*FIXED-RATIO ESCAPE REINFORCEMENT*¹N. H. AZRIN,² W. C. HOLZ, D. F. HAKE, T. AYLLON

ANNA STATE HOSPITAL, ANNA, ILLINOIS

Escape responses of squirrel monkeys were reinforced according to a fixed-ratio schedule. The reinforcement was a period of safety from a stimulus that signalled the delivery of intermittent pain-shocks. When the frequency of shock was gradually reduced, the performance remained at a high level until the shocks were quite infrequent. Similarly, the duration of the period of safety could be reduced to a few seconds with little loss of behavior. Thus, the responses appeared to be reinforced by even a brief period of safety, the actual degree of shock reduction being fairly slight. The changes in responding during this fixed-ratio escape procedure were comparable to the response changes typically obtained during fixed-ratio food procedures.

In a previous study (Azrin, Holz, and Hake, 1962), a method was described in which responses were reinforced by a period of safety from occasional pain-shocks. When a fixed number of responses was required to produce the period of safety, it was found that this fixed-ratio escape reinforcement produced a response pattern that resembled the pattern obtained during fixed-ratio food reinforcement. When the ratio requirement for escape reinforcement was increased, the pauses after reinforcement increased in the same fashion as when the ratio requirement is increased during fixed-ratio food reinforcement. The present study explored other aspects of this fixed-ratio escape reinforcement to ascertain more fully the comparability between the escape and food reinforcement procedures.

METHOD

Subjects

Eight squirrel monkeys were used. Three of the monkeys were studied extensively; the other five were used to replicate, or elaborate upon, parts of the procedures and to redetermine critical points.

Experimental chamber

The experimental space was a chamber 12 by 10 by 8 in. high, ventilated by a blower and containing a masking noise. The grid floor

consisted of $\frac{3}{32}$ in. diameter stainless steel rods spaced $\frac{1}{2}$ in. apart. A Gerbrands response lever was mounted 1 in. from the top of the cage and was enclosed on both sides by stationary rods that reduced accidental contact by the subject. A downward force of 20 g activated the microswitch of the lever and defined a response. A loud click sounded upon the initial depression of the lever. Continuous illumination was provided by an overhead light except during the periods of safety. During the safe periods, the chamber was darkened and a 1000 cps tone sounded.

Shock apparatus

Foot-shock was delivered to the subject through the floor grid at an intensity of 2 ma for .2 sec duration by an Applegate constant current stimulator. The response lever was included in the shock circuit. A scrambling device rapidly changed the polarity on each floor grid so that a given pair of grids was at opposite polarity during a major part of each shock delivery. Electrode shock (Hake and Azrin, in press) rather than foot-shock was used for two of the monkeys that were studied less extensively. The performance obtained during the electrode-shock procedure differed from the performance during the foot-shock procedure in that complications created by the infrequent shorting of the grids by feces were eliminated.

¹This investigation was supported by grants from the Psychiatric Training and Research Fund of the Illinois Department of Mental Health, NIMH, and NSF.

²Reprints may be obtained from Dr. N. H. Azrin, Behavioral Research Lab, Anna State Hospital, 1000 North Main St., Anna, Illinois.

Programming and recording were accomplished by electromagnetic circuits located in a different room.

Procedure

Each experimental session lasted 6 to 8 hr and was arranged daily. At the start of the first session, the overhead light was dimmed, a 1000 cps tone sounded, and no shock was delivered. After 5 min the overhead light was brightened, the tone was terminated, and shocks were delivered at irregular intervals averaging one shock every 15 sec. After 5 min, the stimuli reverted to the original condition. This cycle of 5 min of safe stimulus followed by 5 min of the shock-associated stimulus was alternated for the duration of the session. The purpose of this procedure was to associate the stimulus with the presence or absence of shock. Responses were recorded but were not effective during this stimulus association procedure. On the second day, the same procedure was followed except that the average interval between shocks was increased to 30 sec. On the third day, the average interval was increased to 1 min and on the fourth day to 2 min. On the fifth day, the association procedure was term-

inated and conditioning began. The shocks were still delivered at irregular intervals averaging 2 min but the shock-associated stimulus remained in effect until a response occurred. Every response now terminated the shock-associated stimulus (light on, tone off) and initiated the safe stimulus (light off, tone on) for 30 sec (escape reinforcement). The escape period occurred only when a response was made. Responses during the escape period did not extend the escape period. Conditioning continued until the subject responded consistently and within about 1 sec following termination of an escape period. The response requirement was then raised gradually over successive sessions until 25 responses were required to produce the safe period (fixed-ratio schedule). The requirement was increased for each subject only after the subject met the lower response requirements without "strain." Approximately three weeks elapsed from the initial association training until all subjects achieved stable performance on an FR 25 schedule of escape-reinforcement. For two subjects, the requirement was increased to 50 responses. The shocks were delivered as scheduled until the ratio requirement was

