

*THE EFFECTS OF NUMBER OF RESPONSES
ON PAUSE LENGTH WITH TEMPORAL
VARIABLES CONTROLLED¹*

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A change in the size of a fixed-ratio schedule involves a simultaneous change in number of responses, in time to complete the ratio (work time), and in the interval between successive reinforcements (interreinforcement interval). Previous studies have suggested the importance of work time and the interreinforcement interval in controlling the length of the post-reinforcement pause. The present study sought to determine whether number of responses is also a significant factor. Pigeons were trained on a multiple fixed-ratio x fixed-ratio 2 plus timeout schedule in which the size of the fixed-ratio x was manipulated. When the work times (Experiment I) or interreinforcement intervals (Experiment II) were equated for the two components, the pause before the fixed-ratio x was longer than the pause before the fixed-ratio 2 plus timeout. As fixed-ratio x size increased, the relative difference in the lengths of the two types of pauses also increased. Because the fixed-ratio x component contained a larger number of responses than the fixed-ratio 2 plus timeout component, the relatively longer pause preceding the fixed-ratio x indicates that number of responses played a significant role in determining the length of the post-reinforcement pause.

In a simple fixed-ratio (FR) schedule of reinforcement, an increase in the size of the FR requirement produces an increase in the post-reinforcement pause (Felton and Lyon, 1966; Ferster and Skinner, 1957; Powell, 1968). Also, an increase in FR size increases work time, *i.e.*, the time from first to last response (Pliskoff and Goldiamond, 1966; Rilling and McDiarmid, 1965). Together, these increases in post-reinforcement pause length and work time produce an increase in the interreinforcement interval (IRI), the time between reinforcements (Neuringer and Schneider, 1968).

The effect of number of responses on FR performance is unclear, although some studies have attacked the problem. For example, in an attempt to determine whether number of responses or the IRI was important in controlling performance on fixed-interval (FI) and FR schedules, Neuringer and Schneider (1968) scheduled brief timeouts after each nonreinforced response. Increasing the lengths of the timeouts in the FR schedule lengthened the IRI and the subjects

paused longer after reinforcement. In the FI schedule, lengthening the timeouts reduced the total number of responses in the interval, but the post-reinforcement pause did not change. Thus, they concluded that ". . . the time between reinforcements controls responding independently of the number of responses emitted during that time" (Neuringer and Schneider, 1968, p. 666).

On the other hand, Rilling (1967) evaluated time and number of responses as factors controlling discrimination between pairs of FR or FI schedules. He found a low correlation between work time and FR discrimination accuracy but a high correlation between number of responses emitted in the FI schedules and how accurately the animals discriminated different FI schedules.

The issue of whether responses control pause length has not been clarified by these two studies. Neuringer and Schneider (1968) did not manipulate FR size, and whereas Rilling demonstrated the importance of responses in FI discrimination, he made no statements concerning the relationship of responses to pause length. Although the present study did not examine simple FR performance, the size of the FR schedule in one component of a multiple schedule was varied under conditions in which work times (Experiment I) or IRIs

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(Experiment II) were controlled across components. The purpose of this technique was to separate the effects of responses and time on the length of the post-reinforcement pause.

EXPERIMENT I

The strategy in this experiment was to compare pre-ratio pause lengths between two multiple schedule components, the first of which was a simple FR schedule. In the second component, the first response initiated a timeout (TO) and when the TO elapsed, another response produced reinforcement. The lengths of the work times in the two components were equated through a yoking procedure. Thus, the primary difference in the requirements of the two components was that one component required more responses than the other.

METHOD

Subjects

Two experimentally naive homing pigeons, Birds 819 and 665, served.

Apparatus

The experimental chamber was a standard operant conditioning pigeon chamber that contained three translucent response keys of which only the center key was used. The aperture for the feeder hopper was located 10.2 cm below this key. Electromechanical apparatus and a PDP-5 computer (Digital Equipment Corporation), located in an adjacent room, arranged the experimental conditions and recorded the behavior. White noise masked extraneous sounds. The reinforcement was 3-sec access to Purina Racing Pigeon Checkers. Water was available at all times in the home cage.

