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RESPONDING UNDER SEQUENCE SCHEDULES OF ELECTRIC SHOCK PRESENTATION

MICHAEL L. GARDNER AND E. F. MALAGODI

UNIVERSITY OF FLORIDA

Lever pressing by squirrel monkeys was examined under second-order schedules of electric shock presentation in which different discriminative stimuli were associated with consecutive components (sequence schedules). Components were always two-minute fixed-interval schedules, and three different overall schedules were studied. Under an overall eight-minute fixed-interval schedule, the first component completion after at least eight minutes had elapsed produced electric shock. The number of components actually completed ranged from one to four; thus, different discriminative stimuli were occasionally associated with electric shock presentation. Under an overall "yoked" variable-ratio schedule, electric shock was presented after completion of a variable number of components; the required number and the distribution of components were matched to those obtained under the overall eight-minute fixed-interval schedule. Under an overall fixed-ratio schedule, electric shock was presented after completion of four components (chained schedule). Under all three sequence schedules, responding in early components was characterized by a pause followed by a single response after the end of the two-minute interval; responding in later components was characterized by a shorter pause followed by positively accelerated responding. Manipulation of overall schedules of shock presentation in these complex behavioral situations produced changes in responding comparable to those ordinarily obtained after similar manipulation of dependencies under both single and second-order schedules of food presentation. These experiments extend the range of conditions and levels of complexity under which responding can be maintained by presentation of electric shock.

Key words: shock-maintained behavior, schedule-controlled behavior, second-order schedules, sequence schedules, lever press, squirrel monkeys

A growing number of studies have examined the maintenance of responding by intermittent schedules of electric shock presentation. Many relations obtained between responding and experimental manipulations of contingencies of shock presentation have been similar to those obtained when comparable manipulations involving food or water presentation have been made. These include: (1) characteristic rates and patterns of responding maintained under fixed-interval (FI) schedules (e.g., Byrd, 1969, 1972; Kelleher & Morse, 1968, 1969; Malagodi, Gardner, & Palermo, 1978; McKearney, 1968, 1969; Morse, Mead, & Kelleher, 1967; Malagodi, Gardner, Ward, & Magyar, Note 1), variable-interval (VI) schedules (e.g., Barrett, 1975; Barrett & Spealman, 1978; Malagodi, DeWeese, Webbe, & Palermo, 1973b; McKearney, 1974c), concurrent VI VI schedules (Malagodi et al., 1973b; Webbe, 1974), and multiple fixed-interval, fixed-ratio schedules (McKearney, 1970) of electric shock presentation; (2) an inverse relation between rate of responding and parameter value of an FI schedule of shock presentation (Malagodi et al., 1973b, 1980; McKearney, 1969); (3) a direct relation between rate of responding and shock intensity (e.g., 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 cessation of responding during extinction with subsequent recovery of perfor-

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mance following reintroduction of an FI schedule of shock presentation (Kelleher & Morse, 1968; McKearney, 1969); (6) the maintenance of higher rates of responding when presentation of shock depends upon responding than when shocks are delivered independently of responding (Bacotti, 1978; Malagodi et al., 1978; McKearney, 1972b, 1974a; Morse & Kelleher, 1970); and (7) an increase and then a decrease in measures of schedule-induced hose biting as the parameter value of an FI schedule of shock presentation is increased (DeWeese, 1977; Malagodi et al., 1973b). These and other similarities have led most investigators to interpret responding maintained by schedules of electric shock presentation in terms of the processes that ordinarily operate to govern schedule-controlled performance when food or water is presented and, accordingly, to conceptualize these results as exemplifying the process of reinforcement (cf., Morse & Kelleher, 1970, 1977).

Other studies of responding maintained by presentation of electric shock, however, have uncovered effects that contrast with those ordinarily obtained when food or water presentation maintains responding. For example, whereas the effect of scheduling food or water presentation dependent upon each response is usually to maintain a high rate of responding, the comparable arrangement with shock presentation usually results in suppression of responding (Kelleher & Morse, 1968; McKearney, 1972a). Although concurrent schedules of food reinforcement frequently yield "matching" relations between relative response rates and relative frequencies of food presentation (cf., Catania, 1966; de Villiers, 1977), concurrent schedules of shock presentation may produce different results (Webbe, 1974). Although many drugs produce consistent effects on FI responding regardless of whether responding is maintained by food or shock presentation, the effects of other drugs may depend upon whether food or shock presentation is maintaining responding (Barrett, 1976; McKearney, 1974b).