Fig. 1. Brief shocks were being delivered at irregular intervals averaging 2 min as indicated by the brief downward deflection of the lower recording pen. The upper curve is a cumulative record of responses for the first session (6 hr in duration) that followed preliminary training in which a distinctive stimulus had been associated with a period of safety from the electric shocks. Each response now produced a 30-sec period of safety. The periods of safety are indicated by a downward deflection of the cumulative response pen. The recording paper did not move during the periods of safety. The darker appearance of the curve at the end of the session shows that the subject was producing an escape period almost immediately following the termination of a prior escape period. It should be noted that the time values on the abscissa represent the duration for which the safe period was absent since the recording paper did not move during the safe period. This same method of representation is used in all subsequent figures.

completed. Thus, the shocks could, and usually did, occur during the rapid run of responding that characterized ratio performance.

The effect of shock frequency was studied by reducing the frequency of shock gradually over successive sessions from an average frequency of one shock every 2 min to one shock every

6 hr. At least three sessions were provided at each shock frequency. The effect of reinforcement duration (duration of the safe period) was studied by gradually increasing the duration of the safe period from 30 sec to 240 sec over successive sessions. The duration was then decreased gradually to 0 sec.

FREQUENCY OF SHOCK

Fig. 2. Changes in fixed-ratio escape responding as a function of the frequency of shocks. The lower portion of the figure shows the effect of shock frequency on the total number of responses per session (6 hr). The upper portion of the figure presents illustrative segments of the cumulative response records obtained at selected frequencies of shock. The downward deflection of the response pen indicates a period of safety (60 sec) during which time the recording paper did not move. The average rate of shock delivery is indicated for each segment of the response record; the moment of shock delivery was recorded but is not indicated on the figure.

RESULTS

Acquisition. Figure 1 shows a typical acquisition curve obtained in the first conditioning session following the discrimination training in which the stimuli had been selectively associated with the presence or absence of shock. The characteristically low operant level of the responses is evident from the complete absence of responses during the first 15 min of this initial conditioning session. Each downward pip of the recording pen indicates the 2-min reinforcement period (safe period) during which time the recorder paper did not move. It can be seen that acquisition was fairly gradual: only three responses were emitted during the first 30 min. About 20 safe periods were obtained by the first hour after which the responses then increased gradually in frequency. By the end of the 6-hr session, the subject consistently responded within a few seconds following the termination of the escape reinforcement period. All subjects reached this high level of performance within 6 hr (one session) following the first reinforced response.

After acquisition training, the response requirement was gradually increased to 25 (FR 25). Figure 2 shows the performance of a typical subject when the shock frequency was then decreased gradually from 30 shocks per hr to .17 shock per hr. It can be seen that (lower Fig. 2) approximately 8,000 responses were emitted each day at all shock frequencies greater than 1 shock per hr. Even when the shock frequency was as low as 0.5 shocks per hr, about 5,000 responses were made. Only at a frequency of .17 shock per hr (one per day) did the responses drastically diminish. When no shocks were delivered (0 shock per hr) the response rate returned to the near-zero operant level seen prior to acquisition training in Fig. 1. In a few instances, the shock frequency was decreased suddenly, as from one shock every 2 min to one every 20 min. In such instances, the response rate immediately fell to a low level within one session. Hence, the high response rates depicted in Fig. 2 can be expected only if the shock frequency is reduced gradually.

The upper section of Fig. 2 illustrates the local changes in rate that accompanied the gradual changes in the frequency of shock. The local rate of response was about 3 per sec. Little or no pausing existed after rein-

forcement when the shocks were scheduled as infrequently as 2 per hr. At a frequency of 1 shock per hr, pauses began to occur after many of the reinforcements. At a shock frequency of .17 per hr, the pauses after reinforcement often lasted for 1 hr or more; the high local rate was still maintained between reinforcements. All other subjects also maintained an average response rate exceeding 2 per sec as long as a few shocks were delivered each session.

Fig. 3. Changes in fixed-ratio escape responding as a function of the duration of escape reinforcement. The lower portion of the figure shows the rate of responding at durations of escape from 0 to 240 sec. In the upper portion of the figure, segments of the cumulative response records illustrate the pattern of responding at selected escape durations. The escape period is indicated by the downward deflection of the response pen. Since the recording paper did not move during the period of safety, the variations in duration of the safe period are not evident. The shocks (not shown) were delivered at irregular intervals averaging 10 min. Fifty responses were required to produce each safe period.

