 (22.9-38.0)	16.6 (15.0-19.1)	11.6 (9.3-15.1)
2	7.9 (5.4-12.3)	10.5 (8.5-13.4)	18.2 (16.5-25.1)	49.1 (45.2-55.7)	18.5 (15.8-22.2)	18.3 (15.7-22.1)
			22.8 (18.8-28.9)	30.7 (24.3-37.1)		
4	7.7 (6.7-11.5)	11.3 (6.8-18.6)	20.4 (14.9-29.7)	74.4 (63.0-81.6)	18.8 (10.8-21.2)	10.8 (8.7-14.3)
8	5.5 (4.9-8.5)	1.9 (1.1-4.5)	27.1 (20.2-32.4)	74.5 (66.4-83.7)		
			15.6 (11.6-20.7)	18.8 (16.1-24.5)		
16	7.2 (5.6-10.1)	2.3 (1.5-5.1)	52.9 (41.0-68.5)	62.5 (57.6-89.5)		
			51.0 (44.2-60.3)	49.8 (44.8-60.2)		
			15.7 (12.2-21.6)	31.9 (27.9-37.0)		
32	11.6 (8.7-16.6)	0.4 (0.2-0.7)	38.3 (32.8-42.5)	54.3 (47.0-60.0)		
			15.7 (13.5-20.7)	38.7 (34.3-44.6)		
64	10.8 (6.7-13.0)	0.4 (0.0-1.1)				

lar to those of the first monkey in that temporal patterning changed from positive acceleration between successive shocks at 2 shocks per component to negative acceleration at subsequent values (Figure 2B through 2F). The results differed in that responding was maintained at relatively high levels during the 2-min component at all values of the FT schedule (Figures 2B through 2F; 3C; Table 2). Rate of responding was not systematically related to FT value (Table 2).

With Monkey SM-43, positively accelerated responding occurred between FT shocks at the three parameter values examined; there were no systematic rate changes in the 2-min component as the number of shocks was increased (Table 2).

Discussion

Systematically degrading the initial safety period by increasing the frequency and immediacy of unavoidable shocks presented dur-

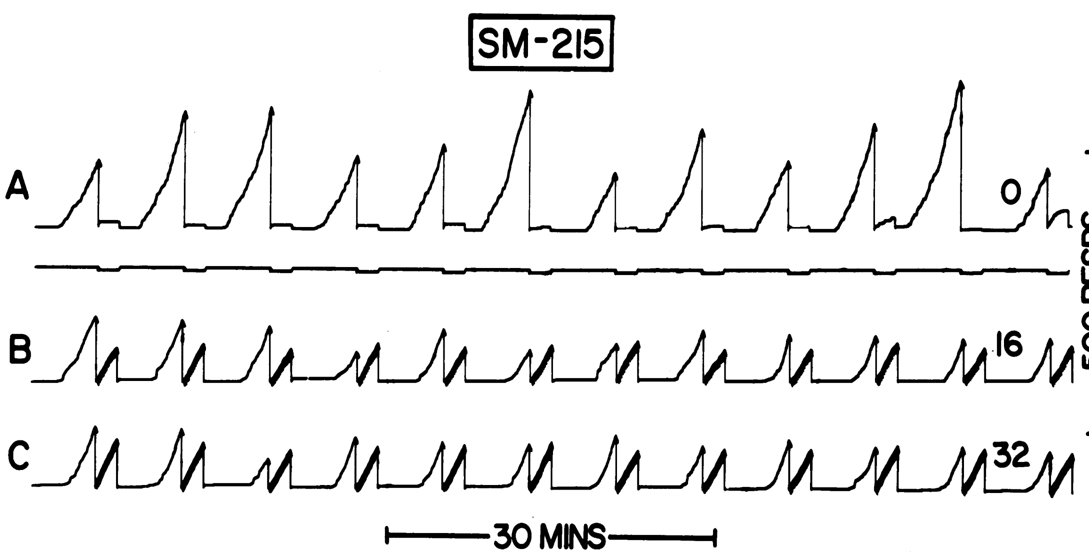

Fig. 3. Portions of cumulative records for Monkey SM-215 from the second series of increases in the number of shocks per 2-min component during Experiment 1. Recording, display, and selection conventions are the same as in Figure 1.

ing the 2-min component had no reliable effects on responding during the preceding FI 6-min component. Although FI responding decreased in rate from baseline levels when the FT shocks were introduced, rate returned to near baseline levels when FT shocks were presented as frequently as every 1.9 sec (64 shocks) with Monkey SM-37N, increased to nearly double baseline levels at 16 shocks during the first series with Monkey SM-215, and essentially remained at baseline levels at the three values examined with Monkey SM-43. Only during the second series of exposures with Monkey SM-215 was FI responding consistently below baseline levels at all values of the FT schedule of shock presentation; although reduced FI responding occurred throughout this series, rate did not decrease across the last three parameter values examined.

These results provide little support for the general contention that postshock safe periods may be necessary for maintenance of responding by FI schedules of electric-shock presentation. It is difficult to conceptualize a condition under which, for example, each FI shock is followed by a 2-min period during which 64 unavoidable shocks are periodically presented, as embodying the defining features of safety. The failure to find an inverse relation between FI response rate and shock frequency during the 2-min component suggests that safety-theory considerations emanating from escape, avoidance, or switching arrangements may not be directly generalizable to conditions under which responding is maintained under intermittent schedules of electric-shock presentation.

EXPERIMENT II

The results of the first experiment suggest that explicit safe periods may not be necessary for the maintenance of responding under FI schedules of electric-shock presentation. However, it is possible to conjecture that the procedures followed in Experiment I may have "moved" the safe period from the 2-min component to the beginning of the subsequent FI component. In this sense, the previous experiment actually may have arranged relatively long safe periods (6 min) in relation to the 2-min unsafe periods. It has been suggested that the reinforcing value of safe periods may be directly related to the relative duration of the safe period to the unsafe period (e.g., Harsh & Badia, 1976). Experiment II was performed in order to determine whether these relatively long shock-free periods during the FI component were necessary to maintain responding when 2-min unsafe periods followed each presentation of FI shock. This was accomplished by decreasing the parameter value of the FI schedule while holding constant the value of the FT schedule.

Method

Subjects and Apparatus

Monkeys SM-37N and SM-215 served in the same apparatus as used in Experiment I.

Procedure

At the end of Experiment I, Monkey SM-37N was responding under the two-component multiple schedule in which an FI 6-min schedule of shock presentation and a 2-min EXT period alternated. Periodic response-independent shocks were then added to the 2-min component over 20 sessions until 32 shocks were delivered during each presentation. Monkey SM-215 was responding under these conditions at the end of Experiment I. Experiment II formally began after responding had stabilized in both components of the multiple schedule. The number of FT shocks presented in the 2-min component was held constant at 32, while the FI value was decreased in separate experimental phases to 4-min, 2-min, 1-min, and .5-min. Each value remained in effect at least 10 sessions and until responding in the FI component was stable over the last five sessions.

Sessions terminated after the 16th 2-min component, and were usually conducted six days per week.

