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CHOICE BETWEEN SEQUENCES OF FIXED-RATIO SCHEDULES: EFFECTS OF RATIO VALUES AND PROBABILITY OF FOOD DELIVERY

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Pigeons were exposed to schedules of food delivery that consisted of two sequential fixed ratios. When alternative sequences provided two food deliveries per 50 responses, the schedule with the shorter initial fixed-ratio value was consistently preferred. Progressively reducing from 1.0 to .25 the probability of food delivery following completion of the second fixed ratio of the sequence with the shorter initial fixed ratio did not reduce preference for this sequence. Moreover, the sequence with the shorter initial fixed ratio also was preferred when the probability of food delivery following completion of the initial ratio in that sequence was progressively reduced from 1.0 to .5, although preference shifted to the alternative when the probability was reduced to 0. These findings suggest that the length of the initial fixed ratio was a primary determinant of choice. Subsequent manipulations demonstrated, however, that when the initial fixed ratios of the two alternatives were equal, changes in the ratio value and probability of food delivery following completion of the second fixed ratio lawfully affected choice.

Key words: fixed-ratio schedules, operant behavior, concurrent chains, choice, key peck, pigeons

To live is to choose. To choose is to emit operant behavior, which is controlled by current and historical variables. Behavior analysts have expended considerable effort in isolating these variables, especially as they affect choice under concurrent free-operant schedules (de Villiers, 1977). Discrete-trial procedures also have been used in choice research, and are noteworthy in enabling researchers to examine variables not readily studied with free-operant procedures. The role of fixed-ratio (FR) sequences in controlling preference is an example of such a variable. This variable was evaluated by Hall-Johnson and Poling (1984), who gave pigeons a choice between schedules that consisted of two sequential FRs, the completion of each being followed by food delivery. When each alternative provided two food deliveries per 100 responses, the schedule with the shorter initial FR value was consistently preferred. Subsequent attempts were made to shift this established preference by (1) increasing the ratio requirement in the second FR of the preferred schedule; (2) increasing the duration of food delivery in the second FR of the nonpreferred schedule; (3) decreasing the duration of food delivery in the first FR of the preferred schedule; and (4) shortening the second FR of the nonpreferred schedule. Preference shifted from the schedule with the shorter initial FR only when the duration of food delivery correlated with the first FR of that schedule was too brief to allow eating. Under all other conditions, pigeons strongly preferred the schedule with the shorter initial FR even when, overall, that schedule yielded briefer access to food or required more responses to produce equivalent access.

These findings and those of related investigations (e.g., Gardner & Lewis, 1977; Green, Fisher, Perlow, & Sherman, 1981; Rachlin & Green, 1972; Shull, Spear, & Bryson, 1981) demonstrate that the effects of temporally prior reinforcers can overshadow those of subsequent reinforcers. The purpose of the present study was to examine further the behavior of pigeons given a choice between sequences of fixed-ratio schedules. General procedures were similar to those employed by Hall-Johnson and Poling (1984), except that during initial conditions two reinforcers were delivered per

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Table 1

Sequence of conditions, number of sessions under each condition, and the key color that accompanied the constant sequence for each subject.

	Subject 4				Subject 5			
Phase	Varied schedule		Constant key color	Number of sessions	Varied schedule		Constant key color	Number of sessions
1	FR 25	FR 25		11	FR 25	FR 25		10
	FR 5	FR 45	Red	13	FR 35	FR 15	Blue	20
	FR 35	FR 15	Red	36	FR 5	FR 45	Red	11
	FR 45	FR 5	Blue	22	FR 45	FR 5	Blue	22
	FR 15	FR 35	Blue	33	FR 15	FR 35	Blue	23
3	FR 5 (.25)	FR 45 (1.0)	Blue	27	FR 5 (.25)	FR 45 (1.0)	Red	28
	FR 5 (.75)	FR 45 (1.0)	Blue	10	FR 5 (0.0)	FR 45 (1.0)	Red	14
	FR 5 (.50)	FR 45 (1.0)	Red	34	FR 5 (.50)	FR 45 (1.0)	Red	13
	FR 5 (0.0)	FR 45 (1.0)	Red	12	FR 5 (.75)	FR 45 (1.0)	Blue	12
4	FR 5 (1.0)	FR 45 (.75)	Red	26	FR 5 (1.0)	FR 45 (.75)	Red	10
	FR 5 (1.0)	FR 45 (.25)	Red	10	FR 5 (1.0)	FR 45 (.50)	Blue	11
	FR 5 (1.0)	FR 45 (.50)	Blue	22	FR 5 (1.0)	FR 45 (.25)	Red	8
2	FR 25	FR 15	Red	26	FR 25	FR 5	Red	18
	FR 25	FR 45	Blue	21	FR 25	FR 45	Red	31
	FR 25	FR 5	Red	47	FR 25	FR 15	Red	70
	FR 25	FR 35	Red	33	FR 25	FR 35	Red	21
	FR 25	FR 1	Red	71	FR 25	FR 1	Red	18
5	FR 25 (1.0)	FR 25 (.25)	Red	17	FR 25 (1.0)	FR 25 (.25)	Red	40
	FR 25 (1.0)	FR 25 (.75)	Blue	29	FR 25 (1.0)	FR 25 (.50)	Blue	14
	FR 25 (1.0)	FR 25 (.50)	Blue	23	FR 25 (1.0)	FR 25 (.75)	Red	60

