Sequences of Fixed-Ratio Schedules of Reinforcement: The Effect of Ratio Size in the Second and Third Fixed-Ratio on Pigeons' Choice

Susan Goeters
Western Michigan University

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SEQUENCES OF FIXED-RATIO SCHEDULES OF REINFORCEMENT:
THE EFFECT OF RATIO SIZE IN THE SECOND AND THIRD
FIXED-RATIO ON PIGEONS' CHOICE

by

Susan Goeters

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
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Department of Psychology

Western Michigan University
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The present study used a discrete-trials procedure to examine choice in pigeons presented with various three-component sequences of fixed-ratio schedules of reinforcement. An experimenter-controlled stimulus was correlated with each sequence and pigeons were presented with a specified number of forced-exposure and choice trials. Three phases were implemented in an effort to investigate the conditions under which fixed-ratios other than the first in a sequence of three affect choice. In Phase 1, pigeons were given a choice between a fixed-ratio X fixed-ratio 1 fixed-ratio 25 and a fixed-ratio X fixed-ratio 25 fixed-ratio 1 sequence of food delivery. Across conditions, X was 1, 5, 20, 35, and 50; food delivery followed completion of each fixed-ratio. Results indicated that fixed-ratios other than the first had little effect on choice. Because it was possible that the food presentations following the initial fixed-ratio in both sequences were disrupting control by the shorter second fixed-ratio, Phases 2 and 3 were implemented. Results of Phases 2 and 3 indicated that the food presentations following the initial fixed-ratios were disrupting sensitivity to the fixed-ratios that followed. During Phase 3, when hopper light presentations rather than food followed the initial fixed-ratios, all subjects were sensitive to fixed-ratios other than the first, and the majority of choice responses was allocated to the sequence with the shorter second fixed-ratio. Moreover, the effects of fixed-ratios other than the first depended on the size of the initial fixed-ratio. Preference for the sequence
with the shorter second fixed-ratio schedule increased as the size of the initial fixed-ratio decreased. These findings complement previous results with concurrent chain procedures.
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Sequences of fixed-ratio schedules of reinforcement: The effect of ratio size in the second and third fixed-ratio on pigeons' choice

Goeters, Susan, Ph.D.
Western Michigan University, 1991
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It goes without saying (although I will say it) that I could not have completed my graduate work without the love and support from my parents, Donald William and Elizabeth Rose Goeters, and my very good friend and colleague forever, Victoria M. Pelletiere. I thank you all.

Susan Goeters
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CHAPTER I

INTRODUCTION

Choice occurs when two or more responses are available and the occurrence of one response is incompatible with the occurrence of the others. Choice is operant behavior, and choice is ubiquitous. As Poling, Blakely, Pellettiere, and Picker (1987) stated, "To live is to choose [and] to choose is to emit operant behavior, which is controlled by current and historical variables" (p. 225). Identifying and examining those variables has been the goal of many researchers (e.g., Chung & Herrnstein, 1967; Davison, 1968, 1972; Fantino, 1967, 1969; Hall-Johnson & Poling, 1984; Picker & Poling, 1982; Poling et al., 1987; Rider, 1979, 1983).

The variables that influence choice often have been evaluated under concurrent schedules (de Villiers, 1977). Under such schedules, the alternative that engenders the most behavior (responses or time spent in responding) is assumed to be preferred. When organisms are exposed to concurrent schedules of reinforcement, they characteristically prefer the alternative yielding larger reinforcers, more reinforcers, or shorter delays to reinforcement (Chung, 1965; Chung & Herrnstein, 1967; de Villiers, 1977; Herrnstein & Loveland, 1975; Neuringer, 1967).

For example, in a study by Herrnstein (1961), pigeons were exposed to concurrent variable-interval variable-interval (VI VI) schedules of food delivery. The values (lengths) of the VI components were systematically varied across phases. Under these conditions, a reliable functional relation was obtained between relative overall rate of responding and relative reinforcement frequency. This relation was described in the earliest version of the matching equation:
\[ \frac{R_1}{R_1 + R^2} = \frac{r^1}{r^1 + r^2} \]

where \( R \) refers to the number of responses generated by a specific schedule and \( r \) refers to the number of reinforcers earned under a specific schedule (de Villiers, 1977, p. 236).

In the equation, the number of responses generated under one schedule, \( R_1 \), is divided by the number of responses generated by the sum of the two schedules together, \( R_1 + R^2 \). The measure which results is a proportion and it is approximately equal to the proportion obtained when the number of reinforcers, \( r^1 \), generated under one schedule is presented in proportion to the total number of reinforcers, \( r^1 + r^2 \), earned under both schedules added together.

Delay of reinforcement as well as rate of reinforcement affects choice under concurrent VI VI schedules. In an early demonstration of this relationship, Chung and Herrnstein (1967) compared concurrent VI 1-min VI 1-min schedules where each schedule was correlated with a specific key and those schedules when completed imposed different delays to food delivery. During certain sessions, one key was correlated with more immediate reinforcement than another key. During those sessions, the key correlated with more immediate reinforcement was always preferred. Quantitative analysis of results revealed a matching relation between the relative overall response rates generated on each schedule and the relative immediacies of reinforcement. These results were consistent with earlier findings by Chung (1965).

Effects of delay of reinforcement on choice also were demonstrated by Fantino (1967), who used a concurrent chain procedure to demonstrate that pigeons preferred mixed-ratio schedules to similarly valued fixed-ratio schedules. For example, all birds preferred mixed FR 10 FR 90, FR 1 FR 99, and FR 25 FR 75 schedules over
an FR 50 alternative. Under the mixed schedule, each of the two alternatives appeared on half of the trials. Thus, in terms of average responses required for food delivery, mixed FR 10 FR 90, FR 1 FR 99, and FR 25 FR 75 schedules are equivalent to a simple FR 50. All require, on average, 50 responses per food delivery. However, under the mixed schedules, some food deliveries occur after fewer than 50 responses (e.g., after 1 when a mixed FR 1 FR 99 is arranged), whereas others occur after more than 50 responses (e.g., after 99 when a mixed FR 1 FR 99 is arranged). Apparently, the availability of some reinforcers after relatively little delay (or effort) was responsible for the birds' preference for the mixed schedule. Interestingly, even when the FR values of the alternatives were as low as FR 20 and FR 25, subjects preferred a mixed FR 1 FR 99. In this case, average responses per reinforcer was higher under the mixed schedule.

