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VARIABILITY OF RESPONSE LOCATION FOR PIGEONS RESPONDING UNDER CONTINUOUS REINFORCEMENT, INTERMITTENT REINFORCEMENT, AND EXTINCTION[1]

DAVID A. ECKERMAN AND ROBERT N. LANSON

UNIVERSITY OF NORTH CAROLINA AND COLUMBIA UNIVERSITY

The effect of several reinforcement schedules on the variability in topography of a pigeon's key-peck response was determined. The measure of topography was the location of a key peck within a 10-in. wide by 0.75-in. high response key. Food reinforcement was presented from a magazine located below the center of the response key. Variability in response locus decreased to a low value during training in which each response produced reinforcement. Variability increased when fixed intervals, variable intervals, random intervals, or extinction were scheduled.

Schedules of reinforcement have been shown to control dimensions of responding other than rate, such as force (Bregman and Berryman, 1956; Notterman and Mintz, 1965; Skinner, 1938, p. 313), duration (Margulies, 1961; Millenson and Hurwitz, 1961; Millenson, Hurwitz, and Nixon, 1961), latency (Stebbins and Lanson, 1962), displacement (Herrick, 1965; Herrick and Bromberger, 1965, p. 394-395), and topography (Antonitis, 1951; Herrnstein, 1961). This control is seen even when no explicit differential reinforcement of particular response values has been scheduled, although the very definition of a response class ultimately implies some minimal value below which no reinforcement is delivered. Further, just as the absolute value of these response properties can be modified by reinforcement contingencies, the variability along any one response dimension has also been shown to be a function of the reinforcement contingencies.

One such demonstration of reinforcement control over response variability has been presented by Antonitis (1951). Using rats, this investigator measured the variability in topography of a nose-poking response along a 50-cm horizontal strip. Response stereotypy increased during training in which each response produced a food pellet in a dispenser located on the wall opposite the response strip (CRF). Variability increased during extinction. A return to CRF, however, reduced variability even below that observed during initial CRF training. Two predictions might thus be derived from the Antonitis study concerning the relation between response variability and intermittent reinforcement. Insomuch as intermittent reinforcement resembles extinction, increased variability would be expected; and as intermittent reinforcement resembles multiple reconditionings, decreased variability would be expected.

Herrnstein (1961), using pigeons, investigated the effect of intermittent reinforcement on response variability by measuring the properties of key pecking along a 10-in. horizontal strip during CRF and a variable-interval 3-min schedule of reinforcement (VI 3-min). As in the Antonitis study, the feeder was placed on the wall opposite the response area. Herrnstein found that during CRF, the birds showed preferences for the ends of the key. A shift to VI 3-min led to decreased variability by accentuating these end preferences within the first 15 min of VI training.

Since so few responses are reinforced, it seems curious that a VI 3-min schedule of reinforcement should produce results resembling those of reconditioning more than those of extinction. The present research attempted to reexamine the relation between schedule

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of reinforcement and response variability by replicating Antonitis' procedure with pigeons and then by determining the effects of intermittency of reinforcement on response topography. The experimental apparatus used was similar to Herrnstein's, the only significant departure being the location of the feeder which was centered below the response key rather than on the opposite wall.

METHOD

Subjects

Five White Carneaux cock pigeons, 4 to 5 yr old, were maintained at 80% of their free-feeding weights. They were housed individually with water and grit available at all times except during experimental sessions.

Apparatus

A 10-in. wide by 0.75-in. high response area was 8.5 in. above the floor centered on a 14-in. wide wall of the experimental chamber. Responses were recorded on twenty 0.5-in. wide Plexiglas keys which filled the 10-in. width. These keys were exposed to the bird and were slightly separated (average approximately 0.03 in.). Minimum excursion and force requirements varied between keys and from time to time. The range of force values was 4 to 12 g with excursions of 0.5 to 3.8 mm needed to activate the microswitch. Forces and excursions did not covary, nor were they systematically related to position along the width. Maximum excursion of a key was limited to ⅜ in. by a stop located behind the keys. Inasmuch as two adjacent keys could be simultaneously activated, rather than count these pecks as responses in both positions, such double-key pecks were separately recorded and later included in the tally for the right-hand key of the pair. The response area was evenly back-illuminated by white light. The light intensity was 1.1 log foot-lamberts in Exp. I and II and 1.25 log foot-lamberts in Exp. III. In addition, a dim houselight was present.

