Negative correlation between tone (S-) and water increases target biting during S- in rats

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Eighteen Long-Evans rats were exposed to a MULT VT 30-sec EXT schedule of water presentations. The EXT schedule was signaled by a 2500-Hz, 70-dB tone. Mean number of bites of a plastic target during a tone (S-) increased across sessions, whereas the mean number of target bites during the VT component signaled by no tone (S+) decreased across sessions. Changing the multiple schedule to MULT EXT EXT produced a decrease in target bites during the tone. Reinstating the original MULT VT 30-sec EXT schedule produced an increase in number of target bites during the tone (S-). Changing the multiple schedule to VT 30-sec VT 30-sec produced a decrease in target bites during the tone. The results indicate that target biting in rats increases in the presence of the exteroceptive tone (S-) of the MULT VT 30-sec EXT schedule, and that target biting during the tone varies directly with the negative correlation between tone and water presentations.

The presentation of an exteroceptive stimulus correlated with an extinction schedule of positive reinforcement produces an increase in aggressive behaviors in pigeons (Azrin, Hutchinson, & Hake, 1966). Other investigators employing multiple schedules and pigeons as subjects have also reported that alternating signaled periods of positive reinforcement with signaled periods of extinction produces an increase in aggressive behaviors in the presence of the exteroceptive stimulus (i.e., S-) correlated with the extinction schedule. Aggressive behaviors reported in pigeons during the extinction component of multiple schedules include attack of restrained conspecifics (Azrin et al., 1966; Knutson, 1970; Rilling & Caplan, 1973, 1975) and attack of mirror targets (Moore & Thompson, 1978; Moore, Tychsen, & Thompson, 1976).

The amount of aggressive behaviors observed in the presence of the S- stimulus correlated with extinction is often reported to be directly related to the amount of reinforcement available during S+. For example, Azrin et al. (1966) reported that the rate of attack in extinction is directly related to the duration of access to food during the component prior to extinction. Similarly, Rilling and Caplan (1975) reported that amount of attack of a restrained conspecific in the presence of an extinction stimulus (S-) is determined by the schedule in effect during S+. More attack was observed when the pigeon's keypeck responses were reinforced either on an FR 1 or a VI 30-sec schedule during S+ than when a VI 5-min schedule was used. Thus, it appears that an exteroceptive S- increases aggressive behaviors in pigeons to the degree that S- is negatively correlated with the positive reinforcer.

Such effects have also been reported in humans. Investigators employing multiple schedules of positive rein-

forcement have reported an increase in punching behavior in young children when an exteroceptive stimulus correlated with extinction is presented (Peterson, 1971; Todd, Morris, & Fenza, 1989; see also Gentry, 1970; for a review, see Frederiksen & Peterson, 1977). Similar effects have been reported in college students (see Harrell, 1973; Kelly & Hake, 1970; Nation & Cooney, 1982).

An increase in aggressive behaviors during S- has also been reported by investigators employing multiple schedules of positive reinforcement that do not provide for an extinction schedule during one of the components. For example, pigeons exhibit aggressive behaviors during the component of multiple FR FR schedules with the higher ratio requirement (Ator, 1980; Cohen & Looney, 1973; Cole & Litchfield, 1969; Looney & Cohen, 1974; Looney, Cohen, & Yoburn, 1976; see also Webbe, DeWeese, & Malagodi, 1974). Pigeons exhibit aggressive behaviors during the component of multiple FI FI schedules with the longer interval (Flory & Ellis, 1973; see also Dove, 1976, and Flory, Smith, & Ellis, 1977). Thus, in studies employing multiple schedules of intermittent positive reinforcement, the exteroceptive stimulus correlated with the component of the multiple schedule providing for less positive reinforcement (i.e., S-) is often associated with an increase in aggressive behavior in pigeons.

