

# Interval duration and the sequential effects of reinforcement magnitude on FI performance

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Rats were reinforced on a fixed-interval schedule in which 3-min intervals alternated with 1-min intervals in even-numbered sessions and with 5-min intervals in odd-numbered sessions. The 1- and 5-min intervals ended with either one or three pellets. The number of responses in the 3-min interval was greater following one pellet than three pellets. There were also more responses during the 3-min interval when it alternated with a 1-min interval than when it alternated with a 5-min interval.

Several recent studies have shown that subjects reinforced on a fixed-interval (FI) schedule responded at higher rates during an interval following a small reinforcement than during an interval following a large reinforcement (Meltzer & Howerton, 1973, 1975; Staddon, 1970). However, it is not known what effect interval duration has on this phenomenon, if any. The question can be asked with regard to several different duration parameters, but in this experiment it was decided to vary the duration of an interval, at the end of which a rat would receive either of two different amounts of reinforcement. The effects of interval duration and amount of reinforcement would then be determined by examining the subjects' responses during an alternating interval which was always of the same duration and which always ended with the same amount of reinforcement.

## METHOD

### Subjects

The subjects were nine male hooded rats, approximately 90 days old at the beginning of the experiment. Each animal was placed on a 22-h food deprivation schedule 5 days before the beginning of the experiment and was maintained on that deprivation schedule until the experiment ended. Water was always available in an animal's home cage.

### Apparatus

Each of the three identical chambers (Lehigh Valley Electronics No. 1316) had the following specifications. Interior dimensions were 21.0 x 30.5 x 18.0 cm. A bar requiring a force of 18-20 g was located on the left side of the front wall, 3.5 cm above the grid floor. Food reinforcement consisted of one, two, or three 45-mg Noyes pellets, delivered into a food hopper located in the middle of the front wall. If two or three pellets were to be delivered, the time between pellet presentations was no longer than .5 sec. Two incandescent white lights, each emitting 37.1 fL of illuminance, measured 2.5 cm from the source, were located on either side of the front wall 9.0 cm above the floor. A Knight pure-tone generator was used in

presenting an 830-Hz tone, 3.5 dB above background noise, through a speaker mounted just outside the chamber.

White noise was present in the experimental room to mask extraneous sounds. Electromechanical programming and recording equipment was in an adjoining room.

### Procedure

During the first three sessions, the rats were reinforced every time they pressed the bar. Beginning with the fourth session, all subjects were placed on an FI schedule. Two different multiple schedules were used for the rest of the experiment in alternate sessions. There were 17 fixed intervals in each session. In multiple schedule A the cue light was always on during odd intervals: the first, third, fifth, etc. intervals in a session. These intervals were always 3 min long and always ended with a reinforcement consisting of two 45-mg Noyes pellets delivered .5 sec apart. The light was always off during even-numbered intervals (i.e., the second, fourth, sixth, etc., intervals) and the tone was on.

The even-numbered intervals were 1 min long; four of them ended with a one-pellet reinforcement, while the other four ended with a 3-pellet reinforcement. The three pellets were delivered .5 sec apart. Thus, there were discriminative stimuli—light plus no tone during 3-min intervals, no light plus tone during 1-min intervals—which allowed the subject to identify the duration of the current interval. There were no stimuli present that would have allowed the subject to predict the size of the reinforcement which would be delivered. We decided to use this procedure because previous work (Meltzer & Howerton, 1975) had shown that there was a very small difference in performance following signaled as opposed to unsignaled variations in amount of reinforcement.

The sequence of one- and three-pellet reinforcements was arranged so that, if the intervening two-pellet reinforcement was ignored, a one-pellet reinforcement was equally likely to be followed by one pellet or three pellets at the end of the next 1-min interval. And, in the same way, a three-pellet reinforcement was equally likely to be followed by one or three pellets at the end of the next 1-min session.

The alternate sessions, in which multiple schedule B was used, also had a constant 3-min two-pellet light interval in every odd position. However, the even-numbered intervals were now 5 min long and neither light nor tone was on during these intervals. Thus, it was possible for the subject to discriminate between the 3- and 5-min intervals within these schedule B

**Table 1**  
**Response Rates During the First and Second Halves of the 1- and 5-Min Intervals**

Interval	First Half	Second Half
1 Min	6.1	24.3
5 Min	8.3	19.1

sessions and also to discriminate between the 5- and 1-min intervals between sessions. The 5-min intervals ended with either a one- or three-pellet reinforcement, just as the 1-min intervals did, and, just as in the 1-min intervals, there were no stimuli present that would allow the subject to predict the amount of reinforcement which would be delivered at the end of the current interval.

