PARTIAL NEGATIVE REINFORCEMENT: FIXED-RATIO ESCAPE

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Rats were unable to sustain performance when eight bar-presses turned off shock (—FR 8). In a second experiment, thirsty rats were able to maintain a moderate response rate when performance on —FR 8 was also reinforced with water. Some rats continued to bar-press on —FR 8 after withdrawal of positive reinforcement, but at a much lower rate. A possible explanation of the results is that during intermittent escape conditioning in a free-responding situation the absence of shock itself acquires aversive properties.

It is widely assumed that behavioral laws based on positive reinforcement hold also in the case of negative reinforcement. However, attempts to verify this assumption have been made in only a few instances. In particular, a great deal is known about the effects of intermittent positive reinforcement, while very little is known about the effects of intermittent negative reinforcement. The purpose of the present experiments was to investigate the establishment and maintenance of behavior by intermittent (fixed-ratio) shock-reduction.

EXPERIMENT I

Subjects and Apparatus

Two male albino rats (Ss) about 120 days old at the beginning of the experiment were used. Some days before training began, one subcutaneous stainless steel electrode was implanted on each side of the rib cage. During the experiment electric shock was delivered between these electrodes and the floor and walls of the experimental chamber. The resistance of the rats was measured from time to time and found to vary between 10k and 50k ohms.

The aluminum experimental chamber was $10 \times 5\frac{1}{4} \times 19$ in. high, with an open top. Subjects could be observed through the top half of one wall, made of clear plastic. The floor was four aluminum alloy rods $\frac{5}{8}$ in. in diameter, mounted on $1\frac{1}{8}$ in. centers and

running the length of the chamber. A hard plastic bar protruded $\frac{1}{2}$ in. from one (narrow) wall at a height of $3\frac{1}{2}$ in. above the grid. A force of 20 g operated the bar.

The electric shock was taken through a 220k ohm series resistor from a voltage divider across the output of a mains transformer. Current was delivered to the rat through a wire slung from an overhead boom which kept it under slight tension. The current was pulsed—1.25 sec on, 0.5 sec off.

Procedure

Each S was run for sessions lasting 6 to 8 hr, with successive sessions separated by at least a day. A 200 v shock and associated apparatus noise could be turned off for 60 sec by bar-pressing. At first, every bar-press turned off the shock when it was on—the normal escape training procedure. Once performance had stabilized, the number of responses required to turn off shock was raised to 2, 4, and finally 8. These "partial escape" schedules are denoted as —FR 2, —FR 4, *etc.*

Results

A moderately aversive intensity of shock was chosen. Both Ss rapidly learned the escape response. After the first session the response latency from onset of shock was rarely more than about 1 sec. Both Ss continued to perform well on —FR 2. However, performance on —FR 4 was irregular: the rate was uneven and there were short periods of non-responding. These irregularities persisted through two sessions, and became accentuated on the change to —FR 8.

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Fig. 1. Performance of S31. At first, every fourth, and later every eighth, bar-press during shock turns it off for 60 sec.

Figure 1 is a record of the performance over the transition from $-FR\ 4$ to $-FR\ 8$. (In this and other cumulative records in this report a full excursion of the pen requires 100 responses. The paper feed is stopped during shock-off, responses then being recorded as a vertical line. The pips indicate reinforcement—i.e., cessation of shock.) The deterioration in performance seen towards the end of Fig. 1 continued during the rest of that session and during later sessions. Figure 2 shows performance on the second session of $-FR\ 8$. Similar results were obtained with the other S.

In the earlier sessions Ss had usually stayed close to the bar and pressed it vigorously when shock came on. After one or two sessions of $-FR\ 8$ their behavior changed dramatically. They often “froze” at the opposite end of the chamber from the bar. At other times they persistently leaped up the walls of the chamber, often landing on the bar. At the end of the experiment bar-pressing by this method was producing several reinforce-

ments in a session, whereas the usual bar-pressing behavior had completely disappeared. Normal bar-pressing could not be re-established by increasing the intensity of shock.

EXPERIMENT II

Behavior of the Ss in Exp. I suggests that, as the FR was increased, responses instigated by pain and fear competed with bar-pressing. The animals made frantic attempts to escape from the location of shock by leaping up the walls, instead of terminating the shock by bar-pressing.