Although the experimental history, the prevailing schedule, and the ongoing characteristics of responding are important factors (cf., McKearney & Barrett, 1978; Morse & Kelleher, 1970, 1977), at present, no theoretical framework exists that precisely predicts whether presentation of electric shock will produce effects similar to, or in contrast with, those produced by presentation of food or water under comparable conditions. The absence of such a framework suggests a need for further research designed to examine the "boundary conditions" under which responding may be maintained by shock presentation. The present experiment therefore sought to determine whether responding could be maintained under second-order schedules in which shock presentation was dependent not upon the emission of relatively simple responses such as individual lever presses, but upon sequences of responses that themselves may be conceptualized as units of behavior (cf., Gollub, 1977; Kelleher, 1966a, 1966b; Marr, 1969, 1979). Second-order schedules of food presentation have been valuable for examining whether schedule variables that operate at a relatively simple behavioral level (i.e., single responses) operate similarly at more complex levels (i.e., sequences of responses and stimuli), and have revealed great generality across these differing levels of analysis (e.g., Davison, 1969; Findley, 1962, Malagodi, Webbe, & Waddell, 1975; Marr, 1971; Shull, Guilkey, & Witty, 1972; Webbe & Malagodi, 1978). Similar generality under conditions in which responding is maintained by presentation of electric shock would increase the range of conditions, and levels of complexity, under which such responding is similar to that engendered by food or water presentation. A failure to find similar effects, however, would be helpful in delineating boundary conditions.

Previous experiments on responding under second-order schedules of shock presentation, using brief-stimulus arrangements, have yielded disparate results. In one experiment (Byrd, 1969), key pressing in cats was maintained when shock presentation followed completion of three consecutive FI 5-min components. During one experimental phase, a brief burst of white noise occurred at completion of the first two components, but not at completion of the third, when shock was presented (nonpaired-stimulus condition). In another phase, the brief burst of noise occurred at completion of all three components (paired-stimulus condition). Responding was suppressed under the paired-stimulus condition compared to both the nonpaired-stimulus condition and a condition under which white noise was not presented at completion of components. These results contrast with those frequently seen un-

der second-order brief-stimulus schedules of food presentation (e.g., deLorge, 1971; Kelleher, 1966a, 1966b; Malagodi, DeWeese, & Johnston, 1973a), and with those of a second experiment (Byrd, 1972) in which lever pressing in squirrel monkeys was maintained under second-order schedules of shock presentation. In that experiment, effects comparable to those engendered under second-order schedules of food presentation were obtained; responding within FI components was enhanced under paired-stimulus conditions compared to nonpaired-stimulus conditions.

The present experiment examined responding under second-order schedules similar to those previously examined by Byrd (1969, 1972) in that shock presentation was dependent upon completion of FI components. The experiment differed in two major respects: the variable of primary interest was the schedule according to which completion of components produced shock presentation; and, another form of second-order schedule—a sequence schedule—was studied. Under a sequence schedule, different discriminative stimuli are presented throughout successive components (cf., Marr, 1979). The experiment sought to determine whether (a) responding could be maintained under second-order schedules in which different discriminative stimuli were associated with consecutive components, (b) such responding resembled that maintained under comparable schedules of food presentation (e.g., Marr, 1971), and (c) patterns of responding would vary with manipulations of dependencies of shock presentation in a manner comparable to those ordinarily engendered by similar manipulations of dependencies under single and second-order schedules of food presentation.

METHOD

Subjects

Two adult male squirrel monkeys (*Saimiri sciureus*), SM-38 and SM-39, served. 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. A 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 could be provided by four pairs of 7-W 115-V ac houselights (yellow, blue, red, and white) located at the top of the front wall. White noise was present in the chamber except when otherwise indicated. Electromechanical programming and recording equipment was located in an adjoining room.

Procedure

Pre-experimental histories. 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). Sessions lasted 90 min. After 19 (Monkey SM-38) and seven (Monkey SM-39) sessions, an FI schedule of electric shock presentation was added to the avoidance schedule (FI 10-min for Monkey SM-38 and FI 8-min for Monkey SM-39). Under these conjoint schedules of shock postponement and shock presentation, lever presses continued to postpone shock programmed according to the avoidance schedule, and the first response after each fixed interval had elapsed resulted in immediate shock presentation and initiated another fixed interval. Sessions terminated after the fifteenth response-produced shock. After ten (Monkey SM-38) and two (Monkey SM-39) sessions under the conjoint schedules responding became slightly positively accelerated between FI shocks. The avoidance component was then removed, leaving only the FI schedule of electric shock presentation.

Prior to the present experiment the two monkeys were exposed to two different series of experimental manipulations, both involv-

ing the maintenance of responding under schedules of electric shock presentation. Monkey SM-38 responded under several second-order brief-stimulus, VI, concurrent VI VI, and two- and three-component tandem and chained schedules of electric shock presentation for over one thousand experimental sessions of varying durations—the VI and concurrent VI VI procedures are detailed in Webbe (1974). Monkey SM-39 responded under several multiple and second-order chained and tandem schedules of electric shock presentation, containing FI 2-min schedules as components, for approximately 100 experimental sessions of between two and three hours duration.

Experimental procedures. At the beginning of the present study both monkeys were exposed to a second-order schedule of FI 8-min (FI 2-min) under which different colored houselights were presented for the duration of each consecutive FI 2-min component. That is, the first lever press after 2 min in the presence of each component stimulus produced either (1) the next component stimulus—if less than 8 min had elapsed since the beginning of the overall FI 8-min schedule, or (2) immediate electric shock presentation—if 8 min or more had elapsed since the beginning of the overall FI 8-min schedule. A 15-sec timeout period followed each shock presentation. During this period the chamber was dark, white noise was absent, a clicking sound was present, and responses had no scheduled consequences. After each timeout another 8-min interval was begun; the yellow houselights were illuminated first, and the order of component stimuli was always yellow (S_4), blue (S_3), red (S_2), and white (S_1). Thus, shock could be delivered following a response in the presence of any of the four component stimuli depending on how much time had elapsed within the overall FI 8-min schedule at the time of component completion.