Similar results were obtained in a study using interval rather than ratio reinforcement schedules conducted by Davison (1972), who gave pigeons a choice between fixed-interval (FI) and mixed-interval (MI) reinforcement schedules. Throughout several conditions of the study, the MI contained an interval value shorter than that offered in the alternative FI schedule. Under these conditions, the distribution of responses during the initial links of a concurrent chain procedure indicated preference for the MI schedules. Under conditions where the FI value was shorter than or equal to any of the values of the MI schedule, the FI was usually preferred. Thus, these findings, which do not confound effort and delay to reinforcement, support the notion that the immediacy of reinforcement is important in controlling choice.

In an attempt to examine further the effects of delay of reinforcement on choice, Poling and associates (Hall-Johnson & Poling, 1984; Poling et al., 1987) employed a discrete-trials procedure with pigeons. In this procedure, the subject was presented
with a choice between two schedules of reinforcement, each comprising a sequence of two FRs. An experimenter-controlled stimulus (key color) was correlated with each sequence and subjects were presented with a specified number of forced-exposure and choice trials. Forced-exposure trials guaranteed that all subjects contacted the contingencies of each reinforcement schedule. During the choice trials that followed, subjects were exposed simultaneously to two stimuli, each correlated with a specific sequence of FRs. A response made to either stimulus was defined as the choice response and provided access only to the sequence of FRs correlated with that stimulus; access to the other sequence ended with a choice response. Similar discrete-trials procedures have been used by other researchers (e.g., Green, Fisher, Perlow, & Sherman, 1981; Logan, 1965; Picker & Poling, 1982; Poling, Thomas, Hall-Johnson, & Picker, 1985; Rachlin & Green, 1972; Young, 1981).

Both the Hall-Johnson and Poling (1984) study and the Poling et al. (1987) study demonstrated that immediacy of reinforcement exercised strong control over choice. In Hall-Johnson and Poling (1984), pigeons were given a choice between two sequences, each consisting of two FRs. One sequence, the comparison, was an FR 50 FR 50 throughout the study. The other sequence was varied and was manipulated across conditions to contain various ratio values. In the first phase of the study, the varied sequences across conditions were FR 10 FR 90, FR 30 FR 70, FR 70 FR 30, and FR 90 FR 10. In the second phase, those sequences across conditions were FR 10 FR 110, FR 10 FR 130, and FR 10 FR 170. Results indicated that almost all choice responses were allocated to the sequence with the shorter initial FR value, even when the overall response requirement was much higher for that sequence than for the comparison. For example, pigeons always chose an FR 10 FR 170 over an FR 50 FR 50. This is of interest given that both sequences yielded two 3-s food deliveries.
In subsequent phases, duration of food delivery was manipulated in both the comparison sequence (i.e., FR 50 FR 50) and the varied sequence (FR 10 FR 90). Except when the duration of food delivery following the initial FR schedule was too brief to allow for eating (0.75 s), the majority of choice responses were allocated to the sequence with the shorter initial FR value (i.e., the varied sequence). This occurred even when the varied sequence yielded less overall access to food. For example, under one condition when the varied sequence yielded 6-s access to food overall and the comparison sequence yielded 15-s access to food overall, all the subjects consistently allocated all of their choice responses to the varied sequence, the one yielding less overall access to food. These results suggested that the value of the initial FR, which determined, in large part, the delay to the initial reinforcer, was the primary determinant of choice.

The importance of this variable also was demonstrated in the study by Poling et al. (1987). Those authors systematically replicated the results of Hall-Johnson and Poling (1984) and then examined the effects of probability of food delivery on choice responding. They found that the majority of choice responses were allocated to the sequence with the shorter initial FR schedule so long as the probability of food delivery following completion of that initial FR was above 0.25.

In the second phase of the study, Poling et al. presented various sequences of FR schedules to examine whether or not the second component of a two-component sequence could control choice. The comparison sequence was always FR 25 FR 25 and the varied sequences across conditions were FR 25 FR 45, FR 25 FR 35, FR 25 FR 15, FR 25 FR 5, and FR 25 FR 1. Results were inconsistent across subjects except when the varied sequences were FR 25 FR 5 and FR 25 FR 1. Under those conditions, all subjects allocated the majority of choice responses to the varied sequence, the one with the shorter second FR schedule. This suggests that under
some conditions the second FR in a sequence of two FRs can control choice responding. One point worth noting, however, was that the sequence with the shorter second FR also required less responding (30 or 26 responses) to yield two 3-s food deliveries than the alternative sequence with the longer second FR (50 responses). This difference in overall response requirement may have contributed to the obtained results.

A follow-up study by Goeters, Schlinger, and Poling (1989) attempted to control for this difference in overall response requirement and determine whether the second FR in a sequence of FRs would control choice under conditions when overall response requirements were held constant for both reinforcement sequences. Although the first FR schedule in a series of two or more appears to be the primary determinant of choice (as evidenced in Goeters et al., 1989; Hall-Johnson & Poling, 1984; Poling et al., 1987), data from several other studies (Blakely & Poling, 1991; Goeters et al., 1989; Poling et al., 1987) using similar procedures indicate that FRs later in the sequence can influence performance when the initial FRs are equal. For example, in the Goeters et al. study, when given a choice between an FR 25 FR 25 sequence and an FR 25 FR 1 sequence, pigeons preferred the latter sequence, as they did in a prior investigation by Poling et al. (1987). The alternative sequences in both of these studies, however, differed also in overall response requirements as well as in the value of the second FR, and it was not clear which of these variables controlled responding. By adding a third FR to each of the sequences, making one an FR 25 FR 25 FR 1 and the other an FR 25 FR 1 FR 25, Goeters et al. attempted to control for this confound; these alternatives each yielded 9-s access to food per 51 responses. Despite this equivalence in overall response requirement and duration of food presentation, the majority of choice responses for all subjects were allocated to the FR
25 FR 1 FR 25 sequence. This indicates that the birds were sensitive to differences in FRs other than the first in a sequence of three.

