A COMPARISON OF TWO TYPES OF EXTINCTION FOLLOWING FIXED-RATIO TRAINING¹

NORMAN W. WEISSMAN AND EDWARD K. CROSSMAN

NASA, AMES RESEARCH CENTER

Five groups of pigeons were food reinforced on various schedules. Half of each group were extinguished in the normal manner; the others were presented with a stimulus change, previously paired with reinforcement, each time they completed their respective fixed ratios. Response rate in training was an increasing negatively accelerated function of the FR. Increasing the FR produced transitory rate changes, the amount of which yielded a quantitative index of ratio strain. Cumulative records of extinction performance revealed that the stimulus change exerted discriminative control by maintaining the cohesiveness of FR response units. Nevertheless, neither the absolute number of extinction responses nor extinction response units differed appreciably for the two extinction procedures.

Extinction procedures have often been used to clarify the effects of reinforcement schedules. Mowrer and Jones (1945), and Boren (1961), noted that the number of lever-press responses after FR training was directly related to the FR value. Mowrer and Jones further observed that the number of extinction response units, when each unit is defined as one complete FR run rather than a single bar press, was a decreasing negatively accelerated function of the ratio requirement (see also Boren, 1961).

These investigations defined response units in extinction by dividing the total number of extinction responses by the value of the FR used in training. As an alternative, Findley (1962) explored empirical procedures for defining a response unit. He showed, for example, that an FR 10 schedule could be treated as a unit by placing it on another schedule of reinforcement. This was accomplished by programming a stimulus change after each block of 10 key pecks and programming food after a fixed number of these blocks. The resulting performance with larger response units of this type had similar characteristics to behavior composed of single key pecks under the same schedule of reinforcement. In other words, an FR 5 schedule composed of FR 10s resembled an FR 5 schedule composed of FR 1s.

The present experiment was designed to compare the responses-divided-by-FR definition with the empirical definition of a response unit using the extinction method. To calculate response units, one group of subjects was given simple extinction after FR training. Then, the total number of extinction responses for each subject was divided by the training FR to produce response units. A second group of subjects, which received the same FR training as the first, was presented with a stimulus change in extinction each time the training FR requirement was completed. This latter procedure defined the experimental response unit.

Some studies have shown that resistance to extinction can be increased by inserting a stimulus, which had been present in training, during extinction (Miles, 1956; Bugelski, 1938; Crowder, Morris, and McDaniel, 1959). But Skinner (1938, p. 103) found no difference between groups of rats given simple extinction and those given a reinforcement-paired stimulus after each extinction response. By comparing the extinction performances of the two groups in the present experiment, it was possible to analyze the reinforcing and discriminative properties of the stimulus change at various fixed ratios. The results of such an analysis are pertinent to the issue of conditioned reinforcement raised by the above studies, since the same measure, resistance to extinction, was common to those experiments and the present one.

¹Reprints may be obtained from Norman W. Weissman, Neurobiology Branch, NASA, Ames Research Center, Moffett Field, Calif.

METHOD

Subjects

Twenty experimentally naive, male, White Carneaux pigeons (Palmetto pigeon plant) served. They were about 1 yr old when the experiment began.

Apparatus

Each of four sound-attenuated chambers was equipped with a Gerbrands translucent plastic pigeon key, mounted on a vertical panel and illuminated by a pair of 28 v dc red-jeweled pilot lamps. Directly below the key was a Lehigh Valley Electronics solenoid-operated food hopper filled with Purina pigeon chow.

Procedure

The birds were maintained at 80% of free-feeding body weight throughout the experiment. All were shaped to peck the illuminated key. Reinforcement consisted of a 3-sec period during which the food hopper was raised, the hopper light illuminated, and the key light turned off.

During each session—4 hr per day, 5 days per week—two dim lamps illuminated the chamber. After 50 reinforcements the key lights were darkened and the key was made inoperative. The birds were not removed until the 4-hr session terminated. After the session they were weighed, returned to home cages, and fed the amount necessary to approximate 80% body weight. Water was continuously available in both experimental and home cages.

All subjects were shaped to peck the key within the first two sessions (50 reinforcers per session) and given a total of 1250 reinforcers in the experiment. These 1250 reinforcers, which included those obtained during shaping, were distributed to each group of four pigeons in the following order:

- Group FR 1—25 sessions at FR 1.
- Group FR 4—2 sessions at FR 1, 23 sessions at FR 4.
- Group FR 16—2 sessions at FR 1, 2 sessions at FR 4, 21 sessions at FR 16.
- Group FR 32—2 sessions at FR 1, 2 sessions at FR 4, 3 sessions at FR 16, 18 sessions at FR 32.
- Group FR 64—2 sessions at FR 1, 2 sessions

at FR 4, 3 sessions at FR 16, 18 sessions at FR 64.