50 responses. Probability of food delivery, a parameter known to affect preference in other assays (e.g., Shimp, 1966, 1967), was the independent variable of primary interest; this variable was manipulated for both the first and second FR of two-FR sequences. Effects of altering length of the first and second FR also were examined in a systematic replication and extension of the Hall-Johnson and Poling study.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons, maintained at 80% of their free-feeding weights, served as subjects. Each bird was housed individually with unlimited access to water and grit in a constantly illuminated room.

Apparatus

Three Lehigh Valley Electronics operant conditioning chambers, measuring 32 cm long, 36 cm high, and 35 cm wide, were used. In each chamber, three response keys 2.5 cm in diameter were located 23 cm from the bottom of the front wall, approximately 5.5 cm apart. The keys could be transilluminated in red or blue-green. A force of approximately 0.2 N was required for key operation. An aperture horizontally centered on the front wall 7.5 cm above the floor allowed access to a hopper filled with mixed grain when the hopper was raised. When raised, the hopper was illuminated by a 7-W white bulb. A 7-W white bulb centrally mounted in the ceiling of the chamber provided continuous ambient illumination during experimental sessions, and a Grason-Stadler white-noise generator supplied masking noise.

Data collection and scheduling of experimental events were accomplished through the use of a Digital Equipment Corporation PDP/8A® minicomputer using interfacing and software (SUPERSKED®) obtained from State Systems, Inc.

Procedure

Subjects initially were exposed to an autoshaping procedure wherein one of the three keys, selected at random, was illuminated in

Table 1 (*Continued*)

Subject 6			
Varied schedule		Constant key color	Number of sessions
FR 25	FR 25		10
FR 5	FR 45	Blue	11
FR 15	FR 35	Red	29
FR 45	FR 5	Red	22
FR 35	FR 15	Blue	26
FR 5 (.25)	FR 45 (1.0)	Blue	16
FR 5 (.75)	FR 45 (1.0)	Blue	11
FR 5 (0.0)	FR 45 (1.0)	Blue	12
FR 5 (.50)	FR 45 (1.0)	Blue	17
FR 5 (1.0)	FR 45 (.25)	Red	15
FR 5 (1.0)	FR 45 (.75)	Blue	17
FR 5 (1.0)	FR 45 (.50)	Red	10
FR 25	FR 45	Red	18
FR 25	FR 5	Red	20
FR 25	FR 35	Red	24
FR 25	FR 15	Red	29
FR 25	FR 1	Blue	33
FR 25 (1.0)	FR 25 (.75)	Blue	42
FR 25 (1.0)	FR 25 (.25)	Red	24
FR 25 (1.0)	FR 25 (.50)	Blue	11

red or blue-green for 6 s, followed by a 3-s response-independent food delivery. Key illuminations were arranged under a random-time 45-s schedule, all combinations of color and position occurred equally often, and daily sessions terminated after 40 key illuminations (trials). When all subjects pecked the lighted key on a minimum of 90% of trials in two consecutive sessions, they were exposed to discrete-trial fixed-ratio (FR) schedules of food delivery.

In early FR training, at 15-s intervals one of the three keys was illuminated in red or blue-green, and remained lighted until pecked. The first peck extinguished key illumination and produced a 3-s food delivery (i.e., an FR 1 schedule was in effect). On each trial, the key that was lighted and the color of key illumination were selected at random. Over several sessions, the FR value was increased gradually from 1 to 45. When all birds reliably completed the FR 45 schedule on all keys during red and blue-green illuminations, the experiment proper was begun.

