RESPONDING UNDER FIXED-RATIO AND MULTIPLE FIXED-INTERVAL FIXED-RATIO SCHEDULES OF ELECTRIC SHOCK PRESENTATION¹

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Squirrel monkeys, initially trained under a schedule of electric shock postponement and then under fixed-interval schedules of electric shock presentation, were studied under multiple fixed-interval fixed-ratio and under fixed-ratio schedules of shock presentation. Under the fixed-interval (10-min) component of the multiple schedule, a pause was followed by a gradual increase in responding to a rate maintained until shock presentation; under the fixed-ratio (3-, 10-, or 30-response) component of the multiple schedule, a brief pause was typically followed by a relatively high and uniform rate of responding until shock was presented. When the 60-sec timeout periods, which usually followed shock presentation, were eliminated from the multiple schedule for one monkey, responding was only transiently affected. In the one monkey studied, responding was maintained under a fixed-ratio schedule alone (with timeout periods), but rates of responding were lower than under the fixed-ratio component of the multiple schedule. Characteristic patterns of responding, similar to those engendered under schedules of food presentation or shock termination, can be maintained under fixed-ratio schedules of shock presentation; further, patterns of responding can be controlled by discriminative stimuli in multiple schedules.

Previous experiments (McKearney, 1968, 1969) have shown that, in monkeys previously trained to respond under a schedule of shock postponement, the presentation of response-dependent electric shock under a fixed-interval schedule can enhance responding, and lead to the development and maintenance of a pattern of positively accelerated responding. At the parameter values studied, performances engendered under fixed-interval schedules of shock presentation were similar to those engendered under similar schedules of food presentation or shock termination, (a) in the characteristic pattern of positively accelerated responding engendered, (b) in the effects of elimination, reinstatement, and variations in intensity of the stimulus maintaining the behavior, and (c) in the effects of variations in the parameter value of the fixed-interval schedule (McKearney, 1969).

The present paper reports the effects of presenting response-dependent electric shocks under fixed-ratio, and multiple fixed-interval fixed-ratio schedules.

METHOD

Subjects and Apparatus

Three adult male squirrel monkeys (*Saimiri sciureus*) were used; all had been used in previously reported experiments involving fixed-interval schedules of shock presentation (McKearney, 1968, 1969). 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 250-msec duration, delivered 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

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audible click of a relay within the chamber, and was recorded as a response. The restraining chair was enclosed in a sound-attenuating chamber (Industrial Acoustics Co., AC-3). A 25-w overhead light illuminated the chamber during sessions. Continuous white noise was present to mask extraneous sounds.

Procedure

In the experiments that preceded these (McKearney, 1969), the monkeys were first trained under a continuous avoidance schedule (Sidman, 1953). Then, concurrently with the avoidance schedule, the first response occurring after 10 min was immediately followed by shock (10-min fixed-interval schedule of shock presentation). After this, the avoidance schedule was eliminated, and the monkeys responded under the fixed-interval schedule alone. The effects of elimination of shock, of addition and deletion of a timeout period following shock, and of variations in shock intensity and fixed-interval duration were then studied (McKearney, 1969). Immediately preceding the present experiments, the effects of various drugs on responding under the 10-min fixed-interval were determined; the drug results are not reported here.

All monkeys were studied under a multiple 10-min fixed-interval 30-response fixed-ratio schedule of electric shock presentation. As before, when the overhead lamp in the chamber was illuminated, the first response after 10 min produced an electric shock (10-min fixed-interval). In the presence of a red stimulus light in addition to the overhead lamp, a shock was presented after the thirtieth response (30-response fixed-ratio). A 60-sec timeout period, during which all lights were extinguished and responding had no scheduled consequences, followed each shock presentation. The fixed-interval and fixed-ratio components alternated throughout the session, separated by the 60-sec timeout period. Initial sessions (1 to 8 for S-101, 1 to 5 for S-65, and 1 to 3 for S-85) consisted of five presentations of each schedule component. Subsequent sessions usually consisted of 10 fixed-interval and 10 fixed-ratio components. For S-101, shock intensity was always 10 mA. For S-65, shock was 10 mA in Sessions 1 to 18, and 5.6 mA during Sessions 19 and 20. For S-85, shock intensity was 10 mA in Sessions 1 to 11 and 13 to 16, and 5.6 mA during Sessions 12 and 17 to 20.