A 2⅜-in. wide by 2-in. high feeder opening was centered below this response key. The bottom of this opening was 5 in. from the center of the key and 7 in. from the ends. Reinforcements consisted of 3-sec presentations of a mixture of 40% vetch, 50% kaffir, and 10% hemp seed. This mixture was also used for feeding outside the experimental chamber.

Procedure

Experiment I. The three subjects for this experiment were trained to eat from the feeder and pecks on the key were shaped. In shaping, each approach to any portion of the response key was reinforced. Once key pecking had been established, the pigeons were given five sessions of 100 reinforcements on a CRF schedule. An extinction session was then begun. The session continued until 100 reinforcements would normally have occurred (*i.e.*, the reinforcement timer continued to operate, but the feeder and feeder light were disconnected). Pecks occurring during reinforcement-timer operation were recorded but were without effect. The seventh session was a reconditioning session in which 100 reinforcements occurred on CRF. The eighth session was again extinction. After the equivalent of 33 reinforcements on this day (again the timer but not the feeder was operating), or after responding had stopped for several minutes, the feeder light was illuminated for 3 sec for each of the next 67 equivalents of reinforced pecks. No food, however, was presented. In the ninth session, CRF was again scheduled for 100 reinforcements.

Experiment II. These same three birds were given five sessions of 100 reinforcements on CRF. Two sessions were then given in which 100 reinforcements were presented according to a fixed-interval 15-sec (FI 15-sec) schedule of reinforcement, the fixed interval being timed by the clock and not by time since reinforcement. In the subsequent seven sessions, probability of reinforcement for the first response in each 15-sec period of the session was reduced to 0.1 ($P = 0.1$). A random series determined which intervals contained reinforcement availability. This schedule is a random-interval schedule with a mean inter-reinforcement interval of 150 sec (RI 150-sec). The RI 150-sec schedule is very similar to a variable-interval schedule with a mean interval of 150 sec as long as responding is well maintained. Thirty-three reinforcements were scheduled in each of these sessions. Probability of reinforcement was then changed for several sessions to $P = 0.2$ (*i.e.*, RI 75-sec) and then to $P = 0.5$ (*i.e.*, RI 30-sec). Two of the birds were then given continued training with $P = 1.0$ (*i.e.*, FI 15-sec) and, finally, with CRF.

Experiment III. Two naive birds were trained to peck at the response key and were given six sessions in which 100 pecks were reinforced on a CRF schedule. A VI 3-min schedule of reinforcement (Fleshler and Hoffman, 1962) was then scheduled for the next 14 sessions. Each of these sessions was 1-hr long.

RESULTS

Experiment I

The function in the upper panel of Fig. 1 shows the median response locus for each 33 responses in the experiment: three points are plotted for each of the 100-reinforcement conditioning sessions. Responses during the 3-sec reinforcement cycles were excluded from this analysis, although their inclusion does not greatly alter the result. For extinction sessions, responses were included only if they would normally have been reinforced, *i.e.*, only if they started the reinforcement timer. Thus, responses included for extinction sessions were separated by 3 sec just as were responses for conditioning sessions, and conditioning and extinction measures are based on similar numbers of responses. Where 33 responses were not emitted during one of the extinction phases, a point was not plotted. Thus, since Bird 36 emitted only 52 responses during Session 6, only one point is plotted. Bird 36 and Bird 266 emitted only 10 and 5 responses respectively during the first phase of Session 8 and thus have no data presented for this phase.

