

*THE DISTRIBUTION OF INTERRESPONSE TIMES IN
THE PIGEON DURING VARIABLE-INTERVAL
REINFORCEMENT¹*

PATRICIA M. BLOUGH AND DONALD S. BLOUGH

BROWN UNIVERSITY

Three pigeons' pecks were reinforced on 1- and 2-min variable-interval schedules, and frequency distributions of their interresponse times (IRTs) were recorded. The conditional probability that a response would fall into any IRT category was estimated by the inter-response-times-per-opportunity transformation (IRTs/op). The resulting functions were notable chiefly for the relatively low probability of IRTs in the 0.2- to 0.3-sec range; in other respects they varied within and between subjects. The overall level of the curves generally rose over the course of 32 experimental hours, but their shapes changed unsystematically. The shape of the IRT distribution was much the same for VI 1-min and VI 2-min. The variability of these distributions supports the notion that the VI schedule only loosely controls response rate, permitting wide latitude to adventitious effects. There was no systematic evidence that curves changed over sessions to conform to the distribution of reinforcements by IRT.

There is good reason to believe that the performance of animal subjects on various schedules of reinforcement depends in part upon the specific characteristics of the reinforced response. One conveniently measured characteristic that has proved meaningful is time since last response (interresponse time or IRT). Yet there is little information about the distributions of interresponse times emitted by a common subject, the pigeon, working on the schedule most often used to generate an operant baseline, the variable interval (VI). Overall VI rates tend to drift and to vary among birds but the manner in which IRT distributions reflect this variability needs investigation. The present paper describes research designed to produce such distributions and to show how they change over the course of time.

METHOD

Subjects

Three White Carneaux pigeons, experimentally naive at the beginning of the study,

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were maintained at approximately 75% of their free-feeding weight.

Apparatus

The experimental boxes, manufactured by Grason-Stadler Co., contained single response keys, which closed on application of about 14-g force. During an experimental session, monochromatic light at 570 μ m illuminated a 0.25-in. spot centered on the otherwise dark key. This light went out during reinforcement, and a light in the food magazine compartment went on. There was no other illumination in the experimental chamber.

A LINC computer (Clark and Molnar, 1964) controlled the experiment and analyzed the data. Three Gerbrands recorders kept cumulative records of the birds' responses independently of the computer.

Procedure

A special schedule shaped the birds' VI performance by moving in steps from continuous reinforcement through 30-sec and 1-min VI's to a VI 2-min schedule. The step to each new schedule occurred when the bird had maintained a steady rate of responding (no IRT greater than 16 sec) for a given period of time. When an IRT greater than 16 sec did occur, reinforcement was set up, and the schedule changed one step backwards; that is, to a VI with a shorter average reinforce-

ment interval. Daily sessions on this special schedule lasted 1 hr or until 59 reinforcements occurred.

Each VI schedule was made up of 20 interval values, arranged in a randomized sequence. The values of the interreinforcement intervals, drawn from a distribution described by Flesher and Hoffman (1962), yield an approximately constant probability of reinforcement with respect to time since reinforcement. The interval values (in seconds) and the order in which they occurred were as follows: for VI 1-min—4.6, 133.1, 23.6, 38.7, 77.5, 1.4, 19.3, 67.5, 51.3, 89.5, 8.1, 28.2, 125.0, 11.6, 25.3, 104.8, 15.4, 38.4, 59.0, 237.7; for VI 2-min—24.6, 3.0, 471.5, 135.0, 250.1, 23.1, 179.2, 102.8, 210.0, 77.3, 30.6, 38.6, 89.4, 47.1, 66.6, 56.5, 16.2, 313.2, 118.0, 8.9.

After initial shaping for 11 sessions, the birds were on a VI 1-min schedule for 32 days. Each daily session lasted 1 hr. At this time, response rates appeared to be stable, and the schedule was shifted to a VI 2-min. The birds were on this condition for 17 days, and, since their rates again appeared to be stable, the experiment was terminated.

The computer recorded each response for each bird by its IRT, coded according to whether or not it had been reinforced. Further data analysis excluded responses following reinforced responses. It also eliminated the few that occurred while the computer was writing data on tape, an event that occupied about 1 sec and took place about every 1.5 min during a session. Responses made during the first 1.5 to 2 min of the session were also omitted.

RESULTS AND DISCUSSION

Overall performance was similar to that reported by Ferster and Skinner (1957). The cumulative records showed generally steady, moderate rates of response, with a gradual rise in rate over the experimental sessions.

Figure 1 shows the distribution of IRTs by 0.1-sec bins for VI 2-min. The graph does not include IRTs greater than 2 sec, but only a small percentage of the responses fell into this category. For all three birds, these distributions are characterized by sharp peaks and valleys in the left-hand portion and by the fact that most responses had relatively short IRTs.