One aim of this second experiment was to see if performance on a fixed-ratio could be established with positive reinforcement in the presence of shock of the same intensity as that used in Exp. I. A second objective was to see if behavior established under these conditions could be maintained by terminal negative reinforcement. Performance was first shaped under two motivations. Thirsty

Fig. 2. Performance of S31 during the session following that shown in Fig. 1. (There is no significance in the fact that the trace does not start from the base line in this and Fig. 3 and 5.)

rats bar-pressed for water, and at the same time, on the same schedule, for reduction of shock. In the second stage of the experiment the positive reinforcement was withdrawn, thus instituting the same partial negative reinforcement schedule used in Exp. I.

Subjects and Apparatus

Ten male albino rats about 150 days old at the beginning of the experiment were used. Six of the Ss (the experimental group) were prepared as before with subcutaneous electrodes. The chamber was the same as that used in Exp. I except that a small brass drinking cup was placed $2\frac{1}{4}$ in. above the grid, just to the side of the bar. The cup was insulated from the rest of the chamber.

Procedure

The experimental Ss were maintained on a 24-hr water deprivation schedule, run for 1 hr per day, and given water for 1 hr after each session. They were trained to bar-press for water on FR 1, then FR 2, then FR 4 (one session each), and FR 8 for the rest of the experiment. Throughout the experiment each reinforcement was followed by a time-out during which no responses could be reinforced. A distinctive noise from the apparatus indicated that time-out had ended. Beginning with the session of FR 4 shock was turned on at the end of time-out and turned off on completion of the prevailing ratio. Over five to seven sessions the shock voltage was raised from an initial value of 50, to 100, 150, and finally 200. The voltage was not raised in the case of any S unless it had maintained performance at the lower voltage. The procedure provides a positive and a negative reinforcement on the same schedule. We have chosen to call this a *concurrent schedule* and to designate it Con $\pm$ FR 4, Con $\pm$ FR 8, etc.

In this experiment the time-out after each reinforcement lasted 45 sec instead of 60 sec as in Exp. I. This change was made to ensure faster training by allowing more reinforcements per hour. Exploratory work had shown that an adequate reinforcement was provided by a shock-off duration of 30 sec or more, and performance showed no obvious variation as a function of shock-off durations greater than 30 sec. Extrapolation of the results of Dinsmoor and Hughes (1956) also suggests

that reinforcement value of shock-off duration, as indicated by the latency of an escape response, does not increase appreciably for durations greater than about 30 sec.

On the fifth session of Con $\pm$ FR 8 (200v) the water pump was disconnected after 15 min. The shock stayed on and could still be turned off by eight bar-presses. This schedule is, therefore, the same as the partial escape schedule of Exp. I ($-$ FR 8). This schedule was continued for eight sessions.

Control Ss were reinforced with water only and never shocked. They were given one session of FR 1, followed by 12 sessions of FR 8. The procedure was otherwise the same for control as for experimental Ss.

Results

Controls. The control Ss were included mainly to verify that normal rapid chaining of responses on FR could develop with the apparatus used and in the general conditions of the experiment. All Ss maintained performance on FR 8. Pauses after reinforcement appeared occasionally in the first few sessions and regularly after sessions six through 10. Terminal response-rate gradually increased. It reached 70 to 80 responses per minute in the case of one S, and up to 400 responses per minute in the case of the other three Ss.

Concurrent positive and negative partial reinforcement. The behavior of one S was severely disrupted by 150 v shock. The responses made by this S became fewer and fewer in succeeding sessions even after the voltage was reduced to 100. The animal eventually stopped bar-pressing altogether. The results presented are based on the performance of the remaining five Ss.

Typical performance on Con $\pm$ FR 8 (200 v) is shown in Fig. 3. The main effect of shock appears in the warm-up at the beginning of the session. The other Ss showed a similar warm-up effect, lasting over a variable time and over a variable number of responses in each session. This effect, interesting in itself, is not important for the purposes of the present investigation.

