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RESPONDING MAINTAINED UNDER FIXED-INTERVAL AND FIXED-TIME SCHEDULES OF ELECTRIC SHOCK PRESENTATION[1]

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Following initial histories under a schedule of electric shock postponement, lever pressing in squirrel monkeys was maintained under fixed-interval and fixed-time schedules of electric shock presentation. No difference in either rate or pattern of responding was obtained when these schedules were presented as components of a multiple schedule. When they were presented singly for long periods of time, the fixed-interval schedule consistently maintained a higher response rate than the fixed-time schedule. The pattern of responding under both schedules was similar, typically consisting of a pause at the beginning of each interval followed by either a steady or a positively accelerating rate of responding. The results suggest that the response-shock dependency is of critical importance in the maintenance of high rates of responding under schedules of electric shock presentation, and support the general view that such responding may be conceptualized as operant behavior under control of many of the same variables that control responding under comparable schedules of food or water reinforcement.

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

Within the past decade, a number of experiments have demonstrated the maintenance of lever pressing under conditions in which presentation of noxious electric shock is intermittently scheduled as the only consequence of responding (Byrd, 1969, 1972; Kelleher and Morse, 1968, 1969; McKearney, 1968, 1969, 1970, 1972*a*, 1974*a*, 1974*b*; Malagodi, DeWeese, Webbe, and Palermo, 1973; Morse, Mead, and Kelleher, 1967; Stretch, Orloff, and Dalrymple, 1968; Stretch, Orloff, and Gerber, 1970). In most of these experiments, responding has been maintained on fixed-interval (FI) schedules, under which the first lever press after a fixed period of time produces a brief electric shock. Rates and patterns of responding under these FI schedules are comparable to those ordinarily obtained under FI schedules of food or water reinforcement. Typically, a pause at the beginning of the interval is followed by either a steady or a positively accelerating rate of responding that terminates with shock presentation.

Most of these experimenters have stressed the role of the response-shock dependency in maintaining these characteristic rates and patterns of responding. Lever pressing under these conditions has been conceptualized as operant behavior exemplifying the process of reinforcement (*cf.*, Morse and Kelleher, 1970, 1977). Other experimenters, however, (Hutchinson, 1977; Hutchinson, Renfrew and Young, 1971; Hutchinson and Emley, 1972) have suggested that similar, if not identical, rates and patterns of responding may be engendered by comparable response-independent fixed-time (FT) schedules of electric shock presentation. The importance of the response-dependent nature of shock presentation in maintaining responding under FI schedules has been questioned (Hutchinson and Emley, 1972), and it has been proposed that responding under these FI and FT schedules may represent a form of shock-elicited behavior, rather than operant behavior maintained by shock presentation (Hutchinson *et al.*, 1971).

Little systematic research has been directed at comparing lever pressing under response-dependent and response-independent schedules of electric shock presentation. The results

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of such experiments should enable determination of the importance of the response-shock dependency in maintaining ongoing behavior and might help to clarify the nature of the behavioral process exemplified. In addition, they would allow for comparisons with the results of experiments that have studied response-dependent and response-independent schedules of food reinforcement (*e.g.*, Appel and Hiss, 1962; Herrnstein, 1966; Lattal, 1972; Zeiler, 1968).

Extending a previous experiment by McKearney (1974*a*), the present experiment studied lever pressing in squirrel monkeys under both FI and FT schedules of electric shock presentation. These schedules were presented under conditions in which they alternated within experimental sessions (multiple schedule) and under conditions in which they alternated in separate experimental phases.

METHOD

Subjects

Three adult male squirrel monkeys (*Saimiri sciurea*) served. Two monkeys (SM-43 and SM-44) had previous histories under schedules of shock postponement and shock presentation (Malagodi *et al.*, 1973). The third monkey, SM-37, was experimentally naive.

Apparatus

A Plexiglas chair, similar to the one described by Hake and Azrin (1963), was used. Each monkey was restrained in the seated position by a waist lock, with its tail clamped in a small stock. Electric shock (350 V ac, 60 Hz) was delivered 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 electrodes. Electric shock was 100 msec in duration and 7 mA in intensity throughout the experiment. 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 force greater than 0.2 N briefly operated a feedback relay and activated the programming circuitry. Illumination was provided by two pairs of 7-W, 115-V ac lights (yellow or red) located at the top of the front wall. White noise was present in the chamber except when otherwise indicated. The restraining chair was enclosed within a ventilated, sound-attenuating cubicle, similar to that described by Weiss (1970). Electromechanical programming and recording equipment was located in an adjoining room.

