MAINTENANCE AND SUPPRESSION OF RESPONDING UNDER SCHEDULES OF ELECTRIC SHOCK PRESENTATION¹

JAMES W. MCKEARNNEY

WORCESTER FOUNDATION FOR EXPERIMENTAL BIOLOGY

In squirrel monkeys previously trained under a continuous avoidance schedule, characteristic patterns of responding were maintained under a 3-min variable-interval schedule of shock presentation (response-produced shock). Responding in the presence of a periodically presented stimulus, the termination of which coincided with the delivery of a response-independent electric shock (Estes-Skinner procedure), was not reliably affected. When shocks followed every response during certain signalled portions of the session, and were presented under the variable-interval schedule during the rest of the session (multiple 1-response fixed-ratio, 3-min variable-interval schedule of shock presentation), responding was suppressed during the fixed-ratio component and maintained during the variable-interval component. Environmental consequences do not have immutable properties, and may either support or suppress behavior, depending on the schedule of presentation.

Under certain conditions, responding can be maintained under schedules in which the only consequence of responding is the presentation of intense electric shocks. Morse and Kelleher (1970), Morse, Mead, and Kelleher, (1967) were first to report these results. In one set of experiments (Morse, *et al.*, 1967), a response initially elicited by electric shock was modified by scheduling response-produced shock under a fixed-interval schedule; a pattern of responding after shock was altered to a pattern of maximal responding just before shocks produced under the fixed-interval schedule. In other experiments (Morse and Kelleher, 1970), it was shown that squirrel monkeys with a history of responding under schedules of termination of stimuli associated with shock would continue to respond, and would develop a pattern of positively accelerated responding, under fixed-interval schedules of shock presentation.

Previous experiments have shown that with squirrel monkeys previously trained to respond under schedules of shock postponement (Sid-

man, 1953), a pattern of positively accelerated responding can be engendered and maintained under a fixed-interval schedule of shock presentation (McKearney, 1968). Performances under fixed-interval schedules of shock presentation were shown to be similar to those obtained under fixed-interval schedules of food presentation, first, in the characteristic pattern of responding engendered, second, in the effects of elimination, reinstatement, and variations in magnitude of the stimulus maintaining the behavior, and third, in the effects of variations in the parameter value of the fixed-interval schedule (McKearney, 1969). More recently (McKearney, 1970), it has been shown that characteristic patterns of responding, similar to those engendered with food presentation or shock termination, can be maintained under fixed-ratio, and multiple fixed-interval fixed-ratio schedules of shock presentation.

The present paper reports the effects of presenting response-dependent electric shocks under a variable-interval schedule. In addition, the effects of superimposing pre-shock stimuli, and response-independent electric shocks, on this performance were studied. Finally, responding under a multiple 3-min variable-interval, 1-response fixed-ratio schedule of shock presentation was studied. The results show that patterns of responding similar to those maintained under variable-interval

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schedules of food presentation are maintained under the same schedule of electric shock presentation; that responding is not noticeably changed during a pre-shock stimulus; and that responding can simultaneously be maintained and suppressed, depending on the schedule under which the shock is presented.

METHOD

Subjects and Apparatus

One male (S-221) and one female (S-184) adult squirrel monkey (*Saimiri sciureus*) had both been used in various experiments involving schedules of food presentation, but neither had been exposed to electric shock prior to these experiments. The monkeys were housed individually, and were handled according to the general procedures reported by Kelleher, Riddle, and Cook (1963).

Experiments were conducted with individual monkeys seated in a restraining chair (Hake and Azrin, 1963; Kelleher and Morse, 1964). The monkey's tail was held motionless by a small stock, and electric shocks were delivered through brass electrodes that rested on a shaved portion of the tail. The shock was 650 v ac, 60 Hz, of 200-msec duration, deliv-

ered to the electrodes through variable series resistance. The response key (Lehigh Valley Electronics rat lever, LVE 1352) was mounted on a wall facing the monkey. Each depression of the response key with a force of approximately 20 g (0.196 N) or more produced the audible click of a relay within the chamber, and was recorded as a response. The restraining chair was enclosed in a sound-attenuating chamber. Two 7.5-w white lights illuminated the chamber during sessions. Continuous white noise was present to mask extraneous sounds.

