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INTERRESPONSE TIME DURATION IN FIXED-INTERVAL SCHEDULES OF REINFORCEMENT: CONTROL BY ORDINAL POSITION AND TIME SINCE REINFORCEMENT[1]

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The times between each of the first thirteen responses after reinforcement (the first twelve interresponse times) were determined for two pigeons whose pecking was reinforced on fixed-interval schedules of food reinforcement ranging from 0.5 min to 5 min. These interresponse times were classified with respect to their ordinal position in the sequence of responses and with respect to the time since the preceding reinforcement at which the initiating response occurred. The median interresponse time durations were essentially constant after the sixth response after reinforcement regardless of the time at which the interresponse time was initiated. The durations of the first few interresponse times after reinforcement decreased as the number of preceding responses increased and as the time since the preceding reinforcement increased.

On a fixed-interval (FI) schedule of reinforcement, the first response after an interval of time has elapsed since some event is reinforced. Usually the event that initiates the FI is the termination of the preceding reinforcement. The performance generated by FI schedules consist of a pause after reinforcement followed by an acceleration to a high rate of responding until the next reinforcement. Several investigators have attributed the accelerating response rate during the FI to a temporal discrimination (Skinner, 1938; Ferster, and Skinner, 1957). That is, response rates are thought to increase as the interval elapses because the stimuli mediating the temporal discrimination become increasingly more like stimuli at the moment of reinforcement. An extension of this analysis has been offered by Dews (1962). According to Dews' (1962) formulation, the accelerating response rates throughout the interval result from different delays of reinforcement for responses at different points in the interval. Responses made later in the interval have shorter delays of reinforcement and so are strengthened more than responses made earlier. Both positions assert that response rate is controlled by the passage of time in the interval.

An alternative possibility is that the acceleration in response rate during the FI is only spuriously correlated with the amount of time that has elapsed since the preceding reinforcement. Instead, the response rate may be controlled directly by the number of responses previously made since reinforcement. Although more than one response is not required for reinforcement on FI schedules, usually more than one response is emitted in each interval. 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. The accelerating response rate might reflect the more favorable conditions prevailing as the number of preceding responses increases. Likewise, the acceleration might reflect a warm-up effect—it might take so many responses for responding to occur at the maximum rate. If so, the period of acceleration should be independent of reinforcement and schedule parameters.

Thus, response rate in FI schedules could be controlled by the amount of time that has elapsed since the preceding reinforcement or by the number of responses made since reinforcement or both. Stated in terms of the amount of time between consecutive responses (IRTs) rather than response rate, the duration of an IRT in an FI schedule can depend either on the time in the interval at which the IRT is

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initiated or on the ordinal position in the sequence of responses of the response initiating the IRT. In any single interval, the first response occurs earlier than the second, which occurs earlier than the third and so on. Consequently, in a single interval it is impossible to determine whether the acceleration in response rate is determined by the passage of time or by the number of preceding responses. However, because of variability in responding from one interval to the next, it is possible to find intervals in which a particular ordinal IRT is initiated soon after reinforcement and other intervals in which the same ordinal IRT is initiated at a later time after reinforcement. If response rate is controlled solely by the number of preceding responses, the duration of a particular ordinal IRT should be the same regardless of its time of initiation. Conversely, if time since the preceding reinforcement alone controls response rate, the duration of an IRT should depend on its time of initiation and be independent of its ordinal position in the response sequence.

The present study determined the extent to which the duration of an IRT is controlled by its time of initiation since the preceding reinforcement and by the number of preceding responses. The logic of the analysis was as follows. Each response in a given interreinforcement interval was indexed with respect to the time since the preceding reinforcement and the ordinal position of that response in the interval. The IRT initiated by each response was associated with the two indices of that response. Thus, from a number of interreinforcement intervals separate IRT distributions were obtained for each ordinal IRT as a function of time since reinforcement.

METHOD

Subjects

Two adult male Silver King pigeons obtained from Palmetto Pigeon Plant were maintained at approximately 80% of their free-feeding weight. Both had previous experience with fixed-interval schedules of reinforcement.

Apparatus

The experimental chamber was enclosed in an ice chest. A ventilating fan provided masking noise. A translucent plastic response key was mounted 8.5 in. (216 mm) above the floor behind a 0.75 in. (19 mm) diameter hole through one wall of the chamber. When the key was transilluminated by a blue light, a force exceeding 20 g (0.196N) applied to the key broke an electrical contact which operated control and recording circuits and also produced a click by activating a relay mounted behind the front wall of the chamber. The key was disconnected from the control circuit when darkened. The reinforcing event was a 5-sec presentation of mixed grain, which was accessible through an opening below the key. When grain was available, the feeder opening was illuminated and the key darkened. The only sources of illumination in the chamber were the key light and the feeder light. Power for the key light was obtained from a transformer isolated from the main power supply.