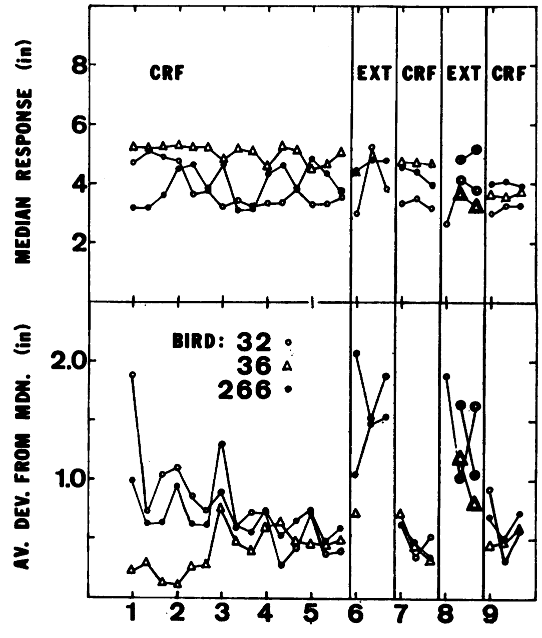

Fig. 1. Median response locus measured from right-hand edge and variability of response locus for each block of 33 responses under continuous reinforcement (CRF), extinction (EXT), and conditioned reinforcement phases. Outlined data points in Session 8 denote conditioned reinforcement phase. Responses during reinforcement-timer cycles were excluded.

Figure 1 shows that birds were responding near the middle of the key. Median response location never shifted beyond 2.3 in. from the center. Birds sometimes shifted their median response position gradually over the course of several sessions (especially Bird 32) and sometimes showed consistent shifts within sessions (especially Bird 266, Sessions 2 to 5).

The lower panel of Fig. 1 shows the changes in response variability during Exp. I. The average deviation around the median response position is plotted for each 33 responses in the experiment. Variability decreased within and across the first five sessions for Birds 32 and 266. Such a trend was also seen for Bird 36, Sessions 3 to 5. The variability for Sessions 1 and 2 was very low for this bird, however. The general statement that variability progressively decreased across continued training under CRF must therefore be qualified by this exception.

Extinction increased variability of responding for all birds. The increase was especially large for Birds 32 and 266. Average deviations averaged 1.59 in. for these two birds. For comparison it might be noted that if all 20 keys were responded to equally often, the variability measure would be 2.5 in.

Figure 2 presents frequency distributions of responses along the key for Session 5 and the first extinction session (Session 6). Responding occurred at more positions during extinction than during CRF. Reconditioning reduced variability to levels observed during initial training. In a second extinction session, variability in position was again high for Bird 32, which continued responding (see Fig. 1). Too few responses were emitted by Birds 36 and 266 to judge variability. However, once the feeder light (3-sec) was presented for responses, response rate rose to equal that obtained during conditioning ses-

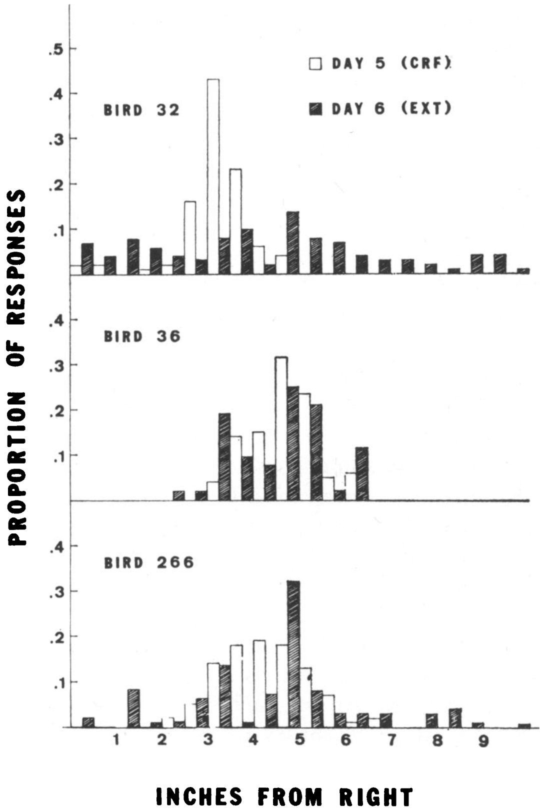

Fig. 2. Relative response frequency as a function of key location for the fifth CRF session (Session 5) and the first extinction session (Session 6).