The order of experimental procedures and number of sessions under each are shown in Table 3.

Results

With both monkeys, positively accelerated responding was maintained in the FI component at all FI values. Figures 4 and 5 show representative cumulative records for Monkeys SM-37N and SM-215, respectively. These records show that durations of initial pausing during FI components decreased as the FI parameter was decreased. Figure 6 summarizes the

Table 3

Summary of procedures and numbers of sessions under each for Experiment II

	Monkey	
FI Value	*SM-37N*	*SM-215*
6-min	32	26
4-min	36	10
2-min.	33	32
1-min.	25	10
0.5-min	36	24

relation of FI response rate to FI value for both monkeys; response rate increased monotonically as FI value was decreased from 6 min to .5 min.

Responding during the 2-min component remained essentially the same as during comparable conditions of Experiment I with both monkeys. Monkey SM-37N responded at near-zero levels at all FI values. Monkey SM-215 responded in negatively accelerated patterns between FT shocks at all FI values; there were no systematic changes in rate of responding between FT shocks across changes in FI value.

Discussion

Decreasing the parameter value of the FI schedule resulted in a monotonic increase in response rate during the FI component. These results are in contrast with predictions derivable from safety theory in general. Decreases in the duration of the FI component were necessarily accompanied by decreases in the proportion of overall safe time to unsafe time from an initial value of 3:1 (at FI 6-min) to 1:4 (at FI .5-min). Extensions from the literature on preference for signaled shock, for example, suggest that this change in relative durations of safe to unsafe periods might have been expected to produce systematic decreases in responding during the FI component (e.g., Harsh & Badia, 1976).

These results, however, do correspond with those from experiments in which response

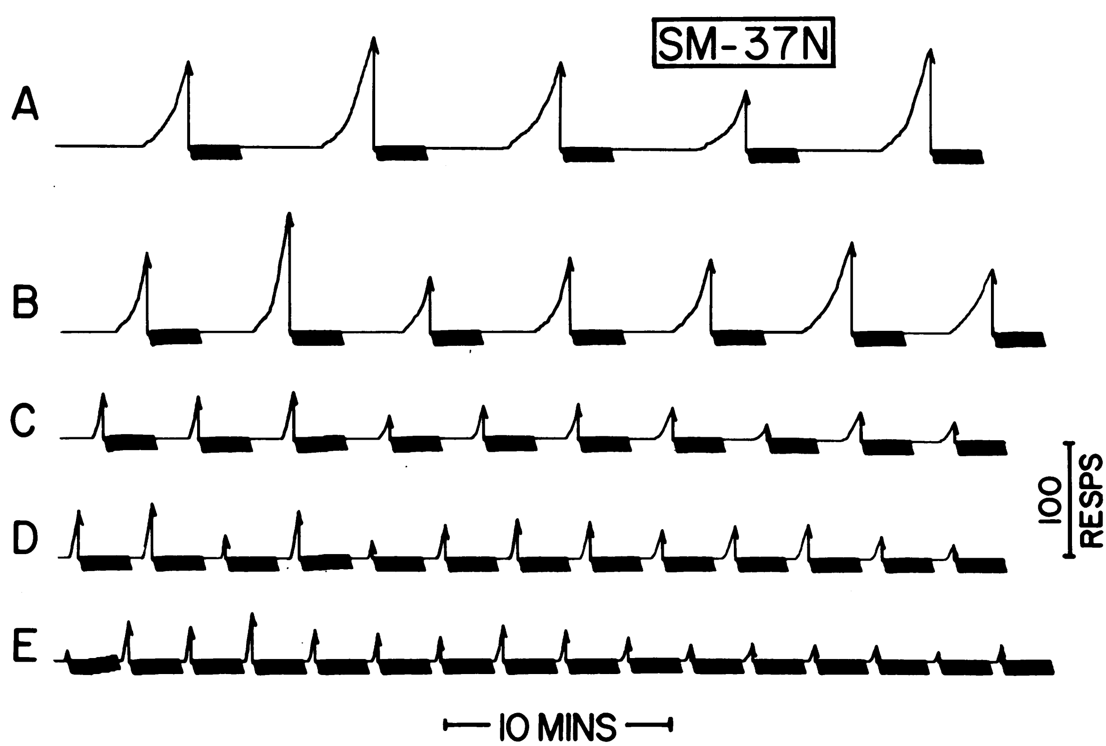

Fig. 4. Cumulative records showing patterns of responding by Monkey SM-37N. The FI duration was systematically decreased while the number of FT shocks presented per 2-min component was held constant at 32. Diagonal marks of the response pen indicate shock presentations. Resets of the response pen indicate component changes. The FI parameter value was 6, 4, 2, 1, and .5 min in records A through E, respectively. Records are from the session with the median FI response rate of the last five sessions at each value. Record E shows a complete session at FI .5-min; all other records show the approximate middle portions of sessions.

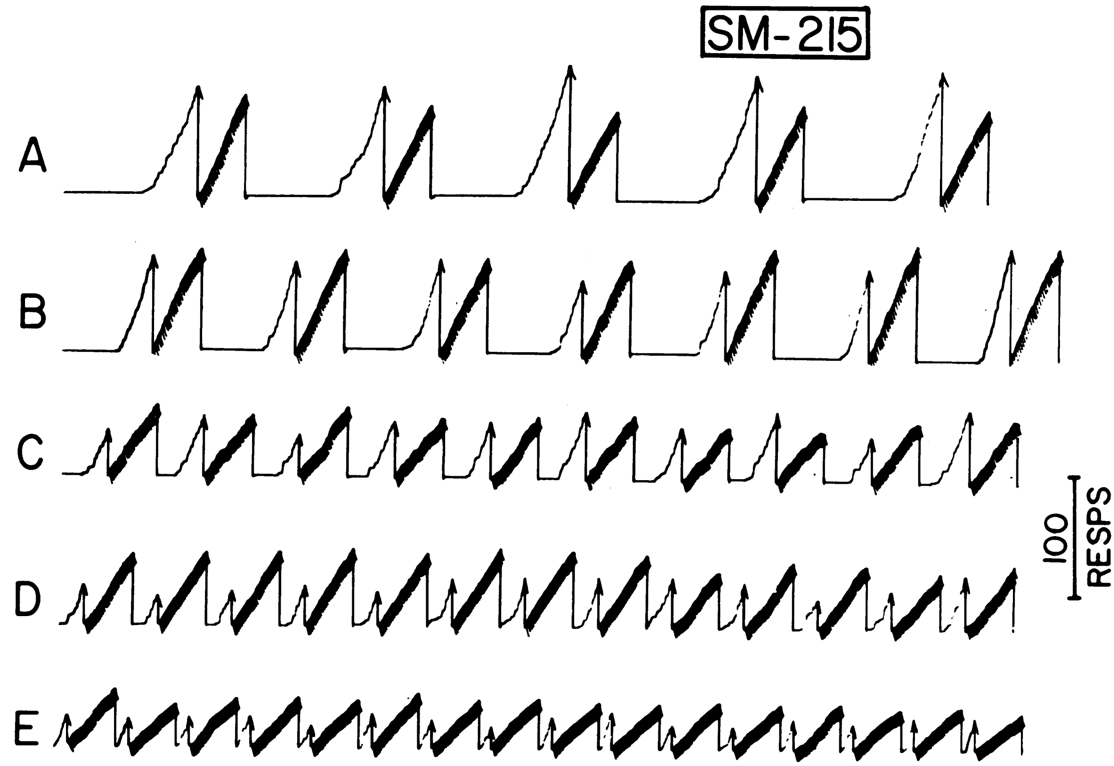

Fig. 5. Patterns of responding by Monkey SM-215 during Experiment II. Recording, display, and selection conventions are the same as in Figure 4.