This conclusion has been supported by other researchers (Blakely & Poling, 1991; Shull, Spear, & Bryson, 1981). Blakely and Poling (1991), for example, investigated the effects of two variables (i.e., the effects of reinforcer magnitude offered by the second FR and the relative effects of magnitude and FR size) as a function of the initial FR size in a sequence of two FRs. As stated by these researchers, "the initial FR size was of interest in the present procedure because previous research with concurrent chains schedules showed that the length of the initial-link schedule influenced the relative effects of terminal-link schedules (e.g., Fantino, 1969)" (Blakely & Poling, 1991, p. 134). Blakely and Poling (1991) gave pigeons a choice between two sequences of FR schedules. One sequence was an FR X FR 5 and the other sequence was an FR X FR 45, where X across conditions was equal to 1, 5, 20, 35, or 50. Completion of the FR 5 in the former sequence was followed by 2-s access to grain and completion of the FR 45 in the latter sequence was followed by 8-s access to grain. The pigeons were exposed to each of these conditions twice. During the first exposure, a 3-s food presentation was the outcome for the completion of the first FR in both sequences (i.e., the FR X FR 5 and the FR X FR 45 sequences) regardless of the value of the first FR schedule. During the second exposure, however, a 0.25-s hopper flash was the outcome. As Blakely and Poling (1991) indicated, "two kinds of outcomes (food, hopper flash) were programmed to investigate whether the relative effects of FR size and reinforcer magnitude in the second FR as a function of initial FR size depended on the type of reinforcer offered by the initial FR schedule. This variable, reinforcer type, has not yet been investigated in research with sequences of FR schedules" (p. 134).
Results of this manipulation illustrated that, during both the food and the hopper flash exposures, the majority of choice responses were allocated to the sequence with the smaller second FR when the initial FR values in both sequences were low (i.e., FR 1 and FR 5) even though that FR yielded less food than the same FR in the alternative sequence. When the values of the initial FRs were higher (i.e., FR 35 and FR 50), most of the subjects switched their preference to the sequence with the larger second FR (which additionally led to a longer food presentation than that which followed the nonpreferred sequence). These data demonstrated that differences in the values of the second FR in a sequence of FRs do affect choice when the initial FR schedules are equal.

The current experiment employed a discrete-trials procedure using both forced-exposure and choice trials to study further the parameters under which the second FR schedule in a sequence of FRs controls choice. The study used procedures similar to those employed by Goeters et al. (1989) in an effort to investigate further the conditions under which FRs other than the first in a sequence controls choice. Research by Goeters et al. (1989) will be extended by examining whether control by the sequence with the shorter second FR is affected by the size of the initial FR schedules. In prior studies, when initial FR schedules were unequal and differed by some minimum value, the majority of the choice responses were allocated to the sequence with the shorter initial FR size and the size of subsequent FRs were of little consequence (Goeters et al., 1989; Hall-Johnson & Poling, 1984; Poling et al., 1987). When initial FRs were equal, however, the data of several researchers (Blakely & Poling, 1991; Goeters et al., 1989; Poling et al., 1987) indicated that subsequent FRs in a sequence of FRs did affect choice. A question not yet addressed is whether, in a sequence of FRs, control by the second FR in a sequence of three FRs changes with the value of the initial FR in each sequence. It is possible, for
example, that an FR 1 FR 1 FR 25 sequence engenders more control over an FR 1 FR 25 FR 1 than an FR 50 FR 1 FR 25 engenders over an FR 50 FR 25 FR 1. Some support for this possibility was provided by Blakely and Poling (1991). In their research, at the lower initial FR values (FR 1 and FR 5), subjects consistently chose the sequence with the shorter second FR (i.e., FR 5) even though completion of that FR provided less overall access to food than completion of the second FR in the alternative sequence (i.e., FR 45). In contrast, when the initial FR values were FR 35 and FR 50, preference switched to the sequence that had the longer second FR value and the longer overall access to food. Although Blakely and Poling (1991) were looking specifically for possible interactions between reinforcer magnitude and second-ratio size as determinants of choice, their findings suggest that the size of the first FR in a sequence per se alters the relative importance of the size of subsequent FRs as a determinant of choice. The first phase of the current experiment was designed to test this possibility.

The results of Phase 1 did not indicate that preference for the sequence with the shorter second FR changed reliably with the value of the initial FR schedule. Results from the Blakely and Poling (1991) study suggested that control by the second FR was possibly disrupted by food presentation following the first FR in each sequence in the current experiment. In that study, regardless of whether food or a flash of the hopper light followed completion of the first FR in each sequence, the majority of choice responses were consistently allocated to the sequence with the smaller second FR when the initial FR values in both sequences were low (i.e., FR 1 and FR 5), even though that FR schedule yielded less food than the same FR in the alternative sequence. And, when the values of the initial FRs were higher (i.e., FR 35 and FR 50), most of the subjects switched their preference to the sequence with the larger second FR (which additionally led to a longer food presentation than that which
followed the nonpreferred sequence). But there were significant differences in the relative preferences for those sequences under the food versus the hopper flash conditions. The authors suggested that the specific reinforcer durations programmed for the food presentation (i.e., 3 s) versus the hopper flash (0.25 s) after completion of the initial FR schedule were probably a factor in the difference obtained in the first phase of their study. However, another explanation is possible. It may be that the food presentation itself disrupted sensitivity to the second FR schedule. The second phase of the current experiment was designed to test this notion.

Phase 2 results suggested that the food delivery following the completion of the first FR may have disrupted control by subsequent FRs, so Phase 3 was implemented. Phase 3 replicated Phase 1 with the exception that food was not delivered after completion of the first FR in each sequence. Instead, a 3-s hopper illumination followed the completion of the first FR in each sequence. If access to food following the completion of the first FR in each sequence was somehow disrupting control by subsequent FR components, removing that food delivery should increase the probability of choice responding to the sequence containing the shorter second FR component. Moreover, preference for that sequence should change functionally with changes in the value of the initial FRs. How these manipulations affect choice responding has not been examined previously.
CHAPTER II

METHODS

Subjects

Five female White Carneaux pigeons were subjects (B1 - B5) in this experiment. The subjects had previously served in a study employing procedures similar to those described in the current study. All subjects were food deprived to 80% of their free-feeding weights and were individually housed in a colony room maintained on a 16/8 hour light/dark cycle. Experimental procedures were approved by the Western Michigan University Institutional Animal Care and Use Committee (see Appendix A).

Apparatus

Three Lehigh Valley Electronics (BRS/LVE) operant conditioning chambers, each 32 cm long, 35 cm wide, and 35 cm high, were used. In each chamber three response keys (2.5 cm in diameter) were located on the front wall 23 cm above the floor. The response keys were separated by 5.5 cm and required a minimum force of 0.2 N to operate. At any point during experimental sessions, keys could be illuminated in red or blue-green. A rectangular opening located 7.5 cm above the floor on the front wall permitted access to food when the food hopper was raised. The hopper light, a 7-W white bulb located in the hopper opening, was illuminated when the hopper was raised. Another 7-W white bulb (houselight), centrally mounted on the front wall 33 cm from the chamber floor, provided continuous ambient illumination during sessions. An exhaust fan supplied masking noise and ventilation.
Scheduling of experimental events and data collection were accomplished through the use of a Digital Equipment Corporation PDP8/A minicomputer using interfacing and SUPERSKED software (Snapper & Inglis, 1978).