Procedure

Preliminary procedures. Lever pressing was established following the 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 30 sec (Sidman, 1953). Thirty-second timeouts were presented every 6 min independently of responding. During timeouts the chamber was dark, white noise was absent, a clicking sound was present, and responses had no scheduled consequences. After nine to 20 sessions under these conditions, 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. The 30-sec timeout now followed each shock presented on the FI 6-min schedule. After 11 to 27 sessions under the conjoint schedule the avoidance component was removed, leaving the FI 6-min schedule (with timeouts) as the only programmed consequence of responding.

Experimental procedures. After 45 and 59 sessions under FI 6-min, Monkeys SM-43 and SM-44 were exposed to a multiple schedule containing the FI 6-min schedule as one component and a 6-min fixed-time schedule (FT 6-min) as the other. Under FT 6-min, shock was presented every 6 min independently of responding. The FI 6-min schedule was in effect in the presence of yellow houselights and the FT 6-min schedule was in effect in the presence of red houselights. The two components of the multiple schedule alternated after every four shocks and the 30-sec timeouts now occurred only between components.

Because of renal failure, Monkey SM-44 was removed from the experiment after 130 sessions under the multiple schedule. After 120 sessions under the multiple schedule, Monkey SM-43 was exposed to the FI 6-min and FT 6-min schedules singly during repeated phases.

The chamber was illuminated with red houselights during the first phase under FT 6-min, and with yellow houselights during all subsequent phases. Timeouts continued to follow every fourth shock presentation.

Monkey SM-37 was added to the experiment after Monkey SM-44 was removed and after the multiple-schedule phase with Monkey SM-43 was completed. After the preliminary procedures, this monkey was exposed only to the FI 6-min and FT 6-min schedules singly during repeated phases. The chamber was illuminated with yellow houselights throughout all phases and 30-sec timeouts followed every fourth shock presentation.

The order of experimental conditions and the number of sessions under each for Monkeys SM-37 and SM-43 are shown in Table 1.

With all the monkeys, sessions terminated after the sixteenth shock presentation, and were usually conducted six days per week.

RESULTS

Rates and patterns of responding were essentially identical in the two components throughout the more than 100 sessions during which Monkeys SM-43 and SM-44 were exposed to the multiple schedule. With Monkey SM-43, the average response-rate and quarter-life values for the last 10 sessions were 11.2 and 0.74 in the FI component and 11.8 and 0.75 in the FT component. With Monkey SM-44, the corresponding values were 20.8 and 0.77 in the FI component, and 19.6 and 0.78 in the FT component. Record A in Figure 1 shows a cumulative record for Monkey SM-43 from one of the last five sessions under the multiple schedule that illustrates the similarities between components in both rate and patterns of positively accelerated responding.

When Monkeys SM-43 and SM-37 were exposed to either the FI 6-min or the FT 6-min schedules during successive experimental phases, responding stabilized at a higher overall rate under FI 6-min. With Monkey SM-43, for example, changing from the multiple schedule to the FT 6-min schedule resulted in a reduction in overall response rate to approximately half of that obtained under the multiple schedule (Figure 1, Record B). Record C in Figure 1 shows a subsequent increase in overall response rate after the schedule was changed from FT 6-min to FI 6-min. Records D and E in Figure 1 illustrate replications of this effect of removing and reinstating the response-shock dependency. The pattern of responding under both schedules typically consisted of a pause at the beginning of each interval followed by either a steady or a positively accelerating rate of responding that terminated with shock presentation.

Table 1

Summary of experimental procedures and number of sessions under each.

Schedule	Monkeys	
	SM-43	SM-37
FT 6-min	76	—
FI 6-min	72	70
FT 6-min	52	120
FI 6-min	70	80
FT 6-min	—	80

Figure 2 shows similar performance with Monkey SM-37. Overall rate of responding was higher under FI 6-min (Records A and C) than under FT 6-min (Records B and D). Although positively accelerated responding typified performance under both schedules, there were occasional instances under FT 6-min of intervals during which no responses were emitted. The end points of such intervals are indicated by the arrows in Records B and D.