rate has been related to parameter value of (1) simple FI schedules of electric shock presentation (Malagodi et al., 1973b; McKearney, 1969); (2) simple FI schedules of food presentation (e.g., Ferster & Skinner, 1957; Schneider, 1969); and (3) second-order FI schedules terminating in periods of food presentation (Waddell, Leander, Webbe, & Malagodi, 1972). These similarities suggest that the variables that ordinarily operate in governing schedule-controlled behavior under conditions of intermittent food or water presentation similarly operate in controlling responding maintained by intermittent schedules of electric-shock presentation (cf. Ferster & Skinner, 1957; Morse, 1966; Zeiler, 1977).

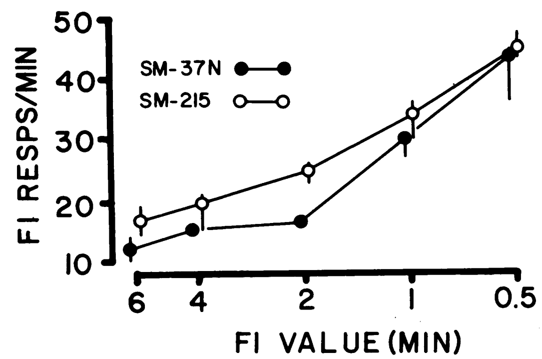

Fig. 6. Summary of the effects on FI rates of responding of decreasing the FI value in Experiment II. Circles show the median response rates for the last 5 sessions at each value; vertical bars represent ranges. Absence of a vertical bar indicates that the range fell within the area occupied by the circle. Note the log scale on the abscissa.

EXPERIMENT III

The first two experiments employed a multiple schedule in which responding was maintained by shock presentation in the first (FI) component, and shocks were presented independently of responding in the second (2-min) component. In Experiment I, varying the frequency of shock presentation in the second component had no systematic effects on responding in the preceding FI component. In Experiment II, decreasing the value of the FI schedule in the first component produced monotonic increases in FI responding, but had no systematic effects on responding in the second component. Although experiments on behavioral contrast and related phenomena have revealed a large number of conditions under which responding in one component of a multiple schedule is sensitive to variables manipulated in an alternating component, they have also shown that responding in one component may be independent of, or only transiently affected by, variables manipulated in another (cf. de Villiers, 1977; Schwartz & Gamzu, 1977). The possibility therefore exists that the multiple-schedule arrangement used in the first two experiments may have produced sufficient independence between components to preclude effects predictable from safety theory. The third experiment examined this possibility by changing the overall schedule from a multiple schedule, in which different discriminative stimuli were associated with the two components, to a mixed schedule, in which one exteroceptive stimulus was presented throughout both components.

Method

Subjects and Apparatus

Same as in Experiment II.

Procedure

Following completion of Experiment II, Monkey SM-215 was placed on a multiple schedule in which an FI 4-min schedule of electric-shock presentation directly alternated with a 2-min period during which 32 unavoidable shocks were periodically presented. The yellow houselights were illuminated during the FI 4-min component, and the blue houselights were illuminated during the 2-min component. After 28 sessions under this procedure, a mixed schedule was introduced; under the mixed schedule, the yellow houselights remained illuminated throughout both components. After 25 sessions under the mixed schedule, the multiple schedule was reintroduced for 46 additional sessions. The same procedures were followed with Monkey SM-37N, except that the FI schedule was 1 min in duration; the multiple, mixed, and multiple schedules were in effect for 12, 21, and 17 sessions, respectively. In all cases, responding was adjudged as being clearly stable for at least 10 sessions before conditions were changed.

Sessions terminated after the 16th 2-min component and were usually conducted six days per week.

Results

Figure 7 shows average stable FI response rates under each condition for both monkeys. With Monkey SM-215, responding in the FI component remained essentially constant at approximately 27 responses per min across all conditions. With Monkey SM-37N, FI response rate increased moderately following the change from the multiple to the mixed schedule, and decreased to slightly below its previous level upon final exposure to the multiple schedule. With both monkeys, response rate during the 2-min component was unaffected by the changes in overall scheduling. Figures 8 and 9 show representative cumulative records. With Monkey SM-215, patterns of responding in the FI component under the multiple schedule (Figure 8A and 8C) were the same as in the previous experiments. Typically, a pause at the beginning of each interval was followed by either steady or positively accelerated responding that terminated with shock presentation. Under the mixed schedule (Figure 8B), a brief burst of responding usually occurred at the beginning of each FI component; otherwise, responding was comparable to that prevailing under the multiple schedule. Although Monkey SM-37N re-

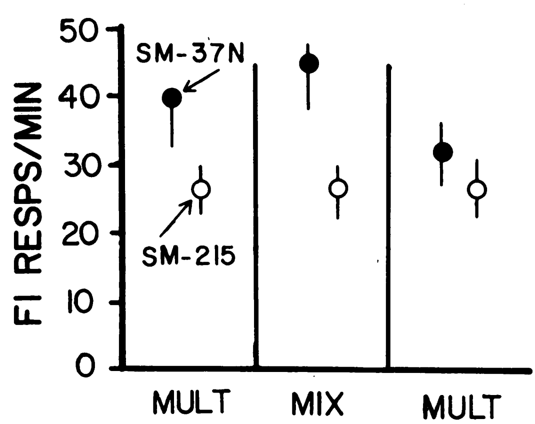

Fig. 7. Summary of the effects on FI rates of responding of presenting different (mult), or identical (mix), exteroceptive stimuli during the FI and 2-min components in Experiment III. The FI value was 4 min for Monkey SM-215 and 1 min for Monkey SM-37N; 32 shocks were presented during each 2-min component with both monkeys. Circles show the median response rates for the last 5 sessions under each condition; vertical bars represent ranges.