A Lehigh Valley #1321 multi-pen event recorder running at a speed of 18 in. per min (457.2 mm per min) was used to record interresponse times.

Procedure

Throughout the experiment the schedule was a fixed-interval schedule of grain reinforcement. That is, a response was followed by grain only after a specified amount of time had elapsed since the termination of the preceding reinforcement. P1 was exposed to three different FI values: FI 1-min (82 sessions); FI 0.5-min (37 sessions) and FI 5-min (60 sessions) in that order. P2 was exposed to FI 1-min (71 sessions) and FI 5-min (60 sessions) in that order.

Sessions were scheduled daily. Each session contained 61 reinforcements and terminated automatically at the end of the sixty-first. Data were not recorded until after the first reinforcement had been obtained in a session.

RESULTS

A. Analysis of Data

Event records of responding were taken on the last five sessions under each FI value. From these records the time from reinforcement until the first response after reinforcement and the time elapsing between each of the next 12 responses (*i.e.*, the first 12 IRTs) were determined to the nearest fourth second for each interval in the session. The first IRT was the time between the first two responses after the preceding reinforcement, not the time between reinforcement and the first response after reinforcement.

In the analysis of the data, the time since the preceding reinforcement at which an IRT was initiated was grouped into five class intervals consisting of successive fifths of the programmed interval. Each IRT was placed in the appropriate cell of the matrix formed by the five values of time since the preceding reinforcement and the 12 values of the ordinal position of the IRT. The data presented are based on cells that contained a minimum of 20 IRTs. The maximum possible was 300 IRTs in a single cell. The actual number of IRTs in a particular cell ranged from 21 to 166. The IRTs within a given cell were rank ordered with respect to duration and arranged in the form of a cumulative frequency distribution. For purposes of analysis, the IRT duration corresponding to the twenty-fifth, fiftieth, and seventy-fifth percentile of the cumulative frequency distribution (*i.e.*, the median and interquartile range values) were obtained for each combination of time of initiation and ordinal position.

B. Presentation of Data

Figure 1 shows the durations of the first IRT and the twelfth IRT as functions of time since the preceding reinforcement for both birds on each of the FI schedules. The median duration of the first IRT generally decreased as a function of time since the preceding reinforcement. The seventy-fifth percentile duration shows an even more consistent decrease, while the twenty-fifth percentile duration is virtually constant across all times of initiation. By contrast, the median and seventy-fifth percentile durations of the twelfth IRT were essentially equal regardless of the time of initiation. The overall shorter duration and the smaller interquartile range of the twelfth IRT compared with the first IRT indicate control by ordinal position at each time since the preceding reinforcement. The twenty-fifth percentile durations were essentially equal for both the first and twelfth IRTs and constant across all times of initiation. None of these effects was related in any obvious way to FI duration.

Figure 2 presents median IRT duration as a function of both ordinal position and time since the preceding reinforcement for both birds on the FI 1-min schedule. The first, second, third, sixth, and twelfth IRTs are presented. At each time since the preceding reinforcement, median IRT duration for both birds decreases as a function of the ordinal position of the IRT until about the sixth IRT. After the sixth IRT there is no correlation between IRT value and ordinal position. For P1 there is little evidence of control by time since the preceding reinforcement. For P2 there is stronger evidence of temporal control of IRT duration: For the first few IRTs, the median IRT duration decreased as the time since the preceding reinforcement at which the IRT was initiated increased. However, the sixth and twelfth IRT durations were constant regardless of the time of initiation. Thus, the sixth and twelfth IRTs were independent of both time of initiation and ordinal position. Figure 3 presents analogous data for P1 and P2 on the FI 5-min schedule. The data for P1 reveal no control either by time of initiation