Figure 2 shows the same data, but plots interresponse times per opportunity (IRTs/op)

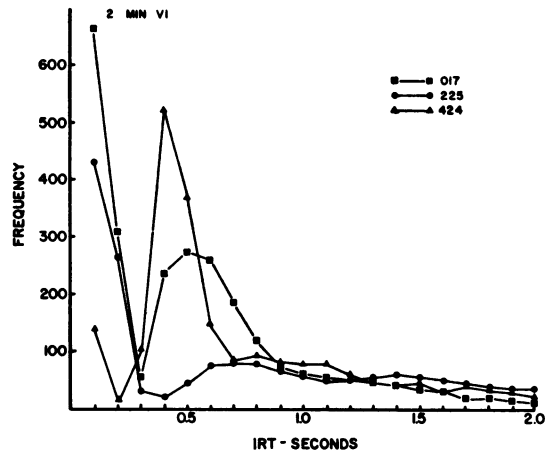


Fig. 1. The distribution of IRTs by 0.1-sec bins during VI 2-min reinforcement. Each point represents one half the total responses per bin averaged over six sessions.

on the ordinate. This transformation estimates the conditional probability of a response, given that a specified time has elapsed since the preceding response. IRTs/op values are calculated by dividing the number of responses in each bin by the total number of responses in that bin and all bins containing longer IRTs (Anger, 1956). The points here are all based on a minimum of 20 opportunities. A constant IRTs/op—graphically, a horizontal line—would indicate that response probability is unaffected by the time since the preceding response. As Fig. 2 shows, this is far from the case in the present results, which are distinguished by peaks and valleys as in Fig. 1.

It is evident from Fig. 2 that the stable overall rate of each bird concealed an irregular

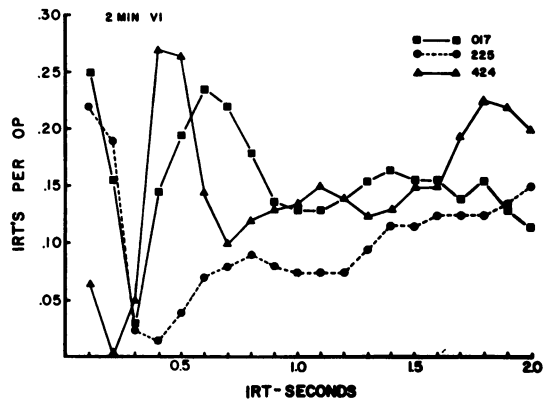


Fig. 2. The distribution of IRTs/op by 0.1-sec IRT bins during VI 2-min reinforcement. For each bird, points are means taken over six days.

and idiosyncratic distribution of interresponse times. The relatively high incidence of certain IRTs suggests the existence of response interdependence, with rate to some extent dependent upon stereotyped behavior patterns. The results of a series of runs tests (Siegel, 1956) support the notion of interdependent IRTs. IRTs were dichotomized into "short" and "long" and the number of runs in the resulting sequence was compared to the number expected by chance. This test was run on data from four of the last six sessions, under both VI 1-min and VI 2-min conditions, for all birds. The test was applied twice to these samples, once with "short IRT" meaning "less than 0.3 sec", once with "short IRT" meaning "less than 0.6 sec" and with "long" including the remaining IRTs. Of a total of 12 tests, 11 showed significantly too few runs ($p < 0.05$). This indicates a tendency for short IRTs to follow short, and long to follow long.

Blough (1966) described a reinforcement schedule designed to yield regular IRT distributions and discourage interresponse dependence. This schedule, the "reinforcement of least-frequent interresponse times" ("LF") schedule, favored a random distribution of IRTs. His method was to reinforce those IRTs that occurred less frequently than they would if the bird were responding randomly in time, and never reinforcing those IRTs that occurred more frequently than they should. The IRT distributions thus produced also had peaks at short IRTs, but beyond about 0.6 sec IRTs/op was approximately constant, as one would expect from randomly distributed IRTs. The present VI data are more variable, both within and between birds; in two cases, the IRTs/op function rose with increasing IRT.

A feature of the VI distributions common to all three birds is the existence of one or two sharp peaks at very short IRTs. One way to view such short IRTs is to consider them the second elements of "double-peck" units, which may be seen as topographic variants of the single peck. Considering short IRT responses as parts of such units, one would not expect them to be independently sensitive to schedule and stimulus parameters, as indeed they seem not to be. For example, short IRTs frequently occur in schedules where they are never reinforced, such as the DRL and Blough's version of the LF schedule (1966), and they yield flat

generalization gradients (Blough, 1963). Correspondingly, variables that might affect topography would be expected to affect the short IRTs. In this regard, it is interesting to note that Shimp (1967) recorded few IRTs of less than 0.3 sec from birds on VI 1-min, but he used a response key less sensitive than that used here; it required about 22-g force rather than the present 14 g.

