Effects of percentage of reinforcement in fear conditioning upon the acquisition of an instrumental response¹

M. J. HOMZIE, *University of Virginia, Charlottesville, Va. 22901*, DAVID W. SHUCARD, and RONALD C. TROST, *University of Denver, Denver, Colo. 80210*

Two experiments with rats were conducted to investigate the effects of partial reinforcement of the CER upon the subsequent acquisition of an instrumental response. In the first experiment, there were no reliable differences, whereas Experiment 2 indicated superior instrumental performance for Ss that had received partial reinforcement during the initial fear-conditioning phase. The heart-rate measures in Experiment 2 were unrelated to the schedule of reinforcement and indicated that the heart rate CR is decelerative.

Although many parameters in fear conditioning have been investigated extensively, partial reinforcement (PR) in the training of the classically conditioned fear response has not been studied, but for a few exceptions (e.g., Armus, 1960; Imada, 1963; Wagner, Siegel, & Fein, 1967). The purpose of the present research was to investigate the effects of PR upon the acquisition of an instrumental response motivated by conditioned fear. The first experiment reports an attempt to study this effect in hurdle box responding. The second experiment simultaneously investigated two response measures, heart rate and latency of instrumental responding, in order to permit a more sensitive analysis of the effects of PR in the acquired fear paradigm.

EXPERIMENT 1

Method

The Ss were 72 experimentally naive male albino rats of the Wistar strain. At the start of the experiment, the animals ranged in age from 60 to 90 days old. The apparatus consisted primarily of a two-compartment hurdle box, 12½ x 7 x 6 in. The nonshock section was painted silver with a wire mesh floor; the shock compartment was flat black with a grid floor. Separating the two sides of the apparatus was a guillotine door. The UCS, a 60-V dc shock of 4 sec duration, was administered directly to the grid floor of the shock compartment through a Lafayette

scrambler. The CS was the 10-sec onset of a 110-V ac light and buzzer.

Three schedules of reinforcement (100%, 50%, and 100% trials control) were employed. The 100% group received four shock conditioning (reinforced) trials per day, whereas the 50% group was administered two shock and two nonreinforced trials. The 100% trials control group received only two conditioning trials per day to equate its number of shock trials with that of the 50% group. The study was comprised of two phases, 3 days of the initial fear training and the subsequent acquisition of the instrumental behavior. Fear training trials consisted of placing the animal into the shock compartment; 15 sec later, the CS came on and terminated with the UCS offset, the CS and UCS overlapping the last 4 sec of the CS duration. Nonreinforced trials merely omitted the UCS. The average intertrial interval was 4 min.

One day after the procedure for the fear training was completed, acquisition of the hurdle response began. Each animal was placed into the shock compartment of the hurdle box; after a period of 15 sec, the CS came on and the guillotine door was raised.

Upon the rat's jumping over the 2-in. hurdle separating the two compartments, his weight on the floor of the nonshock compartment depressed a microswitch which terminated the CS and shut off the Hunter Klockcounter timing S's latency. If the animal failed to jump within 15 sec after the CS onset, he was prodded across the hurdle and a latency of 15 sec was recorded. The rat was allowed to remain in the nonshock section of the apparatus for 20 to 30 sec. At no time during this phase of the experiment did the animals receive the UCS. All Ss received four hurdle acquisition trials per day for a period of 11 consecutive days.

Results

Figure 1 reveals that the percentage of reinforcement during fear conditioning did not have an effect over the initial 12 trials of acquisition, but thereafter the performance curves diverge, with the 50% group the best and the 100% trials control group the worst. An analysis of variance was performed on each S's median latency over the final 24 trials of hurdle-box training. In spite of the apparent differences depicted in Fig. 1, there was no significant groups effect.

EXPERIMENT 2

Even though the results of the first experiment failed to reach statistical significance, certain factors seemed worthy of further consideration. First, after reaching an acquisition peak (Trials 9-12), the latency curves indicated poorer performance with further training trials (cf. Fig. 1). This decrement in performance with further hurdle-box training suggests

Fig. 1. Hurdle jumping for the various groups as a function of successive blocks of acquisition trials.

that the animals were to some degree undergoing experimental extinction. That is, on each and every occasion that S failed to complete the instrumental response within 6 sec after the CS onset (the CS-UCS interval during fear conditioning) constituted an extinction trial of the emotional response to the CS. In order to ascertain whether fear extinction training per se would augment the trend late in training for the partially reinforced animals to perform better than the comparable continuously reinforced Ss, Experiment 1 was partially replicated with the addition of an experimental extinction procedure. Secondly, there is the question of the sensitivity of the dependent measure used in Experiment 1. In order to have another index of the effects of the schedule of reinforcement upon the strength of the conditioned fear response, the animal's heart rates were monitored prior to, during, and after the instrumental responding. To minimize movement artifacts, the hurdle was removed from between the two compartments such that S could shuttle across the apparatus. In addition, Ss were tested under a condition in which they could not cross the shuttlebox. This permitted a comparison of the heart rate of animals that could escape from the shock compartment and terminate the CS with those that could not.