Table 1

Summary of procedures and number of sessions under each.

Schedule	Monkey	
	SM-38	SM-39
seq FI 8-min (FI 2-min)	67	182
seq VR yoked (FI 2-min)	48	125
seq FI 8-min (FI 2-min)	20	37
seq FR 4 (FI 2-min)	7	55
seq FI 8-min (FI 2-min)	138	

This type of schedule arrangement, a second-order schedule with different component stimuli, has been defined as a sequence (*seq*) schedule (Marr, 1971). The *seq* FI 8-min (FI 2-min) schedule remained in effect until daily plots of both the rate of responding and the percentage of shocks delivered in each of the four components showed no systematic trends for either 24 (Monkey SM-38) or 25 (Monkey SM-39) consecutive sessions.

The monkeys were then exposed to a schedule under which the number of component completions required for each shock presentation was determined on the basis of previous performances under the *seq* FI 8-min (FI 2-min) schedule. For each of the last 24 or 25 sessions of stable responding a "yoked" session was derived during which shocks occurred according to the same distribution of component completions that had been obtained during the corresponding session under *seq* FI 8-min (FI 2-min). Thus, the percentages of shocks that occurred in the presence of each of the four component stimuli were identical to those obtained under the FI sequence schedule, but shocks now occurred in a predetermined relation to the component stimuli rather than according to the time that had elapsed since the preceding shock. This schedule will be referred to as the yoked variable-ratio sequence schedule—*seq* VR yoked (FI 2-min). The *seq* VR yoked (FI 2-min) schedule remained in effect until rate of responding in all four components was stable for a minimum of 15 consecutive sessions and until a full complement of 24 or 25 yoked sessions was completed. Both monkeys were then returned to the FI sequence schedule until the rate of responding and percentage of shocks delivered in each of the four components were stable for a minimum of 15 consecutive sessions.

The monkeys were next exposed to a sequence schedule under which four component completions were required for each shock presentation. This *seq* FR 4 (FI 2-min) schedule remained in effect until rate of shock presentation fell below three shocks per hour for three consecutive sessions. Monkey SM-38 was then reexposed to the *seq* FI 8-min (FI 2-min) schedule until the rate of responding and percentage of shocks delivered in each of the four components were stable for 15 sessions.

Sessions terminated after 20 shock presentations under the *seq* FI 8-min (FI 2-min) and

seq VR yoked (FI 2-min) schedules, and after the first shock presentation after three hours had elapsed under the *seq* FR 4 (FI 2-min) schedule. Sessions were usually conducted six day per week. The order of experimental conditions and the number of sessions under each are shown in Table 1.

Data analysis. Average response rates were computed separately for the four components by dividing the number of responses made in the presence of each component stimulus by the time during that stimulus. Overall rates of responding and of shock presentation were calculated by dividing the total number of responses or shock presentations in each session by the total session time. Responses and time were cumulated separately during postshock timeouts and were not used in these computations. Under the FI sequence schedule, the percentage of shock presentations in each component was calculated by dividing the number of shocks that followed a response in the presence of each component stimulus by the total number of shocks (20) per session, and multiplying by 100.

RESULTS

All three sequence schedules engendered stable and reproducible patterns of lever pressing within and across experimental sessions. Figure 1 shows average rates of responding in the presence of each of the four component stimuli under the different schedules. Under the *seq* FI 8-min (FI 2-min) schedule, rate of responding was low in the presence of the stimulus associated with the first component (S_4), increased in S_3, reached a maximum in S_2, and then decreased slightly in S_1.

The major effect of changing from the *seq* FI 8-min (FI 2-min) schedule to the *seq* VR yoked (FI 2-min) schedule was a decrease in rate of responding in S_2. The effect was reliable: in comparisons of pairs of matched FI and VR sessions, rate of responding in S_2 was higher during the FI member of the pair for 24 of the last 25 (Monkey SM-39) or 24 of the last 24 (Monkey SM-38) possible comparisons. Response rates in the other three components were not systematically affected; rate in S_4 increased slightly with Monkey SM-39 and de-