Procedure

All subjects had extensive histories of responding under sequences of FR schedules similar to those employed in this study. Therefore, no keypeck training was required. During all sessions, each bird was exposed to a series of six forced-exposure trials followed by a series of twelve choice trials. In forced-exposure trials, subjects were presented with either a red or blue-green keylight on one of three adjacent response keys, with key color and location selected at random. The probability of any given key (i.e., left, right, center) being illuminated in a given trial was 0.33, and the probability of illumination in a given color (i.e., red or blue-green) was 0.5. Each key color was correlated with a specific sequence of FR components.

At the completion of each FR component in both sequences throughout most phases, food and hopper illumination were presented for 3 s during which the key was darkened. In some phases (Phases 2 and 3), after the completion of the first FR component in both sequences, only the 3-s hopper illumination was presented (see details for Phases 2 and 3 below), but food and hopper illumination were still presented for 3 s after completion of the second and third FRs of those sequences. For all trials, the final food delivery in a sequence was immediately followed by a 15-s intertrial interval (ITI) during which all keylights were darkened. Responses to any of the keys during the ITI resulted in (a) a 2-s timeout where all stimuli in the chamber were inoperative and (b) a resetting of the 15-s ITI.

Choice trials followed forced-exposure trials. Choice and forced-exposure trials...
were similar, except that during choice trials subjects were simultaneously presented with red and blue-green keylights. These keylights appeared on any two of the three response keys. The keys that were lighted and the color of illumination were determined at random. A peck on either of the lighted keys darkened the other key and terminated the availability of the sequence correlated with it. This response was considered the pigeon's choice response on that trial.

Initially, both red and blue-green keylight illuminations were correlated with an FR 1 FR 1 FR 1 sequence. These values were gradually increased to FR 25 FR 25 FR 25. When all subjects responded consistently under this sequence, the experiment proper was begun. Throughout the study, sessions were conducted seven days per week, at approximately the same time each day. Choice responses allocated to each sequence were recorded for all sessions. The experiment proper was conducted in three phases.

Phase 1

The purpose of this phase was to extend procedures used in the second phase of the Goeters et al. (1989) study. Results of that phase indicated that, under some conditions (i.e., where initial FR values in each sequence were equal), the second FR in a sequence of three FR components affected choice. As in the Goeters et al. (1989) study, the initial FR requirements during each condition of Phase 1 of the current study were equal. Unlike that study, however, the specific value of the initial FR requirement was manipulated across sessions. Across blocks of sessions, the initial FR value was an FR X, where X was 1, 5, 20, 35, or 50. The subsequent FR component-values in each sequence remained constant throughout the first phase and the entire study. One sequence, hereafter designated as the varied sequence, referred
to the sequence of FR components where the second component was an FR 1 and the third component an FR 25. For the alternative sequence, hereafter designated as the comparison sequence, the second component was an FR 25 and the third component an FR 1.

Throughout Phase 1, three of the five subjects (B1, B2, B3) were exposed to the various sequences of three FR components where the second and third components remained unchanged (as described above), and changes were made only to the values of the first FR in each sequence. An effort was made to change the parameters of the initial FR in each sequence to see if preference for the varied sequence (FR X FR 1 FR 25) changed predictably with the value of the initial FR. Presumably, preference for the varied sequence would be much greater when the initial value of both sequences was FR 1 than when that value was FR 50. Previous research (Blakely & Poling, 1991) supports this assumption. The following sequences were arranged across the five conditions of this phase: (a) FR 1 FR 1 FR 25 versus FR 1 FR 25 FR 1, (b) FR 5 FR 1 FR 25 versus FR 5 FR 25 FR 1, (c) FR 20 FR 1 FR 25 versus FR 20 FR 25 FR 1, (d) FR 35 FR 1 FR 25 versus FR 35 FR 25 FR 1, and (e) FR 50 FR 1 FR 25 versus FR 50 FR 25 FR 1. Correlations between key color and schedule sequences were counterbalanced across subjects and presented to the subjects in an irregular order. Table 1 shows for each subject the sequence of conditions and number of sessions of exposure during Phase 1. When choice responding under one condition stabilized, a subject was exposed to another condition. Stability was defined as five consecutive sessions, N thru N + 4, in which mean percentage of choice responses allocated to the varied sequence during sessions N, N + 1, and N + 2, did not differ by more than 10% from the same measure for sessions N + 2, N + 3, and N + 4.
Table 1
Sequence of Conditions and Number of Sessions Under Each Condition for Each Subject in Phase 1 and the Return to Phase 1

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Varied Sequence of FRs</th>
<th>Key Color</th>
<th>Number of Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>20, 1, 25 (*)</td>
<td>Red (*)</td>
<td>15 (*)</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 (*)</td>
<td>Blue-green (*)</td>
<td>20 (*)</td>
</tr>
<tr>
<td></td>
<td>35, 1, 25 (*)</td>
<td>Blue-green (*)</td>
<td>22 (*)</td>
</tr>
<tr>
<td></td>
<td>50, 1, 25 (*)</td>
<td>Red (*)</td>
<td>12 (*)</td>
</tr>
<tr>
<td></td>
<td>5, 1, 25 (*)</td>
<td>Blue-green (*)</td>
<td>13 (*)</td>
</tr>
<tr>
<td>B2</td>
<td>50, 1, 25 (35, 1, 25)</td>
<td>Red (Blue-green)</td>
<td>24 (10)</td>
</tr>
<tr>
<td></td>
<td>35, 1, 25 (20, 1, 25)</td>
<td>Red (Blue-green)</td>
<td>12 (10)</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 (1, 1, 25)</td>
<td>Blue-green (Red)</td>
<td>28 (13)</td>
</tr>
<tr>
<td></td>
<td>5, 1, 25 (5, 1, 25)</td>
<td>Blue-green (Red)</td>
<td>26 (19)</td>
</tr>
<tr>
<td></td>
<td>20, 1, 25 (50, 1, 25)</td>
<td>Blue-green (Red)</td>
<td>21 (16)</td>
</tr>
<tr>
<td>B3</td>
<td>1, 1, 25 (*)</td>
<td>Red (*)</td>
<td>13 (*)</td>
</tr>
<tr>
<td></td>
<td>50, 1, 25 (*)</td>
<td>Blue-green (*)</td>
<td>19 (*)</td>
</tr>
<tr>
<td></td>
<td>20, 1, 25 (*)</td>
<td>Blue-green (*)</td>
<td>12 (*)</td>
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<td>5, 1, 25 (*)</td>
<td>Blue-green (*)</td>
<td>16 (*)</td>
</tr>
<tr>
<td></td>
<td>35, 1, 25 (*)</td>
<td>Blue-green (*)</td>
<td>23 (*)</td>
</tr>
<tr>
<td>B4</td>
<td>** (5, 1, 25) **</td>
<td>** (Blue-green)</td>
<td>** (12)</td>
</tr>
<tr>
<td></td>
<td>** (50, 1, 25) **</td>
<td>** (Red)</td>
<td>** (21)</td>
</tr>
<tr>
<td></td>
<td>** (20, 1, 25) **</td>
<td>** (Blue-green)</td>
<td>** (22)</td>
</tr>
<tr>
<td></td>
<td>** (35, 1, 25) **</td>
<td>** (Red)</td>
<td>** (20)</td>
</tr>
<tr>
<td></td>
<td>** (1, 1, 25) **</td>
<td>** (Red)</td>
<td>** (18)</td>
</tr>
<tr>
<td>B5</td>
<td>** (1, 1, 25) **</td>
<td>** (Red)</td>
<td>** (11)</td>
</tr>
<tr>
<td></td>
<td>** (5, 1, 25) **</td>
<td>** (Blue-green)</td>
<td>** (13)</td>
</tr>
<tr>
<td></td>
<td>** (20, 1, 25) **</td>
<td>** (Red)</td>
<td>** (24)</td>
</tr>
<tr>
<td></td>
<td>** (50, 1, 25) **</td>
<td>** (Blue-green)</td>
<td>** (20)</td>
</tr>
<tr>
<td></td>
<td>** (35, 1, 25) **</td>
<td>** (Red)</td>
<td>** (21)</td>
</tr>
</tbody>
</table>