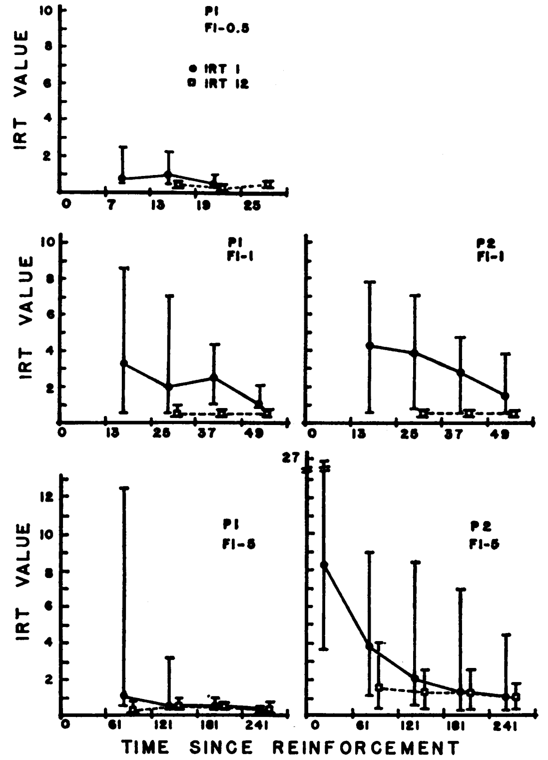

Fig. 1. The duration of the first and twelfth IRT plotted over time since the preceding reinforcement at which the IRT was initiated. The numbers on both axes refer to seconds. Median IRT durations are bracketed by the interquartile range values. Time since the preceding reinforcement represent successive fifths of the FI schedule. As indicated, the FI schedule duration ranged from 0.5 min to 5 min.

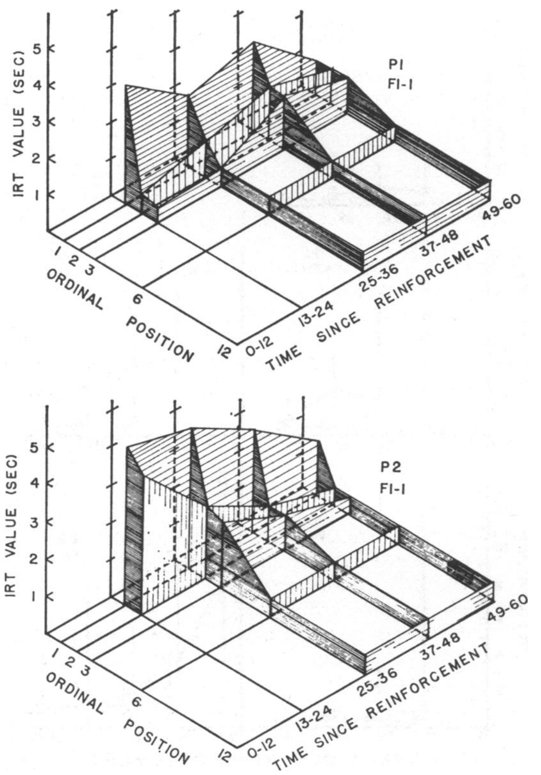

Fig. 2. Median IRT duration plotted over time since the preceding reinforcement at which the IRT was initiated and the ordinal position of the initiating response. The data are for P1 and P2 on the FI 1-min schedule of reinforcement. The numbers for time since reinforcement refer to seconds.

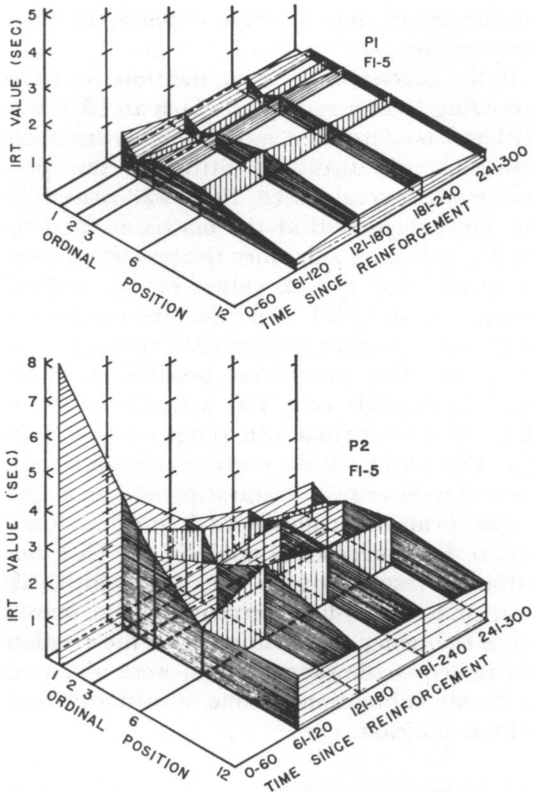

Fig. 3. Median IRT duration plotted over time since the preceding reinforcement at which the IRT was initiated and the ordinal position of the initiating response. The data are for P1 and P2 on the FI 5-min schedule of reinforcement. The numbers for time since reinforcement refer to seconds.

or by ordinal position. The data for P2 show control by time of initiation and by ordinal position for the first few IRTs only. Analogous data for P1 under the FI 0.5-min schedule (not shown) revealed little control over median IRT duration by either dimension.