Method

The animals were 56 experimentally naive male Wistar rats obtained from the University of Denver colony. They were 3 to 4 months old at the start of the experiment and weighed between 300 and 400 g.

The conditioning apparatus, essentially the same as that used in Experiment 1, consisted of a shuttlebox, each compartment being 12½ in. long, 7 in. wide, and 6 in. high. A sliding door separated the two compartments; both compartments had grid floors. The floor of the nonshock side was hinged and connected with a microswitch and Standard electric timer in such a manner as to provide a measure of the animal's latency in crossing from the shock to nonshock compartment. The shock compartment was painted black and the nonshock side silver. The UCS consisted of a grid shock (60 V dc) applied through a Lafayette scrambler. A 110-V ac 15-W light bulb and a standard 110-V door buzzer mounted on the sides of the shock compartment provided the CS. A Grass polygraph was used to record EKG. The heart rate was recorded from three stainless steel wires inserted into the animals' backs just above the front legs, in the mid-dorsal region, and above the rear legs by a method similar to that described by Stern & Word (1961). Alligator clips were used to connect these leads to the polygraph.

One week prior to the start of the experiment, all Ss were anesthetized and implanted with the electrode leads. The experiment consisted of an initial fear-conditioning phase followed by massed extinction of the fear response. Thereafter, one-half of the animals continued on an extinction procedure, and the remaining Ss learned a shuttlebox response motivated by the conditioned fear.

Prior to the start of the fear-conditioning phase, Ss were randomly assigned to one of three groups: a 100% reinforcement group (N = 24), a 50% reinforcement group (N = 24), and a control (N = 8). All groups received two trials a day for 6 days. The 100% group received two shock-conditioning trials per day. The first trial each day was nonreinforced for the 50% group. The control group was also given two shocks a day; these occurred in a separate apparatus structured to be as different from the shuttlebox as possible, e.g., not painted, smaller in size. In addition, this group received two CS presentations per day in the shuttle apparatus. The CS and the UCS presentations for the controls were separated by approximately 3 h, with the CS being presented in a nonsystematic order, sometimes prior to the UCS presentations and other times after.

At the start of each animal's experimental session, S was placed into the shock compartment and the EKG leads were attached. Thirty seconds to 1 min were allowed to elapse before the initiation of a trial. On conditioning trials, the CS was turned on and remained on for 7 sec, during the last 3 sec of which the UCS was applied and terminated with the CS offset. The animals were not allowed to escape from the electric shock. Nonreinforced trials consisted merely of the CS presentation. A 30-sec to 60-sec interval was maintained between all trials.

One day after completion of the fear conditioning, the massed extinction procedure was begun. During this phase of the experiment, Ss were treated in an identical manner as in the fear-conditioning phase except that the UCS was not administered, and the CS remained on for 15 sec. All Ss received four such trials with 30 sec to 1 min intervening between trials. Heart rate was recorded during this phase for all Ss.

The following day, all three groups, viz, 100%, 50%, and control, were divided randomly into heart rate (HR) and heart rate-shuttle (HR-S) Ss. Those Ss that were delineated as HR were treated the same as during massed extinction training, except that the CS duration was shortened to 7 sec (i.e., the duration of the CS during the initial fear-conditioning phase). Those Ss assigned to the HR-S groups were placed into the

shock side of the apparatus. After a 30-sec to 1-min delay, the CS was initiated by opening the sliding door separating the two compartments. This immediately activated a microswitch which started both the CS and a Standard electric timer. The animal's movement into the other compartment depressed a microswitch which terminated the CS and the timer measuring S's latency. If S did not shuttle across to the other side within 7 sec, the animal was prodded into the other compartment and a latency of 7.00 sec was recorded for that trial. At no time was the UCS administered. Once on the other side of the shuttlebox, S was allowed to remain there for approximately 30 sec, after which time the animal was again placed into the shock compartment. After another 30-sec to 1-min delay, the next shuttlebox acquisition trial was begun.

All Ss received their appropriate four trials (i.e., fear extinction or shuttlebox acquisition training) per day for 7 days. Throughout this phase, heart rate was recorded during each trial for both procedures. A total of 28 Ss were run per day. That is, half of the animals were tested from each experimental condition on alternate days.

As mentioned above, heart rate was monitored for the HR-S and HR groups. The 30-sec to 1-min interval maintained between trials was the consequent of allowing each animal's heart rate to return to its normal baseline before the initiation of another trial. The R waves of the EKG were counted over four separate intervals resulting in three indices of the heart-rate response. These intervals were: (1) the 3 sec prior to the onset of the CS, (2) the 2nd through the 4th second of the CS duration, (3) the 5th through the 7th second of the CS duration, and (4) the 4th through the 6th second after the CS offset. The heart rates for the second, third, and fourth intervals were subtracted from the pre-CS measure, resulting in (a) an anticipatory CR measure, (b) a UCR measure—an index of the change in heart rate during the interval the UCS had been presented during the classical conditioning phase, and (c) a post-CS measure.