The transitions in overall response rate after changes from one schedule to another were gradual, requiring between 30 and 80 sessions before relatively stable levels were obtained. Figure 3 shows that, with Monkey SM-43, changing from the multiple schedule to FT 6-min resulted in a gradual decrease in response rate over 30 sessions from approximately 12 responses per minute in both components to approximately six responses per minute under FT 6-min alone. The subsequent change from FT 6-min to FI 6-min resulted in an increase in response rate over a comparable number of sessions before a stable level was reached. The next two transitions each occurred over approximately 40 sessions. Figure 4 shows similar transitions with Monkey SM-37. The first change in schedule from FI 6-min to FT 6-min produced a more gradual decrease in response rate than was characteristic with Monkey SM-43, requiring approximately 80 sessions before stability was obtained. The subsequent increase in response rate after the FI 6-min schedule was reinstated required fewer sessions to reach stability. The final exposure to FT

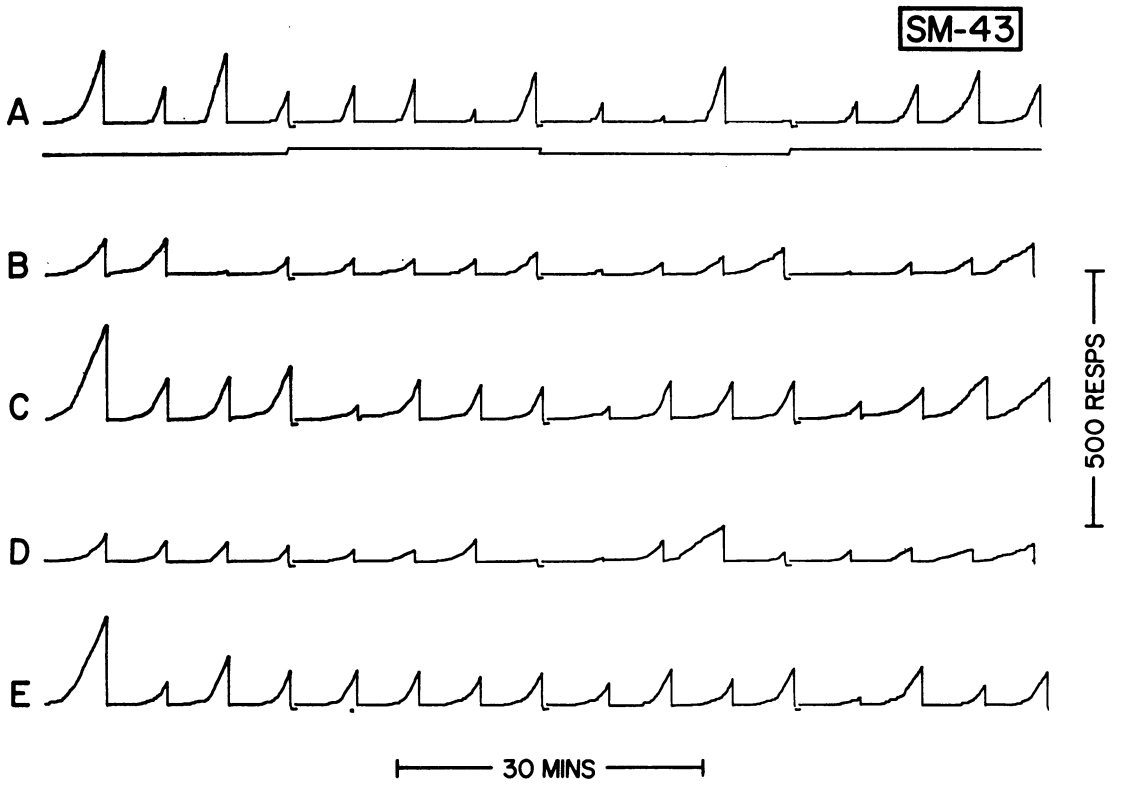

Fig. 1. Representative cumulative records for Monkey SM-43. Resets of the response pen to baseline indicate shock presentations. The response pen was displaced below baseline during the 30-sec timeouts that followed each fourth shock presentation. The schedules in effect were multiple FI 6-min (event pen down) FT 6-min (event pen up) in record A, FT 6-min in records B and D, and FI 6-min in records C and E. The records were selected from the last five sessions under each condition.

