*SCHEDULE-INDUCED BITING UNDER
FIXED-INTERVAL SCHEDULES OF FOOD OR
ELECTRIC-SHOCK PRESENTATION*

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Squirrel monkeys pressed a lever under fixed-interval schedules of food or of electric-shock presentation. Both schedules induced repeated biting on a latex hose. Whether lever pressing was controlled by food or by electric shock, a pattern of decreasing hose biting and increasing lever pressing occurred within fixed-interval cycles. As the fixed-interval duration was increased from 6 to 600 sec, average rates of lever pressing decreased under both schedules. Average rates of hose biting first increased with increasing parameter value, reaching a maximum at values that varied from 60 to 337 sec in different monkeys, and then declined at higher values. *d*-Amphetamine at appropriate doses increased overall rates of lever pressing maintained by food or by shock, but either did not affect or decreased overall rates of hose biting. When no timeout period occurred between fixed-interval cycles, the monkeys bit most frequently immediately after food or electric shock was presented. When there was a timeout period, hose biting began shortly after the start of the fixed-interval cycles, with little or no hose biting immediately after food or electric shock was presented. Most hose biting appeared to be schedule-induced rather than food- or shock-induced.

Key words: fixed-interval reinforcement, fixed-interval shock, schedule-induced aggression, pain-elicited aggression, adjunctive behavior, amphetamines, lever pressing, hose biting, squirrel monkeys

The periodic delivery of electric shock occasions regular sequences of behavior, even though shock is delivered independently of behavior. Fighting after electric shock is delivered has been observed in a variety of species (*e.g.*, Azrin, Hutchinson, and Hake, 1963; O'Kelly and Steckle, 1939; Tedeschi, Tedeschi, Mucha, Cook, Mattis, and Fellows, 1959; Ulrich and Azrin, 1962; Ulrich, Wolff, and Azrin, 1964). Biting an inanimate object by rats (Azrin, Rubin, and Hutchinson, 1968) and squirrel monkeys (Azrin, Hutchinson, and Sallery, 1964) and postshock intromissions and ejaculation by rats (Barfield and Sachs, 1968; Caggiula and Eibergen, 1969) also have been reported. It even has been possible in the squirrel monkey to develop and maintain a response that provides the opportunity to bite

an inanimate object after electric-shock delivery (Azrin, Hutchinson, and McLaughlin, 1965).

The periodic delivery of food occasions regular sequences of behavior both when food is delivered independently of behavior and when food presentation is dependent on another response. Excessive drinking (polydipsia) following food presentation has been observed in a variety of species (Falk, 1961; Schuster and Woods, 1966; Shanab and Peterson, 1969; Palfai, Kutscher, and Symons, 1971; Byrd, 1973). Wheel running by rats (Skinner and Morse, 1957), fighting by pigeons (Gentry, 1968), and pecking or biting an inanimate object by pigeons (Flory, 1969a) or squirrel monkeys (Hutchinson, Azrin, and Hunt, 1968) also have been induced under schedules of food presentation. Moreover, a response that provides the opportunity for rats to drink or for pigeons to fight after food presentation may be developed and maintained (Cherek, Thompson, and Heistad, 1973; Falk, 1966a).

Sequences of behavior induced when electric shock is delivered periodically or under schedules of food presentation share several features: they may occur immediately postshock or postfood; they persist even when no

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consequences are dependent on their occurrence, and the opportunity to engage in these behaviors can reinforce another response. Yet, similar behaviors induced under similar schedules of food or shock have not been directly compared. Generally, in studies of behavior induced when electric shock is delivered periodically, parameters of the shock have been varied (e.g., Dreyer and Church, 1968; Hutchinson, Azrin, and Renfrew, 1968) or subject-related genetic, historical or developmental variables have been manipulated (e.g., Conner, Levine, Wertheim, and Cummer, 1969; Hutchinson, Ulrich, and Azrin, 1965; Knutson and Hynan, 1972; Powell and Creer, 1969). In contrast, behavior induced under schedules of food presentation has generally been studied by varying the parameters of the schedule (e.g., Cherek and Pickens, 1970; Gentry and Schaeffer, 1969; Hutchinson *et al.*, 1968a; Knutson, 1970). In studies using food or shock in which the species, topography of induced behavior, and dependent measures were the same (e.g., Hutchinson *et al.*, 1968a; Hutchinson, Renfrew, and Young, 1971), the schedules of food and shock have been different (e.g., fixed-ratio schedules of food presentation *versus* fixed-time schedules of electric shock, respectively).