* B1 and B3 were not exposed to the return to Phase 1 conditions; those subjects died.

** B4 and B5 were not exposed to Phase 1 conditions at this time; those subjects were exposed to those conditions following Phase 3.

The procedures used in Phase 1 were replicated following the first exposure to Phase 3 conditions (see below for details), and the sequence of conditions and
number of sessions of exposure to those conditions are also shown for each subject (in parentheses) in Table 1. One of the subjects (B2) from the initial exposure to Phase 1 conditions was returned to those conditions following the first exposure to Phase 3 conditions. The two other subjects (B1 and B3) used in the initial exposure to Phase 1 died before they could be returned to the Phase 1 conditions. Two other subjects (B4 and B5) were recruited and were exposed to the Phase 1 conditions for the first time at this point in the experiment.

**Phase 2**

The purpose of this phase was to determine whether the 3-s food delivery following completion of the first FR was disrupting control by later FRs in the sequence. To test this notion, the varied sequence, FR 1 FR 1 FR 25, was compared to the comparison sequence, FR 1 FR 25 FR 1, during conditions where either a 3-s food delivery (and hopper illumination) or a 3-s hopper illumination alone followed the completion of the first FR in each sequence. The varied and comparison sequences were constant throughout all conditions of the second phase, but the outcome following the completion of the first FR in those sequences was different. During two of the four conditions of Phase 2, a 3-s food delivery (and hopper illumination) was the outcome for the initial FRs and a 3-s hopper illumination alone was the outcome for the other two conditions. The completion of the second and third FR components in each sequence still resulted in 3 s of food and hopper illumination, as in Phase 1. The subjects were exposed to each of the four conditions in an ABAB reversal design, with key color and condition order counterbalanced across subjects. Table 2 shows for each subject the sequence of conditions and number of sessions of exposure during Phase 2.
Table 2
Sequence of Conditions and Number of Sessions Under Each Condition for Each Subject in Phase 2

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Varied Sequence of FRs (and outcome following first FR)</th>
<th>Key Color</th>
<th>Number of Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1, 1, 25 Food</td>
<td>Blue-green</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Blue-green</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Food</td>
<td>Blue-green</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Blue-green</td>
<td>20</td>
</tr>
<tr>
<td>B2</td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Red</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Food</td>
<td>Red</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Red</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Food</td>
<td>Red</td>
<td>24</td>
</tr>
<tr>
<td>B3*</td>
<td>1, 1, 25 Food</td>
<td>Blue-green</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Blue-green</td>
<td>10</td>
</tr>
<tr>
<td>B4</td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Red</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Food</td>
<td>Red</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Red</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Food</td>
<td>Red</td>
<td>10</td>
</tr>
<tr>
<td>B5</td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Blue-green</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Food</td>
<td>Blue-green</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Hopper Illumination</td>
<td>Blue-green</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 Food</td>
<td>Blue-green</td>
<td>11</td>
</tr>
</tbody>
</table>

* B3 died after two conditions of Phase 2. At this time, B4 and B5 were recruited for the study.

Phase 3

In Phase 3, the value of the initial FR in each sequence was again altered to see if preference for the varied sequence (FR X FR 1 FR 25) changed with the value of the initial FR. No such functional relation was evident in Phase 1. Because Phase 2 results indicated that the 3-s food delivery following the completion of the first FR may have disrupted control by subsequent FRs, Phase 3 replicated Phase 1 with the
exception that food was not delivered after completion of the first FR in each sequence. Instead, a 3-s hopper illumination alone followed the completion of the first FR in each sequence. The procedures used during Phase 3 were identical to those of Phase 1 where the initial FR components of each sequence were equal and, across blocks of sessions, initial FR values of 1, 5, 20, 35, and 50 were arranged. The only difference in Phase 3 was the outcome following the completion of the first FR in each sequence. Instead of having access to 3 s of food (and hopper illumination) at the completion of the first FR, subjects instead were presented with only 3 s of hopper illumination. If access to food following the completion of the first FR in each sequence was somehow disrupting control by subsequent FR components, removing that food delivery should have the effect of increasing the probability of choice responding to the sequence containing the shorter second FR component (FR X FR 1 FR 25) and preference for that sequence should change functionally with changes in the value of the initial FRs (FR X, where X = 1, 5, 20, 35, or 50). Table 3 shows for each subject the sequence of conditions and number of sessions of exposure during Phase 3.

