VARIABILITY OF RESPONSE LOCATION ON FIXED-RATIO AND FIXED-INTERVAL SCHEDULES OF REINFORCEMENT[1]

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Variability of response location was studied in monkeys performing in a six-lever chamber. Fixed-ratio schedules, ranging from FR 1 to FR 300, generated a high degree of stereotypy of response location. In contrast, fixed-interval schedules of comparable reinforcement frequencies (0.06 to 4 minutes) generated much greater variability. These results failed to confirm any simple relationship between response variability and intermittence of reinforcement. Rather, variability seems to be determined by the particular characteristics of the reinforcement schedule.

Key words: response location, variability, stereotypy, fixed-ratio schedules, fixed-interval schedules, intermittence of reinforcement, monkeys

The schedule of reinforcement has been shown to be one of the variables controlling the variability of response topography. In 1951, Antonitis studied variability of response location during a sequence of conditioning and extinction sessions. Each time a rat thrust its nose into a horizontal slot on one wall of an experimental chamber, the response and its location were recorded. Antonitis found that response stereotypy was characteristic of continuous reinforcement. In contrast, response variability was sharply increased by extinction. The results suggested a relationship between variability of responding and intermittent reinforcement. Based on Antonitis's study, Schoenfeld (in 1950 conference notes, published in 1968) proposed a mechanism by which intermittent schedules in general would increase response variability. He argued that the extinction periods in intermittent schedules should generate response variations, which would then be maintained by the ensuing reinforcement. Herrnstein (1961) attempted to verify this proposal using pigeons and a 25-cm horizontal response strip. The location of a pigeon's peck on this strip was re-

corded during continuous reinforcement and during a variable-interval schedule of 3 min. He found, contrary to Schoenfeld's proposal, that the intermittent schedule engendered less variability than continuous reinforcement.

In 1969, Eckerman and Lanson reexamined the relationship between response location and reinforcement schedule. Except for feeder location, their apparatus was similar to Herrnstein's. Their results, however, were not. They found, as did Antonitis, low variability during continuous reinforcement and greater variability during extinction. In contrast to Herrnstein's data, Eckerman and Lanson also found high variability on several interval schedules of reinforcement. Similar results were obtained by Ferraro and Branch (1968). They reported greater variability of response location on a variable-interval schedule than on continuous reinforcement.

At this point, Schoenfeld's general statement relating intermittent reinforcement to response variability has been supported by the narrow margin of two studies to one. Additional experimentation to broaden the empirical base for a generalization would seem to be indicated. It should also be noted that the previous studies have primarily contrasted continuous reinforcement with variable-interval schedules. Therefore, the present research was designed to expand the information on response variability as a function of reinforcement schedule in two directions. First, two basic schedules, fixed ratio and fixed interval,

were studied to determine if the type of schedule affects the variability of response location. Second, the intermittency of these schedules was explored over a range of values to determine how variability is influenced by reinforcement frequency.

METHOD

Subjects

Two male rhesus monkeys served. Monkey E was experimentally naive at the beginning of this study; Monkey S had an extensive history on a variety of reinforcement schedules. Each monkey was maintained on a diet of 450 Noyes banana pellets (300 mg) per day. The pellets were either earned during the experimental session or, when necessary, fed after the session. Water, fruit, and vitamins were given to each subject after the daily session. Each monkey was housed 24 hr a day in its experimental chamber.

Apparatus

Two identical experimental chambers, measuring 105.4 cm by 73.6 cm by 78.7 cm, were used. An array of six recessed levers were centered and aligned horizontally along one wall of the chamber. The levers were spaced 7 cm apart, center to center, and 32.5 cm from the chamber floor. A yellow pilot lamp (CM 1820) was mounted 4.5 cm above each lever. Below these levers were two reinforcement levers, one for food and one for water, mounted equidistant (26.2 cm) from the side walls and 20.1 cm from the floor. A red pilot lamp was mounted 4.5 cm above each lever. The water dispenser tube and the food pellet aperture were located between the reinforcement levers and equidistant from the middle of the wall. In summary, response and reinforcement devices were symmetrically mounted with respect to the center of the wall such that it was possible for the monkey to reach all devices with minimal movement.

A relay behind the chamber wall clicked audibly when any lever was pressed. The experimental procedures were arranged automatically by solid-state logic. The data were recorded on electromagnetic counters and cumulative recorders.