The purpose of the present experiment was to compare hose biting induced using fixed-interval (FI) schedules of food presentation with hose biting induced using FI schedules of electric-shock presentation. These schedules can control similar rates and patterns of lever pressing in squirrel monkeys (Kelleher and Morse, 1968; McKearney, 1968; 1969; 1970; Morse and Kelleher, 1970). In the present experiment, hose biting was induced with both food and shock schedules and was similarly affected under both types of schedules by changes in FI parameter value, by administration of *d*-amphetamine, and by changes in timeout duration.

METHOD

Subjects

Three mature, male squirrel monkeys (*Saimiri sciureus*) were housed individually. Each monkey had been trained to press a lever on FI schedules of shock and of food presentation. The monkeys were generally handled according to the procedures described by Kelleher,

Gill, Riddle, and Cook (1963). The leash was removed during experimental sessions. The monkeys were maintained at 80% (S-626, 740 g; S-627, 830 g; S-628, 780 g) of their free-feeding body weights and had free access to water in their living cages.

Apparatus

Experiments were conducted with individual monkeys seated in a restraining chair (Hake and Azrin, 1963; Kelleher and Morse, 1964). The response lever (Lehigh Valley Electronics rat lever, LVE 1352) was mounted on a clear panel facing the monkey. Each depression of the lever with a force of approximately 0.196 N or more produced an audible click of a relay within the chamber, and was recorded as a response. On food schedules, a solenoid-operated dipper (Gerbrands) provided a liquid standard monkey diet, manufactured by Nutritional Biochemicals Corporation (Ellison and Riddle, 1961), through a hole in the bottom of a recessed area in the wall facing the monkey. Three pairs of 7.5-W colored light bulbs were mounted behind this clear panel. A bite-hose apparatus similar to that described by Hutchinson, Azrin, and Hake (1966) was mounted directly in front of the monkey. The bite hose was a 16-cm piece of amber latex hose (3 mm wall; 6 mm i.d.) mounted on two metal side brackets and connected to an air-wave switch. Compression of the air in the hose with a pressure of 2 mm/Hg or more closed the switch. The frequency and duration of hose bites were automatically recorded. The hose was also connected to a Statham strain-gauge pressure transducer for recording with a Grass Instrument Company polygraph so that actual bite pressure could be monitored. In experiments involving electric shock, the monkey's tail was held motionless by a stock, and shocks were delivered through brass electrodes resting on a shaved portion of the tail. The shock was 650 V ac, 60 Hz, of approximately 200-msec duration, delivered through a variable resistor in series with the electrodes. The entire chair unit was enclosed in a ventilated, sound-attenuating chamber. White masking noise was continuously present.

Lever-pressing and hose-biting responses were recorded separately on cumulative recorders and on digital counters during successive tenths of the FI schedules and during timeout periods.

Procedure

On the FI shock schedule, the first lever press to occur after a fixed period of time resulted in a 4-mA electric shock. A 10-sec timeout period, during which lever presses had no scheduled consequences, followed each electric shock. The chamber was illuminated by yellow light during each FI cycle and by green light during each timeout period.

On the FI food schedule, the first lever press after a fixed period of time resulted in 3-sec access to 0.2 ml of liquid food. A 10-sec timeout period, during which lever presses had no scheduled consequences, followed each food presentation. The chamber was illuminated by red light during each FI cycle and by green light during each timeout period.