sions and this high rate was maintained throughout the session. Variability in response locus was high for all birds during this phase of the extinction session. Average deviation in responding averaged 1.22 in. compared to 0.49 for the reconditioning session. It was noted that after the tenth presentation of the feeder light, the birds did not approach the feeder during the light-on cycle. This breaking of the chain of behavior represents a loss of the former discriminative function of the feeder light during a time when it was acting as a conditioned reinforcer.

Experiment II

The upper function of Fig. 3 shows median response location. The lower function shows the average deviation from the median location. The abscissa is marked off by blocks of 33 reinforcements. Only reinforced responses were included in these analyses to ensure that data points from various parts of the experiment were based on similar numbers of events. The inclusion of all responses does not greatly alter the results, nor are the results greatly altered if one looks at characteristics of post-reinforcement responses rather than reinforced responses.

Figure 3 shows that intermittent reinforcement increased variability of response location over that observed during CRF. The CRF baseline is close to that previously observed for Birds 32 and 266, although it is somewhat higher for Bird 36. There is one high value for Bird 32 that is attributable to the first five reinforced responses in Session 4. All these responses occurred at the extreme right-hand edge of the key. During the feeder cycles the bird did not eat, but stayed at the end of the key, pecking at it throughout. The measure for the other 28 responses is plotted with closed circle for comparison.

Introduction of the FI 15-sec schedule of reinforcement increased variability in response location for all birds. Birds 32 and 36, however, showed a progressive decrease in variability with continued exposure to the FI schedule. Variability was subsequently increased again during the RI 150-sec, RI 75-sec, and RI 30-sec schedules of reinforcement. No consistent relation between variability and density of reinforcement per unit time was seen for these schedules. Birds 36 and 266 were given further training with an FI 15-sec schedule of reinforcement for 66 reinforcements per day. Variability remained high for Bird 266 but decreased to levels previously observed during CRF for Bird 36. A final return to CRF reduced variability for Bird 266 but not Bird 36.

Median response location shifted over a wide range during the experiment. End "preferences" and center "preferences" were both observed. Frequently, large changes in median response location occurred when the reinforcement schedule was changed. There were no consistent relations, however, between the response location and the reinforcement schedule.

Experiment III

Figure 4 presents for two birds the median and average deviation in response location key pecks reinforced on a CRF schedule for six sessions and on a VI 3-min schedule for 14 sessions. Variability again decreased with training on a CRF schedule and increased under