During the experiment proper, subjects were exposed to a discrete-trial procedure in which sequences of two FR schedules were arranged. In all experimental conditions, one sequence remained constant at FR 25 FR 25; the other was varied as described below. Duration of food delivery was always 3 s, and all trials were programmed under a fixed-time 15-s schedule (i.e., trials were separated by a 15-s intertrial interval [ITI] in which keys were darkened and responses had no scheduled consequences). In the first phase of the study, which systematically replicated the Hall-Johnson and Poling (1984) experiment, the FR values in the varied sequence were arranged so as to total 50 responses, and food delivery followed the completion of each FR in both the constant and the varied schedule. Each session began with 20 forced-exposure trials, followed by 20 choice trials. In forced-exposure trials, one of the three keys was lighted in red or blue-green. The key that was lighted was randomly selected, and red and blue-green illuminations alternated in an irregular order, with each appearing 10 times during the 20 forced-exposure trials. This three-key procedure was employed in an attempt to prevent possible position biases from confounding results.

Initially, for two birds (P4, P5), when a key was lighted in blue-green, the constant schedule was in effect, whereas red illlumination was correlated with the varied schedule. These relations were reversed for the third subject (P6). Completion of the second FR in the sequence extinguished the keylight and initiated a 15-s ITI. Choice trials were similar to forced-exposure trials, except that two of the three keys, chosen at random, were simultaneously lighted, one in red and one in blue-green. The first response on either key during choice trials darkened the alternative and terminated its accompanying schedule until the next trial occurred. A choice trial ended when the two FRs constituting a sequence were completed, and these trials, too, were separated by a 15-s ITI.

In the first phase of the study, the constant FR 25 FR 25 sequence was compared to the sequences FR 5 FR 45, FR 15 FR 35, FR 25 FR 25, FR 35 FR 15, and FR 45 FR 5. These values, and those studied later in the experiment, were compared in an irregular order that differed across birds. Throughout the study, each set of sequences was in effect for at least eight sessions; conditions were changed only when the percentage of choice