6-min resulted in a gradual decline in response rate over 80 sessions.

The differences between the FI 6-min and FT 6-min schedules in the overall response rate ultimately maintained at the end of each phase were characterized by higher rates of responding throughout the interval under FI 6-min. Figure 5 summarizes the temporal distribution of responses during the last 10 sessions of each phase under FI 6-min and FT 6-min. The temporal distributions of responses under the two schedules were similar in that the number of responses increased in each successive tenth of the interval. The distributions differed in that the rate of increase in the latter half of the interval was much greater under FI 6-min.

DISCUSSION

The results of the present experiment were that positively accelerated responding was maintained under both FI and FT schedules of electric shock presentation, no difference in overall response rate between the two schedules was obtained when they alternated within sessions as components of a multiple schedule, and a higher overall rate was maintained under FI 6-min when the two schedules alternated in successive experimental phases. These results may be related to: (a) the results of previous experiments on response-dependent and response-independent schedules of electric shock presentation; (b) the results of experiments that have compared response-dependent and response-independent schedules of food reinforcement; and (c) conceptualizations of the behavioral processes involved in responding maintained under schedules of electric shock presentation.

The rates, patterns, and stability of responding maintained in the present experiment under the FI schedule are comparable to those obtained in previous experiments in which FI

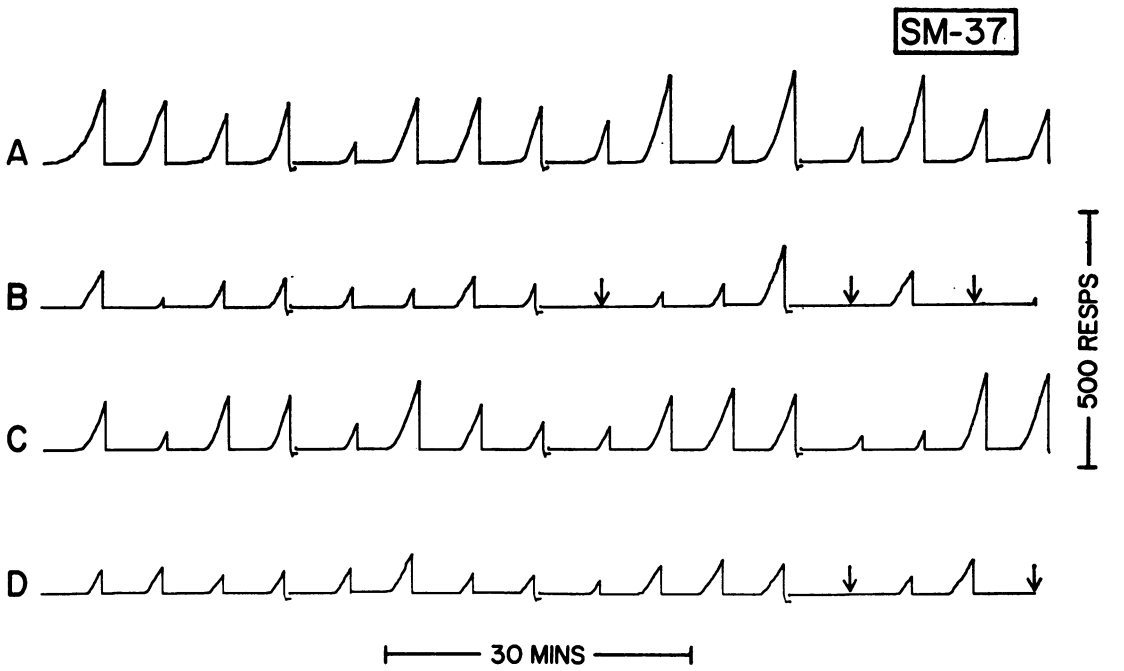

Fig. 2. Representative cumulative records for Monkey SM-37. Recording conventions are the same as in Figure 1. The schedules in effect were FI 6-min in records A and C, and FT 6-min in records B and D. The arrows in records B and D indicate shock presentations at the end of intervals during which no responses were emitted.