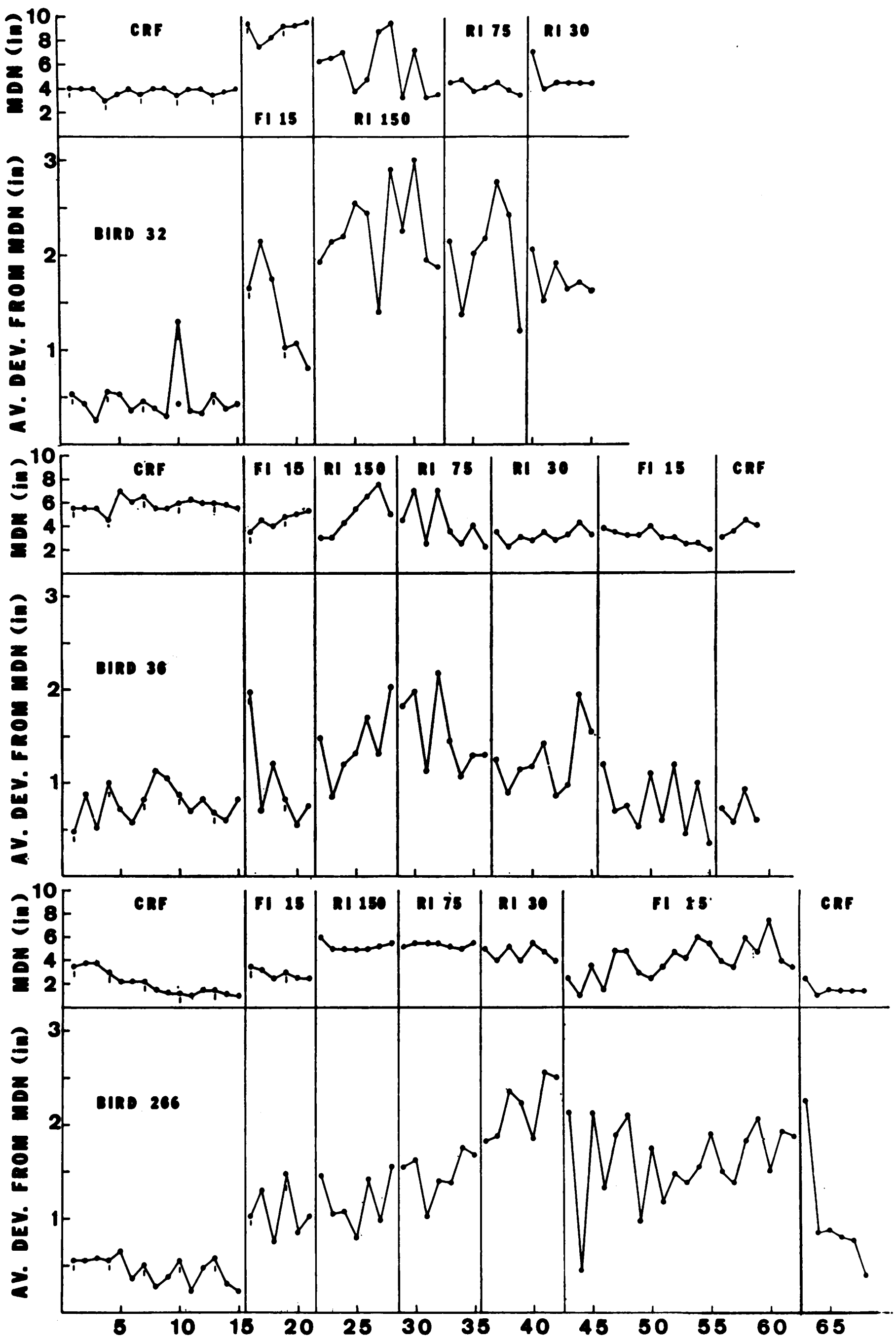

Fig. 3. Median response locus measured from right-hand edge and variability in response locus for blocks of 33 reinforced responses in continuous reinforcement (CRF), fixed-interval (FI 15-sec), and random-interval (RI 150-sec, RI 75-sec, RI 30-sec), schedules of reinforcement. During CRF and FI 15-sec conditions, more than one block of 33 reinforcements were given in a session. The first block of such sessions is denoted by a short vertical mark.

intermittent reinforcement. Variability stayed high throughout the 14 sessions of VI 3-min reinforcement. The median location plot shows, however, that both of these birds developed a preference somewhat near the end of the key during this training. Bird 94 developed such a preference during the CRF stage, only to lose it with the change to intermittent reinforcement. Bird 95 developed an end-preference during the later sessions on VI 3-min.

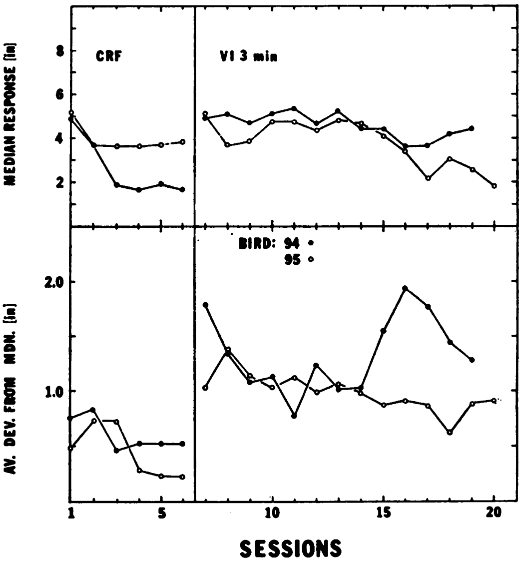

Fig. 4. Median response locus measured from the right-hand edge and variability in response locus for all responses obtained in sessions of continuous reinforcement (CRF) and variable interval (VI 3-min) reinforcement.

