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REINFORCEMENT PROBABILITY AND ORDINAL POSITION OF RESPONSE IN FIXED-INTERVAL SCHEDULES

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Four rats pressed levers and received food pellets under fixed-interval reinforcement schedules of 20, 60, and 180 seconds. The number of responses in each interval was recorded. From these data, the probability of reinforcement was determined as a function of response count. These functions were generally increasing. This finding is consistent with previous suggestions that increasing response rates within fixed intervals may be a function of response count in addition to or instead of elapsed or remaining time.

Key words: reinforcement probability, ordinal position, response sequence, fixed interval, lever press, rats

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Shull and Brownstein (1970) entertained an account of fixed-interval (FI) responding that looks to ordinal position of response, rather than time, as the discriminated dimension. They considered three relations: if (1) the probability of reinforcement of a response increased with ordinal position of that response, and if (2) the rate of responding at each ordinal position of response (here defined as the inverse of interresponse time) varied directly with the accompanying reinforcement probability, then (3) rate of response would necessarily be higher at later ordinal positions of response. Shull and Brownstein investigated this last relation (3) between ordinal position of response and rate of responding (interresponse time).

The present study was concerned with relation (1) above, between the ordinal position of response and the probability of that response being reinforced. Shull and Brownstein (1970) asserted: "Generally, on FI schedules several parameters of reinforcement (e.g., probability and delay) become more favorable as the number of preceding responses since reinforcement increases" (p. 49). The belief that, given variability in total responses per interval and characteristic fixed-interval response patterns, this must occur, is intuitively compelling but not required by logic. To verify this, we may assign to each ordinal position any reinforcement probability value we wish, subject only to the restrictions that (1) each probability value must be between 0 and 1, inclusive, and (2) if probability value 1 is assigned to an ordinal position, then all higher ordinal positions must have the probability value 0. Because the assignments of probability values are arbitrary, the function relating ordinal position and reinforcement probability may increase, or decrease, or be cyclic, or follow any or no particular pattern. From these probability values it is possible to calculate one or more frequency distributions of the number of responses per interval that will yield the probability values. Because the definition of a fixed-interval schedule does not logically constrain the number of responses in the interval (there must, of course, be at least one and it is reasonable to suppose that physiological constraints set an unknown upper limit), there is no logical constraint on the function relating probability of reinforcement to ordinal position of response under FI. Accordingly, the aim of the present study was to make explicit a relation previously only assumed to exist, by describing the function relating reinforcement probability to ordinal position of response that prevails under FI schedules of reinforcement.

There is nothing in the specification of the fixed-interval scheduling arrangements themselves that defines a reinforcement probability at any ordinal position of response. Reinforcement probability at any ordinal position of response is a consequent (Dews, 1970) or in-

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direct (Zeiler, 1977) variable. Over a collection of intervals an estimate may be readily obtained of the probability of reinforcement for the nth response. For each n, count the number of intervals having an nth response (not all intervals will); of this number, the proportion in which the nth response was reinforced is the desired estimate.

The strategy of the present experiment was to expose 4 rats to FI schedules of 20, 60, and 180 s, make the necessary counts for the estimate required as above (count the total number of responses in each interval), and then examine the function relating the obtained estimates of the reinforcement probabilities to ordinal position.

METHOD

Subjects

The subjects were 4 male albino rats (identified as 61, 62, 63, 64), 90 days old and experimentally naive at the start of the experiment. They received supplemental feedings in amounts calculated to maintain their weights within 15 g of 80% of their free-feeding weights throughout the experiment.

Apparatus

Four identical chambers were used. An outer enclosure attenuated sound and light. A fan supplied ventilation and masking noise. Within the enclosure there was an inner chamber about 30 cm by 25 cm by 28 cm. On the center of one wall of the inner chamber, about 5.7 cm from the floor, a pellet tray was mounted. A pellet dispenser delivered 0.045-g Noyes pellets to the tray. A single lever was mounted about 5 cm above the pellet tray; about 7.5 cm above the lever a houselight was mounted. Experimental events were controlled by solid-state programming modules. The total number of responses in each inter-reinforcement interval was recorded by a printing counter.

Procedure

Subjects were housed continuously in the experimental chambers except for brief periods when they were weighed and fed and the chambers were serviced. Water was always available in the chamber. The houselight was lit only during experimental sessions. When the FI schedule was not in effect, the subjects remained in the darkened chamber. This procedure permitted a greater degree of automation and uniformity of treatment of experimental operations. No evidence of stress to the subjects was observed.