Experimental sessions were conducted six days a week and ended after the thirtieth timeout period. Monkey S-628 responded on the shock schedule and Monkey S-626 responded on the food schedule. Monkey S-627 responded on both schedules each session (*mult FI shock FI food*); five shock intervals alternated with five food intervals until the session ended after the thirtieth timeout. The starting component was varied from day to day.

Effects of FI duration. When rates of lever pressing and hose biting had stabilized on FI 60-sec (S-628, S-626) or FI 180-sec (S-627), the parameter value of the FI schedule was reduced to 6 sec and then progressively increased. Performance was studied on 6-, 20-, 60-, 180-, 337-, and 460-sec FI schedules. Monkeys S-628 and S-626 were also studied on FI 600-sec. After exposure to the highest FI value in the series, the parameter was set at 180 sec again. Each FI duration was in effect for 10 successive sessions. A clock set at one tenth of the FI value and operated by each hose bite delayed the possibility of shock or of food presentation, thereby preventing the contiguity of hose biting and presentation of shock or of food.

Effects of d-amphetamine. A range of doses of d-amphetamine sulfate was studied in two monkeys (S-628, S-626) on FI 180-sec with conditions the same as before, except there was no delay program preventing contiguity of hose biting and shock or food presentation. The drug was dissolved in 0.9% sodium chloride solution. The monkeys were injected no more than twice weekly and only when a normally

executed session occurred the previous day. Generally, drug injections were made on Tuesday and Friday of each week with the Thursday session serving as the control. Intramuscular injections into the leg were made immediately before the start of a session. Doses were in terms of the salt, and the volume injected was always 0.5 ml/kg. No systematic order of doses was followed, but a minimum of two replications at each dose was carried out.

Effects of timeout duration. Monkey S-626 responded on FI 180-sec, S-628 on FI 300 sec, and S-627 on both FI 180- and FI 300-sec. The stimuli and consequent events were the same as before. After rates of lever pressing and hose biting had stabilized, timeout durations of 0, 10, 30, 60, and 100 sec were studied from session to session in variable order but with repeated determinations at each duration. Occasionally, timeout duration was changed during a session.

RESULTS

A period of little or no lever pressing at the beginning of each FI cycle was followed by a gradual increase in lever pressing until shock or food was presented. This pattern of lever pressing is similar to that previously described in squirrel monkeys on FI food schedules (Kelleher and Morse, 1964) and on FI shock schedules (Kelleher and Morse, 1968; McKearney, 1968). Bursts of hose biting usually began immediately after the start of an FI cycle and then declined before shock or food was presented. Figure 1 illustrates these patterns, showing alternating episodes of hose biting and lever pressing, with hose biting becoming less frequent and lever pressing more frequent as an FI cycle progressed. At FI parameters that generated hose biting, as in Figure 1, Monkeys S-626 and S-627 bit during most FI cycles, whereas Monkey S-628 seldom bit during all cycles.

Effects of FI duration. Overall rates of lever pressing decreased as the FI parameter value was increased when lever pressing was maintained by shock or by food presentation (Figure 2). The corresponding overall rates of hose biting increased and then decreased as the FI parameter value was increased on either schedule (Figure 3). The mean number of hose bites per FI also increased and then decreased

Fig. 1. Representative cumulative recordings of lever pressing and hose biting for each monkey on an FI 180-sec schedule. The recorders for lever pressing and hose biting operated simultaneously. The first lever press after 180 sec produced 3-sec access to food for S-626, a 4-mA electric shock for S-628, and either food or electric shock for S-627. For each monkey, a 10-sec timeout period followed each FI cycle. The event pen was up during FI cycles when food was the maintenance event and during timeout periods and down during FI cycles when electric shock was the maintenance event. The response pen reset to the bottom of the record at the end of each FI cycle and timeout period. The recorders stopped during the 3-sec food presentations. The records show the second 10 of 30 FI cycles during each session.

as the FI value was increased. The FI duration producing the highest mean rates of hose biting varied from 60 to 337 sec in different mon-

keys. The overall rates of lever pressing maintained by shock and by food were generally similar in Monkey S-627 (Figure 2); overall

Fig. 2. Mean rates of lever pressing as a function of FI duration. Filled symbols: food; open symbols: electric shock. Each point is the mean from the last five sessions at each schedule parameter. Numbers beside symbols indicate the order in which determinations at single parameters were made.