Figure 5 shows frequency distributions for responses at the various positions across the key for the last day of CRF training and the last day of VI 3-min training. Relative frequency distributions are presented since the total number of responses differed markedly between CRF and VI 3-min sessions. Responding was observed at many more locations for both birds under VI 3-min training. These distributions show two of the most extreme end-preferences obtained in this study (Bird 94, Session 6; Bird 95, Session 20). In neither of these distributions is the end position the mode. It should be pointed out that the ends of the key were 2 in. away from the side wall; there was room for the pigeon to peck at the ends. Some pigeons emitted several end-key pecks (see Fig. 2).

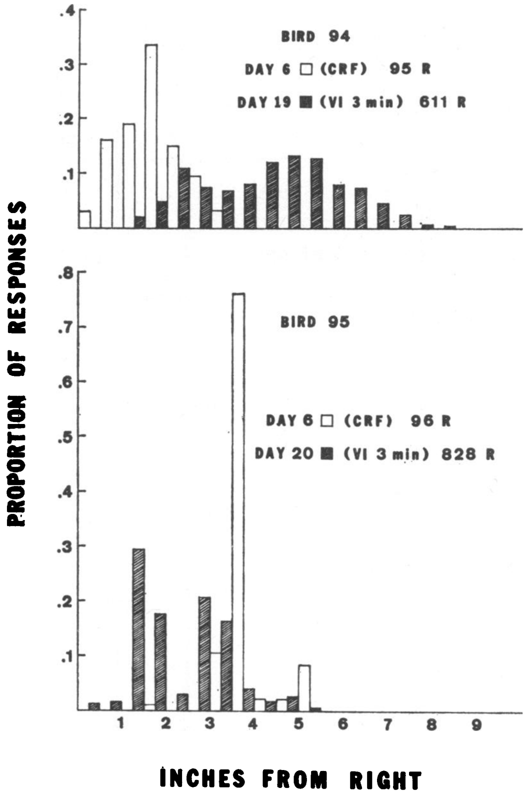

Fig. 5. Relative response frequency distributions as a function of key location for the last CRF session and the last VI 3-min session.

DISCUSSION

Experiment I

The data of Exp. I closely replicate those of Antonitis (1951). Variability generally decreased during CRF training and increased during extinction. One part of the Antonitis result was not found in this study. Antonitis found that reconditioning led to a decrease in variability below that observed at the end of the original CRF training. Such a process was alluded to by Herrnstein (1961) in explaining the decreased variability he found during intermittent reinforcement. The fact that such a result was not obtained may be due to the greater number of reinforcements given in the present study during initial conditioning (500 *vs* 225).

The feeder location in the present experiment probably counteracted the end-preferences observed by Herrnstein (1961). The center of the key in the present apparatus was only 5 in. from the feeder; the ends were 7 in.

If differential reinforcement was thereby given for responses near the center of the key, it was not sufficiently strong to produce a highly stereotyped center-preference. Different birds responded in somewhat different loci, and the modal position shifted from time to time. In Herrnstein's experiment, the feeder was located on the wall opposite the response key. Thus, the center of the key was also closer to the feeder than were the ends. However, since birds might be expected to circle from the feeder back toward the key, one might expect that the ends of the key would be encountered first and thus be functionally closer to the feeder. This analysis seems consistent with the strong end-preferences observed by Herrnstein (although there may be an additional response bias independent of experimenter- or apparatus-controlled reinforcement contingencies). Antonitis found such a location to counteract the rat's tendency toward an end-preference. The fact that Herrnstein found end-preferences may be due to the pigeon's larger turning-radius.

