INTER-REINFORCEMENT TIMES FOR THE BAR-PRESSING RESPONSE OF WHITE RATS ON TWO DRL SCHEDULES^{1, 2}

JOHN FARMER AND W. N. SCHOENFELD

COLUMBIA UNIVERSITY

A knowledge of inter-reinforcement times (IS^RT) seems of interest because, among other reasons, they bear on the variable of "reinforcement density" in behavior theory. IS^RT data were here recorded for bar-pressing responses by two white rats working on DRL 10 sec and DRL 40 sec. Sample inter-response time (IRT) distributions and cumulative records were taken simultaneously for comparison purposes. IS^RT sequences and distributions have certain characteristics that urge further investigation.

No published information appears to exist regarding the spacing of reinforcements obtained on DRL schedules. These inter-reinforcement times (IS^RT) are, of course, different from inter-response times (IRT), and there need be no fixed relation between IRT and IS^RT distributions. Aside from other considerations, the measurement of IS^RTs on DRL schedules would appear to be of focal interest for any behavioral theory or principle which emphasizes "reinforcement density" as a determining variable.

The present paper reports IS^RT data for rats on the two schedules, DRL 10 sec and DRL 40 sec, and, for comparison, some IRT distributions taken concurrently from the same subjects (Ss).

METHOD

Subjects

Two Sprague-Dawley male albino rats, approximately 90 days old at the start of the experiment, were used.

Apparatus

The experimental chamber was a standard Grason-Stadler unit (Cat. No. E3125B) which contained a Gerbrands lever ("standard" lever, no catalogue number). The bar required 19 g

for depression; the reinforcer was .01 cc of a 50% mixture by volume of condensed milk and water. Automatic relay circuitry delivered reinforcements on schedule and recorded data.

Procedure

After arrival in the laboratory, the Ss' free-feeding weights were determined over a period of about three weeks; they were then reduced and maintained within 80% $\pm$ 4% of those levels throughout experimentation. The base weight from which the 80% value was calculated was changed weekly using Zucker's (1953) formula so as to parallel weekly weight increases with age noted in free-feeding Ss. Free access to water was provided at all times.

On Day 1, and without prior shaping of the bar press response, Ss were exposed to 45 min of regular reinforcement. On this day only, the reinforcement dipper was always in the up position (at cage floor level), and a bar press lowered the dipper momentarily into a reservoir containing the milk-water mixture, with the dipper then returning to the up position and remaining there until the next response. In this 45-min session, Rats 1 and 2 received 126 and 187 reinforcements, respectively. On Day 2, daily sessions were lengthened to 1 hr, and the reinforcement schedule was changed to DRL 10 sec (wherein only bar presses which terminated IRT $\geq$ 10 sec were reinforced). Also beginning on Day 2, and throughout the rest of the experiment, reinforcement consisted of only 3-sec access to the dipper in the up position, the dipper remaining down in the reservoir at all other times. On Day 25

¹This research was carried out with the support of the National Science Foundation under grant G-18633. Reprints may be obtained from John Farmer, Dept. of Psychology, Columbia University, New York 27, N.Y.

²We are indebted to C. R. Curran for generous help throughout the experiment.

(after 24 days on DRL 10 sec), the DRL requirement was increased to 40 sec, and sessions were lengthened to 2 hr. The Ss were run on this second schedule for 61 days.

RESULTS AND DISCUSSION

Figure 1 shows that the development of a final form of ISRT distribution on DRL 10 sec was rapid, being already far advanced for both Ss by Day 8. Undoubtedly, the brief exposure of these Ss to the prior regular reinforcement schedule (45 min), in which short

latencies had little time to develop, was contributory.

The final form reached by all the distributions in Fig. 1 gives major modal emphasis to ISRT values at or near the DRL requirement (even Day 60 of Rat 1 on DRL 40 sec is no exception, since 220 sec is a "dump" category for that and all higher values). Starting with a rather flat or rectangular distribution in which all ISRT values have about the same probability of occurrence, the final form approached is hyperbolic, resembling the exponential "random interval" distribution (Farmer, 1962) in which, correspondingly, the modal value is the minimum interval. A rat yoked to the experimental Ss' reinforcement deliveries would, presumably, exhibit behavior appropriate to such a random interval schedule in which the minimum interval was equal to the DRL requirement. The emergence of this final form of distribution has implications, of course, for the stochastic predictability of any ordinarily specified ISRT, given any preceding ISRT value or series of values.