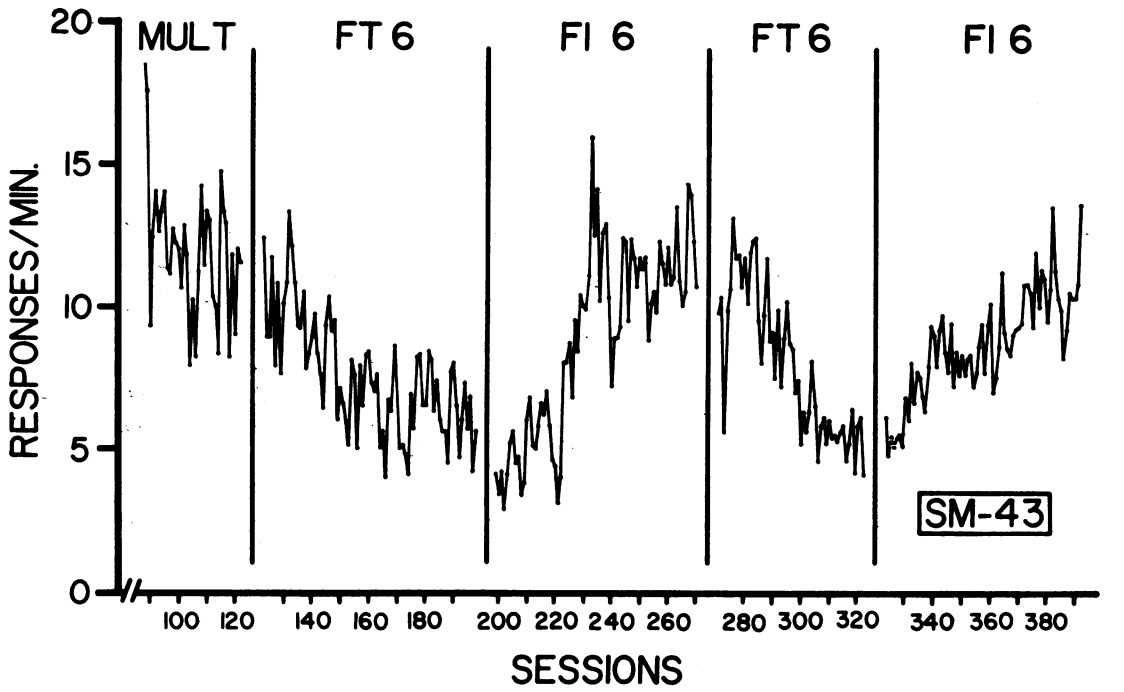

Fig. 3. FI 6-min response rates for Monkey SM-43 during the last 35 sessions of performance under the multiple schedule and of either FI 6-min or FT 6-min performance for all subsequent sessions.