Procedure

Both birds were reduced to 80% of their free-feeding weights and taught to peck the key in the presence of a red light. The schedule was gradually increased to FR 25, and the birds were allowed to consume as much food as possible within the 90-min experimental session. Thus, at the beginning of a session, the birds were on 22.5 hr deprivation. When the FR was raised to FR 200 and FR 300 (see below), the length of the experimental session was increased to 2.5 and 6.0 hr, respec-

tively. During the six days of training each week, these extended sessions permitted sufficient exposure to these larger FR schedules to maintain body weight without supplementary feeding. Supplementary food was given on the other day.

After body weight stabilized on FR 25, both birds were placed on a multiple fixed-ratio 25 fixed-ratio 2 plus timeout (*mult* FR 25 FR 2 + TO) schedule of reinforcement. In this schedule, 25 responses in the presence of a red keylight produced reinforcement and changed the key color to green. In the presence of the green keylight, the first response darkened the entire chamber for the length of the TO, during which responses had no scheduled consequence. After the TO period concluded, the green keylight and the chamber houselights were illuminated again. A single response produced reinforcement, after which the red keylight and the FR 25 schedule were reinstated. The keylight was turned off, and the feeder hopper was illuminated during reinforcement in both components.

As seen in Table 1, the size of FR x was gradually increased, followed by replication of two earlier FR x values. Work time, defined as the time between the first and last responses on either schedule, was equated for the FR x and FR 2 + TO components in the following manner. At a given value of x , the median FR x work time was determined for a session. In the subsequent session, the length of the TO was set equal to the previous session's median FR x work time.

A change in x was based on the stability of the lengths of the pre-ratio pauses, *i.e.*, the pre-FR x and pre-FR 2 + TO pauses. When neither type of pause showed a consistent up or down trend for a period of five consecutive sessions, the next FR x in the series was scheduled, given that a minimum of 10 sessions had occurred. The actual number of sessions is shown in Table 1.

RESULTS

Figure 1 permits a comparison of the lengths of the pre-FR x and pre-FR 2 + TO pauses at each x value. The data represent the median of the last five-session medians for both pauses. As can be seen in Figure 1, the pre-FR x pause was always longer than the pre-FR 2 + TO pause, and the difference between the two pause lengths increased as x got larger.

Table 1
Sequence of Experimental Conditions and Number of Sessions for Each

EXPERIMENT I					
<i>Bird 819</i>			<i>Bird 665</i>		
<i>Schedule</i>	<i>No. of Sessions</i>		<i>Schedule</i>	<i>No. of Sessions</i>	
FR 25		14	FR 25		10
<i>mult</i> FR 25	FR 2 + TO	24	<i>mult</i> FR 25	FR 2 + TO	25
<i>mult</i> FR 50	FR 2 + TO	10	<i>mult</i> FR 50	FR 2 + TO	10
<i>mult</i> FR 100	FR 2 + TO	10	<i>mult</i> FR 100	FR 2 + TO	14
<i>mult</i> FR 200	FR 2 + TO	10	<i>mult</i> FR 200	FR 2 + TO	10
<i>mult</i> FR 300	FR 2 + TO	26	<i>mult</i> FR 300	FR 2 + TO	10
<i>mult</i> FR 25	FR 2 + TO	15	<i>mult</i> FR 25	FR 2 + TO	12
<i>mult</i> FR 50	FR 2 + TO	20	<i>mult</i> FR 50	FR 2 + TO	18

EXPERIMENT II					
<i>Bird 819</i>			<i>Bird 665</i>		
<i>Schedule</i>	<i>No. of Sessions</i>		<i>Schedule</i>	<i>No. of Sessions</i>	
<i>mult</i> FR 50	FR 2 + TO	27	<i>mult</i> FR 50	FR 2 + TO	25
<i>mult</i> FR 50	FR 2 + TO	10	<i>mult</i> FR 50	FR 2 + TO	11
Color Reversal			Color Reversal		
<i>mult</i> FR 25	FR 2 + TO	11	<i>mult</i> FR 25	FR 2 + TO	10

<i>Bird H-12</i>			<i>Bird H-13</i>		
<i>Schedule</i>	<i>No. of Sessions</i>		<i>Schedule</i>	<i>No. of Sessions</i>	
FR 25		22	FR 25		22
<i>mult</i> FR 25	FR 2 + TO	15	<i>mult</i> FR 25	FR 2 + TO	15
<i>mult</i> FR 50	FR 2 + TO	13	<i>mult</i> FR 50	FR 2 + TO	12
<i>mult</i> FR 100	FR 2 + TO	16	<i>mult</i> FR 100	FR 2 + TO	14

Primarily, this increasing difference was due to the lengthening of the pre-FR x pause.