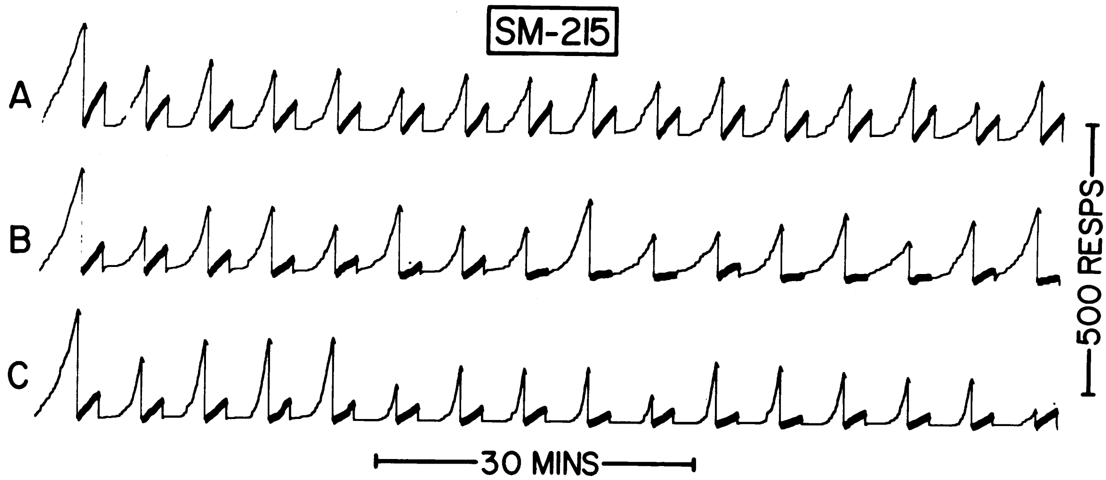

Fig. 8. Patterns of responding by Monkey SM-215 under the multiple (records A and C) and mixed (record B) schedules of Experiment III. Diagonal marks of the response pen indicate shock presentations. Resets of the response pen indicate component changes. The FI value was 4 min, and 32 shocks were presented during each 2-min component. Records were selected from the last 5 sessions under each condition.

sponded at a higher overall rate during the FI 1-min component under the mixed schedule than under the multiple, there were no obvious differences in response patterning between the two conditions (Figure 9).

Discussion

Removing the differential association of discriminative stimuli with the two components had no significant effects on responding in either component other than those congruent with previous comparisons of responding under multiple and mixed schedules of food presentation (i.e., with Monkey SM-215, the brief bursts of responding following changes from the 2-min to the FI 4-min component) (cf. Ferster & Skinner, 1957).

EXPERIMENT IV

The results of the first three experiments provided no evidence that the 2-min component containing repeated inescapable shocks was aversive or unsafe. To the contrary, the

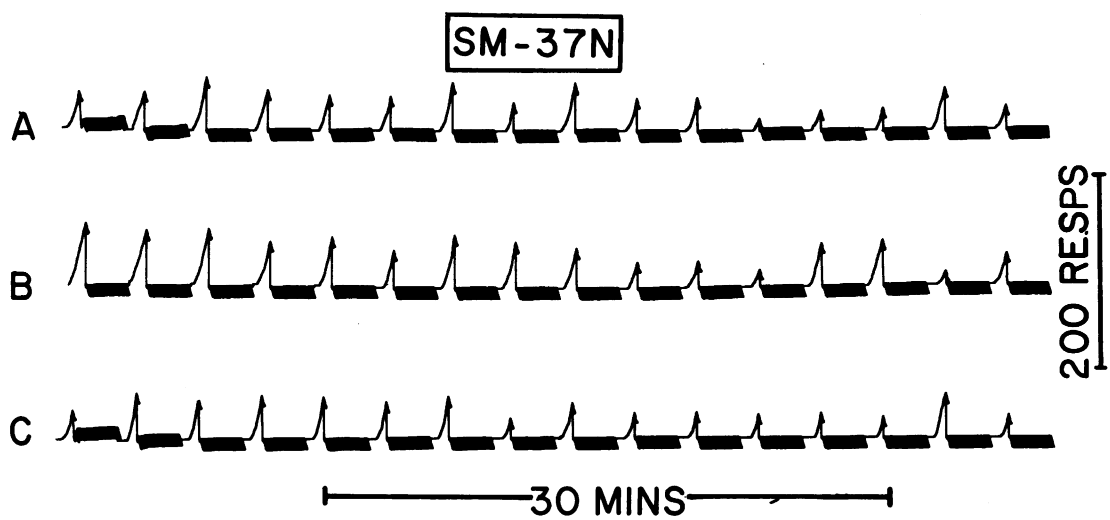

Fig. 9. Patterns of responding by Monkey SM-37N under the multiple (records A and C) and mixed (record B) schedules of Experiment III. Recording, display, and selection conventions are the same as in Figure 8.

most orderly results were those from Experiment II, in which increases in FI response rate were directly related to decreases in duration of the FI schedule. It should be noted that decreasing the FI schedule also involved increasing the rate of presenting the formally defined unsafe periods; the possibility is therefore suggested that increasing the rate of presenting the unsafe periods may have been as responsible as increasing the rate of presenting FI shocks for the results obtained. This consideration further suggests the possibility that the 2-min component might embody reinforcing (response maintaining) properties, rather than the aversive (response suppressing) properties previously considered.

The fourth experiment examined the possibility that the unsafe periods might themselves maintain responding by introducing several chained-schedule arrangements. Chained schedules (of two components) specify dependency arrangements between responding in the initial component and presentation of a discriminative stimulus in the presence of which either response-dependent or response-independent events may be scheduled. Such arrangements frequently have been employed to assess the potential conditioned reinforcing properties of discriminative stimuli associated with various contingencies of food or water presentation, but have not been examined previously with contingencies of shock presentation (cf. Fantino, 1977; Ferster & Skinner, 1957; Gollub, 1977; Kelleher, 1966; Kelleher & Gollub, 1962; Marr, 1969).

Method

Subjects and Apparatus

Same as in Experiment III.

Procedure

Following completion of Experiment III, Monkey SM-215 was placed on a two-component chained schedule containing an FI 4-min schedule as the first component and a 2-min period during which 32 FT shocks were repeatedly presented as the second component. In the first component the houselights were illuminated yellow; the first response after 4 min produced the second component during which the houselights were illuminated blue. After 32 shocks were periodically presented in the presence of the blue houselights, the yellow houselights were illuminated and the FI 4-min schedule was reinstated. After 31 sessions under this procedure, the number of FT shocks was decreased over seven sessions until two FT shocks were presented during each 2-min component (FT 1-min). Then, the schedule in the second component was changed to FI 1-min. Thus, the first response after 4-min in the first component changed the houselight illumination from yellow to blue, and completion of each of two FI 1-min schedules in the second component resulted in shock presentation. This chained schedule remained in effect for 31 sessions. A similar procedure was followed with Monkey SM-37N except that the first component schedule was FI 1-min, and the number of FT shocks presented in the second component was decreased from 32 to 2 over the first seven sessions following completion of Experiment III. In the next session, the schedule in the second component was changed to FI 1-min, as during the final phase with Monkey SM-215. Monkey SM-37N responded for 34 sessions under this two-component chained schedule.

Sessions terminated after the 16th 2-min component and were usually conducted six days per week.

Results

Figure 10 summarizes the results in showing average stable first component response rates during the baseline multiple schedule and both forms of the chained schedule. With Monkey SM-215, response rate in the first (FI 4-min) component was unchanged following introduction of the first chained-schedule arrangement in which 32 response-independent shocks were periodically delivered in the second component. With both monkeys, first-component response rate decreased following introduction of the second chained-schedule arrangement in which two FI 1-min schedules of shock presentation were in effect during the second component.