There were a total of 56 sessions during which the multiple schedules were used, 23 sessions with each schedule. The last 10 sessions using each schedule provided the data used in the analysis.

## RESULTS AND DISCUSSION

The first analysis compared response rates in the first and second halves of the 1- and 5-min intervals, the even-numbered intervals in multiple schedule A and multiple schedule B, respectively. The analysis was performed to insure that subjects were responding at significantly higher rates during the 1-min intervals than during the 5-min intervals. These mean rates are shown in Table 1. Response rate was significantly higher during the second half of the interval ( $F = 51.47$ ,  $df = 1/8$ ,  $p < .01$ ), and there was a greater difference between response rates in the second half as opposed to the first half of the 1- and 5-min intervals ( $F = 11.23$ ,  $df = 1/8$ ,  $p < .025$ ). In brief, this meant that there was very little difference between the mean response rate of 6.0 responses/min during the first half of a 1-min interval and the mean of 8.3 responses/min during the first half of a 5-min interval. However, mean response rate was 24.3 responses/min during the last half of a 1-min interval and 19.1 responses/min during the last half of a 5-min interval. Apparently, subjects discriminated the two types of intervals but response rate differences were only present during the last half of each interval.

The second analysis examined the number of responses subjects made during the three time bins of the 3-min two-pellet intervals—the first 90 sec, the next 60 sec, and the last 30 sec. Number of responses was analyzed rather than response rate because, with time bins of unequal duration, overall rate measures would be distorted. However, the mean number of responses in an interval can be computed correctly regardless of the duration of the different time bins. Table 2 shows that there were different numbers of responses in each time bin, with the greatest number in the bin from 90 to 150 sec ( $F = 26.62$ ,  $df = 2/16$ ,  $p < .01$ ). Subjects made a mean of 37.9 responses during each 3-min interval

following a one-pellet reinforcement and a mean of 31.6 responses during 3-min intervals following a three-pellet reinforcement, which was a significant difference ( $F = 18.30$ ,  $df = 1/8$ ,  $p < .01$ ). And, as Table 2 also shows, the difference in responses following one and three pellets was greatest during the second time bin of the interval, that is, between 90 and 150 sec after the preceding reinforcement. This interaction was also significant ( $F = 6.22$ ,  $df = 2/16$ ,  $p < .05$ ).

The duration of the variable reinforcement interval also had a significant effect on responses during the 3-min interval ( $F = 9.26$ ,  $df = 1/8$ ,  $p < .05$ ). When the alternate interval was 1 min long, there were 42.3 responses during the 3-min interval. When the alternate interval was 5 min long, there was a mean of 27.0 responses during the 3-min interval. Finally, there was a significant interaction between the duration of the alternate interval and the distribution of responses during the 3-min interval ( $F = 5.51$ ,  $df = 2.16$ ,  $p < .05$ ); as Table 2 shows, the greatest differences were again in the time bin between 90 and 150 sec.

Several points can be made regarding the data. First, subjects make more responses after small reinforcements than after large reinforcements, as has been demonstrated many times before. Second, the duration of an alternating interval in a complex multiple schedule has a strong inductive effect. Shorter alternate intervals increase responding; longer alternate intervals reduce it. However, these two effects do not interact. The differences in responding following large and small reinforcement are not affected by the duration of the interval at the end of which the variable reinforcement is delivered; nor does the duration of the interval at the end of which the variable reinforcement magnitude is delivered modify the effects of reinforcement magnitude on response output during the next interval.

Finally, both of these effects are smallest at the beginning of an interval when a subject is responding at a very low rate and at the end of an interval when a subject is responding at a high terminal rate. They are greatest during the middle of the interval.

**Table 2**  
**Mean Number of Responses During Successive Time Bins in Different Types of 3-Min Intervals Ending with a Two-Pellet Reinforcement**

Time Bin	All Intervals	Alternate Interval Duration		Size of Last Reinforcement	
		1 Min	5 Min	One Pellet	Three Pellets
0-90 sec	7.4	9.8	5.0	8.8	6.1
90-150 sec	15.5	19.0	12.0	17.2	13.9
150-180 sec	11.8	13.5	10.0	11.9	11.6
0-180 sec	34.7	42.3	27.0	37.9	31.6

## REFERENCES

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