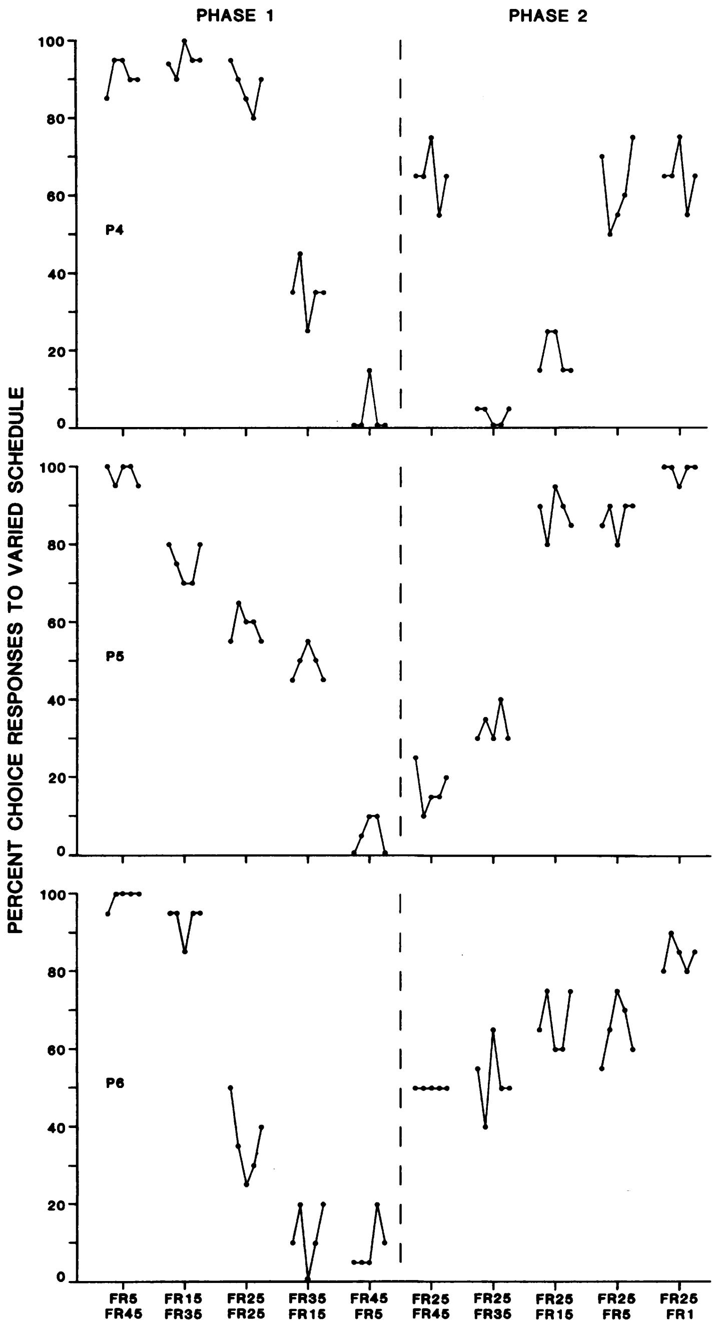

Fig. 1. Percentage of choice responses directed by each bird (P4, P5, P6) to the varied schedule sequence when the alternative (i.e., constant schedule) was an FR 25 FR 25 sequence. Food was delivered following completion of all ratios. Each data point represents performance during one of the final five sessions of exposure to the indicated conditions.