The increased variability in responses under conditioned reinforcement relative to conditions of primary reinforcement seems surprising at first. Why should the conditioned reinforcement data duplicate those of simple extinction? Perhaps the answer lies in the similarity of simple extinction and extinction-with-conditioned-reinforcement. Even simple extinction allows each response to be followed by the click of the key and response-produced feedback. These stimuli may have become conditioned reinforcers during CRF training. The addition of the feeder-light would add another conditioned reinforcer, albeit a strong one, and hence might be expected to produce results similar to simple extinction.

Experiments II and III

In Exp. II and III, intermittent reinforcement produced greater variability in response topography than did CRF. This result is in accord with that obtained for response dimensions other than topography: force (Goldberg, 1959), duration (Millenson *et al.*, 1961: although these authors found the above relation for random-ratio schedules, which arrange an equal probability of reinforcement for any response, and for fixed-interval schedules of reinforcement, they found no difference in duration variability for CRF and FR 5 schedules; thus, for certain schedules, perhaps those which produce a strong superstition or a differentiated high rate, an increased variability of response may not be found), latency (Stebbins and Lanson, 1962), and displacement (Herrick, 1965; Herrick and Bromberger, 1965). This result is, however, in sharp contrast to that obtained by Herrnstein (1961), despite a very close replication of Herrnstein's procedures. The disparity is emphasized when it is realized that Herrnstein found a marked decrease in response variability "in the very first experimental session with intermittent reinforcement. . . . There was increased responding on the modal location after about 15 min of the first session" (presumably, then, approximately three reinforcements) ". . . and . . . the final level was reached by the second or third session." Just what variables account for this lack of agreement in result is not clear. The response dimension, the particular order of procedures, the presence of stereotyped response patterns before the shift to intermittency—all these conditions were the same for the two experiments. The major difference between the two studies seems to be the location of the feeder. The main influence of feeder location would seem to be in producing the difference in delay of reinforcement for different members of the response dimension.

In sum, the present data indicate that variability of response location increased under extinction or under intermittent schedules of reinforcement. The finding of increased variability replicates the observations of Antonitis with topography, as well as similar results in other response dimensions. The increased variability during intermittent reinforcement does not replicate Herrnstein's data obtained for the same dimension with the same species. Variables other than the organism or response dimension must thus underlie this discrepancy.

REFERENCES

Antonitis, J. J. Response variability in the white rat during conditioning, extinction, and reconditioning. *Journal of Experimental Psychology*, 1951, **42**, 273-281.

Bregman, M. and Berryman, R. Response magnitude changes in extinction. Paper read at the American Psychological Association, New York, September, 1956.

Fleshler, M. and Hoffman, H. E. A progression for generating variable-interval schedules. *Journal of* *the Experimental Analysis of Behavior*, 1962, **5**, 529-530.

Goldberg, I. A. *Relations of response variability in conditioning and extinction*. Unpublished doctoral dissertation, Columbia University, 1959.

Herrick, R. M. Lever displacement under a fixed ratio schedule and subsequent extinction. *Journal of Comparative and Physiological Psychology*, 1965, **59**, 263-270.

Herrick, R. M. and Bromberger, R. A. Lever displacement under a variable ratio schedule and subsequent extinction. *Journal of Comparative and Physiological Psychology*, 1965, **59**, 392-398.

Herrnstein, R. J. Stereotypy and intermittent reinforcement. *Science*, 1961, **133**, 2067-2069.

Margulies, S. Response duration in operant level, regular reinforcement, and extinction. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 317-321.

Millenson, J. R. and Hurwitz, H. M. B. Some temporal and sequential properties of behavior during conditioning and extinction. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 97-106.

Millenson, J. R., Hurwitz, H. M. B., and Nixon, L. B. Influence of reinforcement schedules on response duration. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 243-250.

Notterman, J. M. and Mintz, D. E. *Dynamics of response*. New York: John Wiley & Sons, 1965.

Skinner, B. F. *The behavior of organisms*. New York: Appleton-Century Co., 1938.

Stebbins, W. C. and Lanson, R. N. Response latency as a function of reinforcement schedule. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 299-304.

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