Figure 3 illustrates the typical changes in fixed-ratio performance for one subject as a function of the duration of the reinforcement period. The shock deliveries for this subject were scheduled at an average of 6 per hr. It can be seen from the lower Fig. 3 that the

response rate was about 4 per sec when the reinforcement duration was 30 sec. No significant improvement in performance resulted when the reinforcement duration was as long as 240 sec. When the duration was reduced to 10 sec, the response rate decreased only slightly from about 4 per sec to 3 per sec. At reinforcement durations as brief as 2 or 3 sec, the over-all response rate was considerably reduced, but still averaged 20 responses per min. When the escape period was discontinued (reinforcement duration of 0 sec), the response rate fell to a near zero level. The upper section of Fig. 3 shows that the subject responded at a high rate if it responded at all; pauses were localized to the period following the escape reinforcements even when the escape duration was as brief as 3 sec. The other subjects also exhibited the same response pattern of pausing after reinforcement at the briefer reinforcement durations.

When escape reinforcement was discontinued (extinction), the response rate fell to a near-zero level (Fig. 3). Figure 4 shows the changes in the local rate of response during the first day of escape extinction for one subject. Reinforcements had been delivered during

Fig. 4. Cumulative response record illustrating extinction of the escape responses upon discontinuing the escape reinforcement. Shocks were delivered at irregular intervals averaging 2 min. For the first 650 responses, reinforcement consisting of a 30-sec escape period (see arrows) was delivered after every 50 responses. Then the escape periods were discontinued (see upper arrow). The shocks (not shown) continued to be delivered for the remainder of the 2-hr period.

the first $\frac{1}{2}$ hr. At the moment designated by the upper arrow, extinction was begun. During extinction the shocks were still delivered on an average of 30 shocks per hr just as they had been prior to the arrow. After the arrow, however, safe periods could no longer occur. It can be seen that the responses continued to occur at a rate exceeding 3 per sec for approximately 2,000 responses after the safe periods were discontinued. Slight pauses then appeared and these pauses became more frequent and longer in duration until the pause (zero responses) endured for the entire last hour (not shown) of the 6-hr session. No intermediate response rates occurred: responding was either absent or occurred at a rate exceeding 3 per sec. During succeeding sessions of escape extinction (not shown), the responses reappeared at the start of each session and again decreased to zero during the session. Even after several extinction sessions, many responses were emitted at the very beginning of the session.

It had been seen from Fig. 2 that the response rate gradually, but eventually, decreased to zero when the shocks were gradually decreased in frequency. Figure 5 shows the temporal course of this response reduction when a relatively high frequency of shocks (30 per hr) was suddenly reduced to zero. Prior to the session presented in Fig. 5, several sessions had been provided in which shocks had been delivered at this relatively high frequency. No shocks were delivered during the session presented in Fig. 5. It can be seen that 2,000 responses were made before any substantial reduction in rate occurred. The pauses then became progressively longer following the reinforcement periods until responding almost ceased. The local rate of response remained at a high level of about 4 per sec. Only after the pauses had become quite long did intermediate response rates occur (see arrow "A").

A consistent characteristic of the escape performance was the uniformity of the overall rate within each experimental session. On the one hand, no substantial increase in response rate was observed at the beginning of the sessions in contrast with the "warm-up" phenomenon frequently seen when rats have been conditioned by the Sidman avoidance procedure (Sidman, 1960). Nor was there any decrease in responding during the 6-hr session (Fig. 5) during which about 900 reinforcement

Fig. 5. Reduction of escape responding following the sudden absence of shocks. Prior to the period depicted in this figure, 30 shocks had been delivered per hour. During the period represented in this figure, no shocks were delivered. A 30-sec period of escape reinforcement was delivered after every 25 responses (see arrows). The recording paper did not move during these escape periods, indicated by the downward deflection of the cumulative response pen.

periods were provided as the result of the 45,000 responses that were emitted.

DISCUSSION

The present procedure produced a marked degree of control over behavior. Only a brief duration of escape reinforcement was necessary to maintain ratio performance at a maximum level. Similarly, the shocks could be delivered as infrequently as once every hour with little reduction of performance if the originally high frequency of shock was reduced gradually. Less control has been observed when a very similar procedure has been imposed on rats (Dinsmoor, 1962). The lesser degree of control may be attributable to the use of an interval, rather

than a ratio, schedule of escape reinforcement or to the use of rats rather than monkeys.

The control over responding in the present study appeared to require that the responses result in a period of safety from potential shock deliveries. It was essential that a safe stimulus be response contingent and that this safe stimulus be selectively associated with the absence of shocks. When the safe period was eliminated, the response rate eventually fell to a near-zero level. Similarly, control of the responses by stimulus change alone was negligible. When the shock was discontinued, the responses could still produce the safe stimulus. In the absence of shocks, however, the stimulus period no longer constituted a period of safety from potential shocks. As a

consequence, the response rate fell to a near-zero level even though stimulus change still resulted.