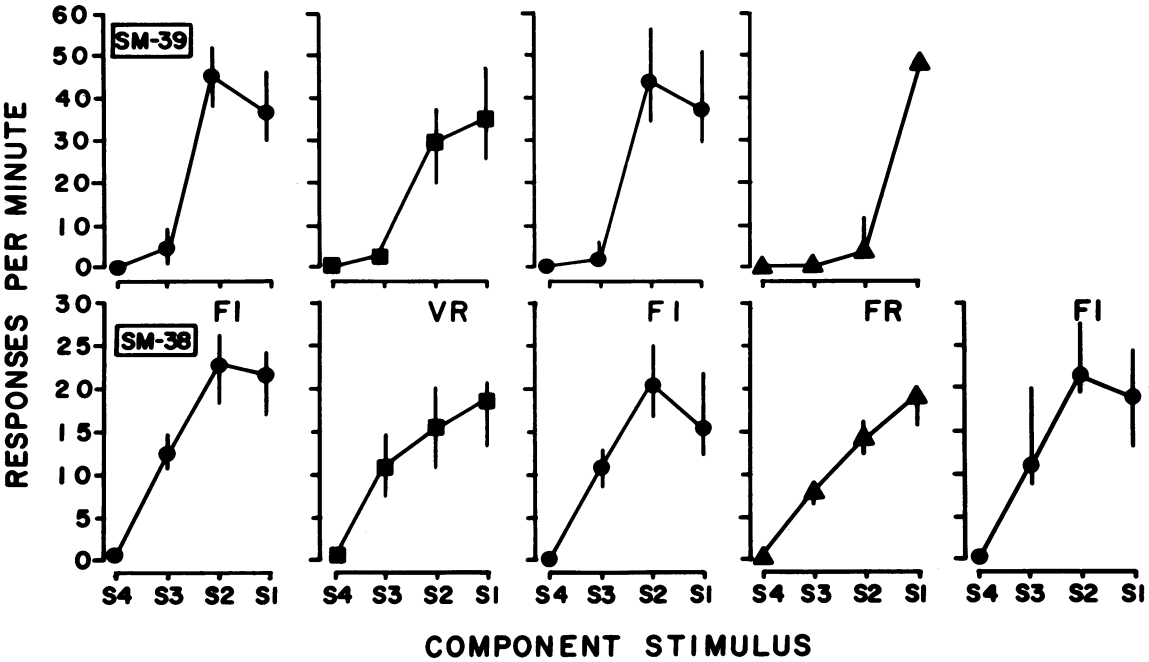

Fig. 1. Distributions of component response rates under all exposures to the three sequence schedules. Circles and squares represent the median values of the last 15 sessions of exposure to the *seq* FI 8-min (FI 2-min) and *seq* VR yoked (FI 2-min) schedules, respectively. Triangles represent the median values of the last three sessions under the *seq* FR4 (FI 2-min) schedule. Vertical lines through the symbols represent ranges; absence of a vertical line indicates that the range lies within the area occupied by the symbol. The top frames contain data for Monkey SM-39 and the bottom frames contain data for Monkey SM-38; note the difference in scale of the ordinates in the upper and lower frames.

creased slightly with Monkey SM-38, whereas rates in S_3 and S_1 were essentially unchanged with both monkeys. The overall result under the VR sequence schedule was a distribution of component response rates that increased directly from S_4 to S_1. The VR value (average number of component completions per shock presentation) was 3.9 for Monkey SM-39 and 3.2 for Monkey SM-38. Following exposure to the *seq* VR yoked (FI 2-min) schedule, the *seq* FI 8-min (FI 2-min) schedule was reinstated and responding essentially identical to that maintained in the first FI 8-min phase was recovered.

When the monkeys were next exposed to the *seq* FR 4 (FI 2-min) schedule, response rates in S_4 and S_3 decreased to levels lower than those maintained under any preceding schedule; with Monkey SM-39, rate in S_2 also decreased to a level lower than those previously seen. As under the VR sequence schedule, component response rates increased directly from S_4 to S_1. Following exposure to the *seq* FR 4 (FI 2-min) schedule, the *seq* FI 8-min (FI 2-min) schedule was reinstated with Monkey SM-38 and responding essentially identical to that maintained in previous FI 8-min phases was recovered.

Figure 2 shows the percentage of shock presentations that followed a response in the presence of each of the four component stimuli during the last 15 sessions of each exposure to the *seq* FI 8-min (FI 2-min) schedule. With both monkeys, the large majority of shock presentations occurred in the presence of the last two component stimuli; the percentages of shocks in S_2 and S_1 were approximately 10 and 90 for Monkey SM-39 and 60 and 30 for Monkey SM-38.

Under all three sequence schedules, Monkey SM-39 rarely responded during the postshock timeouts, whereas Monkey SM-38 made several responses in rapid succession immediately after most shock presentations.

The cumulative records in Figures 3 and 4 show in detail the differences in rates and patterns of responding engendered by the three sequence schedules. Under the *seq* FI 8-min (FI 2-min) schedule (Records 3A and 4A), responding in S_4 typically consisted of a single response after more than 2 min had elapsed. Higher response rates occurred in S_3, and responding was usually positively accelerated (two instances of responding in S_3 that termi-