Results

As can be seen in Fig. 2, all the groups started at about the same performance level, with the 50% HR-S group showing the greatest improvement by the end of training. During the initial 12 trials, the 100% HR-S group's performance was comparable to that of Group 50% HR-S, but shows no further improvement with additional training. As for the HR-S control group, there was no shortening of response latency as a function of shuttlebox experience, indicating no learning of the instrumental response. An analysis of each animal's mean latency in the experimental groups over the entire 28

Fig. 2. Shuttlebox performance for the various groups as a function of successive blocks of acquisition trials.

shuttlebox acquisition trials indicated that the HR-S 50% group's performance was statistically superior to that of Group HR-S 100% (Mann-Whitney $U = 30$, $p < .02$, two-tailed).

For the HR groups, an analysis of variance indicated no significant effects for the 100% vs 50% reinforcement comparisons in terms of mean heart-rate change for the anticipatory measure, UCS measure, and post-CS measure for neither the first nor second phases of the massed extinction training. As compared to the control Ss, however, the experimental animals showed deceleration of their individual heart rates during the CS duration. Such changes in responding have been taken as evidence for heart-rate conditioning (e.g., Fitzgerald, Vardaris, & Brown, 1966). Turning to the heart-rate measures for the animals that engaged in shuttlebox training, the results were essentially the same; once again there were no significant effects in terms of the 100% vs 50% reinforcement comparisons.

Because of movement artifacts, only the post-CS measure permits the comparison of the heart rates of animals that could terminate the CS with those that could not. A 2 by 2 by 7 analysis of variance, performed on each animal's mean heart rate change (in the 50% and 100% groups) per day over the final 7 days of testing, resulted in a significant effect of testing situation [$F(1,40) = 20.03$, $p < .001$] and a significant days effect [$F(6,240) = 3.78$, $p < .001$]. That is, as indexed by the post-CS measure, Ss that could shuttle across the apparatus showed an increment (mean change = 45.9 bpm) in their heart

rates. The HR animals, however, only showed a slight increase (mean change = 8.7 bpm) after the termination of the CS. The heart rate change remained relatively constant for the HR Ss, but increased with further shuttlebox training for the HR-S animals. The Testing Situation by Days interaction, however, was not statistically significant [$F(6,240) = 1.59$].

SUMMARY OF RESULTS

Heart Rate

Experiment 2 indicates that the classically conditioned heart rate is decelerative, and that there is no differential effect of the reinforcement schedule upon the various heart-rate measures. Fitzgerald, Vardaris, & Brown (1966) conditioned the heart rates of three separate groups of rats with a 0%, 50%, or 100% schedule of reinforcement, and also report that: (a) the CR is decelerative (using a pre-CS-minus-the-CS measure), and (b) there is no difference in performance between the 50% and 100% reinforcement conditions.

Turning to the post-CS measure, these results indicate an increment in the heart rate for those animals permitted to perform an instrumental response which led to the immediate cessation of the CS. Stern & Word (1962) ran a somewhat comparable experiment (without the initial classical conditioning phase), in which the animals' response of crossing a barrier terminated the CS and resulted in the avoidance of or escape from an aversive UCS. Their results also indicate an increase in the heart rate following the performance of a response which terminates the CS. Such findings can be interpreted as the result of changes produced indirectly by skeletal movements (cf. Smith, 1954). In the present study, the HR animals (no instrumental responding) showed less of a heart-rate increment following the cessation of the CS than did the HR-S Ss. In a like manner, Stern & Word (1962) report a greater increment in heart rate following an instrumental escape response than an avoidance response. Presumably, escape would involve a more dynamic skeletal change than would an avoidance movement.

Instrumental Behavior

The results of Experiments 1 and 2 are somewhat conflicting. The latter of the two experiments indicated a statistically reliable partial reinforcement effect. That is, in Experiment 2, the acquisition of the instrumental response was superior for those

animals that had received partial reinforcement during the initial classical conditioning phase. Other investigators who have manipulated the schedule of reinforcement in fear conditioning have found no partial reinforcement effect using the startle response (e.g., Armus, 1960), drinking behavior (Imada, 1963) and response suppression (e.g., Wagner, Siegel, & Fein, 1967) as indicants of the effects of the initial fear conditioning. The results of Wagner et al (1967) suggest that the partial reinforcement effect can be obtained when the initial fear conditioning is not separated from the indicant response situation. In the present research, the fear conditioning and subsequent instrumental behavior took place in the same environment. This factor, plus the effect of the interpolated massed extinction trials, seems worthy of further research. Finally, it is interesting to note that the shuttle response and the heart-rate measures in Experiment 2, both supposedly indicants of the animals' fear, were differentially related to the initial schedule of reinforcement. Indeed, for the HR-S animals, the correlations between latency of responding and heart-rate measures were nonsignificant.

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NOTE

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