After a number of sessions under the multiple 10-min fixed-interval 30-response fixed-ratio schedule of shock presentation, each monkey was studied under multiple schedules in which the parameter value of the fixed-ratio was varied. Each monkey received at least five sessions under fixed ratio 3, 10, and 30. Aside from changes in fixed-ratio parameter, all aspects of the multiple schedule were the same as in earlier phases of the experiments. Shock intensity was 5.6 mA throughout.

The effects of elimination of the 60-sec timeout period under the multiple schedule of shock (5.6 mA) presentation were studied in one monkey (S-65).

One monkey (S-101) was studied under a 30-response fixed-ratio schedule of shock presentation. In the presence of the overhead light and of a red stimulus light, a 5.6 mA shock was presented after the thirtieth response. A 60-sec timeout period followed each shock presentation.

RESULTS

Figures 1 to 3 show cumulative records of responding during various sessions after the multiple schedule of shock presentation was introduced.

For Monkeys S-65 and S-85, rates of responding during the fixed-ratio component were quite low during the first session after the fixed-interval schedule alone (Fig. 1A and 2A), but after several sessions rates increased noticeably (Fig. 1B and 2B). By the tenth session, Monkey S-65 had developed a higher rate of responding during the fixed ratio (Fig. 1C), and the long pauses seen in earlier sessions were eliminated. This relatively high rate of responding was maintained over the succeeding sessions, but the pauses before responding were lengthened, with the result that average rates of responding during the fixed-ratio component decreased somewhat (Fig. 1D). Over the 20 sessions under the multiple schedule, the fixed-ratio response rate of Monkey S-85 increased; in contrast to the performance of Monkey S-65, no prolonged pauses developed in S-85 (Fig. 2D). The rate of responding of Monkey S-101 during the fixed-ratio component was quite high during even the initial sessions under the multiple schedule, and increased only slightly over succeeding sessions (Fig. 3).

Fig. 1. Cumulative records of responding under a multiple fixed-interval 10-min, fixed-ratio 30-response schedule of electric shock presentation (Monkey S-65). Ordinate: cumulated responses. Abscissa: time. The recording pen was reset with each shock presentation. Diagonal strokes signify the end of a 60-sec timeout period. Each record is for a complete session (sessions varied in duration). A, B, C, and D represent, respectively, the first, fifth, tenth, and twentieth sessions under the multiple schedule of shock presentation.

Fig. 2. Cumulative records of responding under a multiple fixed-interval 10-min, fixed-ratio 30-response schedule of electric shock presentation (Monkey S-85). Details of recording same as in Fig. 1. A, B, C, and D represent, respectively, the first, third, tenth, and twentieth sessions under the multiple schedule of shock presentation.

Fig. 3. Cumulative records of responding under a multiple fixed-interval 10-min, fixed-ratio 30-response schedule of electric shock presentation (Monkey S-101). Details of recording same as in Fig. 1. A, B, C, and D represent respectively, the first, fifth, tenth, and nineteenth sessions under the multiple schedule of shock presentation.

All monkeys were studied for at least five sessions each under 3-response, 10-response, and 30-response fixed-ratio schedules, in that order. Monkey S-101 showed a consistent pattern of responding under all multiple schedules; responding, once begun, occurred at a relatively uniform rate throughout each fixed-ratio component. Monkey S-65 showed a very similar pattern of responding, but pauses were more prolonged, and brief "breaks" in responding occasionally occurred. For Monkey S-85, initial pauses were more prolonged than in either S-101 or S-65, and rates of responding frequently tended to be positively accelerated, especially under the 10-response and 30-response schedules.