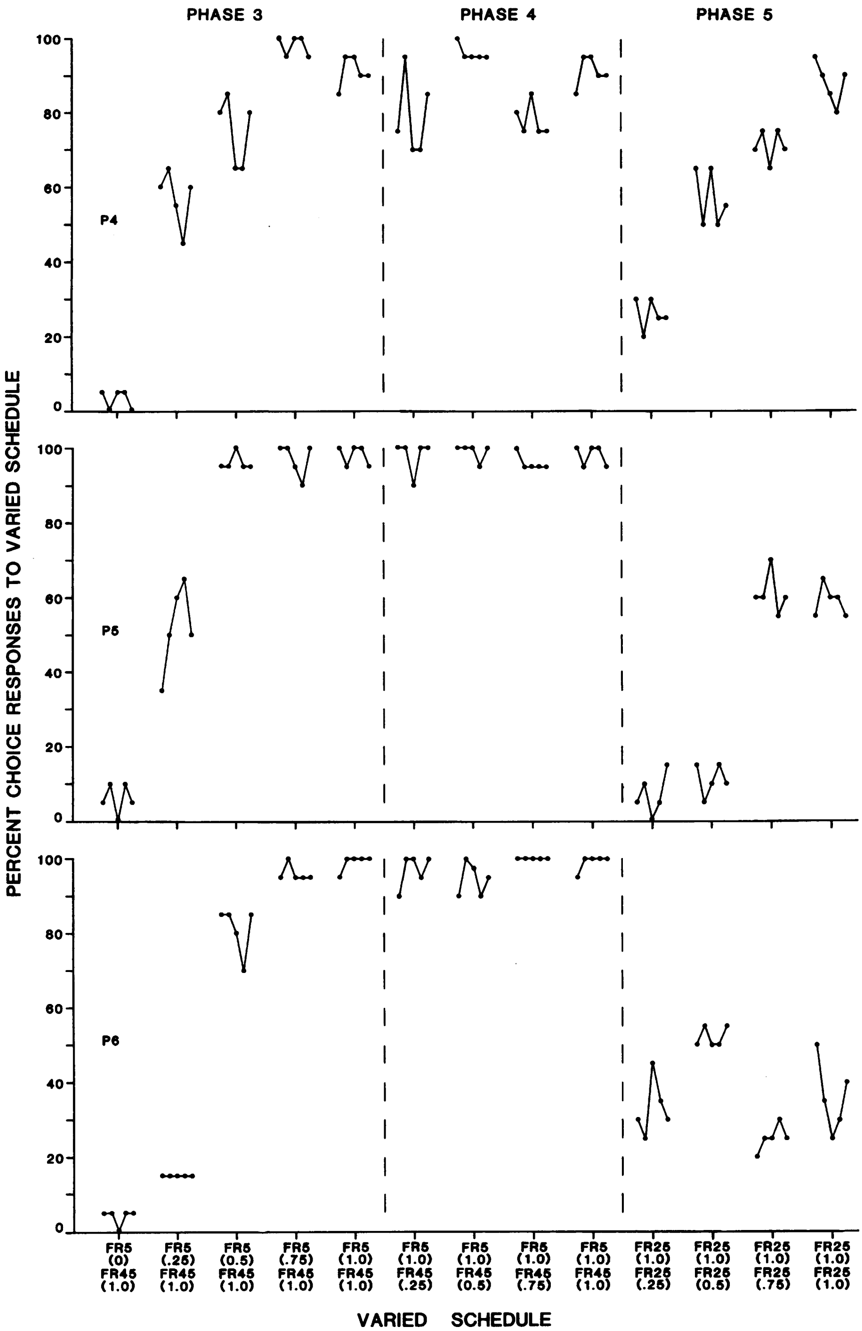

Fig. 2. Percentage of choice responses directed by each bird (P4, P5, P6) to the varied schedule sequence when the alternative (i.e., constant schedule) was an FR 25 FR 25 sequence in which food delivery followed completion of each FR. Values along the abscissa indicate the FR values of the varied schedule sequence; the top value represents the first FR. Numbers in parentheses show the probability of food delivery following completion of the FR listed above.

responses directed to the varied sequence showed no visible trend over five consecutive sessions. To prevent possible color biases from confounding results, over the course of the study the key color accompanying the constant sequence was altered 6 times for P4, 10 times for P5, and 8 times for P6. Table 1 shows for each bird the sequence of experimental conditions, number of sessions under each condition, and the color correlated with the constant sequence.

In the second phase of the study, the FR values in the varied schedule were FR 25 FR 1, FR 25 FR 5, FR 25 FR 15, FR 25 FR 35, and FR 25 FR 45. In other phases the probability of food delivery following completion of the first or second FR of the varied sequence was manipulated. The first such manipulation (Phase 3) compared the constant FR 25 FR 25 sequence to an FR 5 FR 45 sequence in which the probability of food delivery following completion of the FR 5 was 1.0, .75, .5, .25, or 0. Phase 4 compared the constant sequence to an FR 5 FR 45 sequence in which the probability of food delivery following completion of the FR 45 was 1.0, .75, .5, or .25. Phase 5 compared the constant FR 25 FR 25 sequence to an FR 25 FR 25 sequence in which the probability of food delivery following completion of the second FR was 1.0, .75, .5, or .25. In all phases, completion of an initial FR after which food was not delivered resulted in a 3-s period in which all keylights were extinguished and responses had no programmed consequences.

RESULTS

Figures 1 and 2 depict the results of manipulating response requirement and probability of food delivery, respectively. In both figures, the percentage of choice responses directed to the varied schedule is plotted for the last 5 days of each experimental condition. Phase 1 data in Figure 1 show that when both the constant and varied sequence required a total of 50 responses and yielded two food deliveries, all birds directed most choice responses to the sequence with the smaller initial ratio value. This effect was strongest at the extreme values of the varied schedule (i.e., at FR 5 FR 45 and FR 45 FR 5), where birds directed over 80% of choice responses to the schedule with the shorter initial FR. Phase 2 data in Figure 1 demonstrate that manipulating the second FR value of the varied sequence with the value of the first FR held at 25 (i.e., equal to that of the constant sequence) produced effects that differed substantially across subjects. All birds, however, preferred the FR 25 FR 1 and FR 25 FR 5 sequences to the FR 25 FR 25 alternative.

Phase 3 data, shown in Figure 2, indicate that when the probability of food delivery in the first FR of the varied (i.e., FR 5 FR 45) sequence was 0, all birds clearly preferred the constant (i.e., FR 25 FR 25) sequence. At the .25 probability, 1 bird (P6) preferred the constant schedule and the other 2 allocated about half of their choices to each alternative. Probabilities of .5 and above were correlated with preference for the varied schedule. Phase 4 data (Figure 2) show that decreases in the probability of food delivery in the second (i.e., FR 45) component of the varied schedule had no systematic effect on choice responses. However, data from Phase 5 (Figure 2) indicate that when both the varied and constant schedules were FR 25 FR 25 sequences, decreases in the probability of food delivery in the second FR 25 of the varied schedule reliably shifted preference to the constant schedule for 2 of the 3 pigeons. That is, when initial FR values were equal, the probability of food delivery in the second FR of the sequence affected choice.