After magazine training and lever-press response shaping, FI schedules were in effect in which the first response after a fixed-interval produced a food pellet. During successive 30-day periods, the values of the FI were 20, 60, and 180 s. The first interval began when the session started; all other intervals began at the moment of delivery of the reinforcer in the previous interval. A new session started every 12 hr. Sessions lasted 40, 120, or 360 min when the FI value was 20, 60, or 180 s, respectively. In each session, a maximum of 120 pellets could be obtained (or a maximum of 240 per day).

RESULTS

Data were recorded from the last 5 to 7 days at each FI value. A separate analysis was made of the probabilities of reinforcement for each subject at each FI value and at each ordinal position of response. The probability of reinforcement at ordinal position n was estimated by dividing the number of intervals having exactly n responses by the number of intervals having n or more responses. The resulting analysis resembles those based on Anger's (1956) IRTs/op statistic and Weiss's (1970) conditional probability.

A preliminary plot of the probability estimates against ordinal position revealed that the detail at this level was too fine-grained to clearly portray the data. Accordingly, data were averaged over successive ordinal positions of response so that each average was based upon at least 5% of the total data for a given subject and FI parameter. The value 5% was judged to be the best compromise for revealing details in the resulting function while basing each point on an adequate sample of data. For every probability estimate, p, its complement, $q = 1 - p$, was calculated. The average used for the p values was one minus the geometric mean of the q values.

The estimate of reinforcement probability at ordinal position n was based on a sample whose size was simply the number of intervals that had n or more responses. This sample size necessarily decreased with n, affecting the quality of the estimate. For this reason, data from the largest ordinal positions (never more