The procedures used in Phase 3 were replicated following the replication of Phase 1 procedures (see above), and the sequence of conditions and number of sessions of exposure to those conditions are shown for each subject (in parentheses) in Table 3.
Table 3
Sequence of Conditions and Number of Sessions Under Each Condition for Each Subject in Phase 3 and the Return to Phase 3

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Varied Sequence of FRs</th>
<th>Key Color</th>
<th>Number of Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (<em>) * (</em>)</td>
<td>10 (13)</td>
</tr>
<tr>
<td></td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>23 (10)</td>
</tr>
<tr>
<td></td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>13 (21)</td>
</tr>
<tr>
<td></td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>10 (17)</td>
</tr>
<tr>
<td></td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>10 (15)</td>
</tr>
<tr>
<td>B2</td>
<td>20, 1, 25 (50, 1, 25)</td>
<td>Blue-green (Blue-green)</td>
<td>10 (13)</td>
</tr>
<tr>
<td></td>
<td>35, 1, 25 (5, 1, 25)</td>
<td>Red (Red)</td>
<td>23 (10)</td>
</tr>
<tr>
<td></td>
<td>50, 1, 25 (1, 1, 25)</td>
<td>Blue-green (Blue-green)</td>
<td>13 (21)</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 (35, 1, 25)</td>
<td>Blue-green (Red)</td>
<td>10 (17)</td>
</tr>
<tr>
<td></td>
<td>5, 1, 25 (20, 1, 25)</td>
<td>Red (Blue-green)</td>
<td>10 (15)</td>
</tr>
<tr>
<td>B3</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>10 (13)</td>
</tr>
<tr>
<td></td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>14 (24)</td>
</tr>
<tr>
<td></td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>11 (16)</td>
</tr>
<tr>
<td></td>
<td>* (<em>) * (</em>) * (*)</td>
<td>* (<em>) * (</em>) * (*)</td>
<td>13 (15)</td>
</tr>
<tr>
<td>B4</td>
<td>50, 1, 25 (35, 1, 25)</td>
<td>Blue-green (Blue-green)</td>
<td>13 (10)</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 (20, 1, 25)</td>
<td>Red (Blue-green)</td>
<td>11 (10)</td>
</tr>
<tr>
<td></td>
<td>20, 1, 25 (5, 1, 25)</td>
<td>Blue-green (Red)</td>
<td>14 (24)</td>
</tr>
<tr>
<td></td>
<td>5, 1, 25 (50, 1, 25)</td>
<td>Blue-green (Red)</td>
<td>11 (16)</td>
</tr>
<tr>
<td></td>
<td>35, 1, 25 (1, 1, 25)</td>
<td>Red (Red)</td>
<td>13 (15)</td>
</tr>
<tr>
<td>B5</td>
<td>5, 1, 25 (50, 1, 25)</td>
<td>Red (Red)</td>
<td>12 (15)</td>
</tr>
<tr>
<td></td>
<td>35, 1, 25 (1, 1, 25)</td>
<td>Blue-green (Red)</td>
<td>13 (23)</td>
</tr>
<tr>
<td></td>
<td>1, 1, 25 (20, 1, 25)</td>
<td>Red (Red)</td>
<td>15 (16)</td>
</tr>
<tr>
<td></td>
<td>50, 1, 25 (35, 1, 25)</td>
<td>Red (Blue-green)</td>
<td>28 (22)</td>
</tr>
<tr>
<td></td>
<td>20, 1, 25 (5, 1, 25)</td>
<td>Blue-green (Blue-green)</td>
<td>17 (15)</td>
</tr>
</tbody>
</table>

* B1 and B3 died before Phase 3; therefore, no values are presented for these subjects.

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CHAPTER III

RESULTS

Figure 1 depicts the results of Phase 1 for subjects B1, B2, and B3 and for the return to those procedures for subject B2. Additionally, the figure depicts the results of the first exposure of the Phase 1 procedures for subjects B4 and B5. In all figures, the data shown indicate performance during the final five days of each condition.

Figure 1 shows that none of the subjects (B1, B2, B3) showed any preference for the varied sequence (FR X FR 1 FR 25, when X equalled 5, 20, 35 or 50 across blocks of sessions). When X was 1, however, one subject (B3) did show clear preference for the varied sequence (i.e., FR 1 FR 1 FR 25) over the comparison sequence (i.e., FR 1 FR 25 FR 1). Subject B3 allocated 97% of its choice responses to the varied sequence.

During the second exposure to the Phase 1 conditions, subject B2 showed some preference for the FR X FR 1 FR 25 sequence when X was equal to 1, 5, and 50. During these conditions, subject B2 allocated 62%, 77%, and 62% of its choice responses, respectively, to the varied sequence. Subjects B1 and B3 died before they could be re-exposed to the Phase 1 conditions, so no data are available for them. For subjects B4 and B5 (who were added to the study during Phase 2), preference for the varied sequence was evident when the value of the first FR in that sequence was 1 and 5. Subject B4 also preferred the varied sequence when the initial FR value was 50. Subject B4 allocated 87%, 76%, and 72% of its choice responses, respectively, to the FR X FR 1 FR 25 when X equalled 1, 5, and 50. Subject B5 allocated 62% and 72% of its choice responses, respectively, to the FR X FR 1 FR 25 when X
Figure 1. Choice Responding During Phase 1.

Percentage of choice responses allocated by each subject (B1, B2, B3, B4, B5) during the first and second exposures to the varied sequence FR X FR 1 FR 25, where X = 1, 5, 20, 35, or 50, and when the comparison sequence was an FR X FR 25 FR 1, where X = 1, 5, 20, 35, or 50. The filled circles represent performance for subjects (B1, B2, B3) upon first exposure to Phase 1 conditions. The open squares for one subject (B2) represent performance after being re-exposed to Phase 1 conditions. For two other subjects (B4, B5), the open squares represent performance after first exposure to Phase 1 conditions, but occurring at the same time as re-exposure for subject B2. Subjects B1 and B3 could not be re-exposed to those conditions because they had died. Each frame (from left to right) illustrates performance when the varied sequence was FR 1 FR 1 FR 25, FR 5 FR 1 FR 25, FR 20 FR 1 FR 25, FR 35 FR 1 FR 25, and FR 50 FR 1 FR 25. The five data points shown for each condition represent performance during the final five sessions, when responding was stable. Food (and hopper illumination) was available for 3 s following the completion of each FR in a sequence.
equalled 1 and 5. During all other conditions for these subjects, no preference was seen for the varied sequence.

