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Facilitation of licking by response-contingent electric shock*

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Licking behavior of rats maintained by lick-contingent water reinforcement produced electric shocks under three conditions. Shock occurred 1 sec before, simultaneous with, or 1 sec after water reinforcement. Rates of licking rose above prepunished levels at .2-, .4-, and .6-mA intensities but were suppressed at .8 mA for all three groups. Facilitation and suppression effects were the same for the three pairing conditions. Discriminative and elicited functions of shock did not appear to account for this facilitative effect.

Descriptions of facilitative effects of contingent aversive stimuli on appetitively motivated behavior have emphasized three factors. The first has been the discriminative (Azrin & Holz, 1966) or cue (Fowler, 1971) properties of contingent aversive stimuli. Levels of shock capable of maintaining escape and avoidance responding have been shown to result in facilitation of operant responding when shock reliably signals the occurrence of positive reinforcement (Murray & Nevin, 1967; Williams & Barry, 1966). The second factor has been the response-eliciting properties of contingent aversive stimuli (Fowler, 1971). When the response made to shock is compatible with the response being positively reinforced, facilitation of responding has been observed (Fowler & Miller, 1963). The third factor has been shown to be the schedule of shock presentation. Kelleher and Morse (1968) have demonstrated that infrequent periodic (FI 10-min) contingent shock superimposed on a VI 2-min schedule of food presentation will facilitate behavior relative to no-shock baseline. When food was removed, responding was shown to be maintained by shock alone. Frequent presentation (FR 1) of shock resulted in the usual suppression effects. Kelleher and Morse (1968, p. 837) theorize that "conditions that minimize suppression would be favorable for developing responding enhanced by shock."

The present experiment was conducted to determine whether two conditions which minimize suppression would facilitate licking maintained by single-drop water reinforcement. The first condition was a history of gradual introduction of shock intensity. Several reports have indicated that gradual increases in shock intensities attenuate the suppressive effects of contingent shock (Hake, Azrin, & Oxford, 1967; Miller, 1960). The second condition was the close temporal pairing of shock and reinforcement. While a number of experiments have demonstrated the importance of forward pairings of shock and reinforcement (Murray & Nevin, 1967; Williams & Barry, 1966), little is known about the effects of simultaneous and backward pairings of shock and reinforcement. The original notion was that forward, and perhaps simultaneous, pairings of shock and reinforcement would result in greater facilitation effects compared to backward pairings. The lick response and single-drop water reinforcement were chosen because more precise arrangements between shock and reinforcement could be made than for conventionally studied operants.

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METHOD

Subjects

Ss were 15 experimentally naive male albino rats, approximately 120 days old. They were deprived of water and maintained at about 80% of their free-feeding weights.

Apparatus

Three identical Skinner boxes, measuring 23 x 23 x 20 cm, were enclosed in sound-attenuating chambers. A Plexiglas tube was located 4 cm above the floor and positioned 1/8 in. behind a Plexiglas guard. The Plexiglas guard had a .5 x 1.5 cm slot cut into it through which the rat inserted his tongue to lick the drinking tube. Reinforcement consisted of .007 cc of water delivered to the rat's tongue by means of a syringe pump similar to that described by Hulse (1960). This made it possible to reinforce a single lick with a single drop of water.

Shock was administered by a Grason-Stadler (Model 700) constant-current generator and grid scrambler to 18 2-mm-diam grids, spaced 1.5 cm apart, edge to edge. The contact relay was removed completely from the grids and drinking tube during shock. This circuit enabled shock to be delivered through the grid floor and not to the rat's tongue.

Blowers attached to each cubicle and a 70-dB (re 0.0002-μ bar) white noise from an overhead speaker served as masking noise. A 6-W ac bulb located above the rear of the Skinner boxes was used as a houselight. Relay programming equipment was located in an adjacent room.

Procedure

The Ss were trained to make a lick response for a single-drop water reinforcement on a VI 30-sec schedule of reinforcement. Each S was run for 45 min each day for 17 days until a baseline of stable responding was established. The last 4 days of baseline training showed no significant variation [$F(3,42) = 1.42$, $p > .05$] across days and, thus, served as a baseline measure.

The Ss were then divided into three experimental groups. One group (Sc + Reinf) received shock simultaneously with each reinforcement. A second group (Sc – Reinf) received contingent shock 1 sec prior to reinforcement availability, and a third group

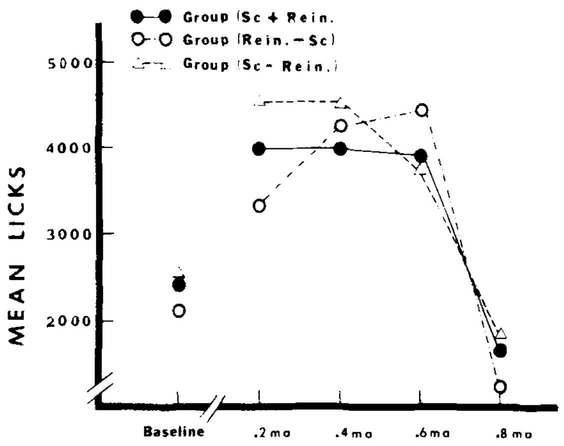

Fig. 1. Mean number of licks across the last two 45-min sessions at each intensity.