After the warm-up period the ratio requirement was usually run off promptly as soon as shock came on. Few responses occurred during shock-off; for example, Fig. 3 shows a total of 420 responses for 51 reinforcements, or 8.23 responses per reinforcement. On the

Fig. 3. Typical performance of S57 when every eighth bar-press during shock turns it off for 45 sec and also produces a drop of water.

last two sessions of Con $\pm$ FR 8 (200v) the average terminal rate (measured near the end of the session) varied between Ss from 53 to 160 responses per minute. The terminal rates for the Control Ss were in the same range following the same number of sessions on FR 8.

Negative partial reinforcement only. Figure 4 shows the decline in terminal rate on the change from Con $\pm$ FR 8 to -FR 8. Terminal rate was measured over the last 12 reinforcements in a session, when performance was more regular, but average rates showed the same general result.

The transition to -FR 8 in the case of one S is shown in Fig. 5. The step-like character

Fig. 4. Means and ranges of terminal response rates of five Ss. The Ss were reinforced with both water and shock-reduction in the first two sessions represented and with shock-reduction only in the last eight sessions.

of the record suggests that the initial effect of stopping the water was simple extinction of the positively reinforced response-chain. This produced a temporal distribution of responses similar to that seen in extinction of +FR (Ferster and Skinner, 1957).

Fig. 5. Typical initial effect of stopping water-reinforcement while maintaining the contingencies of escape (S53).

Two Ss continued to give very few responses throughout the eight sessions of -FR 8. Figure 6 shows the best performance achieved on the eighth session of -FR 8. The highest rate sustained over eight responses is about 60 responses per minute. The performance of the other two Ss showed the same features, with a lower and more irregular rate of bar-pressing.

DISCUSSION

The experiments show that a number of responses maintained by the terminal negative reinforcement of shock-reduction are not performed as rapidly and regularly as they are with either positive terminal reinforcement, or simultaneous positive and negative terminal reinforcement. The ability of Ss to bar-press at a moderate rate while receiving 200 v shock on the concurrent schedule shows that the gross motor disturbance produced by 200 v cannot explain the failure of Ss in

Fig. 6. Final performance on fixed-ratio escape on the eighth session after stopping water-reinforcement (S53).

Exp. II to maintain performance on -FR 8 or rats on the deterioration in performance on -FR 8 in Exp. I.

Kaplan (1956) investigated the performance of rats on -FR schedules, using light as an aversive stimulus. The average rate of bar-pressing during the aversive stimulus for -FR 1, -FR 5, -FR 10, and -FR 15 was less than 30 responses per minute with a range of about 10 to 60 responses per minute (estimated from Kaplan's Fig. 4). Kaplan's results seem to be consistent with those of the present experiments, but, unfortunately, Kaplan did not report on the performance of positively reinforced Ss in the same situation.

Other investigators have found that shock-reduction is an adequate reinforcement in training rats to run a straight alley, and the running speeds are in many cases comparable to those obtained using positive reinforcement (Bower, Fowler, and Trapold, 1959; Campbell and Kraeling, 1953; Fowler and Trapold, 1962; Seward, Shea, Uyeda, and Raskin, 1960; Trapold and Fowler, 1960). In running an alley the S completes a "fixed ratio" of steps, but the differences between alley-running and bar-pressing experiments suggest an explanation of the results of the present experiments. In the discrete-trials situation the shock is turned on by the experimenter and S reduces it, and eventually escapes from the whole situation, by running into the goal box. By contrast, in the free-responding situation used in the present experiments, the Ss cannot escape from the whole situation, but can only escape from shock at the cost of placing themselves in a situation where shock is again imminent. Since the absence of shock in the chamber always precedes the onset of shock, the condition of not being shocked in the chamber will itself acquire aversive properties which will have the effect of weakening the behavior which produces it. Any slowing down of escape behavior may eventually make the absence of shock even more aversive, since it then signals the onset of an even longer duration of shock. Final performance presumably

represents a balance between the aversive consequences of responding and those of not responding. The results of Exp. I suggest that in some cases a situation which regularly precedes shock will become more aversive than the shock itself. This conclusion is supported by results obtained by Sidman (1957) and Sidman and Boren (1957). They showed that a warning signal for avoidable shock acquired aversive properties which could affect shock-avoidance behavior. They concluded that, in their modified discriminated avoidance situation, punishment (by shock) of non-avoidance behavior was counteracted by the reinforcing effect of termination of the warning signal.

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