After training, the birds were divided into two groups, each containing two birds trained at each of the asymptotic FR conditions. Birds in the stimulus-change group (Group SC) received three 4-hr sessions of extinction. During extinction a stimulus change—key light off for 3 sec—occurred after each member of the SC group had emitted the number of responses equal to its final training FR requirement. This stimulus change was only one of the events correlated with reinforcement during training. Birds in the no-stimulus-change group (Group NSC) received simple extinction for three 4-hr sessions in which the key light was on continuously.

RESULTS

Training

Figure 1 shows the relation between overall response rate, which includes reinforcement cycle time, and the FR value. Each point on the solid curve represents the mean rate during the session preceding extinction. Rate of responding increased up to FR 16 and changed little above this value. Variability in response rate was considerably greater at higher FR values.

In addition to these measures of rate based on the final performance at an FR value, a transitory effect was seen on the first session following a change in FR. Increasing the FR

Fig. 1. Mean overall response rate on the last day of training is represented by the solid line. The broken lines illustrate immediate changes in overall rate when FR was increased. Rate during the session preceding a ratio increase is shown by the squares. The open circles are rate values taken from the first session at a new FR.

requirement immediately changed overall rate, the magnitude and direction of which depended upon the FR values. The dashed lines in Fig. 1 show the performance of animals whose FR requirement were increased. The last session at an FR value is represented by the squares; the open circles represent the first session on the higher FR value. Changing the FR from 1 to 4 increased rate by 214%; from 4 to 16, 99%; from 16 to 32, 16%; and from 16 to 64, decreased it by 38%. The latter result reflects the considerable pausing during the run of the ratio and after reinforcement on FR 64; the increases in ratio at the lower FR values were accomplished without this excessive straining. Further evidence of the initial instability in overall rate produced by changing the ratio from FR 16 to FR 64 is that the largest discrepancy between the early performance (open circles) and the final performance (closed circles) occurred at FR 64.

Extinction

Figures 2 and 3 show the last training session and first extinction session for two of the

FR 32 birds. Each bird in the NSC group emitted bursts of responding followed by pauses of unequal length, a pattern typical of simple FR extinction (Ferster and Skinner, 1957). This result is shown in the record (Fig. 2) of bird EN-19, a member of the NSC group. However, the pattern of extinction responding for all subjects in the SC group was quite different. In this case, pauses consistently followed completion of a response unit (*i.e.*, the number of responses equal to the size of the FR during training). This performance is illustrated in Fig. 3, a cumulative record of bird EN-18. Evidence for the stimulus control exerted by turning off the key lights was provided by recording responses on electro-mechanical counters. Responses never occurred during the stimulus change.

Figure 4 shows the total number of responses (A) and response units (B) for each bird during the three extinction sessions. The SC and NSC groups cannot be distinguished on these two measures because of the excessive within-group variability. When corrected for heterogeneity (log transform) an analysis of variance for responses supported this con-

EN-19

Fig. 2. Cumulative records of EN-19, an NSC bird, for the last day of training at FR 32 (A) and first day of extinction (B). Pips indicate the reinforcement cycle. The last 3 hr of extinction were spent in pausing and are omitted. The recorder ran continuously.

Fig. 3. Cumulative records of EN-18, an SC bird, for the last day of training at FR 32 (A) and the first day of extinction (B). Pips indicate the reinforcement cycle in A; in the B record hash-marks indicate the absence of the key light. Consecutive segments of the extinction record have been numbered accordingly. The recorder ran continuously.

clusion ($F < 1$). The same analysis of variance yielded a significant difference among the five ratio groups on total number of responses for the three-day extinction period ($F = 11.88$; $df = 4$; $p < .001$).

DISCUSSION

Training

Ferster and Skinner (1957) have referred to irregular pauses occurring between responses on an FR schedule as "ratio strain". This type of response pattern was evident in the cumulative records of the present experiment when the FR requirement was changed from FR 16 to FR 64. As seen in the dashed lines of Fig. 1, this straining was reflected by a sharp decrease in overall rate at FR 64 during the first session.

Boren (1961) has suggested that a factor which contributes to the increasing negatively accelerated shape of an overall rate function

is the relative amount of session time attributed to reinforcement. Therefore, a more accurate picture of ratio strain may be derived by measuring changes in the inter-reinforcement response rate, which excludes reinforcement time. With this method of calculation the mean inter-reinforcement response rate change was an increase of 130% when the FR was increased from 1 to 4. Changing the FR from 4 to 16 increased mean rate by 24%; from 16 to 32, by 1%; and from 16 to 64, decreased it by 53%. If a decrease in inter-reinforcement response rate is assumed to indicate the amount of straining, then this method of calculation provides an index of the transitory effect resulting from a change in the FR schedule. The accuracy of this straining index depends upon the extent to which the reinforcement-produced negative acceleration in the overall rate curve can be deleted. If access to the reinforcer is timed, deletion can be accomplished most precisely.