Procedure

When a session began, the six yellow stimulus lamps over the six levers were illuminated, and all levers became operative. A response on any one of the levers could satisfy the schedule requirements. Both monkeys had previously been trained to press all six levers. When a reinforced response occurred, the red lamps beside the reinforcement levers and a tone came on, signalling the availability of either food or water reinforcement. Depression of the "water" lever delivered 12 cc of water through a metal tube. A response on the "food" lever produced a 300-mg Noyes banana pellet. Each daily session terminated with 450 reinforcements or 6 hr, whichever occurred first.

In the first phase of the experiment, both monkeys were initially stabilized on a fixed ratio of 100 responses per reinforcement (FR 100). Then, for Monkey S, other fixed-ratio schedules were studied in the following order: FR 200, FR 300, FR 30, FR 5, FR 1 (continuous reinforcement), and FR 100. For Monkey E, the schedules and the order were: FR 200, FR 50, FR 20, FR 5, FR 1, and FR 100. FR 300 for Monkey S and FR 200 for Monkey E were large enough to generate long prerun pauses, averaging about 4 min. Each fixed-ratio value was maintained until response variability was judged to be stable for at least 10 consecutive sessions. The average number of sessions under which each schedule was studied was 19.

In the second phase, fixed-interval (FI) schedules were studied. The interval schedules were chosen as approximate equivalents to the ratio schedules in frequency of reinforcement. This was done by calculating the mean reinforcement frequency for each ratio schedule and then assigning interval values that extended over the same range. Although the exact values of each interval did not precisely equal the mean interreinforcement interval of each ratio, the range, and thus the functional relations shown, correspond quite closely. In other words, the range in reinforcement frequency from FR 1 to FR 300 was the same as for FI 0.06-min to FI 4-min and the individual values were approximate equivalents. For Monkey S, the FI schedules were studied in the following order: FI 4-, FI 0.5-, FI 2-, FI 1-, FI 0.25-, FI 0.06- (in effect, continuous reinforcement), and FI 4-min. The order for Monkey E was FI 1-, FI 2-, FI 0.06-, FI 0.25-, FI 0.5-, FI 4-, and FI 1-min.

RESULTS

Two measures were chosen to evaluate the variability of response location. One was the percentage of responses on the preferred (modal) lever for each session. The other was switches as a percentage of the total responses, where a switch was defined as a change from one lever to another. Thus, low variability would be indicated by a large percentage of responses on the preferred lever and a small percentage of switches. All data are presented as medians and ranges for the last 10 sessions at each schedule value.

Fixed-ratio schedules generated very little variability of response location. Figure 1 shows the data for Monkey S in terms of both per cent responses on the preferred lever and per cent switches. At the lowest fixed-ratio value (FR 1), Monkey S responded on the preferred lever 82% of the time (see upper graph). At FR 5, this percentage increased to 98, and at all larger fixed ratios the percentage approximated 100. The percentage-of-switching measure (see lower graph) showed essentially the same functional relation. About 4% switching occurred on FR 1, and almost no switching occurred at the other fixed-ratio values. Even at FR 300, when Monkey S showed extremely long prerun pauses ("strain"), the variability of response location remained quite low. Note that the second determination of FR 100 (which followed immediately after

FR 1) resulted in a data point almost identical to the first determination, thus indicating reversibility and reliability of the measures in Figure 1.

As shown in Figure 2, the data for Monkey E were similar. On FR 1, 97.4% of the responses occurred on one lever. For all larger fixed ratios, the responding on the preferred lever varied from only 98.5 to 99.8%. As with Monkey S, there was some switching (lower graph) on FR 1 (about 4%) but almost no switching on the other fixed-ratio values. The data point at FR 100 was recovered precisely on the second determination. In summary of the data for the two subjects, then, FR 1 generated a small amount of response variability, but larger fixed ratios reduced the variability to a close-to-zero amount. In other words, a high degree of stereotypy was produced by all fixed ratios larger than FR 1.

In contrast to fixed-ratio schedules, fixed-interval schedules generated substantially more variability in response location. The data for Monkey E are shown in Figure 3. The only fixed interval that generated relatively low variability was FI 0.06-min (the equivalent of FR 1 and CRF). The variability measures for FI 0.06-min were quite comparable to those in Figure 2 for FR 1, as should be the case. Response variability for fixed intervals from FI 0.25-min to FI 4-min was substantially higher, with the per cent responding on the preferred
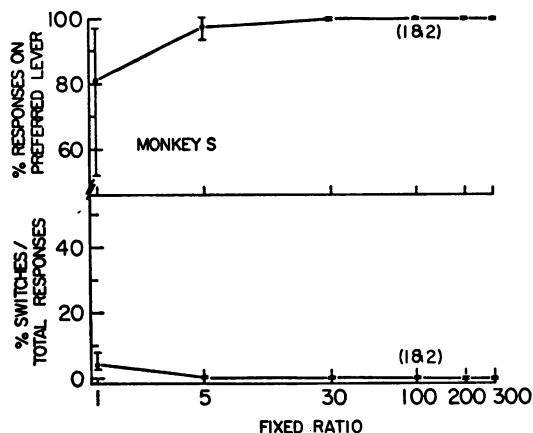