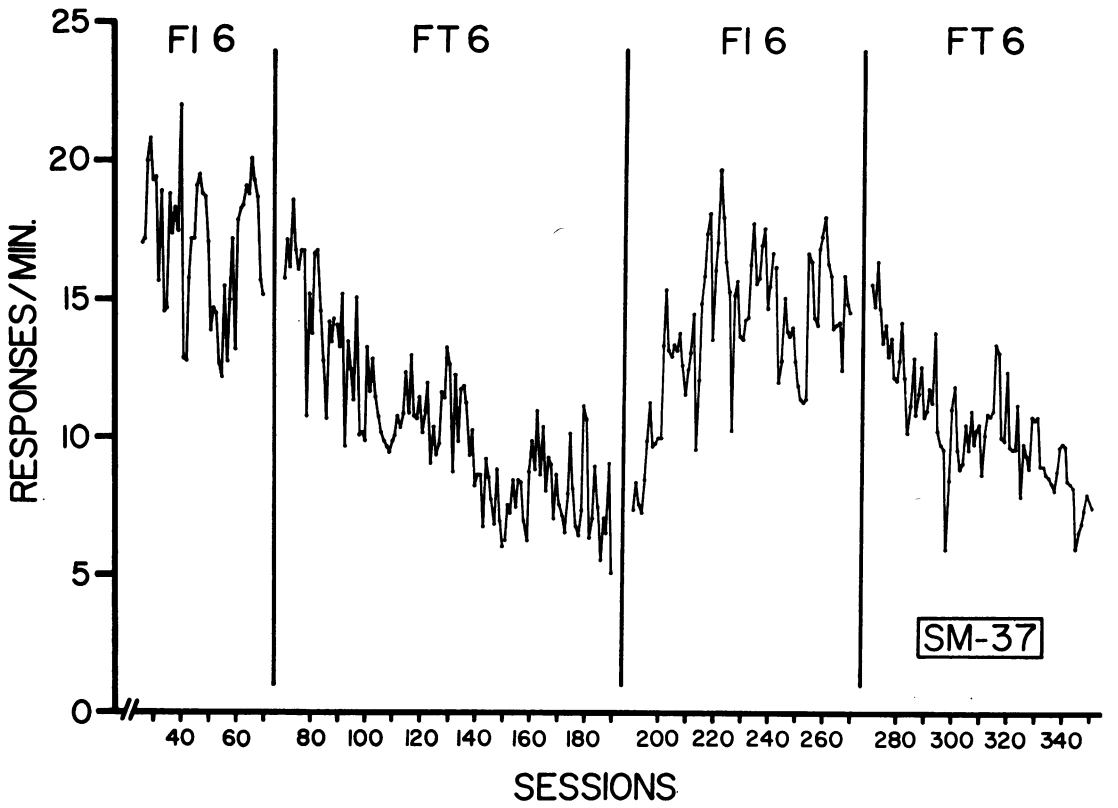

Fig. 4. Response rates for Monkey SM-37 during the last 45 sessions of the first exposure to FI 6-min and all subsequent sessions.

schedules of electric shock presentation were introduced following prior exposure to schedules of food presentation (Kelleher and Morse, 1968), shock avoidance (*e.g.*, Kelleher and Morse, 1969; McKearney, 1968, 1969; Malagodi *et al.*, 1973), or escape from shock (McKearney, 1974*a*). Similarly, the characteristics of responding maintained under the FT schedule in the present experiment are comparable to those previously obtained in experiments in which FT schedules of electric shock presentation were introduced following a history of escape from shock (McKearney, 1974*a*) or introduced with no prior experimental history (Hutchinson, 1977; Hutchinson and Emley, 1972; Hutchinson *et al.*, 1971).

The maintenance of a higher overall response rate under the FI schedule in the present experiment is in agreement with the results of McKearney's (1974*a*) experiment in which a squirrel monkey was exposed to both FI and FT schedules of electric shock presentation following initial exposure to a shock-escape schedule. These results are also in general agreement with those of experiments in which responding under FI and FT schedules of food reinforcement has been compared. Those experiments have consistently found similar patterns of responding under the two types of schedules, with higher overall response rates engendered under FI; similar results have been obtained when the comparisons have been between variable-interval (VI) and variable-time (VT) schedules of food reinforcement (*e.g.*, Appel and Hiss, 1962; Herrnstein, 1966; Lattal, 1972; Zeiler, 1968).

One difference between the present results and those of experiments with response-dependent and response-independent schedules of food reinforcement is that no difference in overall rate was found in the present study when the FI and FT schedules alternated as components of a multiple schedule. This may have been due to either or both of two factors. Some evidence suggests that extended exposure to response-dependent schedules of food rein-

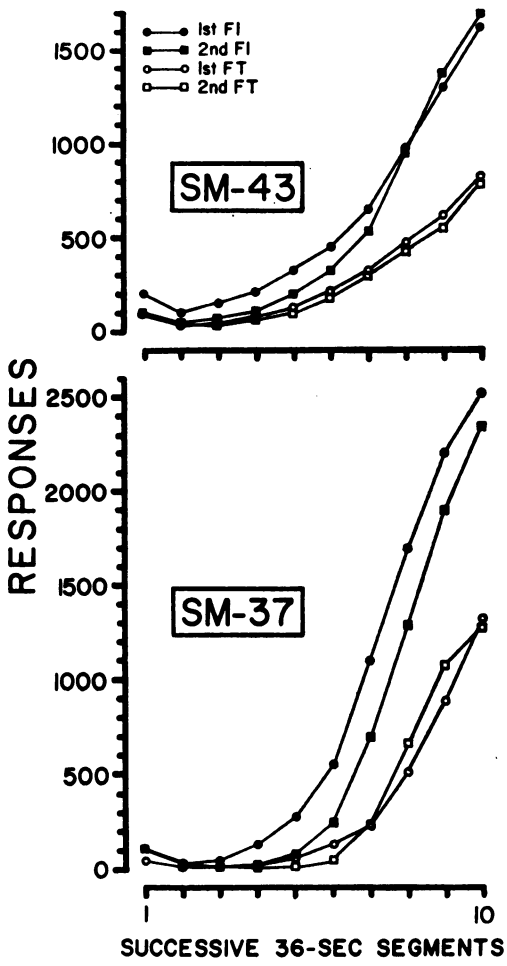

Fig. 5. Total number of responses in successive tenths of the 6-min interval during the last 10 sessions of each exposure to FI 6-min and FT 6-min for Monkeys SM-37 and SM-43.