Procedure

Three-minute variable-interval schedule. Both monkeys were first trained to respond under a schedule of shock postponement (Sidman, 1953). Shocks (5 mA) were scheduled to occur every 10 sec, (S-S 10) but each depression of the response key postponed the delivery of shock for 30 sec (R-S 30). Sessions were approximately 100 min long, conducted five days per week. After 11 (S-221) or 12 (S-184) sessions under the avoidance schedule, each monkey was studied under a variety of procedures before the VI 3-min schedule was introduced. These procedures are listed in Table 1, but

Fig. 1. Rates of responding under a 3-min variable-interval schedule of electric shock presentation (Monkey S-184). Ordinate: response rate (responses/sec). Abscissa: experimental sessions. Filled triangle: mean of last three sessions under fixed-time schedule. Unfilled triangle: mean of last three sessions under concurrent fixed-time and avoidance schedules. The unfilled circle at extreme left represents the mean of the last seven sessions under the avoidance schedule alone (before initial introduction of the variable-interval schedule); unfilled circles in the center represent the last four sessions of avoidance given before the second exposure to the VI. Filled circles represent individual sessions under the 3-min variable-interval schedule.

Table 1

Schedule	Number of Sessions	
	S-184	S-221
avoidance (SS10, RS30)	12	11
concurrent avoidance, ^a	10	14
fixed-time 10-min		
avoidance	7	4
concurrent avoidance, ^a	3	3
fixed-time 10-min		
fixed-time 10-min ^b	3	5
fixed-interval 10-min	—	21
variable-interval 3-min	10	—
fixed-interval 3-min	19	—
TWO-MONTH SUSPENSION OF EXPERIMENTS		
avoidance	7	7
variable-interval 3-min	33	32

^aUnder the concurrent avoidance, fixed-time schedule, responses postponed for 30 sec shocks that otherwise would occur every 10 sec, and a single, response-independent shock of the same intensity was presented every 10 min. In addition, it was specified that this response-independent shock could not be presented until 3 sec had elapsed since the last response.

^bUnder the fixed-time schedule, a response-independent electric shock was presented every 10 min. Responding had no schedule consequences, except that the shock could not be presented until 3 sec had elapsed since the last response.

since they are not relevant to present considerations, they are not discussed in detail here.

Under the VI 3-min schedule of shock presentation, an electric shock was presented fol-

lowing the first response to occur after the passage of a variable period of time (averaging 3 min). The delivery of shocks under this schedule was the only scheduled consequence of responding. Monkey S-184 was first studied under the VI schedule for 10 sessions, followed by a number of sessions under a fixed-interval schedule of shock presentation. Then (because of a change in location of the laboratory), there was a two month period during which no experiments were conducted. Monkey S-184 received 10 sessions under the VI schedule before this time, but Monkey S-221 was not exposed to this schedule until after the two-month period. When experiments were resumed, both monkeys received seven sessions under the avoidance schedule described earlier, and were then studied under the VI 3-min schedule.

Pre-shock stimuli. After performance had stabilized under the VI schedule, both monkeys received a number of sessions under 3-min and 10-min fixed-interval schedules of shock presentation. These results will not be discussed, because performance under fixed-interval schedules of shock presentation has been described previously (McKearney, 1968, 1969). After this, both monkeys were again placed under the VI 3-min schedule; as before, a pair of white stimulus lights illuminated the chamber during operation of the VI schedule.

Fig. 2. Rates of responding under a 3-min variable-interval schedule of electric shock presentation (Monkey S-221). Unfilled circle: mean of last three sessions under avoidance schedule. Filled circles: individual sessions under the 3-min variable-interval schedule. Other details same as in Figure 1.