Figures 3, 4, and 5 show the IRTs/op curve (solid lines) for VI 1-min over the course

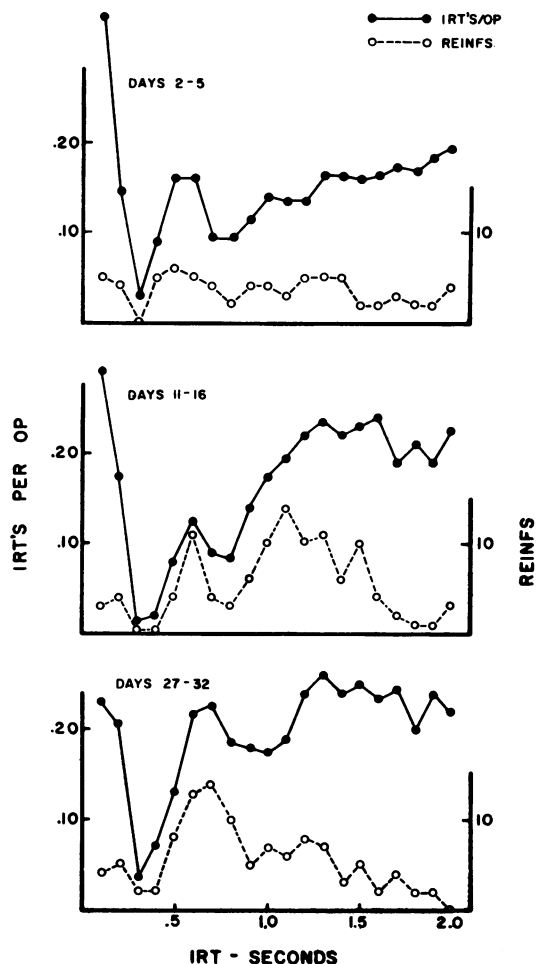


Fig. 3. Solid lines show the distribution of IRTs/op by 0.1-sec bins during VI 1-min for Bird 017. The points in the top graph are means taken over four hourly sessions. For the other two graphs, the points are based on six sessions. Dashed lines show the distribution of reinforcements summed over the corresponding sessions. These curves should be inspected for shape only, since the one at the top is based on sums over fewer sessions than the other two. The three sections of the graph are arranged in order of days elapsed since initial session on VI 1-min.

of the experiment. The dashed lines represent the distribution of reinforcements over corresponding sessions. In each set of graphs, the top pair of curves show data from the second through the fifth day after the birds had started on the standard VI 1-min schedule. (This excludes about 11 hr of prior experience on the shaping program described above.) The lower pairs of curves show later performances, as indicated by their dates.

curves seem to change in the opposite direction. There are many possible reasons for the differences between these findings and Anger's: the difference in species (Anger used rats), the difference in the type of VI (Anger used a VI 5-min), the distribution of reinforced intervals, the difference in the range of IRTs shown (Anger's data went to IRTs of 20 sec or more), and the fact that Anger's early curves were based evidently on an earlier stage in VI training.

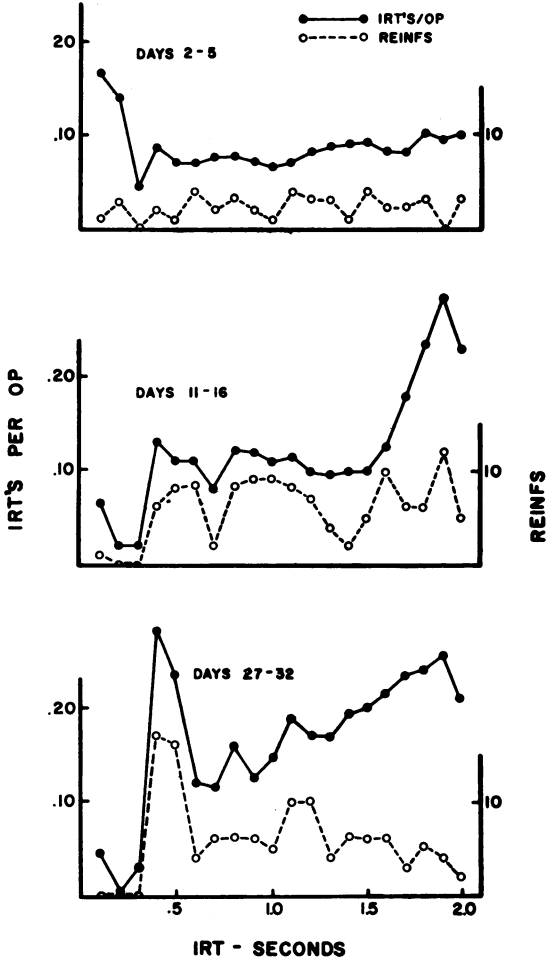


Fig. 4. Bird 225. Curves correspond to those in Fig. 3.