Because the length of the TO in a given session was based upon the previous session's median FR x work time, there was an opportunity for some variance between the work times of the two components. However, the method used to equate work times was reasonably accurate at FR values less than 300, with deviations in work times for the two components being less than 2 sec.

EXPERIMENT II

In Experiment I, the work times in the two components of the multiple schedule were equated. Because Neuringer and Schneider (1968) had suggested that IRI may control the length of the post-reinforcement pause, the multiple schedule from Experiment I was modified such that the lengths of the IRIs of the two components were equated through a yoking procedure.

METHOD

Subjects

Two experimentally naive White King pigeons, H-12 and H-13, served as subjects. Birds 819 and 665 from Experiment I also were used.

Apparatus

The apparatus was identical to that used in Experiment I.

Procedure

Birds H-12 and H-13 were trained to respond on an FR 25 schedule, with the same procedure used in Experiment I. After body weight stabilized on FR 25 under 22.5 hr of deprivation, both H-12 and H-13, and the subjects from the previous experiment, were placed on *mult* FR x FR 2 + TO schedules.

In this experiment, the IRIs, rather than work times, were equated. The IRI of the FR x component was measured by the computer.

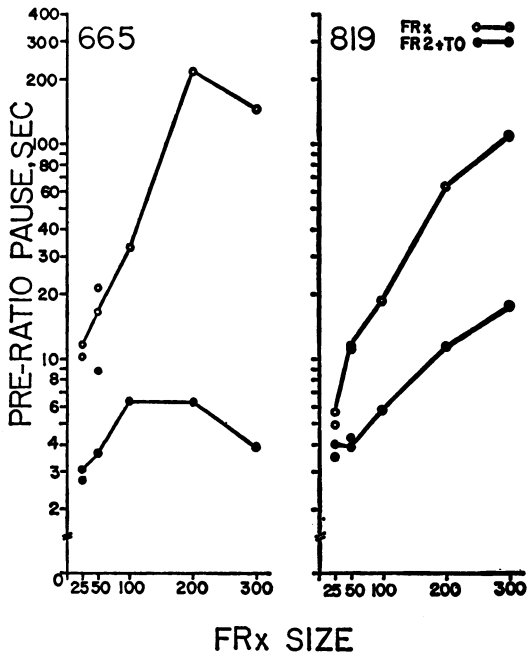


Fig. 1. Pre-ratio pause lengths as a function of x in the *mult* FR x FR 2 + TO schedule with work times equated. Data are medians of the last five-session medians. The pre-FR x pauses are represented by open circles and the pre-FR 2 + TO pauses by closed circles. The unconnected points are redeterminations.

The duration of the subsequent FR 2 + TO component was then based on this interreinforcement interval. If a response occurred in the FR 2 + TO component before this predetermined interreinforcement interval had elapsed, the chamber was darkened and responses had no effect. When the predetermined IRI elapsed, the green keylight and chamber houselights were illuminated again. A single response produced reinforcement followed by a red keylight and the FR x schedule. Thus, if the pre-FR 2 + TO pause was relatively short, the computer increased the length of the TO so that the sum of the pre-FR 2 + TO pause and the TO would be equal to the IRI of the previous FR x . On the other hand, if the pre-FR 2 + TO pause was long, the TO was set to a shorter value. However, if the predetermined interval elapsed before a response occurred, the FR 2 + TO component terminated without reinforcement and the FR x component was reinstated.