Details of these results are illustrated in Figure 11. With Monkey SM-215, responding in both components of the first chained-schedule arrangement (Figure 11A) was essentially the same in both rate and temporal patterning as shown previously under the comparable multiple schedule (Figure 8C); responding in the first component was positively accelerated at moderate to relatively high rates, and responding in the second component was nega-

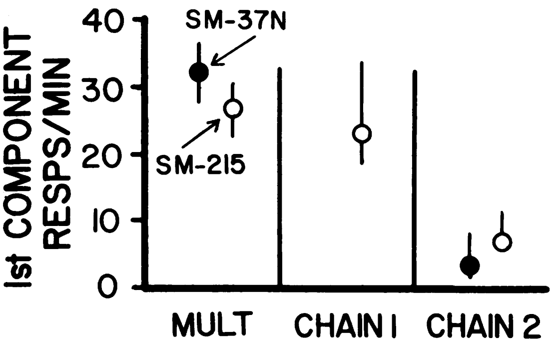

Fig. 10. Summary of differences in FI rates of responding under the multiple schedule (mult) and the chained schedules (chain 1 and 2) of Experiment IV. Data from the multiple schedule condition are the same as those in the right panel of Figure 7. With Monkey SM-215 the first component was always an FI 4-min schedule; the second (2 min) component consisted of 32 FT shock presentations under the mult and chain 1 condition, and two FI 1-min schedules under the chain 2 condition. With Monkey SM-37N the first component was always an FI 1-min schedule; the second (2-min) component consisted of 32 FT shock presentations under the mult condition and two FI 1-min schedules under the chain 2 condition. Circles show the median response rates for the last five sessions under each condition; vertical bars represent ranges.

tively accelerated between successive shock presentations. Changing the contingencies of shock presentation in the second component from 32 FT shock presentations to two FI 1-min shock presentations changed responding in both components. Initial pauses during the first component increased in duration, and positively accelerated responding occurred prior to each shock presented in the second component (Figure 11B). Similar performance was engendered under the second chained-schedule arrangement with Monkey SM-37N, except that responding during the first component was more frequently characterized by instances of a single response being emitted shortly after the end of the 1-min interval (Figure 11C).

Discussion

In the present experiment FI responding was maintained in the first component of a chained schedule under conditions in which, during the second component, either response-independent or response-dependent electric shock was presented. One particular aspect of these results is in contrast to predictions derivable from safety theory in general: with Monkey SM-215, reducing the frequency of shock presentation in the second component from 32 shocks to 2 shocks resulted in a decrease in first-component response rate. Interpretation of the procedures in terms of safety theory suggests that the second component should have become less "unsafe" as shock frequency was reduced; accordingly, response rate during the first component might have been expected to increase, rather than decrease. These results, however, are in general agreement with those from studies of responding under chained schedules in which frequency of food presentation, immediacy of food presentation, or number of food presentations have been varied (e.g., Fantino & Herrnstein, 1968; Ferster & Skinner, 1957; Findley, 1962; Hanson & Witoslawski, 1959; Kendall, 1967; Malagodi, Webbe, & Waddell, 1975; Thomas, 1967). The rates and temporal patterns of responding generated in the first component with both monkeys under both forms of the chained schedule are also in agreement with the literature on chained FI schedules of food presentation (Ferster & Skinner, 1957; Gollub, 1958; Malagodi, DeWeese, & Johnston, 1973).

These similarities between responding maintained under chained schedules terminating in presentation of electric shock and responding under chained schedules terminating in food or water presentation suggest that the second component may be conceptualized as embodying reinforcing rather than aversive characteristics (see Fantino, 1977; Gollub, 1977; Kelleher, 1966; Kelleher & Gollub, 1962; and Marr, 1969 for discussions concerning interpretations of chained schedule performance in terms of conditioned reinforcement).

GENERAL DISCUSSION

Responding was well maintained throughout 885 experimental sessions with Monkey SM-215, and 575 sessions with Monkey SM-37N, under FI schedules that terminated in presentation of either electric shock (Experiments I through III) or a discriminative stimulus associated with shock presentation (Experiment IV). The failure to find an inverse relation between response rate in the FI component and frequency of shock presentation in

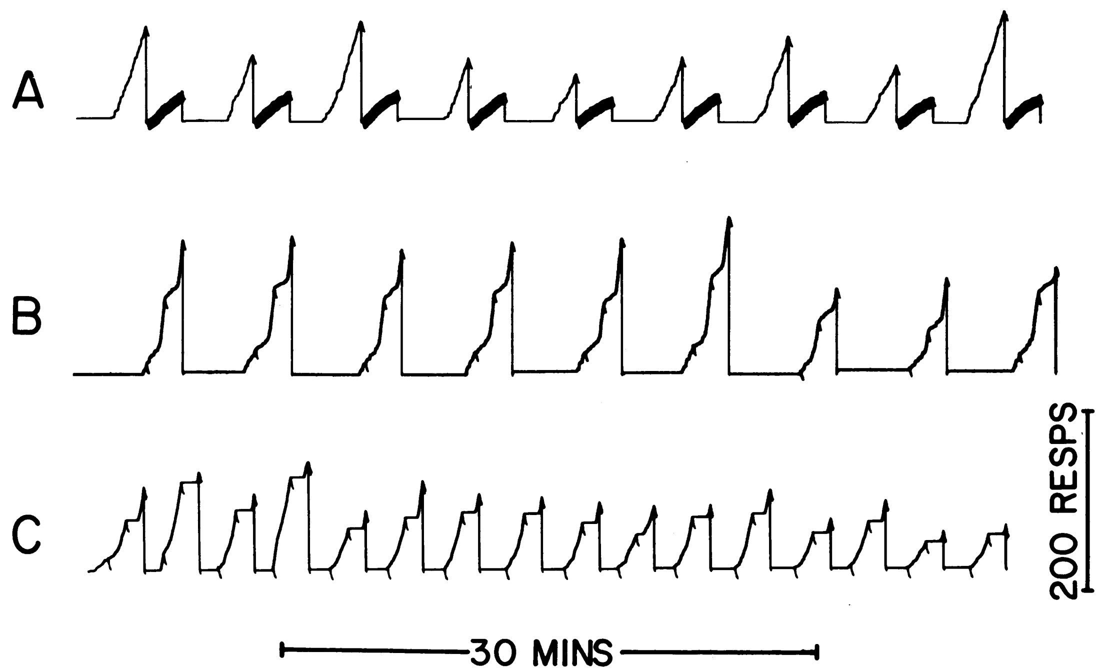

Fig. 11. Patterns of responding by Monkeys SM-215 (records A and B) and SM-37N (record C) under the chained schedules of Experiment IV. In record A, the first diagonal mark and accompanying reset of the response pen in each cycle of the chained schedule indicates completion of the first (FI 4-min) component. Subsequent diagonal marks indicate shock presentations during the second (2-min) component. The second reset of the response pen indicates completion of the second component. In records B and C, the first diagonal mark of the response pen in each cycle indicates completion of the first component (FI 4-min in record B with Monkey SM-215; FI 1-min in record C with Monkey SM-37N). The next two diagonal marks indicate shock presentations under the two FI 1-min schedules of the second component. Pen resets indicate completion of the second component. Records were selected from the last 5 sessions under each condition. A complete session is shown in record C while the approximate middle portions of sessions are shown in records A and B.

the 2-min component (Experiment I), and the obtaining of an inverse relation between response rate in the FI component and FI parameter value (Experiment II) are in contrast to predictions derivable from safety theory in general. Positively accelerated responding was well maintained during the FI component under both multiple and mixed schedule arrangements, suggesting that the results of the first two experiments cannot be attributable simply to possible independence between two components of a multiple schedule (Experiment III). Responding was maintained under conditions in which the consequence of completing an FI schedule was presentation of a discriminative stimulus in the presence of which shocks were presented; these results suggest that the signal for shock presentation might have positively reinforcing, rather than aversive, characteristics (Experiment IV). In sum, the results from the four experiments stand in sharp contradiction to those predictable from notions suggesting that shock-maintained behavior may be generally accounted for in terms of safety theory.