Fig. 3. Mean rates of hose biting as a function of FI duration. Filled symbols: food; open symbols: electric shock. Each point is the mean from the last five sessions at each schedule parameter. Numbers beside symbols indicate the order in which determinations at single parameters were made.

rates of biting were also similar (Figure 3). When redeterminations were made at a particular FI parameter, however, the rate of hose biting was more variable than the rate of lever pressing.

At FI parameter values that occasioned biting, the highest rates of hose biting occurred in the first third of the FI cycle, and the highest rates of lever pressing occurred in the last third of the FI cycle. Figure 4 summarizes the

distribution of hose bites and lever presses under FI 180-sec for each monkey. The decrease in rate of hose biting within FI cycles was more consistent for S-627 when lever pressing was maintained by shock than when lever pressing resulted in food. Additionally, availability of food or shock was delayed by hose bites that occurred in the tenth segment of an FI cycle; nevertheless, hose biting during this period was more probable with food schedules than with shock. The distribution of hose bites within the interval was consistent for every monkey at all the FI parameter values that occasioned biting.

Little or no lever pressing occurred during 10-sec timeout periods following shock or food presentation, except under FI 6-sec. There were no consistent changes in hose biting during timeout periods as a function of shock or of food presentation or of schedule parameter. Monkey S-628 bit a few times during the timeout periods following shock presentation at every FI duration. Monkey S-626 similarly bit a few times during the timeout periods following food presentation under FI 6-, 20-, and 60-sec schedules only. Monkey S-627 seldom bit during the timeout periods following shock or following food under any FI parameter value.

Effects of d-amphetamine. Predrug rates and patterns of lever pressing and hose biting for S-626 (FI 180-sec food) and S-628 (FI 180-sec shock) were generally similar to those shown in Figure 1. Increasing doses of *d*-amphetamine increased and then decreased mean rates of lever pressing but only decreased mean rates of hose biting (Figure 5). Lever-pressing rates were increased substantially at doses that decreased hose-biting rates to less than 50% of control rates (0.1 mg/kg, S-626; 0.3 mg/kg, S-628). For both monkeys, rates of hose biting were almost completely suppressed at 0.3 mg/kg *d*-amphetamine, while rates of lever pressing remained equal to or above predrug rates.

Effects of timeout duration. Although S-628 bit two or three times immediately after every shock presentation and S-626 bit after food presentation at FI parameter values shorter than 60 sec, generally little or no hose biting occurred during the 10-sec timeout periods used in the previous experiments. When timeout duration was varied from 0 to 100 sec, no consistent changes occurred in the absolute number of hose bites during timeout. Hose

biting began at the start of FI cycles whether 0 sec or 100 sec had elapsed since shock or food presentation. Figure 6 shows representative cumulative records of hose biting for two monkeys whose lever pressing was maintained by shock. Monkey S-628's typical hose-biting performance with the 10-sec timeout is shown in the middle record of the top portion of Figure 6. S-628 bit two or three times immediately after shock presentation and then paused for the remaining 9 sec or so of the timeout period. Hose biting usually began again immediately at the start of each FI cycle. The pattern of hose biting was different when there was no timeout (top record for S-628, Figure 6); biting continued after shock delivery, with few interbite times of as long as 9 sec, and then stopped for the remainder of each FI cycle. When the timeout periods were 30 sec (bottom record for S-628, Figure 6), two or three hose bites still occurred immediately after shock presentation, but hose biting then ceased. Hose biting began again only at the start of a FI cycle, 30 sec after shock presentation.