The sequence of schedule conditions is listed in Table 1. Since Birds 819 and 665 had histories of pairing a red keylight with the

FR x component and a green keylight with the FR 2 + TO component when the work times were equated, key color might have controlled the pre-FR x and the pre-FR 2 + TO pause lengths for these two birds. Accordingly, for Birds 819 and 665 in the *mult* FR 50 FR 2 + TO schedule with the IRIs equated, the colors were reversed; a red key was present during the FR 2 + TO component and a green key during the FR x component.

RESULTS

Figure 2 shows the pre-FR x and the pre-FR 2 + TO pause lengths at various values of x with IRIs equated. The data represent the median of the last five-session medians for both pauses. The pre-FR x pause was always longer than the pre-FR 2 + TO pause for all four birds. Both the pre-FR x and pre-FR 2 + TO pauses varied directly with x . However, as x increased, the pre-FR x pause always increased more than the pre-FR 2 + TO pause.

DISCUSSION

A seemingly simple change in FR size actually represents the simultaneous change of a number of variables. Among these, number of responses, work time, and interreinforcement interval (IRI) are directly proportional to FR size. The present study concentrated on the role played by the number of responses when either work time or IRI was controlled. In two experiments, subjects were exposed to two alternating components of a multiple schedule. The first component, an FR x schedule, involved three variables: number of responses, work time and IRI. In the other component, the FR 2 + TO schedule, work time or IRI varied in accordance with work time or IRI in the first component, while the number of responses in the second component was held constant at two. In addition to the different response requirements of the two components, the second component included a stimulus change, the darkening of the chamber during TO.

For all subjects, pauses before the first response on the FR x schedule were consistently longer than pauses before the first response on the FR 2 + TO schedule, when either work times (Experiment I) or IRIs (Experiment II) were equated for the two components. Differences in the lengths of the two pauses were