(Reinf – Sc) received contingent shock 1 sec following collection of reinforcement. Ss received 4 days of each of four levels of shock, .2, .4, .6, and .8 mA, respectively. Shock was of .1-sec duration throughout all phases.

RESULTS

Shock produced a twofold increase in the number of licks throughout the first three shock intensities. Figure 1 shows the increase in the mean number of licks across the last two sessions at each intensity. Figure 1 indicates that shock produced reliable changes across intensities [$F(4,48) = 14.75$, $p < .01$]. Licking, however, was not influenced by the temporal relations between shock and reinforcement ($F < 1$), nor was there any interaction between shock intensity and the different treatment conditions ($F < 1$).

Post hoc comparisons of the effect of the different shock intensities were made with a Newman-Keuls procedure. The first three intensities, .2, .4, and .6 mA, resulted in a significant increase above baseline ($p < .01$), while .8 mA resulted in a significant reduction of responding below the baseline ($p < .01$).

DISCUSSION

The data indicate a facilitative effect of lick-contingent shock at intensities which have been shown to result in severe response suppression when introduced suddenly (Bertsch, 1972). Intensities of .4 and .5 mA (.1 sec) completely suppressed licking behavior in the previous study. Other studies have indicated that prolonged exposure in a graduated series of intensities greatly attenuates suppressive effects of shock (Hake et al, 1967; Miller, 1960). Few studies, however, have shown an above baseline increase of responding as found in the present study. Increases in responding are most often found in situations where an aversive stimulus serves as a discriminative stimulus for the occurrence of positive reinforcement (Murray & Nevin, 1967; Williams & Barry, 1966). The absence of differences between the temporal pairing conditions would suggest that this is not the case in the present study. An explanation of the results in terms of elicited effects of shock on licking shares a similar fate. Observations of the rats in this study, as well as those of previous studies using the lick response (Bertsch, 1972), support the notion that shock tends to momentarily disrupt rather than elicit further licking.

A plausible explanation of the facilitative effect might be derived from the work on schedules of shock presentation. Kelleher and Morse (1968, p. 837) suggest that the effectiveness of shock depends as much on "favorable temporal relations between behavior and an effective consequence" as on "the quantitative properties of the preceding behavior." The unique aspects of licking, a high-rate behavior, may have combined with a history of gradually introduced shock to generate facilitated performances. Sudden introduction of moderate levels of shock result in very different effects on licking (Bertsch, 1972, Experiment I). As yet, there are no reports demonstrating schedule-induced facilitation by shock in the rat that would permit comparisons with the present data. Kelleher and Morse (1968, Experiment III) found that decreases in shock intensity led to decreases in response rates and that the highest intensity shocks led to the greatest facilitation of responding. In the present study, increases in intensity of shock to .8 mA resulted in suppression of licking. The apparent differences in functional relationships between shock intensity and facilitation effects may simply reflect species differences or, more importantly, differences in the experimental history of the Ss in the two studies.

The present study does not permit assessment of effects of intensity independent of the manner of introduction of shock. In other words, the effect of each intensity in producing facilitation may well depend on the order of introduction of different intensities. Further, the present design does not demonstrate an effect of each intensity in a manner which would be possible in a between-groups design or in a within-Ss design, where each intensity is preceded by a baseline without shock. More work will be needed to determine whether the facilitative effects of contingent shock depend more on intensity, order of introduction of intensities, or he joint effect of both variables.

Another possible explanation of facilitation effects on licking is the response type selected for study, nonarbitrary species-specific behavior. Mild contingent shock has been shown to produce facilitative effects when contingent on sexual behavior in rats (Beach, Conovitz, Steinberg, & Goldstein, 1956), mirror display in fighting fish (Melvin & Ervey, 1973), and licking in rats (Martin & Ross, 1964). Strong shock, on the other hand, results in rapid and durable response suppression of these behaviors (Beach et al, 1956; Melvin & Ervey, 1973; Bertsch, 1972).

A related interpretation would be that mild shock produces an arousal of the drive level and, thus, an enhancement of ongoing behavior (Martin & Ross, 1964). The argument is supported by the finding that noncontingent shock facilitates sexual (Barfield & Sacks, 1968) and eating behaviors (Ullman, 1951). The magnitudes of the noncontingent facilitation effects found in these studies, however, do not appear to be as large as the twofold increase in the present study. The fact that the magnitude of shock effects on licking changed with shock intensity argues for the importance of the contingency used in the present study. Comparisons of contingent and noncontingent shock have much greater effects when contingent on responding (Camp, Raymond, & Church, 1967; Rachlin & Herrnstein, 1969). The suppression observed at .8 mA further supports this argument, since durations and intensities much higher than that fail to produce suppression when delivered independent of behavior (Camp et al, 1967).[1]

The present study demonstrates a very strong facilitative effect of contingent shock. Whether the results would be best viewed as a type of schedule-controlled facilitation or an interaction between response type and schedule of shock presentation is not yet clear. What is most important, however, is the finding that the outcome of a contingent shock procedure may be either facilitation or suppression, depending upon the intensity and manner of shock introduction.

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NOTE

1. An argument might be advanced that lower intensities of shock used in the experiment would not be sufficient to maintain escape or avoidance behavior. Two rats from this study were used in a pilot study of Sidman avoidance schedules. Intensities of .4 mA and .6 mA (.1-sec duration) were found to be adequate to maintain avoidance responding.

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