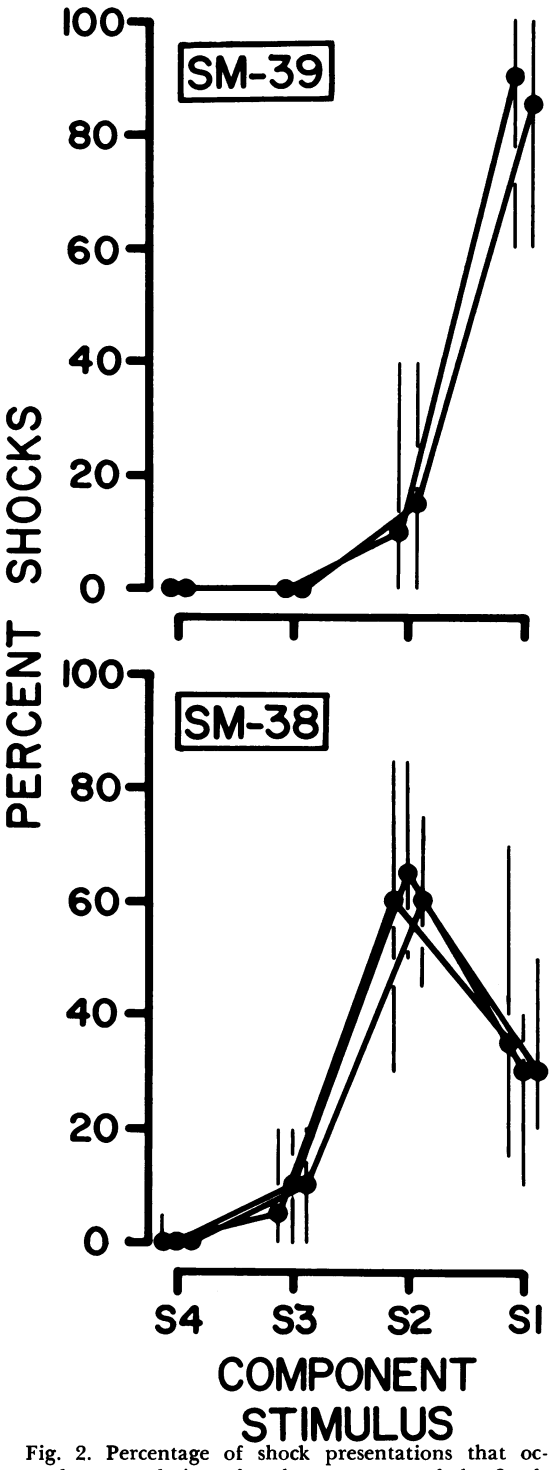

Fig. 2. Percentage of shock presentations that occurred at completion of each component of the fixed-interval sequence schedule for Monkeys SM-39 (top panel) and SM-38 (bottom panel). Circles and vertical bars represent medians and ranges of the last 15 sessions of each exposure. Leftmost symbols are from the first exposure and symbols from subsequent exposures are displaced, in order, to the right.