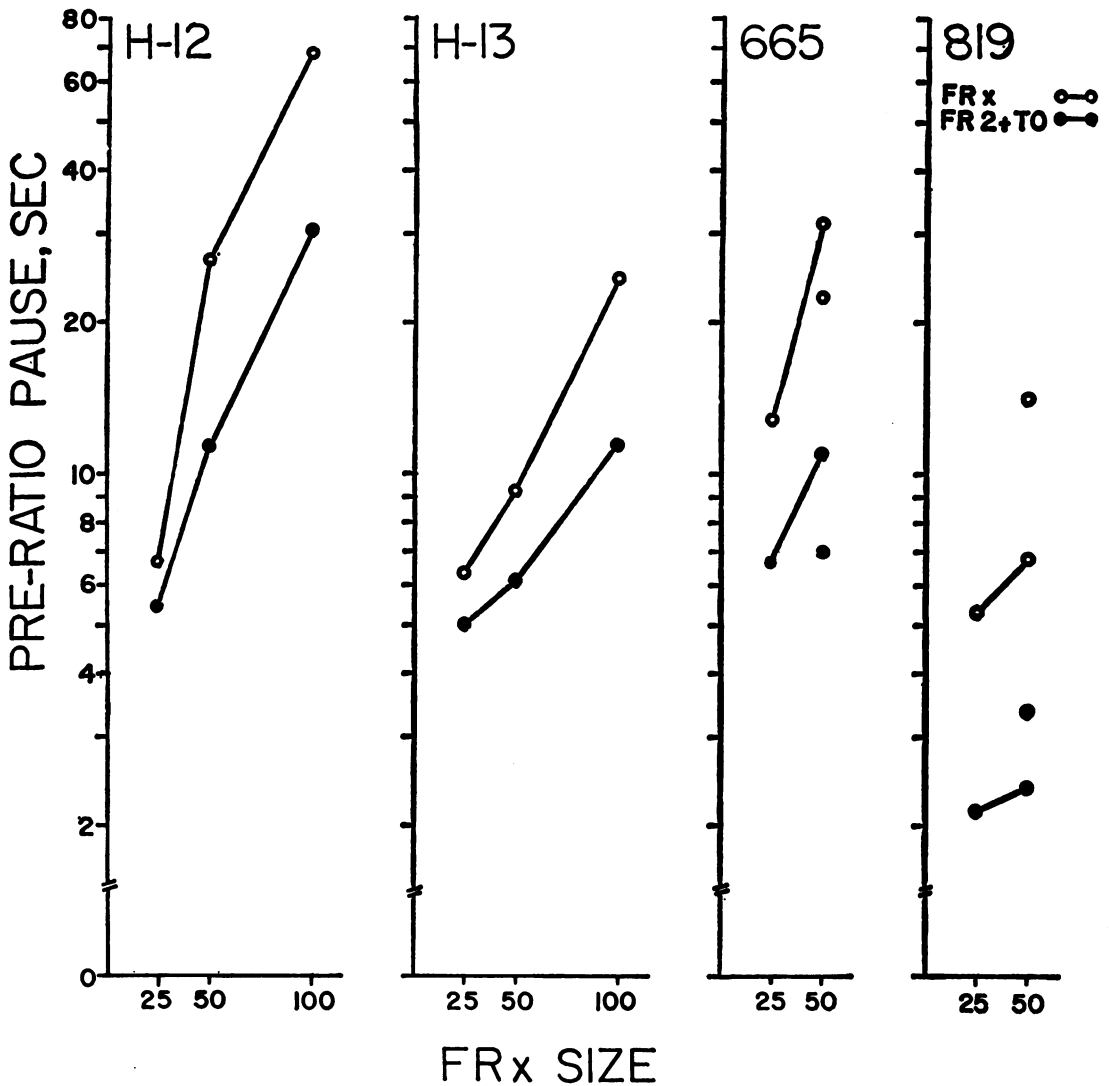


Fig. 2. Pre-ratio pause lengths as a function of x in the *multi* FR x FR 2 + TO schedule with interreinforcement intervals equated. Data are medians of last five-session medians. The pre-FR x pauses are represented by open circles and the pre-FR 2 + TO pauses by closed circles. The unconnected points are redeterminations and represent the color reversal for Birds 819 and 665.

enhanced as x increased. While these data suggest that the relatively longer pause preceding the FR x schedule may have been due to the larger number of responses in this component, several other factors may have been important.

The first of these concerns the stimulus changes in the FR 2 + TO component. Since a single response following the timeout produced reinforcement, short latencies in the presence of the green keylight resulted. Failure to discriminate this green light from the one present at the beginning of the FR 2 +

TO component may have caused a short pause before the first response of this component. However, observation of the cumulative records revealed that the pre-FR 2 + TO pause was almost always substantially longer than the pause following the timeout. Moreover, as the size of x increased, the pre-FR 2 + TO pause increased, but the pause following the timeout showed little change.

A second factor was the omission of reinforcement, which occurred in Experiment II when the pre-FR 2 + TO pause equalled the IRI of the previous FR x component. This

contingency could have produced short pre-FR 2 + TO pauses, since long pauses resulted in the loss of reinforcement. However, this loss of reinforcement occurred less than about 1% of the time.

Another possible source of error could occur if the birds paused before emitting the last response in the FR 2 + TO component. The IRI for this component then would be longer than that for the preceding FR x component. This could bias the pre-FR 2 + TO pause, probably making it longer. In practice, however, the birds usually responded as soon as the keylight and houselights were turned on after the TO had elapsed.

These data stand in opposition to a number of studies that have suggested that number of responses is not a significant factor in controlling the length of post-reinforcement pauses. Neuringer and Schneider (1968) showed that the pause preceding the first response of an FI schedule was not systematically related to the number of responses in the FI. Also, Killeen (1969) attempted to separate responses from time on fixed-ratio schedules by yoking pairs of birds, one member of which was on an FR schedule, such that the IRIs for each pair were approximately equal. He found that even though the number of interreinforcement responses differed for the two members of the yoked pair, the post-reinforcement pauses did not. On the other hand, Dukich (1971), in a choice situation, found that birds preferred the smaller of two FRs when IRIs for the two FRs were equated.

Although the different procedures used in the above studies make comparisons difficult, one important difference may be the relationship between number of responses and reinforcement frequency. In studies that have in-

dicated that number of responses had little effect on the post-reinforcement pause, *i.e.*, Killeen (1971) and Neuringer and Schneider (1968), the rate of responding did not significantly alter reinforcement frequency. However, in the present study, and in that of Dukich (1971), reinforcement frequency was a direct function of the rate at which responses were emitted.

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