

SUCCESSIVE INTERRESPONSE TIMES IN FIXED-RATIO AND SECOND-ORDER FIXED-RATIO PERFORMANCE¹

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Three rats were trained on a schedule in which every sixth response produced a timeout of 5 sec minimum duration, and food was delivered at the onset of timeout. Successive inter-response times were measured under these conditions, and also when behavior was maintained by second-order fixed-ratio and fixed-interval schedules. Under the second-order schedules, each six-response fixed-ratio component was followed by a timeout, and occasionally food was delivered at the onset of a timeout. In the fixed-ratio schedule, the successive interresponse times showed a decrease followed by an increase before food delivery, but this systematic variation in interresponse times was not found when the performance was under second-order reinforcement. Under both second-order schedules the latencies of successive components, and the successive interresponse times within each component, showed a decrease as food delivery was approached.

In a second-order schedule, a schedule-controlled pattern of responding is treated as a unitary response and is itself reinforced according to some schedule of reinforcement (Kelleher, 1966a). Kelleher (1966b) reported that when food presentation followed the first fixed-ratio (FR) 20 component completed after 10 min (fixed-interval 10-min), the temporal patterning of the second-order components was similar to the patterning of individual responses under a fixed-interval (FI) schedule. The latency of the initial response in each component decreased throughout the 10-min interval, but the interresponse times (IRTs) of the other responses comprising each second-order FR component remained constant. Kelleher (1958) also examined responding in the chimpanzee when a token was delivered after each FR component and a fixed number of tokens was required to exchange for food. Performance during the sequence of components was similar to the usual pattern of FR responding under long ratios. Further research (Findley and Brady, 1965; Thomas and Stubbs, 1967) has also shown similarities between responding during individual components and responding during sequences of

components. On the basis of such results, Kelleher (1966a) and Morse (1966) have suggested that second-order schedule performances may be useful in the analysis of schedule control.

The present experiment examined performance maintained by fixed-ratio schedules and by second-order schedules comprising fixed-ratio schedule components. Successive IRTs were measured under a FR schedule and under second-order FR and FI schedules comprising fixed-ratio components. In the terminology of Kelleher (1966a), the schedules used were FR 6:S, FR 6(FR 6:S) and—FI 1-min (FR 6:S).

METHOD

Subjects

Three experimentally naive female albino rats, three months old at the beginning of experimentation, were maintained at 80% of their free-feeding body weights.

Apparatus

Experimental contingencies were controlled by remotely placed Grason-Stadler electromechanical equipment. The experimental chamber (Grason-Stadler E3125B, with only one lever operative) was placed in a sound-attenuating box. Chamber illumination was provided by a 10-w houselight. Reinforcement consisted of a single 45-mg Noyes food pellet and supplementary feeding was given after

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each session. Water was available in the experimental chamber.

Interresponse times were measured by delivering pulses (17 per sec) from a Hunter timer into a Grason-Stadler class-time analyzer. Pulses occurring between consecutive bar presses were counted and written down by the experimenter during the timeout after each run of six responses.

Procedure

Experimental sessions were conducted daily and were terminated after 150 reinforcements or after 120 min, whichever occurred first. After magazine training and bar-press shaping, one training session was given in which each response was followed by food delivery. During the next two sessions every sixth response was followed by food delivery. Thereafter, a timeout period was scheduled to occur after every sixth response and food was delivered at the onset of each timeout. During timeout, the houselight, which provided the entire chamber illumination, was extinguished and responses served only to reset the timeout duration to 5 sec. The scheduled duration of the timeout was initially small and was gradually extended to 5 sec over three sessions to minimize any contrast effects.

Under all procedures, a minimum 5-sec timeout followed every sixth response emitted in the presence of the houselight. Under the FR 6:S procedure, a food pellet was delivered at the onset of each timeout; under the FR 6(FR 6:S) procedure, a food pellet was delivered at the onset of every sixth timeout; and under the FI 1-min(FR 6:S) procedure, a food pellet was delivered only at the onset of the first timeout occurring after 1 min had elapsed since the previous food delivery. For all animals, the sequence of experimental conditions was FR 6:S, FR 6(FR 6:S) and FI 1-min(FR 6:S). Training under each condition continued until the cumulative records indicated stable performance. Usually, 40 to 60 sessions were required to obtain stability.

Data on successive IRTs were recorded in the final three sessions under each experimental condition. In the first condition (FR 6:S), data were taken at three periods in the session: up to the twentieth reinforcement, from the fiftieth to the seventieth reinforcement, and from the one-hundredth to the one-hundred twentieth reinforcement. In the

second condition, FR 6(FR 6:S), data were taken up to the twentieth reinforcement only, and in the third, FI 1-min(FR 6:S), up to the twenty-fifth reinforcement only.