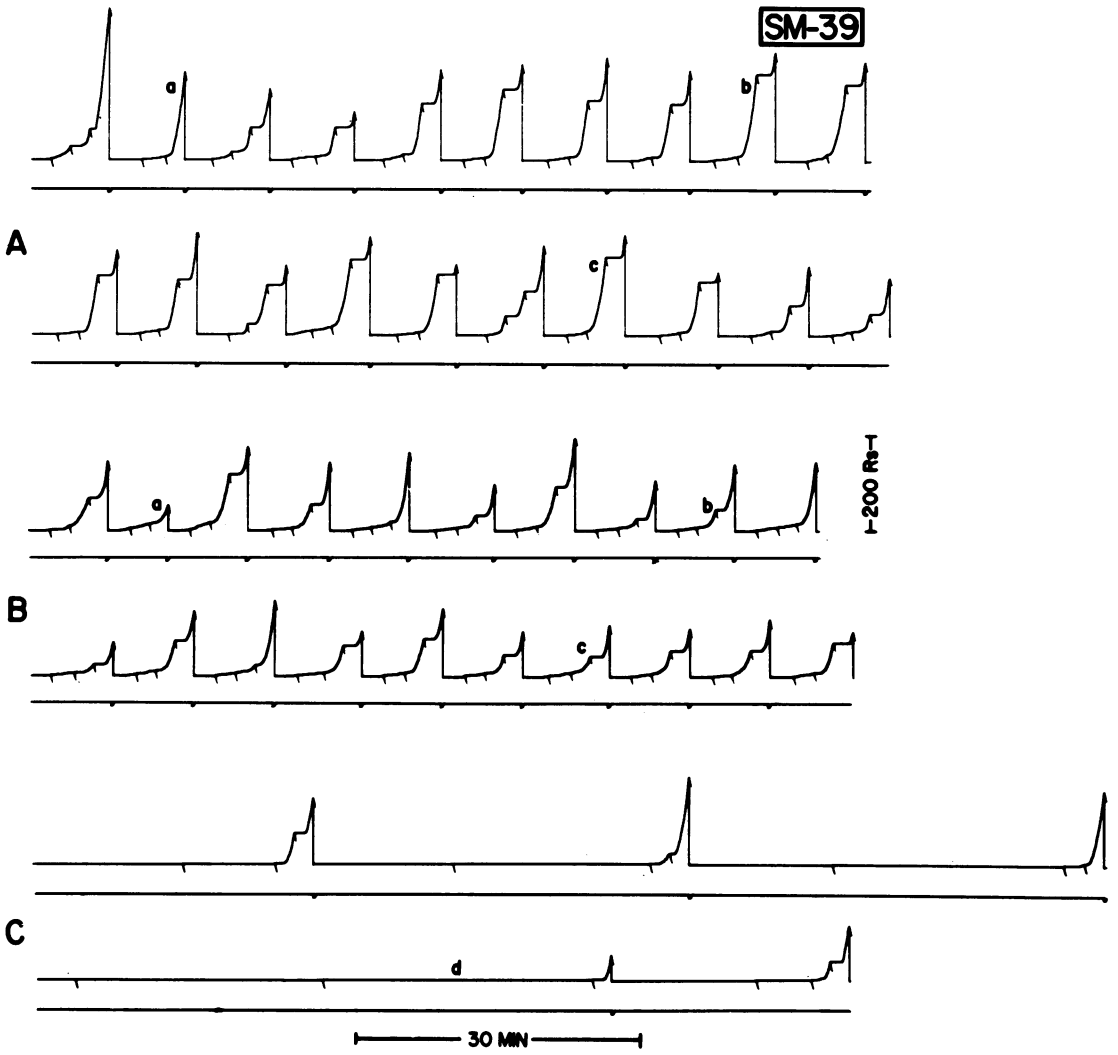

Fig. 3. Representative patterns of responding under the three sequence schedules for Monkey SM-39 (two record segments taken together comprise one complete experimental session). Diagonal marks of the response pen indicate component changes, resetting of the response pen to baseline indicates shock presentations, and the event pen was displaced downward during the 15-sec timeouts that followed each shock presentation. The schedules in effect were *seq* FI 8-min (FI 2-min) beside letter A, *seq* VR yoked (FI 2-min) beside letter B, and *seq* FR 4 (FI 2-min) beside letter C. Record A is from Session Number 177 of this monkey's first exposure to the overall FI schedule, and Record B is from the last session under the overall VR schedule for which the distribution of component-shock pairings was derived from the session shown in Record A. The letters *a*, *b*, and *c* mark corresponding points between the two records, illustrating the lower response rates that were maintained in S_2 under the VR yoked schedule. Record C is from the last session under the overall FR schedule; the letter *d* marks a prolonged pause during S_2.

nated with electric shock presentation are shown for Monkey SM-38 at *b* and *c* in Record 4A). Despite considerable interval-to-interval variability with both monkeys, the pattern of responding in S_2 often consisted of a short pause followed by acceleration to a sustained high rate of responding. Examples of such responding are shown in Record 3A for Monkey SM-39 when responding terminated with either electric shock presentation (as at *a*) or presentation of S_1 (as at *b* and *c*). Response rates in S_1 were often lower than in S_2, primarily due to longer initial pauses. This pattern of a high rate in S_2 followed by a lower rate in S_1 was not as pronounced with Monkey SM-38 as it was with Monkey SM-39; however,