Extinction

It was possible to evaluate the discriminative and reinforcing properties of the stimulus change (key light turning off) by comparing the extinction performance of the SC and NSC groups. Since the stimulus change had been concurrent with the reinforcement cycle, it might serve a discriminative function for those behaviors that followed and a reinforcing function for those that preceded the stimulus change.

Figure 3 shows that the stimulus change was effective in breaking the behavior into discrete units of responding. Without the stimulus change such divisions in the extinction performance were absent (see Fig. 2). Other studies (Zimmerman and Ferster, 1964; and Zimmerman, 1963) have also shown that patterns of responding could be maintained by programming stimulus changes similar to those which occurred when food was presented.

Although the discriminative aspect of the key light turning off was clear enough, Fig. 4 indicates no consistent difference between total extinction responses or response units for the SC and NSC groups. While they confirm the decreasing negatively accelerated function reported by Mowrer and Jones (1945), the data plotted in Fig. 4B fail to differentiate between a response unit derived from an arithmetic calculation (NSC group) and one derived from an empirical operation (SC group).

Kelleher and Gollub (1962) reviewed experiments which have studied conditioned reinforcement by the extinction method. Although some of the conditions differed from those of the present study, the general finding that a stimulus associated with unconditioned reinforcement increases resistance to extinction is relevant (Bugelski, 1938; Miles, 1956; Crowder *et al.*, 1959). Whether or not the lack of a conditioned-reinforcing effect in the present data arises from some such procedural variation cannot be determined at present. As mentioned earlier, however, Skinner (1938) also noted that presenting the magazine click after each extinction response did not significantly alter resistance to extinction.

One of the major questions considered in the Kelleher and Gollub (1962) monograph is the determination of conditions necessary to

Fig. 4. Absolute number of responses (A) and response units (B) of all birds for the first three days of extinction. The SC group is represented by open circles; the NSC group by closed circles.

establish a positive conditioned reinforcer. They concluded that, under some conditions, a conditioned reinforcer may be without discriminative properties. Present results indicate the related but converse effect. A stimulus shown to exert strong discriminative control was found not to be an effective positive conditioned reinforcer.

It can be argued that failure to realize a conditioned-reinforcing effect may have been a function of having presented only one of those events which accompanied reinforcement during training. Adding the illumination and elevation of the hopper to the key-light-off condition for the SC group might have increased resistance-to-extinction for birds in this group. This possibility awaits further empirical study.

REFERENCES

- Boren, J. Resistance to extinction as a function of the fixed ratio. *J. exp. Psychol.*, 1961, 61, 304-308.

- Bugelski, R. Extinction with and without sub-goal reinforcement. *J. comp. Psychol.*, 1938, **26**, 121-134.
- Crowder, W. F., Morris, J. B., and McDaniel, M. H. Secondary reinforcement or response facilitation?: I. Resistance to extinction. *J. Psychol.*, 1959, **48**, 299-302.
- Crowder, W. F., Gill, K., Jr., Hodge, C. C., and Nash, F. A., Jr. Secondary reinforcement or response facilitation?: II. Response acquisition. *J. Psychol.*, 1959, **48**, 303-306.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Findley, J. D. An experimental outline for building and exploring multi-operant behavior repertoires. *J. exp. Anal. Behav.*, 1962, **5**, 113-166.
- Hearst, E. Resistance-to-extinction functions in the single organism. *J. exp. Anal. Behav.*, 1961, **4**, 133-144.
- Kelleher, R. T. and Gollub, L. R. A review of positive conditioned reinforcement. *J. exp. Anal. Behav.*, 1962, **5**, 543-597.
- Miles, R. C. The relative effectiveness of secondary reinforcers throughout deprivation and habit-strength parameters. *J. comp. physiol. Psychol.*, 1956, **49**, 126-130.
- Mowrer, O. H. and Jones, H. Habit strength as a function of the pattern of reinforcement. *J. exp. Psychol.*, 1945, **35**, 293-311.
- Skinner, B. F. *The Behavior of organisms*. New York: Appleton-Century-Crofts, 1938.
- Zimmerman, J. Technique for sustaining behavior with conditioned reinforcement. *Science*, 1963, **142**, 682-684.
- Zimmerman, J. and Ferster, C. B. Some notes on time out from reinforcement. *J. exp. Anal. Behav.*, 1964, **7**, 13-19.

Received February 26, 1965