Records of hose biting for Monkey S-627 are shown in the bottom portion of Figure 6. When a 10-sec timeout period was used, S-627 never bit immediately after shock presentation but usually began hose biting shortly after the start of each FI cycle. There was seldom as much as 60 sec between presentation of a shock and the first hose bite when the timeout was 10 sec. When the timeout was changed to 60 sec, biting never began before the start of a FI cycle. When timeout duration was varied on food schedules, the results similarly indicated that much or all of the hose biting was controlled by the schedule, rather than elicited by food or by shock.

DISCUSSION

Bursts of hose biting were induced by FI schedules of shock presentation and by FI schedules of food presentation. A pattern of decreasing hose biting and increasing lever pressing was observed in individual FI cycles. In one monkey, whose rates and patterns of lever pressing under the two schedules were similar, rates and patterns of hose biting were similar under food and shock schedules. For all monkeys, regardless of the maintenance event, overall rates of hose biting increased and then decreased as FI duration increased.

Fig. 4. Mean rates of hose biting (solid bars) and lever pressing (open bars) during successive segments of FI schedule. Rates of responding were recorded separately during successive tenths of each cycle and cumulated for these segments during each session. The tenth segment also included the time from the end of the interval until food or shock was presented. The mean of these rates for the last five sessions at FI 180-sec during the ascending series is shown for each of the monkeys.

In different monkeys, maximal overall rates of hose biting occurred at FI parameter values ranging from 60 to 337 sec.

Previous studies of changes in induced behaviors related to changes in minimum inter-food interval have reported similar relation-

Fig. 5. Effects of *d*-amphetamine on mean rate of lever pressing (filled symbols) and hose biting (open symbols). Lever pressing produced either food (S-626) or electric shock (S-628) according to an FI 180-sec schedule. Mean rates of lever pressing during the FI cycles were 0.283 (S-626) and 0.829 (S-628) responses per second. Mean rates of hose biting during the FI cycles were 0.244 (S-626) and 0.100 (S-628) responses per second. Unconnected points with vertical lines indicate the means of 15 control sessions ± 1 standard error of these means. The means from two sessions when saline was administered are shown at the left. The points for each dose are means of at least two determinations.

ships with maxima in the same general range as in the present experiment. These include studies of induced fighting in pigeons using fixed-time (Flory, 1969), response-initiated FI (Cherek, Thompson, and Heistad, 1973), and FI schedules of food presentation (DeWeese, Webbe, and Malagodi, *in press*) as well as studies of polydipsia in rats using FI food schedules (Falk 1966*b*; Flory, 1971).

There have been two studies of changes in fighting or hose biting related to changes in intershock interval. In the first, Ulrich and Azrin (1962) used brief foot shocks to paired rats and varied the intershock interval from 1.6 to 600 sec. The percentage of shocks that induced the assumption of a fighting posture decreased as the intershock interval increased.

Unlike the present study (see Figure 3) and previous studies in which increasing interfood intervals produced increases or increases and then decreases in induced behavior, instances of assuming a fighting posture did not increase with increasing intershock intervals. Perhaps this difference occurred because Ulrich and Azrin (1962) recorded only the presence or absence of fighting in each interval in contrast with the continuously variable dependent measures, such as rate, used in the other experiments discussed. In the present study, a measure roughly comparable to that used by Ulrich and Azrin (1962) was the percentage of intervals containing at least one hose bite. As two of the monkeys bit during almost every interval at all parameter values, this measure was less sensitive than rate of hose biting or number of hose bites per food or per shock presentation. In the second study, Hutchinson *et al.* (1971) studied hose biting in squirrel monkeys with intershock intervals ranging from 15 to 240 sec. As the intershock interval was increased, the number of hose bites per interval increased. As 240 sec is in the range of FI parameter values where maximal rates of hose biting were recorded in the present experiment, perhaps intershock intervals of longer than 240 sec would have decreased hose biting in the study by Hutchinson *et al.* (1971), as they did in the present study.