The only systematic effect of VI experience seems to be upon the height of the distributions, with the later curves indicating a higher probability of response. The shape of the distribution appears to drift differently for each bird. There is no evidence of the phenomenon described by Anger: the change over time from a flat curve to one that falls off at the longer bins. If anything, the present

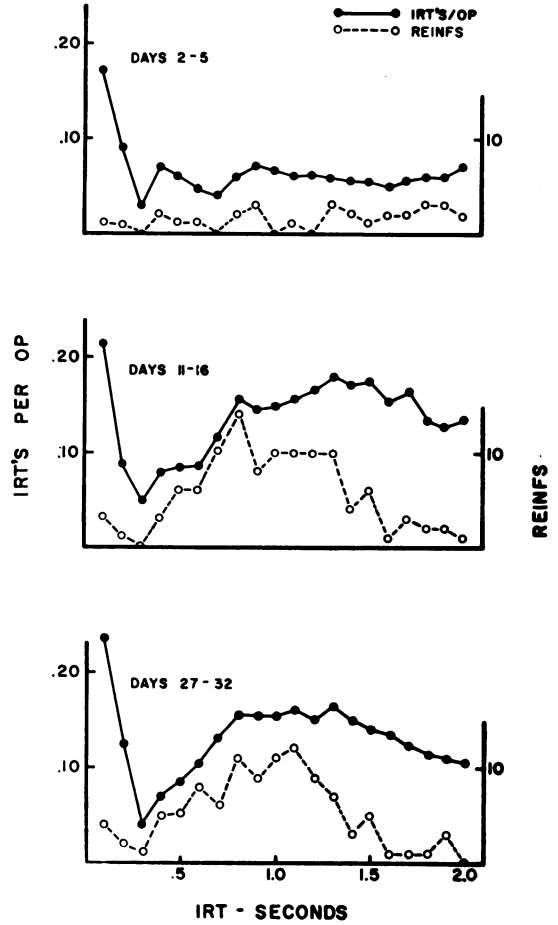


Fig. 5. Bird 424. Curves correspond to those in Fig. 3.

The distributions of reinforcements shown in these figures bear on the relationship between this variable and IRTs/op. Anger hypothesizes a circular effect in which the reinforcement distribution not only depends on the IRTs/op distribution, but also affects it. The first half of this relationship is a mathematical necessity, since, on a VI schedule, the probability of reinforcement at a given IRT bin

must increase with the number of responses in that bin. The second half of the relationship is not necessary, however; and its demonstration would require empirical evidence of an effect on IRTs/op of the reinforcement distribution. In other words, one might expect the pigeon to respond more at the IRTs that had in the past been reinforced more frequently. Anger noted such an effect in the tendency over the course of time of the IRTs/op distribution to approximate the distribution of reinforcements per hour. Such an effect is not evident in the present data.

By appropriate comparisons between the curves in Fig. 1 and those in Fig. 3, 4, and 5, it is possible to note the effect of total reinforcements per hour on the IRTs/op distribution. During the VI 2-min shown in Fig. 1, the birds received just a little more than half the reinforcements they had received during VI 1-min in an hourly session. With fewer total reinforcements, Anger predicted a shift to the right in the peak of the reinforcements-per-hour curve and a corresponding shift in the IRTs/op distribution. The present data show no such effect.

The present data suggest that a highly variable distribution of IRTs underlies the rela-

tively regular overall response rate produced by a VI schedule. They suggest further that response rate does not depend entirely on external variables, but that it is also controlled by such factors as response topography and internal stimuli produced by on-going behavior.

REFERENCES

- Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. *J. exp. Psychol.*, 1956, **52**, 145-161.
- Blough, D. S. Interresponse time as a function of continuous variables: a new method and some data. *J. exp. Anal. Behav.*, 1963, **6**, 237-246.
- Blough, D. S. The reinforcement of least-frequent interresponse times. *J. exp. Anal. Behav.*, 1966, **9**, 581-591.
- Clark, W. A. and Molnar, C. E. The LINC: A description of the Laboratory Instrument Computer. *Ann. N.Y. Acad. Sci.*, 1964, **115**, Art. 2, 653-668.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Fleshler, M. and Hoffman, H. S. A progression for generating variable-interval schedules, *J. exp. Anal. Behav.*, 1962, **5**, 347-352.
- Shimp, C. The reinforcement of short interresponse times. *J. exp. Anal. Behav.*, 1967, **10**, 425-434.

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