An alternative account of shock-maintained behavior is derived from studies of the disparate effects of certain consequent events. It has been noted that some drugs (e.g., Goldberg, Hoffmeister, Schlichting, & Wuttke, 1971), subcortical brain stimulation (Steiner, Beer, & Shaffer, 1969), and noxious electric shock (e.g., Barrett & Glowa, 1977; Barrett & Spealman, 1978; Kelleher & Morse, 1968, 1969; McKearney, 1972a) all may either maintain or suppress responses which produce them, or maintain responses which postpone or terminate them, depending upon a number of extra-stimulus factors. These contrasting effects of consequent events have been incorporated within a general framework that emphasizes the modulation of responding by variables traditionally assigned to the domain of "schedule-controlled behavior" (Morse & Kelleher, 1970, 1977).

The strongest evidence in support of the general notion that shock-maintained behavior may be conceptualized as schedule-controlled behavior comes from experiments in which manipulations of a number of variables have resulted in effects similar to those ordinarily engendered by comparable manipulations involving food or water presentation. These results include: (1) characteristic patterns of responding maintained under FI schedules (DeWeese, 1977; Kelleher & Morse, 1968, 1969; Malagodi et al., 1973b; Malagodi et al., 1978; McKearney, 1968, 1969; Morse, Mead, & Kelleher, 1967; Stretch, Orloff, & Dalrymple, 1968; Stretch et al., 1970), VI schedules (Bacotti, 1978; Barrett, 1975; Barrett & Spealman, 1978; Malagodi et al., 1973b; McKearney, 1972a, 1974c; Webbe, 1974), concurrent VI VI schedules (Malagodi et al., 1973b; Webbe, 1974), multiple FI FR schedules (McKearney, 1970), and second-order schedules of electric-shock presentation (Byrd, 1972); (2) an inverse relation between rate of responding and parameter value of FI schedules (Malagodi et al., 1973b; McKearney, 1969); (3) a direct relation between rate of responding and shock intensity (Kelleher & Morse, 1968; McKearney, 1969); (4) a decrease in rate of responding following introduction of a brief delay between the effective response and shock presentation (Byrd, 1972); (5) the maintenance of a higher rate of responding under response-dependent than under response-independent schedules (Bacotti, 1978; Malagodi et al., 1978; McKearney, 1974a; Morse & Kelleher, 1970); (6) the cessation of responding under extinction with subsequent recovery of performance following reintroduction of an FI schedule (Kelleher & Morse, 1968; McKearney, 1969); and (7) an increase and then a decrease in schedule-induced hose biting correlated with increases in an FI schedule (DeWeese, 1977; Malagodi et al., 1973b).

Although these results establish an impressive correspondence between experiments on shock-maintained behavior and those examining comparable arrangements with food or water presentation, other studies of shock-maintained behavior have yielded contrasting results. For example, whereas concurrent schedules of food presentation usually generate "matching" relationships between relative response rates and relative frequencies of food presentation (cf. Catania, 1966; deVilliers, 1977), concurrent schedules of shock presentation may produce different results (Webbe, 1974). Whereas the effect of following each response with food or water presentation is usually the maintenance of responding at maximum frequency, the comparable arrangement with shock presentation has resulted in suppression of responding (Kelleher & Morse, 1968; McKearney, 1972a). Although administration of certain drugs may show consistent effects independently of whether FI responding is maintained by food or shock presentation (e.g., DeWeese, 1977; McKearney, 1974b) the effects of other drugs may depend upon whether food or shock presentation is maintaining responding (Barrett, 1976; McKearney, 1974b).

The interpretation of shock-maintained behavior as schedule-controlled behavior has emphasized the importance of three aspects of the development of schedule-controlled behavior in general: (1) experimental histories; (2) qualitative and quantitative characteristics of ongoing behavior at the time at which a stimulus is introduced; and (3) the schedule under which the stimulus is either presented, terminated, or postponed (Morse & Kelleher, 1970, 1977). Although this framework suggests a wide array of possible determinants of shock-maintained behavior, the exact characteristics of these variables are not yet well understood. For example, it appears that ultimate maintenance of responding by intermittent shock presentation is relatively independent of the *specific* kind of experimental arrangement initially employed to generate responding. Shock-maintained behavior has developed following initial experimental histories under VI schedules of food presentation (Kelleher & Morse, 1968), FI schedules of food presentation (Barrett, 1976), shock-postponement schedules (e.g., Kelleher & Morse, 1969; Malagodi et al., 1978; McKearney, 1968, 1969), shock-termination schedules (McKearney, 1974a; Morse & Kelleher, 1970), and response-independent shock presentation (Morse et al., 1967). Similarly, response maintenance by shock presentation also appears to be relatively independent of the *specific* ongoing temporal pattern of responding at the time at which shock presentation is introduced. Responding has been maintained when baseline response patterning has been constant (e.g., Kelleher & Morse, 1968; Malagodi et al, 1978; McKearney, 1968, 1969), positively accelerated (e.g., Kelleher & Morse, 1969; McKearney, 1974a), and negatively accelerated (Morse et al., 1967). In general, baseline rates of responding prior to introduction of shock presentation have ranged from "moderate" to "substantial" levels.