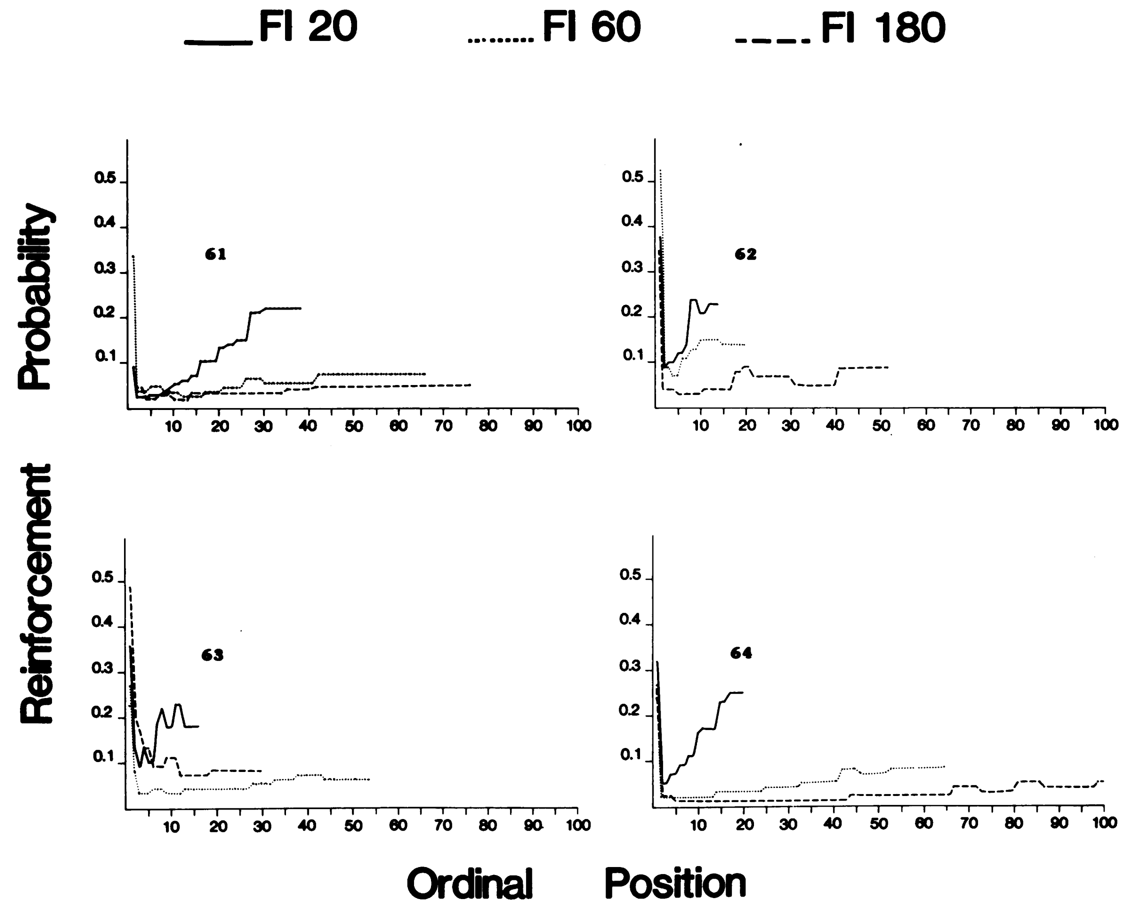

Fig. 1. For each ordinal position of response in an interreinforcement interval, the estimated probability of reinforcement for a response in that ordinal position has been plotted. The functions are presented separately for each subject and for each value of the fixed-interval parameter that was investigated.

than 5% of the data collected) are not presented.

The resulting probability estimates (from each subject at each FI value) are presented in Figure 1. The abscissa is the ordinal position of response and the ordinate is the estimate of the corresponding reinforcement probability. Each curve is based upon between 503 and 1,243 reinforcement intervals. The data indicate a strong tendency, with important exceptions to be noted shortly, for reinforcement probability to increase with increasing ordinal position of response. The increase was more rapid when the FI was shorter. An important exception to this general relation between ordinal position of response and reinforcement probability occurred at the first response in the interval. Here, reinforcement probability was much greater than that observed for the rest of the function. At the first response, reinforcement probability was often about .33 to .50 and even at its lowest value was not less than about .09. For each ordinal position for which data were available to make the comparison, the reinforcement probability at that ordinal position was greatest at FI 20 and least at FI 180. An exception of a different kind occurred for the data of Subject 63 at FI 180. The function was observed to be decreasing over most of its range and the entire set of values was elevated above those obtained for FI 60.

DISCUSSION

Under FI schedules, the probability of reinforcement usually increased with the ordinal position of the response. This relation, previously only assumed to exist, now finds empirical support. The finding establishes a necessary, but not sufficient, condition for a theoretical explanation for the increasing rates of response observed within interreinforcement intervals under FI schedules: As the number of unreinforced responses accumulates, the likelihood of the next response being reinforced increases, and this increasing likelihood of reinforcement is accompanied by decreasing IRTs (faster responding). This account, proposed by Shull and Brownstein (1970) and partly supported by their finding relating IRT value to ordinal position of response, receives further support from the present data.

The large number of intervals with a single response is surprising. This performance, although unusual, is not unique. Hanson, Campbell, and Witoslawski (1962, Figure 4) found that the mean postreinforcement pause for one of their rats on FI 2 min exceeded the interval length. They report, "This rat did not respond to a high percentage of intervals in this condition until after the FI requirements had already expired" (p. 333). Lowe and Harzem (1977, Figure 5) found a sufficient number of intervals having a single response to enable them to plot data points for which the postreinforcement pause equaled the FI value. Mechner, Guevrekian, and Mechner (1963, Figure 1, row 3) found, for 6 rats on FI 30 s, that pausing exceeded the interval value about 10 to 20% of the time. Ferster and Skinner (1957, pp. 173–174) regarded this as a problem resulting from too small a reinforcer; they used 0.050 g compared to the 0.045 g used here. It should be emphasized that in each case the subjects were rats and the response was lever pressing.

The reinforcement probability values reported in Figure 1 for each ordinal position n depend only on the number of intervals having n or more responses. Therefore, the number of intervals having a single response affects only the first point of each curve. Changes in the number of intervals having a single response would not affect the conclusions drawn here. Other studies performed in this laboratory with the same apparatus and employing the same general procedure, but with variations on FI schedules of reinforcement, produced much lower numbers of intervals with one response. The number of single-response intervals therefore seems to derive from the particulars of the schedule.

The present data do not demonstrate that probability of reinforcement actually is a controlling variable. They merely document that possibility. In the analysis of performance under FI schedules, relatively more attention has been paid to the temporal dimension and less to ordinal position of response. So, too, has correspondingly more attention been given to rate of reinforcement and less to reinforcement probability. There remains to be analyzed the dynamics of the process by which the reinforcement probabilities and the response patterns come to have the characteristics they do and the implications this might have for the explanation of fixed-interval performance.

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