Fig. 1. Per cent responses on the preferred (modal) lever and per cent switches per total number of responses as a function of fixed-ratio size. The data are plotted as medians and ranges for the last 10 sessions at each value and are for Monkey S.
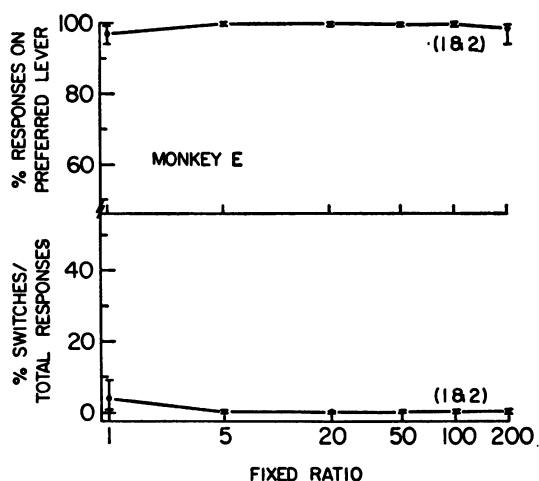

Fig. 2. Per cent responses on the preferred (modal) lever and per cent switches per total number of responses as a function of fixed-ratio size. The data are plotted as medians and ranges for the last 10 sessions at each value and are for Monkey E.
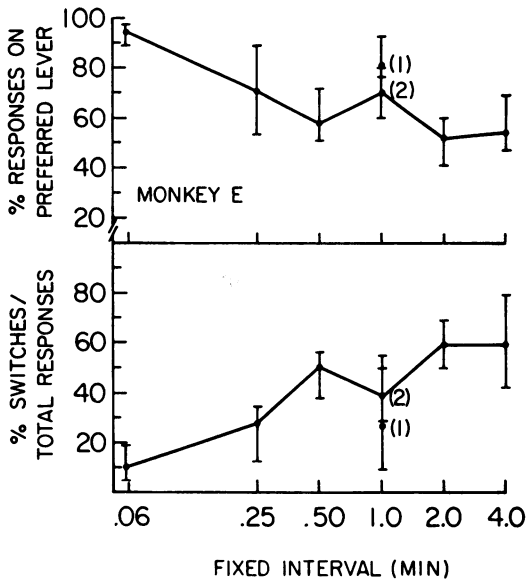
Fig. 3. Medians and ranges for per cent responses on the preferred lever and per cent switches per total number of responses as a function of fixed-interval duration. The data are for Monkey E.
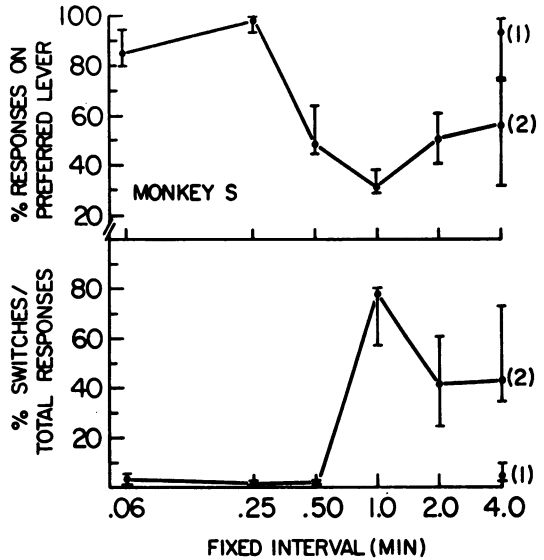

Fig. 4. Medians and ranges for per cent responses on the preferred lever and per cent switches per total number of responses as a function of fixed-interval duration. The data are for Monkey S.

lever ranging from only 50.6% on FI 2-min to 71.7% on FI 1-min (second determination). Similarly, the per cent of switching also increased with the longer fixed intervals. The second determination at FI 1-min showed greater response variability than the first determination, probably because the first point was determined just after the study of fixed-ratio schedules. In comparing the variability under fixed-interval schedules (Figure 3) with that under fixed-ratio schedules (Figure 2), it is clear that the interreinforcement interval is noncritical. Any substantial fixed interval generated more variability than any substantial fixed ratio.