Monkey S-65 was studied for 10 sessions under a multiple fixed-interval 10-min fixed-ratio 30-response schedule with no timeout period following shock. Rates of responding and quarter-life values under the fixed-interval component were not systematically affected by

eliminating the timeout. The overall rates of responding under the fixed-ratio component first decreased slightly, but then increased to levels comparable to those prevailing when the timeout was presented after shock.

Monkey S-101 was studied for eight sessions under a 30-response fixed-ratio schedule alone with a 60-sec timeout period after each shock. Figure 4 shows cumulative records of responding under this schedule. Rates of responding first increased, and then decreased over sessions, while pause duration increased during the later sessions. In general, typical fixed-ratio patterns of responding in this monkey were not as well maintained under the fixed-ratio schedule alone as they had been under the multiple fixed-interval fixed-ratio schedule.

DISCUSSION

The schedule under which an event is presented, the characteristics of behavior existing

at the time the event is presented, and the organism's history of reinforcement, interact to determine the effects that event will have on behavior (Morse and Kelleher, 1966; Kelleher and Morse, 1968; McKearney, 1969). Previous experiments have shown that, under certain conditions, responding can be maintained under fixed-interval schedules of presentation of response-dependent electric shock (Morse, Mead, and Kelleher, 1967; Kelleher and Morse, 1968; McKearney, 1968, 1969; Byrd, 1969). The present experiments have shown that characteristic patterns of responding can also be maintained under multiple fixed-interval, fixed-ratio schedules and under fixed-ratio schedules of electric shock presentation. Further, patterns of responding engendered under schedules of electric shock presentation can be controlled by discriminative stimuli in multiple schedules.

Under the 10-min fixed-interval component of the multiple schedule, the pattern of responding consisted of a pause followed by a gradual increase in responding to a rate that was maintained until shock was presented. Under the 30-response fixed-ratio component of the multiple schedule, there was typically a brief pause followed by a relatively high and uniform rate of responding until shock was presented. During the 60-sec timeout periods that followed each shock, little or no responding occurred. These patterns of responding are similar to those obtained under multiple fixed-interval fixed-ratio schedules of food presentation (Ferster and Skinner, 1957; Kelleher and Morse, 1964), and under multiple fixed-interval fixed-ratio schedules of termination of stimuli associated with the delivery of electric shock (Morse and Kelleher, 1966).

Responding was maintained under a fixed-ratio schedule of shock presentation in the one monkey studied. However, over the course of the eight sessions under this schedule, response rates decreased and pauses lengthened somewhat. Nevertheless, overall rates of responding in excess of one per second were obtained in the terminal sessions under the fixed-ratio schedule. Whether or not responding can be maintained for extended periods under fixed-ratio schedules is uncertain; for example, Kelleher and Morse (1969) reported an eventual suppression of responding under certain fixed-ratio schedules of shock presentation.

Fig. 4. Cumulative records of responding under a 30-response fixed-ratio schedule of electric shock presentation (Monkey S-101). In the first record, diagonal strokes indicate the beginning of FR components; the recording pen reset to baseline at shock presentation. In the remaining records, diagonal strokes indicate shock presentations, and the pen reset at the end of each 60-sec timeout period. From top to bottom, the records are for successive sessions under the FR schedule. Because of equipment malfunction, two FR cycles at the beginning of the first session were not recorded.

There are, of course, many situations in which response-dependent electric shocks do not maintain behavior, as the vast literature on the suppressive effects of electric shock will attest. It is important to realize, however, that this lack of constancy of effect of a stimulus is in no way peculiar to electric shock. There are many situations in which food presentation will not maintain behavior, and there are some cases in which it will suppress responding; similarly, there are many circumstances under which electric shock will not suppress behavior, and some cases in which its presentation will engender and maintain responding, as the present experiments have shown. The ubiquity with which food presentation can maintain behavior, and with which electric shock can suppress behavior, obscures

these important cases and consequently leads to biases that impede analysis of how environmental consequences affect behavior.

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