While the increase in aggression associated with an exteroceptive S- signaling either extinction or a reduction in the probability of positive reinforcement has been extensively documented in studies employing pigeons and humans, there is only one published study evaluating the effects of multiple schedules on aggressive behaviors in rats. Hutchinson and Renfrew (1978) have investigated the effects of a multiple CRF EXT schedule on the aggressive behavior of rats. They reported that S- was associated with a *decrease* rather than an increase in the rate of biting a small rubber hose. In their study, the posi-

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tive reinforcer was electrical brain stimulation, and the frequency of biting was observed to increase when the positive reinforcing stimulus was terminated. There are no other published reports of the effects of an exteroceptive S— signaling the absence of positive reinforcement on aggressive behaviors in rats.

Although there are no reports of an increase in aggression related to the introduction of an exteroceptive S— in studies employing rats, there are numerous reports from studies not employing exteroceptive extinction cues suggesting that aggression in rats increases when conditions providing for positive reinforcement are followed by extinction (Davis & Donenfeld, 1967; Gallup, 1965; Thompson & Bloom, 1966). There are, moreover, a number of reports of aggression induced in rats by intermittent schedules of positive reinforcement. In these studies, aggressive behaviors are often reported to occur most frequently following presentation of the positive reinforcer (Gentry & Schaeffer, 1969; Huston & DeSisto, 1971; Knutson & Schrader, 1975; but see Hymowitz, 1971).

Thus, while conditions associated with reductions in the probability of positive reinforcement have been reported to increase the frequency of aggressive behaviors in rats, only one study has previously assessed control by an exteroceptive S— of aggressive behavior in rats (Hutchinson & Renfrew, 1978). While the results of that study are not in accord with those reported by investigators employing other species, the discrepancy may be due to the short-term behavioral effects produced by positively reinforcing electrical brain stimulation procedures (Trowill, Panksepp, & Gandelman, 1969).

The present experiment explores the effects of a tone (S—) signaling the absence of water presentations on the biting of a small plastic target by water-deprived rats. Target-biting behavior is readily produced in rats by the application of aversive stimulation (Azrin, Rubin, & Hutchinson, 1968; Hutchinson, 1973; Nabert et al., 1983; Wagner & Schimpf, 1985), and in rats and mice the effects of environmental (Nabert et al., 1983; Wagner & Schimpf, 1985), hormonal (Wagner, Beuving, & Hutchinson, 1979a, 1979b), and pharmacological variables (Carelli & Wagner, 1988; Wagner & Carelli, 1987) on target biting are similar to the effects of these variables in the intruder-evoked attack paradigm.

Biting of the target was recorded during the MULT VT 30-sec EXT schedule of water presentations employed during Phases 1 and 3. The effects of eliminating the negative correlation between tone S— and water presentations were evaluated by changing the schedule in effect to non-differential MULT EXT EXT during Phase 2 and to non-differential MULT VT 30-sec VT 30-sec during Phase 4.

METHOD

Subjects

Eighteen adult Long-Evans male rats were individually housed in suspended stainless steel cages and maintained on a 12-h light:dark cycle (lights on at 0700 h). Animals had free access to food (Purina Lab Chow) and were water deprived 22.75 h/day. The animals

were approximately 90 days old at the beginning of the study. Two subjects (1 and 3) died during the study. Up to the point that they were eliminated from the study, their data are included in the analyses. Missing data were assigned the value of the mean of the remaining subjects and 1 *df* was subtracted from the error term.

Apparatus

Experimental sessions were conducted in two operant chambers (27×19×26 cm) housed in a ventilated sound-attenuating enclosure. A bite target, consisting of a strip of Plexiglas (5 mm thick, 8 mm wide, 80 mm long) wrapped in vinyl tape, was located on the front wall, 7 cm above the floor and 9 cm to the right of the centerline. The bite target was attached to a Gerbrands Model 16082 switch. Bite targets were replaced whenever they were shredded by bite marks. A water dipper (which delivered 0.1 ml tap water) was located on the centerline, level to the floor of the operant chamber. The water dipper in the upright position was accessible to the subject. The dipper remained in the upright position between successive water presentations. A GE 1813 bulb (mounted 7 cm to the right of the centerline and 4 cm above the bite target) provided chamber illumination during the session. A 13-cm loudspeaker was mounted on the wall of the outer chamber, which was flush with the rear of the operant chamber. The loudspeaker provided a tone of 2500 Hz at an intensity of 70 dB.