RESULTS

The performance of Subject 46 was characteristic of the rates and patterns of responding under the three schedules (Fig. 1). Overall response rates were highest under FR 6:S and lowest under FI 1-min(FR 6:S) and, apart from the different durations of pausing, before emitting the first response after timeout, the pattern of responding within FR 6 components appears similar in each schedule. Response rates during timeout were lowest under the FR 6:S procedure and highest under the FR 6(FR 6:S) procedure (Table 1). Under the fixed-ratio schedule, responses seldom occurred during the first 3 to 4 sec of timeout, but under the second-order schedules responding was at its maximum in the first 3 to 4 sec.

Because the data were biased towards short IRTs and were not distributed normally, the data were normalized using a logarithmic transformation. In all cases logarithmic means of the IRTs are reported.

Under the FR 6:S procedure, the latency of the initial response of each fixed-ratio, *i.e.*, the time elapsing between the end of timeout and the first response of the next ratio, was longer

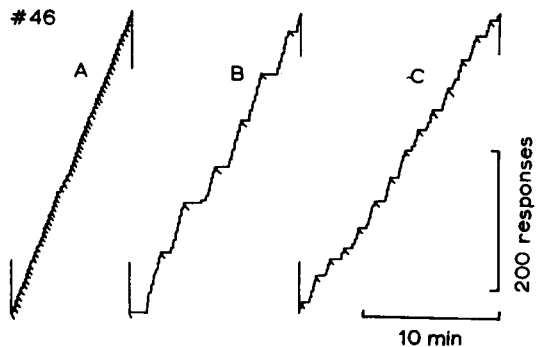


Fig. 1. Retraced cumulative records of the performance of Subject 46 under three schedules of reinforcement in which every sixth response produced a timeout and: (A) food was delivered at the onset of each timeout, (B) food was delivered at the onset of every sixth timeout, and (C) food was delivered at the onset of the first timeout occurring after 1 min had elapsed since the previous food delivery. Responses during each timeout reset the timeout duration to 5 sec. The delivery of food is shown by an oblique slash, and the recorder was operative during timeout.

Table 1

Mean rates of responding (per minute) during timeout in the final three training sessions under each experimental condition. Responses during timeout reset the timeout duration to 5 sec.

Animal	FR 6:S	FR 6 (FR 6:S)	FI 1-min (FR 6:S)
8	1.5	21.8	9.5
46	6.0	36.9	19.5
48	2.8	41.2	19.6

than the IRTs of the remaining responses (Fig. 2). The shortest IRT was either the second, third, or fourth response. Data from the three periods in the last three sessions were combined when changes in performance during the session were found to be small. Each

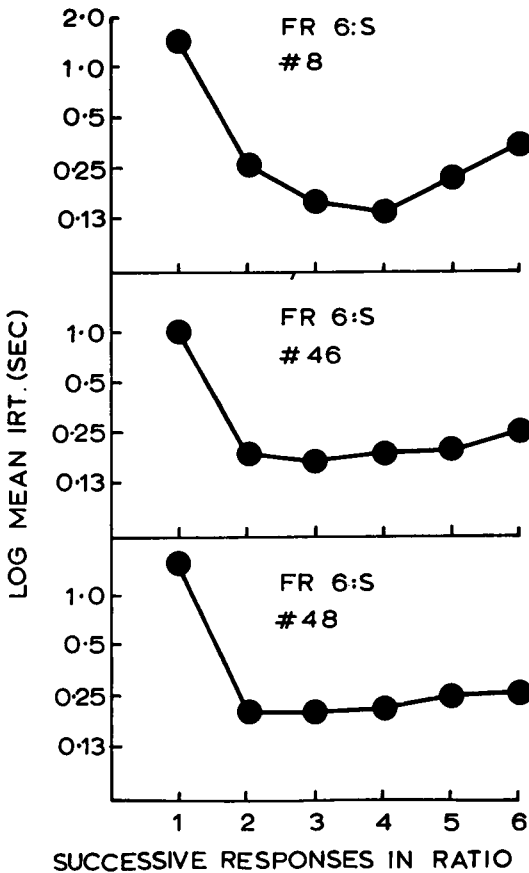


Fig. 2. Logarithmic mean interresponse times of successive responses when every sixth response produced timeout and food was delivered at the onset of each timeout. Responses during each timeout reset the timeout duration to 5 sec.

point plotted in Fig. 2 shows the logarithmic mean of 180 measures.