Thus, although experimental histories and the characteristics of ongoing behavior at the time at which an event is introduced have been suggested to be fundamental determinants of the subsequent effects of presenting electric shock, it is clear that precise specification of their qualitative and quantitative dimensions remains to be accomplished. Details are similarly lacking concerning the important features of the schedule under which shock is initially presented. Responding has been chronically maintained following introduction of shock presentation on FI schedules ranging in duration from 5 to 10 min (e.g., Kelleher and Morse, 1968, 1969; Malagodi et al., 1978; McKearney, 1968, 1969) and VI schedules ranging from 1 to 3 min (Malagodi et al., 1973b; McKearney, 1974c; Webbe, 1974). Diverse results have been obtained following introduction of shock presentation on fixed-ratio (FR) schedules. Suppression of responding has occurred following introduction of FR 1 (Kelleher & Morse, 1968; McKearney, 1972a) and FR 100 to FR 300 schedules of shock presentation (Kelleher & Morse, 1969), while responding has been maintained under alternative FR FI schedules (Kelleher & Morse, 1969), multiple FR FI schedules (McKearney, 1970), and —for a limited number of sessions—under FR 30 alone (McKearney, 1970). These results indicate that intermittency per se is not a general variable that operates in isolation to determine whether responding will be maintained or suppressed following introduction of shock presentation. As suggested by Morse and Kelleher (1977), shock-maintained behavior exemplifies multiply determined behavior. Presumably, other schedule variables (e.g., interval and ratio relationships, interstimulus time, temporal factors, interresponse-time dependencies, etc.), operate in dynamic interaction in determining whether schedule-controlled patterns of responding will be maintained or suppressed following introduction of certain consequent events such as noxious electric shock (see Ferster & Skinner, 1957; Morse, 1966; Morse & Kelleher, 1977; and Zeiler, 1977 for discussions of control of schedule performances by interactions among these and other direct and indirect variables).

It remains to be seen whether future research will succeed in isolating determinants of shock-maintained behavior in the general category of schedule variables, or whether yet other classes of variables may be implicated. In any event, it is becoming increasingly clear that conceptualizations of the processes of reinforcement and punishment must accommodate the large number of experiments that have demonstrated the chronic maintenance of responding by presentation of noxious electric shock. It should be emphasized that the importance of these experiments is not solely restricted to theories of reinforcement and punishment. They have major implications for general notions about "behavioral pathology" (e.g., Davidson, 1979; Kimmel, 1971; Sandler, 1964; Sandler & Davidson, 1973; Sidman, 1960), for theoretical accounts of presumably related phenomena such as the "vicious circle" effect (e.g., Brown, 1969; Melvin, 1971), and for conceptualizations of human self-injurious behaviors (e.g., Lovaas, Frietag, Gold, & Kassorla, 1965; Lovaas & Simmons, 1969; Newsom, Carr, & Lovaas, 1979).

REFERENCES

Azrin, N. H., Holz, W. C., Hake, D. F., & Ayllon, T. Fixed-ratio escape reinforcement. *Journal of the Experimental Analysis of Behavior,* 1963, **6,** 449-456.

Bacotti, A. V. Responding under schedules combining response-dependent and response-independent shock delivery. *Journal of the Experimental Analysis of Behavior,* 1978, **29,** 267-272.

Badia, P., Harsh, J., Coker, C. C., & Abbott, B. Choice and the dependability of stimuli that predict shock and safety. *Journal of the Experimental Analysis of Behavior,* 1976, **26,** 95-111.

Barrett, J. E. The Estes-Skinner procedure: Inadequacy of traditional interpretations. *Psychological Record,* 1975, **25,** 167-172.

Barrett, J. E. Effects of alcohol, chlordiazepoxide, cocaine and pentobarbital on responding maintained under fixed-interval schedules of food or shock presentation. *Journal of Pharmacology and Experimental Therapeutics,* 1976, **196,** 605-615.

Barrett, J. E., & Glowa, J. R. Reinforcement and punishment of behavior by the same consequent event. *Psychological Reports,* 1977, **40,** 1015-1021.

Barrett, J. E., & Spealman, R. D. Behavior simultaneously maintained by both presentation and termination of noxious stimuli. *Journal of the Experimental Analysis of Behavior,* 1978, **29,** 375-383.

Branch, M. N., & Gollub, L. R. A detailed analysis of the effects of *d*-amphetamine on behavior under fixed-interval schedules. *Journal of the Experimental Analysis of Behavior,* 1974, **21,** 519-539.

Brown, J. S. Factors affecting self-punitive locomotor behavior. In B. A. Campbell & R. M. Church (Eds.), *Punishment and aversive behavior.* New York: Appleton-Century-Crofts, 1969.

Byrd, L. D. Responding in the squirrel monkey under second-order schedules of shock delivery. *Journal of the Experimental Analysis of Behavior,* 1972, **18,** 155-167.

Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application.* New York: Appleton-Century-Crofts, 1966.

Davidson, R. S. Experimental analysis and modification of pathological behavior. In R. S. Davidson (Ed.), *Modification of pathological behavior.* New York: Gardner Press, 1979.

de Villiers, P. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior.* Englewood Cliffs, N.J.: Prentice-Hall, 1977.

DeWeese, J. Schedule-induced biting under fixed-interval schedules of food or electric-shock presentation. *Journal of the Experimental Analysis of Behavior,* 1977, **27,** 419-431.

Dews, P. B. Studies on responding under fixed-interval schedules of reinforcement: II. The scalloped pattern of the cumulative record. *Journal of the Experimental Analysis of Behavior,* 1978, **29,** 67-75.

Dinsmoor, J. A. Variable-interval escape from stimuli accompanied by shocks. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 41-47.

Eubanks, J. L., Killeen, P., Hamilton, B., & Wald, B. A. The effect of timeout on performance on a variable-interval schedule of electric-shock presentation. *Journal of the Experimental Analysis of Behavior,* 1975, **23,** 457-463.

Fantino, E. Conditioned reinforcement: Choice and information. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior.* Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Fantino, E., & Herrnstein, R. J. Secondary reinforcement and number of primary reinforcements. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 9-14.

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

Findley, J. D. An experimental outline for building and exploring multi-operant behavior repertoires. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 113-166.

Goldberg, S. R., Hoffmeister, F., Schlichting, V. V., & Wuttke, W. Aversive properties of nalorphine and naloxone in morphine-dependent rhesus monkeys. *Journal of Pharmacology and Experimental Therapeutics,* 1971, **179,** 268-276.

Gollub, L. R. *The chaining of fixed-interval schedules.* Unpublished doctoral dissertation, Harvard University, 1958.

Gollub, L. R. Conditioned reinforcement: Schedule effects. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior.* Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Hake, D. F., & Azrin, N. H. An apparatus for delivering pain shock to monkeys. *Journal of the Experimental Analysis of Behavior,* 1963, **6,** 297-298.

Hanson, H. M., & Witoslawski, J. J. Interaction between the components of a chained schedule. *Journal of the Experimental Analysis of Behavior,* 1959, **2,** 171-177.

Harsh, J., & Badia, P. A temporal parameter influencing choice between signalled and unsignalled shock schedules. *Journal of the Experimental Analysis of Behavior,* 1976, **25,** 327-333.

Hendry, D. P. Concluding commentary. In D. P. Hendry (Ed.), *Conditioned reinforcement.* Homewood, Ill.: Dorsey, 1969.

Herrnstein, R. J. Method and theory in the study of avoidance. *Psychological Review,* 1969, **76,** 49-69.

Herrnstein, R. J., & Hineline, P. N. Negative reinforcement as shock-frequency reduction. *Journal of the Experimental Analysis of Behavior,* 1966, **9,** 421-430.

Hineline, P. N. Negative reinforcement without shock reduction. *Journal of the Experimental Analysis of Behavior,* 1970, **14,** 259-268.

Kelleher, R. T. Chaining and conditioned reinforcement. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application.* New York: Appleton-Century-Crofts, 1966.