Procedures

The rats were run a minimum of 5 days per week. On the remaining days, the rats were given 15-min access to water. The study consisted of four successive phases. There was no dipper training or habituation to the apparatus prior to the initiation of the experiment.

During the first phase, a MULT VT 30-sec EXT schedule was in effect. The duration of each component of the multiple schedule was 3 min. In the first 3-min period of each session, water was presented to the animal on the VT 30-sec schedule. In the second 3-min period of each session, a tone S— signaled extinction (i.e., no water presentations). These two conditions alternated during the 1-h session. Phase 1 continued for 55 sessions. Target bites were collected for each schedule component and cumulated over the entire session. Unsystematic observation of the subjects during the course of the experiment revealed that they were biting the target with a chewing motion of the mouth that necessitated frequent replacement of shredded targets. Rats received 15-min access to water in their home cages beginning 1 h after the session.

During the 19 sessions of Phase 2, a MULT EXT EXT schedule was in effect. The no-tone and tone stimulus conditions alternated as before; however, water was not presented during either component of the multiple schedule.

During Phase 3, the MULT VT 30-sec EXT schedule employed during Phase 1 was reinstated. Subjects 1–10 received 45 sessions during Phase 3; Subjects 11–18 received 28 sessions during Phase 3.

During the 15 sessions of Phase 4, a MULT VT 30-sec VT 30-sec schedule of water presentations was in effect. The no-tone and tone stimulus conditions alternated as before; however, water was presented during both the no-tone and tone conditions.

RESULTS

Fifty-five sessions of training were provided during Phase 1; however, following the 40th session no further increases in the mean number of target bites per session during tone (S—) were observed. The mean number of target bites during tone (S—) and no-tone (S+) for the first 40 sessions (in blocks of two sessions) of Phase 1 are presented in Figure 1. During the first block, the mean target bites during tone (S—) and no tone (S+) were com-

Figure 1. Mean target bites per session during tone (S-) and no tone (S+) as a function of blocks of 2 sessions during the first 40 sessions of Phase 1 (MULT VT 30-sec EXT schedule).

parable. Across blocks, target bites during tone (S-) increased reliably [one-way repeated measures analysis of variance (ANOVA), $F(19,323) = 2.06, p < .05$], whereas target bites during no tone (S+) decreased reliably [one-way repeated measures ANOVA, $F(19,323) = 2.16, p < .05$].

The mean number of target bites during tone (S-) and no tone (S+) for the last five sessions of each phase are presented in Figure 2. Rates of observed target biting were higher during the last five sessions of Phases 1 and 3 than during the last five sessions of Phases 2 and 4. A one-way repeated measures ANOVA on target bites during tone revealed a statistically reliable effect of phase [$F(3,48) = 3.67, p < .05$]. Fisher's LSD ($\alpha = .05$) revealed reliable differences between Phase 1 vs. Phase 2, Phase 1 vs. Phase 4, Phase 2 vs. Phase 3, and Phase 3 vs. Phase 4. On the other hand, during the last five sessions of Phases 1 and 3, the rates of target biting during no tone (S+)

Figure 2. Mean target bites per session during tone (S-) and no tone (S+) during the last five sessions of each phase. The vertical bar represents the standard error of the mean. The MULT VT EXT schedule was in effect during Phases 1 and 3, the MULT EXT EXT schedule was in effect during Phase 2, and the MULT VT VT schedule was in effect during Phase 4.

were comparable to those observed during the last five sessions of Phases 2 and 4. A one-way repeated measures ANOVA on target bites during no tone revealed no statistically reliable effect of phase [$F(3,48) < 1$].

DISCUSSION

The results reveal that across sessions of training with the MULT VT 30-sec EXT schedule, target biting in rats increased during the extinction component and decreased during the VT component. This produced a much higher rate of target biting during the tone S- that signaled extinction than during the no-tone S+ component that signaled the VT schedule of water presentations. The higher rate of target biting during the tone S- was eliminated when the negative differential contingency between the tone S- and water presentations was removed. This was done in Phase 2 by employing a MULT EXT EXT schedule and in Phase 4 by employing a MULT VT 30-sec VT 30-sec schedule. These results are consistent with the conclusion that target biting in the presence of the tone varies directly as a function of the negative correlation between the tone and water presentations.