DISCUSSION

With the FI schedules studied, median IRT durations were essentially constant after the sixth IRT regardless of the time since the preceding reinforcement at which the IRT was initiated. Since P1 made an average of 147 responses per interval on the FI 5-min schedule, and P2 made an average of 104 responses per interval on the FI 5-min schedule (median values based on the last five sessions), the correlation of IRT duration with either time of initiation or ordinal position involves a very small portion of the total responding in the interval. In addition, there was no evidence of more extensive periods of accelerated response rates with the longest FI schedules. Such data are consistent with descriptions of FI performance as two-state (Schneider, 1969) or break-and-run (Skinner, 1953; Cumming and Schoenfeld, 1958; Sherman, 1959; Mechner, Guevrekian, and Mechner, 1963; Staddon, 1967). The implications of such data are clear: an adequate theory of FI performance does not have to provide a mechanism to account for decreasing IRT durations throughout the FI.

The few IRTs that did change systematically were controlled both by time of initiation and by ordinal position. If one wished to postulate a stimulus dimension associated with ordinal position, responding on FI schedules could be considered to be under multi-dimensional control with at least time since the preceding reinforcement and number of preceding responses as two of the dimensions. Since number of responses has been shown to function as a discriminable dimension in other contexts (Mechner, 1958; Rilling and McDiarmid, 1965; Pliskoff and Goldiamond, 1966; Rilling, 1967), such an account seems plausible. However, in the context of FI schedules, the shorter IRT durations associated with the higher ordinal values need not be considered a consequence of stimulus factors at all. They might result from response factors such as warm-up, topographical adjustments, etc. The fact that the extent of the accelerating response rate was independent of the FI duration supports this latter view. It is also significant that a reduction in IRT duration for the first few responses after reinforcement followed by relatively constant IRT durations has been noted with variable-interval and variable-ratio schedules (Kintsch, 1965). It would appear that a reduction in duration of the first few IRTs after reinforcement is characteristic of several reinforcement schedules and not limited to situations favoring the development of temporal discriminations.

The control over IRT duration by the number of preceding responses might seem to contradict Dews' (1962) observation that the pattern of responding on FI schedules remains intact even when the on-going sequence of responses is interrupted. However, differences in the level of analysis make comparisons between the present study and Dews' study difficult. Dews was concerned with a gross analysis of responding throughout the interval, whereas the present study reported a fine-grained analysis of individual IRTs.

Lastly, the systematic changes in IRT duration did not result from shifts in the entire IRT distribution, since a significant portion of the distribution (at least the lower 25%) was essentially constant over all values of time since reinforcement and ordinal position. Instead, the greatest change in IRT duration resulted from changes in the frequency and length of the longer IRTs. Similar differential effects of factors on long IRTs relative to short IRTs have been reported in other situations (Blough, 1963; Schaub, 1967).

REFERENCES

Blough, D. S. Interresponse time as a function of continuous variables: a new method and some data. *Journal of the Experimental Analysis of Behavior,* 1963, **6,** 237-246.

Cumming, W. W. and Schoenfeld, W. N. Behavior under extended exposure to a high-value fixed interval reinforcement schedule. *Journal of the Experimental Analysis of Behavior,* 1958, **1,** 245-263.

Dews, P. B. The effect of multiple S^{Δ} periods on responding on a fixed-interval schedule. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 369-374.

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

Kintsch, W. Frequency distribution of interresponse times during VI and VR reinforcement. *Journal of the Experimental Analysis of Behavior,* 1965, **8,** 347-352.

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

Mechner, F., Guevrekian, L., and Mechner, V. A fixed-interval schedule in which the interval is initiated by a response. *Journal of the Experimental Analysis of Behavior,* 1963, **6,** 323-330.

Pliskoff, S. S. and Goldiamond, I. Some discriminative properties of fixed ratio performance in the pigeon. *Journal of the Experimental Analysis of Behavior,* 1966, **9,** 1-9.

Rilling, M. Number of responses as a stimulus in fixed interval and fixed ratio schedules. *Journal of Comparative and Physiological Psychology,* 1967, **63,** 60-65.

Rilling, M. and McDiarmid, C. Signal detection in fixed-ratio schedules. *Science,* 1965, **148,** 526-527.

Schneider, B. A. A two-state analysis of fixed-interval responding in the pigeon. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 677-687.

Schaub, R. E. Analysis of interresponse times with small class intervals. *Psychological Record,* 1967, **17,** 81-89.

Sherman, J. G. *The temporal distribution of responses on fixed interval schedules.* Unpublished doctoral dissertation, Columbia University, 1959.

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

Skinner, B. F. Some contributions of an experimental analysis of behavior to psychology as a whole. *American Psychologist,* 1953, **8,** 69-78.

Staddon, J. E. R. Attention and temporal discrimination: factors controlling responding under a cyclic-interval schedule. *Journal of the Experimental Analysis of Behavior,* 1967, **10,** 349-359.

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