The results of Phase 2 are depicted in Figure 2. During all conditions of Phase 2, four subjects (B1, B2, B4, and B5) clearly preferred the FR 1 FR 1 FR 25 (varied) sequence over the FR 1 FR 25 FR 1 (comparison) sequence. One subject (B3) allocated its choice responses indifferently between these two sequences. The data of particular interest, however, are those which compare the degree of preference for the varied sequence for all subjects during the conditions when either a 3-s food delivery or a 3-s hopper illumination (without food) were the outcomes upon completion of the first FR schedule in both sequences. For subjects B1, B3, and B5, the degree of preference for the varied sequence clearly was greater when a 3-s hopper illumination (HI) was the outcome for the first FR schedule in both sequences than when a 3-s food (F) delivery was the outcome. For subject B1, exposed first to the food condition, then to the hopper illumination condition, then again to the food condition, and finally to the hopper illumination condition, 27%, 83%, 70%, and 97% of its choice responses, respectively, were allocated to the varied sequence. Subject B3 allocated 50% and 57% of its choice responses, respectively, to the varied sequence when exposed first to the food and then to the hopper illumination condition. Subject B3 died at this point, thus, re-exposure to these conditions was impossible. Subject B5, during exposure to the hopper illumination, food, hopper illumination, and food conditions, allocated 97%, 93%, 97%, and 93% of its choice responses, respectively, to the varied sequence.

Two other subjects (B2 and B4) exposed to these same conditions showed early indications of a greater degree of preference for the varied sequence when hopper illumination was the outcome following the first FR in each sequence than when food was the outcome. However, during re-exposures to these conditions, a greater
Figure 2. Choice Responding During Phase 2.

Percentage of choice responses allocated by each subject (B1, B2, B3, B4, B5) to the varied sequence FR 1 FR 1 FR 25 during the first and second exposures to food (F) conditions and the hopper illumination (HI) conditions when the comparison sequence was FR 1 FR 25 FR 1. During the food conditions, a 3-s food delivery (and hopper illumination) was the outcome for the completion of each FR schedule in both sequences. During the hopper illumination conditions, a 3-s food delivery (and hopper illumination) was the outcome for the completion of all FR schedules in both sequences except the first FR schedule, where a 3-s hopper illumination (without food delivery) was instead the scheduled outcome. Subject B3 died after a single exposure to each experimental condition. The five data points shown for each condition represent performance during the final five sessions, when responding was stable.
degree of preference for the varied sequence was seen when food was the outcome for the first FRs in each sequence. For subject B2, exposed first to hopper illumination, then to food, then to hopper illumination, and finally to food, 95%, 85%, 97%, and 98% of choice responses, respectively, were allocated to the varied sequence. Subject B4 showed a similar increase in the degree of preference for the varied sequence when food was the outcome for the first FRs in both sequences during the latter conditions. After being exposed first to the hopper illumination and to the food conditions, B4 allocated 97% and 93% of its choice responses, respectively, to the varied sequence. Upon re-exposure to those conditions (first hopper illumination and then food), B4 allocated 97% and 100% of its choice responses, respectively, to the varied sequence, illustrating an increased preference for the varied sequence when food was the outcome following the first FR in both sequences.

Phase 3 results are depicted in Figure 3. Upon first exposure to most of the Phase 3 conditions, all of the subjects (B2, B4, and B5) allocated the majority of their choice responses to the FR X FR 1 FR 25 sequence, regardless of whether X equalled 1, 5, 20, 35 or 50. Exceptions occurred with subject B2 when the varied sequence equalled FR 1 FR 1 FR 25 and FR 50 FR 1 FR 25. That subject allocated 52% and 43% of its choice responses, respectively, to the varied sequence under these conditions. Additionally, subject B5 allocated 53% of its choice responses to the varied sequence when it equalled FR 50 FR 1 FR 25. Throughout all the remaining conditions, however, clear preference for the varied sequence was exhibited by the subjects.

During the second exposure to the Phase 3 conditions, all of the subjects continued to show a clear preference for the FR X FR 1 FR 25 sequence when X equalled 1, 5, 20, 35, or 50. For example, during the final five days of each
Figure 3. Choice Responding During Phase 3.

Percentage of choice responses allocated by each subject (B2, B4, B5) during the first (filled circles) and second (open squares) exposures to the varied sequence FR X FR 1 FR 25, where X = 1, 5, 20, 35, or 50 and the comparison sequence was an FR X FR 25 FR 1, where X = 1, 5, 20, 35, or 50. Each frame (from left to right) illustrates performance when the varied sequence was FR 1 FR 1 FR 25, FR 5 FR 1 FR 25, FR 20 FR 1 FR 25, FR 35 FR 1 FR 25, and FR 50 FR 1 FR 25. No data are available for subjects B1 and B3 because they died. The five data points shown for each condition represent performance during the final five sessions when responding was stable. Food and hopper illumination was available for 3 s following the completion of the second and third FRs in a sequence and completion of the first FR in each sequence was followed by exposure to 3 s of hopper illumination alone.
condition, on average, subject B2 allocated 71%, 90%, 67%, 78%, and 65% of its choice responses to the varied sequence when that sequence equalled FR 1 FR 1 FR 25, FR 5 FR 1 FR 25, FR 20 FR 1 FR 25, FR 35 FR 1 FR 25, and FR 50 FR 1 FR 25, respectively. Subject B4 allocated 92%, 88%, 87%, 55%, and 75% of its choice responses to the varied sequence when exposed to these same sequences. Similarly, subject B5 allocated 93%, 95%, 65%, 67%, and 77% of its choice responses to the varied sequence under these conditions.
CHAPTER IV

DISCUSSION

Results from the first phase of the present study were rather variable, and indicated only a weak and inconsistent preference for the varied sequence, FR X FR 1 FR 25, relative to a FR X FR 25 FR 1 comparison sequence. Such preference characteristically was observed when X was equal to 1 or 5, but not when it was equal to 20, 35, or 50. However, even when X was 1 or 5, the varied sequence was not always preferred. Although not compelling, Phase 1 data are consistent with previous reports indicating that FRs after the first in a sequence usually exercise weak, although sometimes detectable, control over choice (Goeters et al., 1989; Poling et al., 1987). Those researchers also used a discrete-trials procedure that employed forced-exposure and choice trials to assay the variables controlling pigeons' choice responding. The present study replicated their research by showing that, under some conditions, fixed-ratios other than the first lawfully, although weakly, influence choice.

Control of choice by FRs other than the first in a sequence of three was clearly apparent in Phases 2 and 3 of the present study. A possible explanation for the difference in results when Phases 2 and 3 are compared to Phase 1 is that, in Phase 1, food presentations following the initial FRs in both sequences somehow disrupted control by subsequent FRs. This notion is supported by results reported by Blakely and Poling (1991), who employed procedures similar to those used in the present experiments. In their study, two kinds of outcomes (a 3-s food delivery and a 0.25-s hopper flash) were programmed to discern whether or not the relative effects of FR

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size and reinforcer magnitude in the second FR depended on the magnitude of reinforcer offered by the initial FR, as well as on initial FR size. In that study, the type of reinforcer delivered after the initial FRs did seem to make some difference in the control exerted by subsequent FRs. Blakely and Poling (1991) concluded, however, that the difference in the duration of reinforcer delivery (3 s for food versus 0.25 s for the hopper flash) was the important variable accounting for the differences observed.