These results are consistent with numerous demonstrations of increased aggression in the presence of S- in pigeons (Azrin et al., 1966; Knutson, 1970; Moore & Thompson, 1978; Moore, Tychsen, & Thompson, 1976; Rilling & Caplan, 1973, 1975), and provides the first report of such an effect in rats. While the increase in target-biting behavior in the presence of S- is consistent with previous reports of aggression related to extinction conditions in rats (Davis & Donenfeld, 1967; Gallup, 1965; Gentry & Schaeffer, 1969; Huston & DeSisto, 1971; Thompson & Bloom, 1966), previous studies have not signaled the extinction condition with an exteroceptive cue.

In the present study, extinction increased the frequency of the biting of an inanimate target; in previous studies reporting an increase in aggression by extinction conditions in rats, live targets had been employed. Attacks against live rats have been reported by investigators employing intermittent schedules of food (Davis & Donenfeld, 1967; Gallup 1965; Knutson & Schrader, 1975; Thompson & Bloom, 1966) or water (Gentry & Schaeffer, 1969) reinforcement, and frog killing was induced in rats by ratio schedules of electrical brain stimulation (Huston & DeSisto, 1971).

Substantial variability between subjects in rates of target biting was observed in the present study. This observation is consistent with previous reports of large between-subject differences in the induction of aggression by schedules of positive reinforcement (Azrin et al., 1966; Cohen & Looney, 1973; Flory et al., 1977; Gentry & Schaeffer, 1969; Knutson, 1970; Knutson & Kleinknecht, 1970; Looney & Cohen, 1974).

While target biting during tone increased during Phases 1 and 3 (i.e., when the MULT VT 30-sec EXT schedule was in effect), these increases are not necessarily wholly attributable to the negative correlation between tone and water in effect at those times. Some investigators have

suggested that schedule-induced aggression may be related to the interreinforcement interval by an inverted U-shaped function (Looney & Cohen, 1982). According to this view, the overall rate of reinforcement during Phases 1 and 3 (1/min) may be more conducive to the expression of aggressive behavior than was the overall rate of reinforcement in effect during either Phase 2 (0/min) or Phase 4 (2/min).

The data provide two arguments against an interpretation based solely on the effects of the interreinforcement interval. First, when the MULT VT 30-sec EXT schedules were employed during Phases 1 and 3, the frequency of target bites during no tone and tone were dramatically different, suggesting that target biting was under the control of the exteroceptive stimulus. Second, target biting during no tone did not systematically vary as a function of the overall rate of reinforcement, but rather remained at a stable and low level during all phases of the study. Therefore, it seems unlikely that the increases in target biting that were observed to occur only during the tone component in Phases 1 and 3 could be solely attributed to changes in the overall rate of reinforcement.

Intermittent schedules of positive reinforcement induce a variety of behaviors, most notably excessive fluid consumption, or polydipsia (Christian, Schaeffer, & King, 1977; Falk, 1961). A number of investigators (Lashley & Rosellini, 1980; Millenson, Allen, & Pinker, 1977; Minor, 1987; Minor & Coulter, 1982; Staddon, 1977) have proposed that schedule-induced behaviors may be particularly likely to be displayed in the presence of stimuli, including exteroceptive cues, associated with a reduction in the probability of reinforcement. While a number of investigators have reported evidence of schedule-induced drinking during the S- component of multiple schedules employing food reinforcers (Dougan, McSweeney, & Farmer, 1985; Keehn & Colotla, 1971; Minor, 1987; Minor & Coulter, 1982), other investigators have failed to obtain evidence of such an effect (cf. Hamm, Porter, & Kaempff, 1981; Jacquet, 1972; for reviews see Lashley & Rosellini, 1987; Minor, 1987; Porter & Hamm, 1984).

The results of the present study suggest that the increase in target biting associated with an exteroceptive S- is more robust and long-lived than is the increase in drinking associated with an exteroceptive S-. The conditions under which S- contributes to the expression of target biting, as well as other schedule-induced behaviors, warrant further study.

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