In Figure 4, the data for Monkey S also show that the larger FIs generated more variability in response location than the smaller FIs, although the function was less smooth than for Monkey E. On FI 0.06-min, Monkey S made 86.4% of its responses on one lever, and on FI 0.25-min, 98.5%. At the longer interval schedules, Monkey S's percentage of responding on the preferred lever was much lower, ranging from 32.1% on FI 1-min to 59.4% on FI 4-min (second determination). Again, switching increased as responding on the preferred lever decreased. Similar to the other monkey, the first determination at FI 4-min was probably

affected by a carryover of the low variability from the immediately preceding fixed-ratio schedules. Therefore, the second determination is probably more reliable.

DISCUSSION

These data show that intermittent schedules of reinforcement can generate either high levels of variability in response location or very low levels. The amount of variability was found to be a function of the type of intermittent schedule. On a continuous reinforcement schedule (where FR 1 and FI 0.06-min were the equivalent), response variability was found to be relatively low. On fixed-ratio schedules ranging from FR 5 to FR 300, variability was even lower than that on FR 1. In a related experiment with pigeons by Zeiler (1968), three keys were transilluminated with three colors. At the end of the fixed ratio, reinforcement always followed a response to one particular stimulus (the S+), but responses to the other stimuli counted toward fulfilling the ratio requirement. Thus, Zeiler could observe variability among three stimulus keys, as he changed the fixed-ratio size from 1 to 205 responses per reinforcement. Although a few more S— responses occurred under the larger fixed ratios, the percentage of responses on the

S+ key was found to be very high (usually 98 to 100%) for all fixed-ratio sizes.

In contrast to the stereotypy on fixed-ratio schedules, variability on fixed-interval schedules was much greater. On fixed-interval schedules (ranging from FI 0.50-min to FI 4-min), response variability was higher than on CRF and higher than on any fixed-ratio schedule studies. In this respect, these results were similar to those found by both Eckerman and Lanson (1969) and by Ferraro and Branch (1968). The results were dissimilar, however, to those of Herrnstein (1961), who found decreased response variability on a variable-interval schedule. The exact reasons for the discrepancy (perhaps feeder location, cage design, *etc.*) are unknown.

Although it is difficult to know just which property of the two types of schedules was responsible for the observed results, one can speculate that switching from lever to lever during a fixed-ratio schedule would disrupt the "cohesive" chaining (Mechner, 1958) and increase the interreinforcement time. Therefore, the monkey should press rapidly on one lever to maximize reinforcements per unit time. Although the animal could receive a food pellet and then proceed to choose another lever (and press rapidly on it until reinforcement), this possibility occurred very rarely. One can speculate that the reinforcement after a press on a particular lever caused the monkey to return to the same lever, thus yielding another reinforcement from that lever and, over the long term, resulting in the observed response stereotypy. On the other hand, quite different reinforcement contingencies were operating on the fixed-interval schedules. Since reinforcement depended only on the passage of time plus one response, the monkey could switch from lever to lever with little or no increase in interreinforcement time. Furthermore, if the animal switched levers from time to time (as it did), the reinforcement was likely to occur after pressing on a variety of levers, thus resulting in the observed response variability. This analysis, while speculative, is logically consistent with the reinforcement contingencies characteristic of interval and ratio schedules (Ferster and Skinner, 1957).

Previous theorizing (*e.g.*, Schoenfeld, 1968) about a direct relationship between response variability and intermittence of reinforcement in general is, by the expansion of the data base from this experiment, rendered improbable. As the schedule was changed in this study from CRF to larger FRs (greater intermittence), response variability tended to decrease. As the schedule was changed from CRF to longer FIs (also greater intermittence), response variability increased. Furthermore, the variability generated by any interval schedule of substantial size was greater than that generated by any ratio schedule. Since the ratio and interval schedules were arranged to deliver the same range of reinforcements per minute, differences in variability can not be attributed simply to differences in frequency of reinforcement. Instead, variability of response location seems to be determined by the properties of the particular schedule of reinforcement.

REFERENCES

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

Eckerman, D. A. and Lanson, R. N. Variability of response location for pigeons responding under continuous reinforcement, intermittent reinforcement, and extinction. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 73-80.

Ferraro, D. P. and Branch, K. H. Variability of response location during regular and partial reinforcement. *Psychological Reports*, 1968, **23**, 1023-1031.

Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.

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

Mechner, F. Probability relations within response sequences under ratio reinforcement. *Journal of the Experimental Analysis of Behavior*, 1958, **1**, 109-121.

Schoenfeld, W. N. On the difference in resistance to extinction following regular and periodic reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 259-261.

Zeiler, M. D. Stimulus control with fixed-ratio reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 107-115.