Then, the procedure was changed so that during certain minutes of each session, additional lights were illuminated (two each of red and green). When these lights went out, at the end of the predetermined period of time, the

monkey received a response-independent shock of the same intensity that was presented under the VI schedule. The red and green lights are hereafter referred to as the "pre-shock stimulus", and the entire procedure of superim-

Table 2
Rates of responding (responses/sec) during FR 1 component, and during equal periods before and after.

Session and Procedure	S-221			S-184		
	Before	During	After	Before	During	After
last pre-shock stimulus	0.211	0.250	0.183	0.978	0.811	0.806
first FR 1 (1 min)	0.206	0.100	0.328	1.167	0.717	1.406
last FR 1 (1 min)	0.578	0.011	0.350	1.322	0.622	1.039
first FR 1 (3 min)	0.548	0.083	0.652	1.411	0.370	1.024
fifth FR 1 (3 min)	0.311	0.026	0.391	1.130	0.031	0.906

Fig. 3. Cumulative records of responding under the avoidance schedule and under the variable-interval schedule of shock presentation (Monkey S-184). A: last session under the avoidance schedule (*i.e.*, session that immediately preceded the second exposure to the VI schedule). B: first session under 3-min variable-interval schedule (second exposure). C: thirtieth session under variable-interval schedule. In A, shocks are denoted by diagonal strokes on the response record, while in B and C, shock presentations are indicated by diagonal strokes on both the response and event records. In A, the response pen was reset every 10 min, while in B and C, it reset with the accumulation of 1100 responses.

S-221

Fig. 4. Cumulative records of responding under the avoidance schedule, and under the 3-min variable-interval schedule of shock presentation (Monkey S-221). A: last session under the avoidance schedule. B and C: first and thirtieth sessions under the VI schedule. Details of recording same as in Figure 3.

posing this stimulus and attendant response-independent shock upon the ongoing behavior is referred to as the "Estes-Skinner procedure" (Estes and Skinner, 1941). Each monkey was studied for a number of sessions with pre-shock stimuli of 5-min, 3-min, and 1-min duration. Regardless of the duration of the pre-shock stimulus, it was presented three times per session (minutes 15-20, 35-40, and 55-60 for the 5-min duration; minutes 15-18, 45-48, and 75-78 for the 3-min duration; and minutes 16-17, 49-50, and 82-83 for the 1-min duration of the pre-shock stimulus). Rates of responding were recorded separately for an equal period before and after the stimulus period (e.g., if the pre-shock stimulus was 5 min, responding during the 5 min before and after this was recorded).

Multiple 3-min variable-interval, 1-response fixed-ratio. Both monkeys were then studied under a multiple schedule of shock presentation. Stimulus conditions were the same as before (*i.e.*, stimulus lights changed during

certain periods), but now each response during these periods was followed by shock presentation (there was no response-independent shock at the end of the period). This is a 1-response fixed-ratio schedule, and the entire procedure is a multiple 3-min variable-interval, 1-response fixed-ratio schedule of electric shock presentation. Both monkeys were studied for a number of sessions in which the duration of the FR 1 component was 1 min or 3 min.

RESULTS

Three-minute variable-interval schedule. Figures 1 and 2 summarize the development of responding under the VI 3-min schedule of shock presentation for Monkeys S-184 and S-221, respectively. Characteristic variable-interval patterns of responding (Ferster and Skinner, 1957) were maintained in both subjects. Rates of responding of both monkeys were eventually higher under the variable-interval schedule than under the continuous

Fig. 5. Average rates of responding (responses/sec) during pre-shock stimuli of different durations, and during equivalent time periods before and after. b: period before. s: during stimulus. a: period after stimulus. Each point is the mean of 8 (5 min), 6 (3 min), or 34 (1 min) experimental sessions. Vertical lines indicate two standard errors above and below the mean.

avoidance schedule. Figures 3 and 4 show cumulative response records at various stages. The pattern of responding was no different under the avoidance and variable-interval schedules, but the rate of responding was eventually considerably higher under the schedule of shock presentation.