forcement may delay or prevent the emergence of differential responding upon subsequent exposure to a multiple schedule containing both response-dependent and response-independent schedules (Weisman and Ramsden, 1973). In the present experiment, Monkeys SM-43 and SM-44 had been exposed to 45 and 59 sessions, respectively, under FI 6-min before being exposed to the multiple schedule. They had also served in a previous experiment during which responding had been maintained for several hundred sessions under FI shedules of electric shock presentation (Malagodi *et al.*, 1973). It is also possible that induction (*e.g.*, Reynolds, 1961) between components prevented the emergence of differential response rates. Lattal and Maxey (1971), found that response rate in the response-independent component of a multiple schedule was greater when the alternating component was a response-dependent schedule than when both components consisted of response-independent schedules.

The maintenance of a higher overall response rate under the FI schedule than under the FT schedule, when the two schedules alternated in successive experimental phases, supports the suggestions of Morse and Kelleher (1970, 1977) and McKearney (1972*b*, 1974*a*) that the response-shock dependency is of critical importance in maintaining high levels of responding. These results do not lend support to suggestions that responding maintained under FI schedules of electric shock presentation may be interpreted as being due solely to the response-generating characteristics of long-term periodic presentations of electric shock (Hutchinson, 1977; Hutchinson and Emley, 1972; Hutchinson *et al.*, 1971). The correspondence between the present results and those of comparable experiments with response-dependent and response-independent schedules of food reinforcement supports the general view that responding maintained under schedules of electric shock presentation may be conceptualized as operant behavior under control of many of the same variables that govern responding under comparable schedules of food or water reinforcement (*cf.* Morse, 1966; Morse and Kelleher, 1970, 1977; Zeiler, 1977). Additional support for this view may be found in the results of previous experiments with response-dependent schedules of electric shock presentation which have shown: (a) characteristic rates and patterns of responding under VI (McKearney, 1972*a*, 1974*b*; Malagodi *et al.*, 1973), concurrent VI VI (Malagodi *et al.*, 1973), multiple fixed-interval fixed-ratio (McKearney, 1970), and second-order (Byrd, 1972) schedules of electric shock presentation; (b) an inverse relationship between response rate and parameter value of FI schedules (McKearney, 1969; Malagodi *et al.*, 1973); (c) a decrease in response rate following introduction of a brief delay between the effective response and shock presentation (Byrd, 1972); and (d) cessation of responding under extinction with subsequent recovery of performance following reintroduction of the FI schedule (Kelleher and Morse, 1968; McKearney, 1969).

The present results add to the growing body of evidence in support of the notion that the past history of an organism and the current scheduling variables may be more important than any intrinsic properties of a stimulus in determining the effects of consequences of responding (*cf.* McKearney, 1972*b*; Morse and Kelleher, 1970, 1977). Under some conditions, such as those of the present experiment, response-dependent presentations of noxious electric shock enhance ongoing behavior in comparison with response-independent presentations. Under other conditions, such as those in which electric shock is conjointly scheduled with food presentation, response-dependent presentations of noxious electric shock lead to greater suppression of responding than do response-independent or delayed presentations (*e.g.*, Azrin, 1956; Cohen, 1968; Schuster and Rachlin, 1968). Thus, when a consequent stimulus—whether food or electric shock—maintains behavior and exemplifies the process of reinforcement, the optimum arrangement is the immediate response-dependent presentation of the stimulus. When a consequent stimulus such as electric shock suppresses ongoing behavior, exemplifying the process of punishment, the optimum arrangement is also the immediate response-dependent presentation of the stimulus. Although the historical and current variables that determine whether noxious electric shock functions as a reinforcer or a punisher are not yet entirely understood, it is clear that in either case, similar schedule variables operate in governing the effectiveness of stimulus presentation.

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