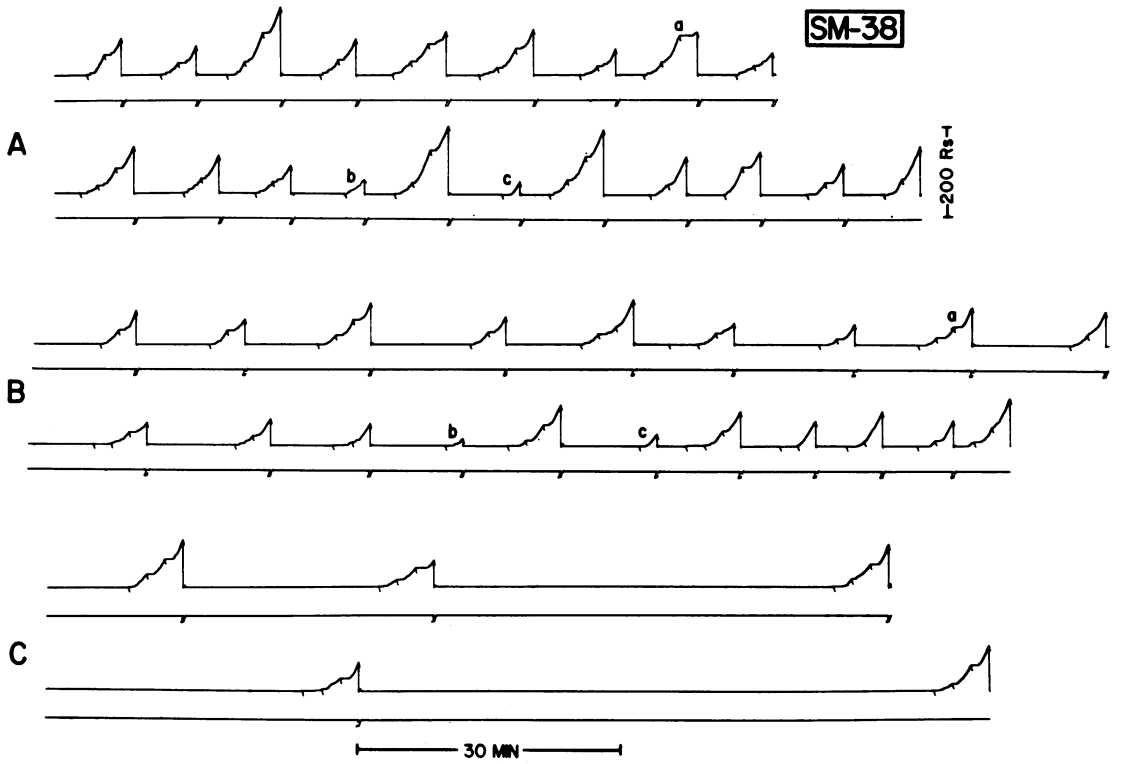

Fig. 4. Representative patterns of responding under the three sequence schedules for Monkey SM-38. Display and recording conventions are the same as in Figure 3. The schedules in effect were *seq* FI 8-min (FI 2-min) beside letter A, *seq* VR yoked (FI 2-min) beside letter B, and *seq* FR 4 (FI 2-min) beside letter C. Record A is from Session Number 64 of this monkey's first exposure to the overall FI schedule, and Record B is from the last session under the overall VR schedule for which the distribution of component-shock pairings was derived from the session shown in Record A; the letters *a*, *b*, and *c* again mark corresponding points between the two records. Record C is from the last session under the overall FR schedule.

one clear instance with Monkey SM-38 is shown at *a* in Record 4A.

Under the *seq* VR yoked (FI 2-min) schedule, responding in S_4 again generally consisted of a single response emitted after more than 2 min had elapsed (Records 3B and 4B). Average pause durations in S_4 decreased slightly with Monkey SM-39 and increased with Monkey SM-38, resulting in a higher overall rate of shock presentation for Monkey SM-39 (7.3 shocks per hour under the VR sequence schedule vs. 7.0 shocks per hour under the FI sequence schedule) and a lower rate of shock presentation for Monkey SM-38 (5.1 shocks per hour vs. 7.0 shocks per hour). Rate of responding in S_3 decreased slightly with Monkey SM-39 and remained unchanged with Monkey SM-38. Comparison of Records A and B in Figures 3 and 4 shows that responding in S_2 was still positively accelerated under the VR sequence schedule, but that it generally occurred at a lower rate than under the FI sequence schedule. Responding in S_1 was similar to that previously maintained under the FI sequence schedule with both monkeys.

Under the *seq* FR 4 (FI 2-min) schedule (Records 3C and 4C), extended pauses developed in S_4 and S_3 with both monkeys, and occasionally in S_2 with Monkey SM-39 (at *d*, Record 3C). When prolonged pauses did not occur in a given component responding generally was positively accelerated.

DISCUSSION

Rates and patterns of responding within individual components and throughout sequences of components under second-order schedules are controlled by interactions among (1) the type and parameter value of the component schedule; (2) the type and parameter value of the overall schedule; and (3) the manner of presenting exteroceptive stimuli at completion of components. In the present study,

performance within the FI 2-min components was generally characterized by either a relatively long pause followed by a single response after more than 2 min, or by a shorter initial pause followed by positively accelerated responding until component completion. With few exceptions, the first pattern occurred in S_4, and is characteristic of performance during early FI components of sequence schedules of food presentation (e.g., Byrd, 1971; Findley, 1962; Gollub, 1958; Kelleher & Fry, 1962; Malagodi et al., 1973a; Marr, 1971). The second pattern, which predominated in S_3, S_2, and S_1, is characteristic of performance under both single FI schedules of food presentation (e.g., Branch & Gollub, 1974; Dews, 1978; Ferster & Skinner, 1957; Schneider, 1969) and during later FI components of sequence schedules of food presentation.

Rates and patterns of responding across sequential components in the present study depended upon the overall schedule of shock presentation. Under the *seq* FI 8-min (FI 2-min) schedule, rate of responding was low in S_4, increased in S_3, peaked in S_2, then decreased slightly in S_1. Although completion of only one component was required for each shock presentation, most shocks occurred after completion of three or four components, in the presence of either S_2 or S_1. The characteristics of lever pressing under the FI sequence schedule were very similar to those previously reported by Marr (1971) for key pecking by pigeons under comparable sequence schedules of food presentation. In Marr's (1971) study, completion of component FI 1-, 2-, or 4-min schedules produced grain according to overall FI 4-, 8-, or 16-min schedules, respectively, and consecutive component stimuli differed. The highest rate of responding often occurred in S_2 and most grain presentations occurred in either S_2 or S_1. Responding under the FI sequence schedule in the present study was also similar to responding in previous studies in which key pecking by pigeons produced brief stimulus changes according to either FR (e.g., Kelleher, 1966a; Shull et al., 1972) or FI (e.g., deLorge, 1967; Stubbs, 1971) component schedules, and component completions produced grain according to overall FI schedules. In those studies, rates of responding were lowest immediately after grain presentation and either increased or reached steady levels as sequential components were completed. As in the present study and Marr's (1971) previous study with FI sequence schedules, the average number of component completions under the FI brief-stimulus schedules far exceeded the minimum requirement of one per interval.