Whether lever pressing was maintained by shock or by food presentation, overall rates of lever pressing decreased with increases in FI duration from 6 to 600 sec. These results agree with the findings in previous experiments in which FI durations was varied in food schedules (Ferster and Skinner, 1957; Skinner, 1938; Wilson, 1954) and shock schedules (McKearney, 1969). Further, the present experiment extends the parameter range under which lever pressing can be maintained at high rates by electric shock to FI durations as short as 6 sec. The difference in the form of the functions for lever pressing and for hose biting as the FI parameter was varied makes it seem unlikely that response-dependent lever pressing under FI schedules of electric-shock presentation is a variation of schedule-induced behavior.

At appropriate doses, *d*-amphetamine increased overall rates of operant lever pressing, but only decreased the rates of induced hose biting. It has previously been found that *d*-am-

Fig. 6. Effect of timeout duration on hose biting under FI 180-sec schedules of electric-shock presentation. Recording as in Figure 1, except that records of the lever pressing have been omitted. Records for S-628 are from different experimental sessions; records for S-627 are from the same session.

phetamine had similar effects on lever pressing maintained by FI schedules of food or of shock (Kelleher and Morse, 1964; McKearney, 1972), and the present results support these findings. That the drug affected hose biting induced under food schedules in a way similar to its effects on hose biting induced under shock schedules is further evidence of the functional similarity of hose biting induced by food schedules and by shock schedules. However, the ef-

fects of *d*-amphetamine on lever pressing and hose biting were different, as has been found in other studies comparing the effects of amphetamines on operant responses with effects on schedule-induced polydipsia (Byrd, 1973; Falk, 1964; Segal, Oden, and Deadwyler, 1965; Segal and Deadwyler, 1964; Segal and Oden, 1968; Wuttke and Innis, 1972). One possible reason for the different effects of *d*-amphetamine on lever pressing and on hose biting may

relate to the topography of the two responses. The importance of topography could be evaluated by arranging hose biting on an FI schedule and redetermining the effects of *d*-amphetamine. Such experiments have not been done with hose biting, but similar experiments have been carried out with drinking. Teitelbaum and Derks (1958) studied rats that postponed electric shock by drinking, and Wuttke (1970) studied squirrel monkeys under schedules in which drinking resulted in food delivery; under both circumstances, amphetamine markedly increased drinking. Thus, the lack of increase in schedule-induced drinking does not appear to be due to the nature of drinking as a response. Whether these findings would also extend to biting has yet to be determined.

Hose biting started immediately after food or shock presentation when no timeout period followed these events. When a timeout period did occur after each food or shock presentation, before the onset of the next FI cycle, little or no hose biting occurred just after food or after shock. Instead, hose biting began at the start of FI cycles. The alteration in the time between food or shock presentation and the start of hose biting by introducing a timeout period indicated that hose biting was not caused by presentation of shock or withdrawal of food, as has been claimed (Hutchinson, 1971). Rather, the present results support Falk's (1971) contention that behavior induced under schedules of food presentation (in this case, hose biting) is not elicited, and extends this conclusion to hose biting induced under response-dependent schedules of electric-shock presentation as well.

Because a fighting response followed shock without prior conditioning, Ulrich and Azrin (1962) considered the fighting to be elicited as an unconditioned reflex. Behaviors induced following food presentation, however, have usually not been thought to be reflexive (Falk, 1969; 1971; Flory, 1969*b*). If similar behaviors induced by schedules of food and of shock presentation have different properties, then different changes in the frequency of these behaviors might be expected from varying inter-shock time and interfood time. In the present experiment, however, changes in FI parameter value, doses of *d*-amphetamine, and changes in timeout duration had effects on hose biting induced under schedules of food presentation that were similar to their effects on hose biting

induced under schedules of shock presentation. Hose biting did not appear to be reflexive or to bear any special relation to noxious stimuli. The finding that hose biting under FI schedules of either food or electric shock was schedule induced suggests a possible relation between shock-elicited behavior and schedule-induced or adjunctive (Falk, 1971) behavior.

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