DISCUSSION

When choice is arranged between differently valued fixed-ratio schedules that repeat throughout the session, responding is almost exclusively allocated to the lower valued schedule, given that the difference between the two schedules is greater than some minimum value (Herrnstein & Loveland, 1975; Neuringer, 1967). However, Hall-Johnson and Poling (1984) found that pigeons given a choice between schedules that consist of two sequential FRs frequently prefer the alternative with the shorter initial FR, even when that schedule overall yielded briefer access to food or required more responses to produce equivalent access. For example, when, in that study, the alternative sequences each yielded two 3-s food deliveries per 100 responses, the majority of choice responses were directed to the sequence offering the smaller initial FR. Data from Phase 1 of the present study replicate this finding under conditions where a total of 50 responses yielded two food deliveries.

Hall-Johnson and Poling (1984) attempted to shift preference from an FR 10 FR 90 sequence to an alternative through a variety of manipulations involving duration of food delivery and FR values. Preference shifted from the schedule with the shorter initial FR only when the duration of food delivery produced by completion of the first FR of that schedule was too brief to allow eating. In view of this, they concluded that "across the range of parameters studied, preference for the FR FR sequence with the shorter initial FR was little affected by the value of the second FR in that sequence, or by the relative magnitude of reinforcement correlated with the alternative sequence" (p. 134). Data from Phase 4 of the present study suggest that preference for the sequence with the shorter initial FR (i.e., the FR 5 FR 45 sequence) also is not altered by reducing the probability (at least to .25) of food delivery following completion of the second FR of that sequence. Moreover, data from Phase 3 indicate that an FR 5 FR 45 sequence is preferred to an FR 25 FR 25 sequence even when the probability of food delivery following completion of the FR 5 is as low as .25. These results, like those reported by Hall-Johnson and Poling, demonstrate that the value of the initial FR in two-FR sequences is a very powerful determinant of choice and that the effects of temporally prior reinforcers can overshadow those of subsequent reinforcers.

Data from Phases 2 and 5 of the present study demonstrate, however, that there are conditions under which pigeons' choice responding is sensitive to changes in the second ratio of a two-FR sequence. In Phase 2, when the initial FR of both alternatives remained at 25, as did the second FR of the constant schedule, decreasing the second FR of the varied schedule from 25 to 15, 5, and 1 resulted in clear preference for the varied schedule. Decreasing the probability of food delivery following completion of the second FR of the varied FR 25 FR 25 sequence in Phase 5 also shifted preference, in this case to the constant FR 25 FR 25 sequence in which completion of the component ratios always produced food. These findings, in contrast to those of Poling and Hall-Johnson (1984) and other phases of the present investigation, clearly indicate that manipulating the second FR of a two-FR sequence can control choice. A comparison of data from Phases 4 and 5 of the present study indicates that the effects of one such manipulation, altering the probability of food delivery in the second FR, obviously affects choice when both of the alternative sequences are equivalent (i.e., FR 25 FR 25), but has a much weaker effect when the alternatives differ (i.e., the constant sequence is FR 5 FR 45, the varied sequence FR 25 FR 25).

Concurrent and concurrent-chains schedules often are used to examine choice, and studies employing such schedules have yielded results similar to those of the present study. Several experiments have shown that pigeons prefer mixed-ratio (MR) to FR schedules that require on average an equal number of responses per reinforcer, so long as the MR schedule arranges some ratios shorter than the fixed ratio (Fantino, 1967; Rider, 1979, 1983). In general, preference for the mixed ratio increased progressively as the value of the shortest ratio programmed under that schedule decreased.

Comparable findings have been obtained with fixed-interval (FI) schedules. For example, Hursh and Fantino (1973) exposed pigeons to concurrent-chains schedules with equal variable-interval initial links in which two reinforcers (food deliveries) were arranged in each terminal link. In one alternative there were two FI 30-s schedules in the terminal link; in the other, there were two differing FI schedules whose total value was 60 s. Across conditions (Experiment 2), the values arranged were FI 5-s FI 55-s, FI 10-s FI 50-s, FI 20-s FI 40-s, FI 40-s FI 20-s, FI 50-s FI 10-s, and FI 55-s FI 5-s. Pigeons preferred the alternative with the shorter initial FI value in the terminal link, and preference increased with the difference between initial FI values. Similar data have been obtained by Davison (1968, 1972) and by Cicerone (1976).

Results of these studies, like those of the present investigation, make it clear that proximity to initial food delivery is a powerful determinant of choice, which may in some cases reduce the control exerted by otherwise operative variables.

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