The present avoidance procedure appears to differ from other avoidance procedures in the degree of shock reduction necessary to maintain the response. For example, a typical avoidance procedure provides for several seconds of shock presentation if no response is made, but 0 sec of shock if a response is made (Solomon, Kamin, and Wynne, 1953). Thus, the degree of shock reduction is often complete once the avoidance response is acquired. Similarly, a typical Sidman avoidance procedure ($R-S = S-S = 20$ sec) will provide 120 shocks per hr if no responses are made. Acquisition of avoidance responses, however, often reduces this potential number of shocks to about 2 per hr (about 98% reduction). Typically, other avoidance procedures also provide a high degree of shock reduction for each response. This reduction was over 95% in the present study when the average interval between shocks was 1 min and each response produced a safe period of 1-min duration. As the interval between shocks was increased, or the safe periods became briefer, the extent of the shock reduction was lessened. As an actual example (Fig. 6), an average of 6 min between shocks was sufficient to maintain FR 50 responding when the safe period was only 10 sec in duration. By maintaining a very high response rate of 4 per sec, the monkey reduced the frequency of shocks received from a theoretical maximum of 10 per hr to about 6 per hr, a reduction of only 40%. Thus, only a slight degree of shock reduction resulted from even this maximal level of responding. These results raise the intriguing possibility that operant responses might be maintained by an apparent period of safety even when no shock reduction is permitted. Such a procedure would constitute an instance of pure conditioned reinforcement uncontaminated by changes of the frequency of shock presentation.

The present procedure appears to be similar to positive reinforcement regarding the general procedural details of acquisition. First, it was noted that a high shock frequency was necessary during initial acquisition but a lower frequency of shocks was sufficient to maintain responses once initial acquisition occurred. Similarly, in studies of food reinforcement, Ferster and Skinner (1957) have found it neces-

sary to use a lower body weight during initial acquisition than was necessary to maintain the responses once conditioning occurred. Secondly, it was noted in our exploratory studies that ratio performance under this procedure was often erratic unless an initial history was provided in which every response produced a safe period (continuous reinforcement). Ferster and Skinner (1957) have also noted that continuous reinforcement by food was necessary for subsequent intermittent reinforcement to be reliably effective. A third point of comparability is the common procedure of "magazine training" even before beginning continuous food reinforcement. In the absence of magazine training, the delivery of food can not safely be interpreted as a reinforcement and the acquisition process is lengthened. Similarly, we noted in exploratory studies that acquisition was more rapid and reliable if the subject was first given an initial period of discrimination training during which the periods of safety were clearly differentiated from periods of shock delivery. In summary, the present procedure resembled

Fig. 6. Cumulative response record of the escape responses during an entire 6-hr session. Every 50th response produced a 10-sec period of safety, indicated by the small downward deflections of the recording pen. The recording paper did not move during these periods of safety. Shocks (not shown) were being delivered at a rate of 10 per hr in the absence of the safe periods. About 900 reinforcements, safe periods, were obtained as a result of the 45,000 responses emitted. Because of the 900 safe periods, the animal spent about 40% of the session in the safe period.

food reinforcement in that intermittent reinforcement functioned best when the escape period was first differentiated (magazine training), a high frequency of shock was initially available (high degree of motivation) and when every response produced an escape period (continuous reinforcement).

The above considerations indicated that response acquisition by escape reinforcement was fairly comparable to response acquisition during food reinforcement. Once the responses were acquired, the present fixed-ratio schedule of escape reinforcement was also comparable to fixed-ratio schedule of food reinforcement in the manner in which the responses were maintained: 1) a high local rate of response could be maintained, 2) pauses occurred primarily following reinforcement (safe period), 3) the response pattern was characterized by a progressive lengthening of pauses during extinction, 4) pauses after reinforcement increased (Azrin, Holz, and Hake, 1962) when the ratio requirement was increased, 5) spontaneous recovery resulted after a previous period of extinction, 6) the over-all rate increased to a maximum as the duration of reinforcement was increased, and 7) an increased level of responses resulted when the motivational level was increased (high frequency of shocks). The present procedure appeared to differ from food reinforcement in that satia-

tion did not occur, as seen from Fig. 6 in which several hundred reinforcements (safe periods) were given with no loss of strength of the behavior. This absence of satiation appears to follow reasonably from the non-nutritive nature of escape reinforcement.

Fixed-ratio escape reinforcement appears to be comparable to fixed-ratio food reinforcement in the manner in which responses are maintained, as well as the manner in which the responses are acquired.

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Received October 22, 1962