Results consistent with those of the present study also have been obtained with rats when lever pressing produced tokens according to FR schedules, and token presentations produced the opportunity to exchange the tokens for food according to FI exchange schedules (Malagodi et al., 1975; Waddell, Leander, Webbe, & Malagodi, 1972). Numerous tokens were obtained during most FI exchange intervals and rate of responding increased as the intervals elapsed. It seems that just as single FI schedules generate few responses early in the interval and many responses near the end of the interval (cf., Ferster & Skinner, 1957; Killeen, 1975), second-order FI schedules operate similarly to control patterns of responding across sequences of component schedules. Performance under the FI sequence schedule of the present study probably reflected the interaction between component FI and overall FI schedule dependencies (cf., Marr, 1971, 1979). Responding in S_1, which always terminated with shock presentation and may have been controlled primarily by the component FI 2-min schedule, was characterized by the distinctive initial pause typical of single FI schedules. Responding in S_4, S_3, and S_2, which only intermittently terminated with shock presentation, may have been under greater control by the overall FI 8-min contingencies, reflecting this control in accelerated responding across the first three components.

Changing from the *seq* FI 8-min (FI 2-min) schedule to either the *seq* VR yoked (FI 2-min) or *seq* FR 4 (FI 2-min) schedule had effects on responding consistent with the results of previous studies of single and second-order schedules of food presentation, and with interpretations of such responding that emphasize the combined influence of component and overall schedules and of discriminative control by component stimuli (cf. Marr, 1979). The *seq* VR yoked (FI 2-min) schedule eliminated the fixed relation between time and the availability of shock presentation without changing the percentages of shock presentations that occurred in the presence of each component stimulus. Under the VR sequence schedule, the high rate of responding in S_2 decreased, but re-

sponding throughout the sequence of components was still well-maintained. The *seq* FR 4 (FI 2-min) schedule eliminated both the fixed relation between time and the availability of shock presentation and the possibility that shock could occur in the presence of the first three component stimuli. Under the FR sequence schedule, prolonged periods of pausing developed in the early components. These results are consistent with the finding that, at large parameter values, single VR and FI schedules of food presentation can maintain an average of many more responses per food presentation than matched FR schedules (Zeiler, 1979). And in a study in which lever pressing by rats produced tokens under an FR 20 schedule, and token presentations produced the opportunity to exchange the tokens for food pellets under either VR 6 or FR 6 exchange schedules (Webbe & Malagodi, 1978), pauses prior to the initiation of lever pressing were shorter, and response rates were higher, under the VR than under the FR exchange schedule. The effects of associating shock presentation with early component stimuli (under both the FI and VR sequence schedules) are consistent with those obtained under similar conditions of food presentation. The intermittent association of food presentation with several component stimuli in a sequence increases rates of responding in the presence of those stimuli (e.g., Byrd, 1971; Findley, 1962; Kelleher & Fry, 1962; Marr, 1971). Performance under sequence schedules in which food is associated with only the last in a fixed sequence of components is generally very similar to that maintained under the FR sequence schedule in the present study; prolonged pauses and low rates of responding occur in the early components (e.g., Byrd, 1971; Findley, 1962; Gollub, 1958; Kelleher & Fry, 1962; Malagodi et al., 1973a; Marr, 1971).

The present results are also related to those obtained by Byrd (1972) in a study of responding by squirrel monkeys under second-order brief-stimulus schedules of electric shock presentation. In one phase of Byrd's study, completion of four consecutive FI 4-min components was required for shock presentation and a brief flash of light was presented at completion of each component (paired stimulus—S). This FR 4 (FI 4-min: S) schedule is formally similar to the *seq* FR 4 (FI 2-min) schedule of the present study in both type of component schedule (FI) and type and parameter value of overall schedule (FR 4); it differs in the manner of presenting stimulus changes at component completions (brief vs. continuous). Positively accelerated responding was maintained in all four components of the FR 4 (FI 4-min: S) schedule. Extended pauses, such as those that characterized responding during early components of the *seq* FR 4 (FI 2-min) schedule in the present experiment, did not occur. Responding is often well-maintained during the early components of second-order brief-stimulus schedules of either food presentation or drug injection, even when the completion of a large number of components is required (e.g., Byrd & Marr, 1969; Katz, 1979; Kelleher, 1966b; Kelleher & Goldberg, 1977; Marr, 1970). In contrast, responding is usually poorly maintained during the early components of similar sequence schedules (cf., Fantino, 1977; Gollub, 1977; Kelleher 1966a; Marr, 1969, 1979), and sometimes of token reinforcement schedules (Kelleher, 1957), that require completion of the same or a fewer number of components.

The complexity of the present behavioral situations in which responding was maintained by response-dependent presentation of noxious electric shock is perhaps the most important aspect of the present experiment. Manipulations of schedule variables within these complex behavioral situations produced changes in responding comparable to those obtained with conventional maintaining events such as food, thus extending the generality of shock-maintained behavior and of schedule-controlled behavior to more complex situations. The present study also provides support for Morse and Kelleher's (1977) suggestion that presentation of electric shock may be more likely to maintain responding when there has been a history of schedule-controlled responding, and when that responding is multiply determined. In previous studies, responding under single FR schedules of electric shock presentation has not been maintained for more than a few sessions (Kelleher & Morse, 1969; McKearney, 1970). In the present study, however, responding under the FR sequence schedule was well-maintained with one monkey for over 50 sessions. The similarities between results of the present study and those of previous studies, across different species, responses, maintaining events, and levels of analysis, at-

test to the extensive influence of schedules in the control of behavior.

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