A second mode appears at 20-24 sec in the final DRL 10 sec distributions, and is suggested at 80 sec in the DRL 40 sec distributions. These may be thought of as a proba-

Fig. 1. Relative frequency distribution functions of ISRT for both Ss on DRL 10 sec and DRL 40 sec. All ISRTs on the indicated days enter the distributions, the N of each being as shown. On DRL 10 sec, Day 24 was the last day of exposure; on DRL 40 sec, the "Day 60" distributions are the sum of ISRTs on the last three days of exposure (Days 59, 60, and 61) in order to build up the N. Each plotted point is at the lower bound of the class interval (5 sec intervals for DRL 10 sec, and 10 sec intervals for DRL 40 sec) between its corresponding abscissa value and the next higher one. Thus, for Rat 1 on Day 24 of DRL 10 sec, the first plotted frequency is that of ISRTs falling between and including 10 and 14 sec. The last plotted point on each distribution is a "dump" category that includes all the frequencies at the highest abscissa value and above.

Fig. 2. Relative frequency inter-response time (IRT) distributions for both Ss on terminal exposure days corresponding to those in Fig. 1. All IRTs on the indicated days enter the distributions, the N of each being as shown. In this figure, "day 60" on DRL 40 sec represents the IRTs of that day only (the N being large enough not to necessitate the pooling of data from Days 59 and 61 with those of Day 60). Each plotted point is the lower bound of its class interval (1-sec intervals for DRL 10 sec, and 4-sec intervals for DRL 40 sec), as in Fig. 1; again, the highest class interval is a "dump" category. The vertical dashed lines separate the reinforced and non-reinforced portions of the distributions.

bility bias in time sampling by the "system" (rat). What happens, descriptively, is that when the animal makes an "anticipation error" by responding with a sub-reinforcible IRT, the "missing" of a reinforcement is followed by several other rapid responses (as in an extinction "burst") the last of which serves as the base for a new timing of the DRL requirement. These bursts become more likely following anticipation errors that come late (Sidman, 1956).

The IRT distributions in Fig. 2, which are quite similar to those in the literature, are clearly different from the IS^RT distributions in Fig. 1. The latter are replicas of neither that portion of the IRT distributions above the criterion DRL values, nor of that portion beyond the modes, and this is especially true of the DRL 40-sec IRT distributions which have either a weak mode above the DRL criterion (Rat 2) or a mode displaced to below

the DRL criterion (Rat 1). To pass from IRT to IS^RT distributions, requires that the former be available as raw sequential data. The pooling of data into an IRT distribution represents, of course, a loss of information about response sequence. One example and consequence of this loss is the inability to extract IS^RT information from the IRT distribution, although an IS^RT distribution, in its turn, also represents a loss of sequential information. It is possible that the sequential analysis of IS^RTs, even as of IRTs, will eventually be of greater import for an understanding of behavior than the display of their frequency distributions.

Figure 3 shows that, on Day 1, overall response rates on DRL 10 sec were already low and not very different from Days 8 and 24, despite the large change in number of reinforcements obtained and in the distributions of IS^RTs. On the other hand, rates are quite

Fig. 3. Sample cumulative response curves, each DRL 10 sec record being of a complete 60-min experimental session, while the two DRL 40 sec records are each of the last 60 min of a 2 hr session. The pips represent reinforcements.

different on DRL 40 sec from DRL 10 sec Day 1, being lower and markedly steadier in the former case despite a general similarity in reinforcement density. Finally, the Ss did not discriminate 40 sec as efficiently as 10 sec (reinforcement rate on DRL 40 sec being less than one quarter that on DRL 10 sec), mainly because of a relative increase at DRL 40 sec in "anticipatory" responding with IRTs below the minimal requirement (see Fig. 2). This loss in discriminative efficiency, however, does not seem to impair the general steadiness of responding.

REFERENCES

- Farmer, J. Properties of behavior under random interval reinforcement schedules. *J. exp. Anal. Behav.*, 1963, **6**, 607-616.
- Sidman, M. Time discrimination and behavioral interaction in a free operant situation. *J. comp. physiol. Psychol.*, 1956, **49**, 469-473.
- Zucker, L. "Growth criteria," in *Rat quality, a consideration of heredity, diet and disease*. New York: National Vitamin Foundation Inc., 1953.

Received June 20, 1963