Another explanation is possible. It may be that the important variable was not the quantitative difference (i.e., duration) between reinforcers, but rather the qualitative difference (i.e., food versus hopper light) between reinforcers. Phase 2 of the current experiment was designed to test this notion. It was possible, for example, that the 3-s food delivery following the initial FRs was disrupting and/or weakening sensitivity to subsequent FR schedules. Support for this was offered by Hall-Johnson and Poling (1984) who stated a "possible explanation for the failure of the second FR in an FR FR sequence to consistently affect choice responding is that primary reinforcement (food delivery) following the initial component obscures control that would otherwise be exerted by the terminal component. Studies using concurrent chained schedules have convincingly demonstrated that terminal components influence choice when responding in the initial components leads only to access to the terminal components and not directly to food delivery (see de Villiers, 1977; Fantino, 1977)" (p. 134).

This notion was tested in the second phase of the current experiment by comparing preference for two sequences, FR 1 FR 1 FR 25 versus FR 1 FR 25 FR 1, under conditions where a 3-s food delivery did and did not follow the initial FRs in each of the sequences. During one phase, a 3-s food delivery (and hopper illumination) was programmed; during another phase, a 3-s hopper illumination alone was programmed. In general, preference for the FR 1 FR 1 FR 25 sequence was
greater under the latter condition. This suggests that food delivery following completion of an initial FR influences the behavioral effects of subsequent FRs in a sequence. Phase 3 data provide additional support for this conclusion.

In Phase 3, pigeons were given a choice between a varied FR X FR 1 FR 25 sequence and a comparison FR X FR 25 FR 1 sequence, where X was equal to 1, 5, 20, 35, and 50 across conditions. Food was not delivered following completion of the initial FR in either sequence. With this exception, conditions of Phase 1 and Phase 3 were identical.

The results of Phase 3 differed substantially than those of Phase 1. The results during both the first and second exposure to Phase 3 conditions illustrated that all subjects preferred the varied sequence, FR X FR 1 FR 25, when X was equal to 1, 5, 20, 35, and 50. Additionally, for two of the three subjects (B4 and B5), the preference for the FR X FR 1 FR 25 sequence did seem to change functionally with the value of the initial FR. That is, those subjects preferred the FR X FR 1 FR 25 sequence more strongly when the initial X value was equal to 1 than when the initial X value was equal to 50. Moreover, preference for the varied sequence did, for the most part, decrease as the values of the initial FRs in both sequences increased. These results extend previous findings (Blakely & Poling, 1991; Goeters et al., 1989; Poling et al., 1987) by showing that the effects of FRs other than the first in a sequence of three FRs depend, in part, on the size of the first FRs in the alternative sequences.

Phase 3 findings also are congruent with those of several other researchers who studied choice under concurrent chain schedules (Abarca & Fantino, 1982; Fantino, 1969, 1977; Squires & Fantino, 1971). The studies using concurrent chain schedules showed, in general, that choice is partly dependent on the size of the initial-link component. As stated by Abarca and Fantino (1982), for example, "Fantino (1969)
and Squires and Fantino (1971) showed that with sufficiently long initial links, organisms are almost indifferent between the terminal links and that with sufficiently short initial links, the subject responds exclusively to the key leading to the shorter terminal link" (p. 119).

In the present study, the discrete-trials procedure arranged in Phase 3 was similar to a concurrent chain schedule because completion of the initial FRs in each sequence did not produce primary reinforcement. Instead, meeting the requirements of the initial FRs led to (a) a 3-s hopper illumination (putative conditioned reinforcement) followed by (b) access to the remaining FRs in the sequence. Completion of those FRs produced primary reinforcement (food). This may explain why, during the "hopper illumination" condition of Phase 3, pigeons chose the FR X FR 1 FR 25 sequence over the FR X FR 25 FR 1 sequence. The FR X FR 1 FR 25 sequence is the sequence that provided a shorter delay to primary reinforcement (i.e., food delivery). Interestingly, when the initial FRs of both of the sequences were high (FR 35 or FR 50), the pigeons generally were indifferent between the sequences. This is consistent with the choice literature using concurrent chain procedures; with sufficiently long initial links, subjects are not strongly affected by differences in terminal links (Abarca & Fantino, 1982; Fantino, 1969; 1977; Squires & Fantino, 1971). In the current study, when the initial FRs were low (FR 1, FR 5, or FR 20), the majority of choice responses were allocated to the sequence with the shorter second FR component. This is also consistent with the choice literature using concurrent chain procedures; with sufficiently short initial links, subjects will choose the key leading to the shorter terminal link (Abarca & Fantino, 1982; Fantino, 1969; 1977; Squires & Fantino, 1971).

In all, the present findings are consistent with much of the literature on choice as examined under concurrent chain schedules (Davison, 1969; Duncan & Fantino,
1970; Fantino, 1967; Herrnstein, 1964; Killeen, 1968). In this literature, according to Fantino (1969), "the critical variable determining choice is the amount of reduction in expected time to primary reinforcement signified by entry into one terminal link relative to the reduction in expected time to reinforcement signified by entry into the other terminal link" (p. 724). The findings of the current experiment, which confirm that FRs other than the first in a series may, but do not necessarily, affect preference, appear to be consistent with such a delay-reduction analysis of choice.
Appendix A

Institutional Animal Care and Use Committee Protocol Clearance
INVESTIGATOR CERTIFICATION

Title of Project: Sequences of Fixed-Ratio Schedules: The Effects of Ratio Size in the Second Fixed-Ratio on Pigeons' Choice Behavior

If any of the above procedures are changed, I will submit a new protocol.

I understand that any failure to comply with the Animal Welfare Act, the provisions of the DPHS Guide for the Care and Use of Laboratory Animals and requirements set down by the IACUC may result in the suspension of my animal studies.

Signature: Principal Investigator

Signature: Psychology Department Date

REVIEW BY THE INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE

Disapproved  Approved  Approved with the provisions listed below

Provisions:

or

Explanation

IACUC Chairperson  Date

Researcher's Acceptance of Provisions:

Signature: Principal Investigator Date

IACUC Chairperson Final Approval Date

Approved IACUC Number

Revised June, 1988

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BIBLIOGRAPHY