When food delivery occurred only at the onset of every sixth timeout, the latency of the initial response of each second-order FR component was still longer than the remaining IRTs in the component. The IRTs, however, tended to be of uniform length within each component under this procedure (Fig. 3). The latency of second-order FR components progressively decreased through the sequence of six components (Fig. 4) and, similarly, all IRTs tended to be longest in the first component and to decrease in each successive component.

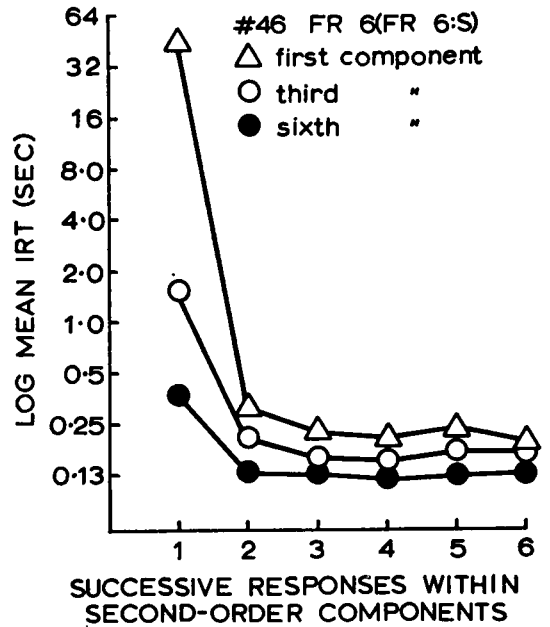


Fig. 3. Successive interresponse times within the first, third, and sixth second-order FR components when a timeout followed every sixth response and food was delivered only at the onset of every sixth timeout. Responses during each timeout reset the timeout duration to 5 sec.

Performance under the FI 1-min(FR 6:S) procedure was similar to performance under the FR 6(FR 6:S) procedure. The latency of the initial response in each second-order FR component was longer than the IRTs of the remaining responses, which tended to be of uniform length. In each sequence of components, IRTs were longest during the first component and decreased with each successive component (Fig. 5). In all subjects, the latency

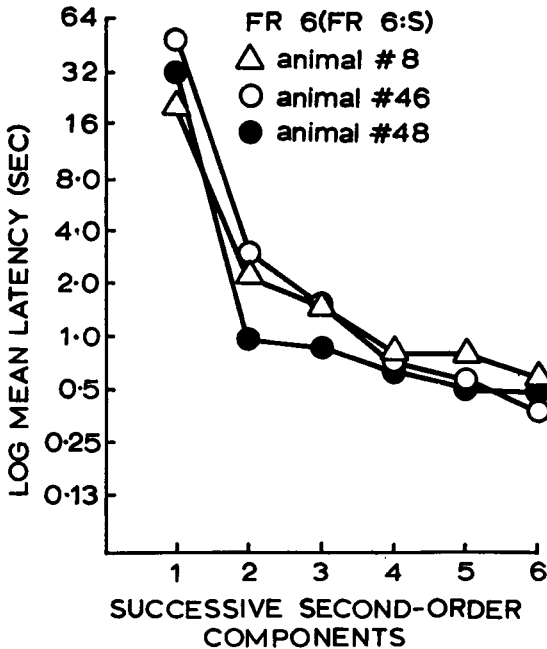


Fig. 4. Latencies of initial responses of successive second-order FR components comprising a schedule in which a timeout followed every sixth response and food was delivered only at the onset of every sixth timeout. Responses during each timeout reset the timeout duration to 5 sec.

of second-order FR components also decreased through each sequence of components (Fig. 6).

DISCUSSION

Successive responses during the terminal run of FR performance usually have a short and constant IRT (Ferster and Skinner, 1957). Such a description of FR performance is supported by Blough's (1963) analysis of the successive IRTs emitted by a pigeon on the second day of training under FR 25. The present experiment, and the results of Davison (1968), have shown a decrease in IRT followed by an increase before reinforcement in successive responses emitted under FR 6:S. A similar pattern of responding may be seen in the data reported by Richardson and Donahoe (1967) for performance under FR 20 with an added counter. These differences in performance may reflect differences in the accuracy of control over behavior by the number of responses emitted in each ratio. Mechner (1958) showed that positional control is more accurate in short ratios than in long ratios,