Kelleher, R. T., & Gollub, L. R. A review of positive conditioned reinforcement. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 543-597.

Kelleher, R. T., & Morse, W. H. Schedules using noxious stimuli: III. Responding maintained with response-produced electric shocks. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 819-838.

Kelleher, R. T., & Morse, W. H. Schedules using noxious stimuli: IV. An interlocking shock-postponement schedule in the squirrel monkey. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 1063-1079.

Kendall, S. B. Some effects of fixed-interval duration on response rate in a two-component chain schedule. *Journal of the Experimental Analysis of Behavior,* 1967, **10,** 341-347.

Kimmel, H. D. Introduction. In H. D. Kimmel (Ed.), *Experimental psychopathology.* New York: Academic Press, 1971.

Lovaas, O. I., Freitag, G., Gold, V. J., & Kassorla, I. C. Experimental studies in childhood schizophrenia: Analysis of self-destructive behavior. *Journal of Experimental Child Psychology,* 1965, **2,** 67-84.

Lovaas, O. I., & Simmons, J. Q. Manipulation of self-destruction in three retarded children. *Journal of Applied Behavior Analysis,* 1969, **2,** 143-157.

Malagodi, E. F., DeWeese, J., & Johnston, J. M. Second-order schedules: A comparison of chained, brief-stimulus, and tandem procedures. *Journal of the Experimental Analysis of Behavior,* 1973, **20,** 447-460. (a)

Malagodi, E. F., DeWeese, J., Webbe, F. M., & Palermo, G. Responding maintained by schedules of electric-shock presentation. *Bulletin of the Psychonomic Society*, 1973, **2**, 331 (Abstract). (b)

Malagodi, E. F., Gardner, M. L., & Palermo, G. Responding maintained under fixed-interval and fixed-time schedules of electric shock presentation. *Journal of the Experimental Analysis of Behavior*, 1978, **30**, 271-279.

Malagodi, E. F., Webbe, F. M., & Waddell, T. R. Second-order schedules of token reinforcement: Effects of varying the schedule of food presentation. *Journal of the Experimental Analysis of Behavior*, 1975, **24**, 173-181.

Marr, M. J. Second-order schedules. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Ill.: Dorsey, 1969.

McKearney, J. W. Maintenance of responding under a fixed-interval schedule of electric shock-presentation. *Science*, 1968, **160**, 1249-1251.

McKearney, J. W. Fixed-interval schedules of electric shock presentation: Extinction and recovery of performance under different shock intensities and fixed-interval durations. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 301-313.

McKearney, J. W. Responding under fixed-ratio and multiple fixed-interval fixed-ratio schedules of electric shock presentation. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 1-6.

McKearney, J. W. Maintenance and suppression of responding under schedules of electric shock presentation. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 425-432. (a)

McKearney, J. W. Schedule-dependent effects: Effects of drugs, and maintenance of responding with response-produced electric shocks. In R. M. Gilbert & J. D. Keehn (Eds.), *Schedule effects: Drugs, drinking, and aggression*. Toronto: University of Toronto Press, 1972. (b)

McKearney, J. W. Differences in responding under fixed-time and fixed-interval schedules of electric shock presentation. *Psychological Reports*, 1974, **34**, 907-914. (a)

McKearney, J. W. Effects of *d*-amphetamine, morphine, and chlorpromazine on responding on fixed-interval schedules of food presentation or electric shock presentation. *Journal of Pharmacology and Experimental Therapeutics*, 1974, **190**, 141-153. (b)

McKearney, J. W. Responding under a constant-probability schedule of electric shock presentation. *Psychological Reports*, 1974, **35**, 907-914. (c)

Melvin, K. B. Vicious circle behavior. In H. D. Kimmel (Ed.), *Experimental psychopathology*. New York: Academic Press, 1971.

Morse, W. H. Intermittent reinforcement. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966.

Morse, W. H., & Kelleher, R. T. Schedules as fundamental determinants of behavior. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules*. New York: Appleton-Century-Crofts, 1970.

Morse, W. H., & Kelleher, R. T. Determinants of reinforcement and punishment. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Morse, W. H., Mead, R. N., & Kelleher, R. T. Modulation of elicited behavior by a fixed-interval schedule of electric shock presentation. *Science*, 1967, **157**, 215-217.

Newsom, C. D., Carr, E. G., & Lovaas, O. I. The experimental analysis and modification of autistic behavior. In R. S. Davidson (Ed.), *Modification of pathological behavior*. New York: Gardner Press, 1979.

Sandler, J. Masochism: An empirical analysis. *Psychological Bulletin*, 1964, **62**, 197-204.

Sandler, J., & Davidson, R. S. *Psychopathology: Learning theory, research, and applications*. New York: Harper and Row, 1973.

Schneider, B. A. A two-state analysis of fixed-interval responding in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 677-687.

Schwartz, B., & Gamzu, E. Pavlovian control of operant behavior. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Seligman, M. E. P. Chronic fear produced by unpredictable electric shock. *Journal of Comparative and Physiological Psychology*, 1968, **66**, 402-411.

Seligman, M. E. P., Maier, S. F., & Solomon, R. L. Unpredictable and uncontrollable aversive events. In F. R. Brush (Ed.), *Aversive conditioning and learning*. New York: Academic Press, 1971.

Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953, **118**, 157-158.

Sidman, M. Normal sources of pathological behavior. *Science*, 1960, **132**, 61-68.

Steiner, S. S., Beer, B., & Shaffer, M. M. Escape from self-produced rates of brain stimulation. *Science*, 1969, **163**, 90-91.

Stretch, R. Development and maintenance of responding under schedules of electric shock presentation. In R. M. Gilbert & J. R. Millenson (Eds.), *Reinforcement: Behavioral analyses*. New York: Academic Press, 1972.

Stretch, R., Orloff, E. R., & Dalrymple, S. D. Maintenance of responding by fixed-interval schedule of electric shock presentation in squirrel monkeys. *Science*, 1968, **162**, 583-586.

Stretch, R., Orloff, E. R., & Gerber, G. J. Multiple interruptions of responding maintained by a fixed-interval schedule of electric-shock presentation in squirrel monkeys. *Canadian Journal of Psychology*, 1970, **24**, 117-126.

Thomas, J. R. Chained and tandem fixed-interval schedule performance and frequency of primary reinforcement. *Psychological Reports*, 1967, **20**, 471-480.

Waddell, T. R., Leander, J. D., Webbe, F. M., & Malagodi, E. F. Schedule interactions in second-order fixed-interval (fixed-ratio) schedules of token reinforcement. *Learning and Motivation*, 1972, **3**, 91-100.

Webbe, F. M. *Maintenance and suppression of responding under concurrent schedules of electric-shock presentation*. Unpublished doctoral dissertation, University of Florida, 1974.

Weiss, S. J. An effective and economical sound-attenuation chamber. *Journal of the Experimental Analysis of Behavior,* 1970, **13**, 37-39.
Zeiler, M. Schedules of reinforcement: The controlling variables. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of operant behavior.* Englewood Cliffs, N.J.: Prentice-Hall, 1977.

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