Pre-shock stimuli. Figure 5 summarizes rates of responding before (b), during (s), and after (a) pre-shock stimuli of 5-, 3-, or 1-min duration. Aside from a slight suppression during the period after response-independent shock presentation for one monkey (S-184, 1 min), the pre-shock stimuli had little systematic effect on rates of responding under the variable-interval schedule of shock presentation.

Multiple 3-min variable-interval, 1-response fixed-ratio. When the procedure was changed so that a shock was presented after every response during 1-min periods, there were immediate effects on responding. Table 2 summarizes rates of responding during the first and last sessions when FR periods were 1 min in duration, and during the first and fifth sessions when this component was 3 min in duration. Figures 6 and 7 show cumulative response records from corresponding sessions. Response rates were noticeably suppressed during the 1-min FR 1 periods, but to a much greater extent in Monkey S-221. How-

Fig. 6. Cumulative records of responding under a multiple 3-min variable-interval, 1-response fixed-ratio schedule of shock presentation (Monkey S-184). A: last session under Estes-Skinner (pre-shock stimulus) procedure. B, C, and D: second, tenth, and twenty-fourth sessions in which, in addition to the VI schedule, shocks followed every response during certain (signalled) 1-min periods. E and F: first and fifth sessions in which these FR 1 periods were 3 min rather than 1 min in duration. The response pen was displaced downward during the pre-shock stimulus (A), or during the FR 1 periods (B-F). In B-F, responses during the FR 1 period are indicated by an upward mark on the response record. Shocks presented under the VI schedule are indicated on the event record only.

ever, within a few sessions after the duration of the FR 1 components was increased to 3 min, responding of both monkeys was approxi-

mately equally suppressed. Changes in responding immediately before and after the FR component were slight and non-systematic.

DISCUSSION

Characteristic patterns of responding were maintained under the variable-interval schedule of shock presentation in monkeys previously trained under an avoidance schedule. This complements previous findings that characteristic patterns of responding can be maintained under fixed-interval, and multiple fixed-interval fixed-ratio schedules of electric shock presentation.

Over the range of parameters explored in these experiments, responding under the VI schedule was not systematically affected by presenting a stimulus before the delivery of a response-independent shock. The effects of such a procedure are very complexly determined, and subtle changes in procedure (e.g., duration of stimulus, intensity of shock, number of presentations per session) possibly could produce reliable changes in rate during the pre-shock stimulus. Further, Azrin and Hake (1969) noted that changes in responding during a stimulus preceding a response-independent event are less consistent when the response-dependent and response-independent events involved are the same. In the present experiments, electric shock of the same intensity was presented under the VI schedule, and was delivered at the termination of the pre-shock stimulus.

When shocks were presented after every response during certain portions of the experimental session, rates of responding were suppressed. Electric shocks of the same intensity simultaneously maintained responding under the variable-interval schedule, and suppressed responding under the 1-response fixed-ratio schedule. Kelleher and Morse (1968) have shown, similarly, that electric shocks can maintain responding under a fixed-interval schedule, but suppress responding when presented after each response. Such results provide forceful demonstration of the conclusion that the schedule under which an event is presented can be of overriding importance in determining the effects that event will have on behavior. Environmental consequences may either support or suppress behavior, depending on the schedule of presentation.

Fig. 7. Cumulative records of responding under a multiple 3-min variable-interval, 1-response fixed-ratio schedule of shock presentation (Monkey S-221). A: last session under Estes-Skinner (pre-shock stimulus) procedure. B, C, and D: first, tenth, and twenty-third sessions in which FR 1 periods were 1 min in duration. E and F: first and fifth sessions in which the FR 1 periods were 3 min in duration. Other details same as in Figure 6.

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