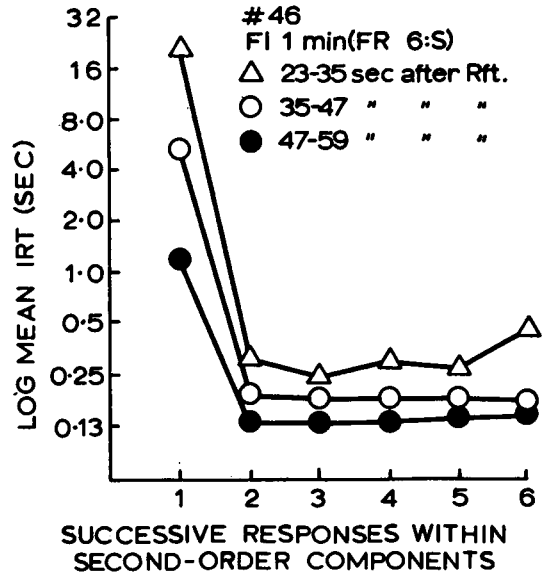


Fig. 5. Successive interresponse times within second-order FR components initiated at various times since reinforcement when a timeout followed every sixth response and food was delivered at the onset of the first timeout occurring when 1 min had elapsed since the previous food delivery. The time of initiation of each FR component was measured from the previous food delivery to the initial response of that FR component. Responses during each timeout reset the timeout duration to 5 sec.

and added counters, such as used by Richardson and Donahoe (1967), would be expected to enhance such control in longer FR performances. Hull (1934), who found a similar slowing before reinforcement in the straight runway performance of rats, suggested that the effect might be due to the emission of responses which were appropriate to food-taking but incompatible with running. In the present case, the increase in IRT before reinforcement may have been due to occasional brief investigations of the food tray before food was delivered (Hurwitz, 1962).

The pattern of responding under the FI 1-min(FR 6:S) procedure is consistent with Kelleher's (1966b) report that the latencies of second-order schedule components decreased during each interval. The present research, however, does not support Kelleher's finding that IRTs within FR components remain constant over the interval. Under FI 1-min(FR 6:S), the IRTs of responses within second-order schedule components showed a reliable decrease as reinforcement was approached. This inconsistency may be due to procedural

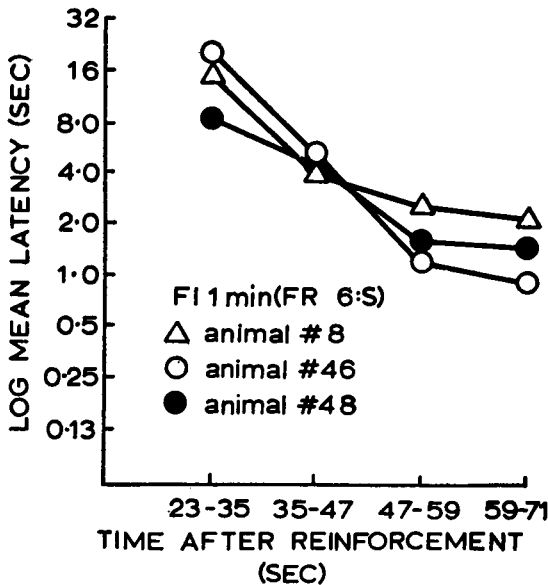


Fig. 6. Latencies of initial responses of successive second-order FR components comprising a schedule in which a timeout followed every sixth response and food was delivered at the onset of the first timeout occurring when 1 min had elapsed since the previous food delivery. Latencies are plotted as a function of the time elapsed between food delivery and the initial response of an FR component. Responses during each timeout reset the timeout duration to 5 sec.

differences between the two experiments, since Kelleher scheduled reinforcement to follow, rather than precede, stimulus presentation. Also, the present experiment used a stimulus change which reset in duration if responses were emitted in its presence, it thus being discriminative for non-responding. The effects of stimulus changes with these contingencies have not previously been investigated in the context of second-order schedules.

Similarly, further research is clearly necessary to account for the two, possibly interrelated, findings from the FR 6(FR 6:S) performance: the decrease in the latency of successive second-order schedule components; and the parallel decrease in the IRTs of responses within successive second-order schedule components. Two related findings seem to suggest promising directions for research. First, Notterman and Mintz (1965) reported curvature in FR performance when the effort requirement for responses was high. Second, Ferster and Skinner (1957) reported that FR terminal run rates were higher on *chain* FR 20 FI 1-min than on *chain* FR 20 FI 2-min,

suggesting control by conditioned reinforcement strength.

As Kelleher (1966a) pointed out, higher-order performances may be important in analyzing the mechanisms of control by schedules of reinforcement. The present results show that second-order schedules may not merely amplify certain aspects of performance, but may produce important variations in patterns of behavior. These variations may constitute a fruitful source of data for theories of schedule control.

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