**PREFERENCE IN PIGEONS GIVEN A CHOICE BETWEEN SEQUENCES
OF FIXED-RATIO SCHEDULES: EFFECTS OF RATIO VALUES
AND DURATION OF FOOD DELIVERY**

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Pigeons were exposed to schedules that consisted of two sequential fixed ratios, the completion of each followed by food delivery. When each alternative provided two food deliveries per 100 responses, the schedule with the shorter initial fixed-ratio value was consistently preferred. Subsequent attempts were made to shift this established preference by (1) increasing the ratio requirement in the second fixed ratio of the preferred schedule; (2) increasing the duration of food delivery in the second fixed ratio of the nonpreferred schedule; (3) decreasing the duration of food delivery in the first fixed ratio of the preferred schedule; and (4) shortening the second fixed ratio of the nonpreferred schedule. Preference shifted from the schedule with the shorter initial fixed ratio only when the duration of food delivery associated with the first fixed ratio of that schedule was too brief to allow eating. Under all other conditions, pigeons strongly preferred the schedule with the shorter initial fixed ratio even when, overall, that schedule yielded briefer access to food or required more responses to obtain equivalent access.

Key words: choice, fixed-ratio schedules, operant behavior, key pecking, pigeons

Performance under concurrent variable-interval variable-interval (VI VI) schedules has been examined in many studies, and the factors that influence behavior under such schedules are rather well understood (e.g., de Villiers, 1977). It is, for example, generally established that overall response (or time) allocation under concurrent VI VI schedules proportionally matches overall frequency of reinforcement, a relation quantified in recent versions of the "matching equation" (de Villiers, 1977).

Behavior under other kinds of concurrent schedules has been explored less frequently than behavior under concurrent VI VI schedules. Concurrent ratio schedules in particular have been little studied. Herrnstein (1958) and Herrnstein and Loveland (1975), however, have shown that pigeons exposed to concurrent fixed-ratio

fixed-ratio (FR FR) or concurrent variable-ratio variable-ratio (VR VR) schedules respond exclusively on the component with the shorter ratio requirement, given that the difference between the two component ratios is greater than some minimum value. These findings are in keeping with a large body of literature indicating that organisms typically prefer the response option yielding more immediate reinforcement, or requiring less effort (e.g., Catania, 1966; Chung, 1965; Kimble, 1961; Logan, 1965; Strotz, 1956).

The purpose of the present studies was to examine pigeons' performance under discrete-trial schedules involving two sequential fixed ratios, the completion of each followed by food delivery. The first study explored behavior under conditions in which two alternative schedules yielded two food deliveries per 100 responses, although the specific fixed ratios they arranged were different (e.g., one alternative might be a FR 90 FR 10, the other a FR 50 FR 50). Subsequent manipulations determined the extent to which alterations in ratio values and duration of food delivery would alter established preferences. Previous studies have not examined the role of FR sequences in control-

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ling preference, except as these values determine the overall response/reinforcer ratio under concurrent FR FR and concurrent VR VR schedules. In contrast to the free-operant paradigm frequently used to assay preference, the present experiments involved a discrete-trial procedure wherein forced-exposure and choice trials were arranged in each experimental session. Such a procedure has previously been shown to be a sensitive measure of autoshaped key pecking (Picker & Poling, 1982; Poling, Thomas, Hall-Johnson, & Picker, in press), and in addition allows for a ready determination of the role of FR sequences in controlling responding. Thus its use in the present context appears justified.

EXPERIMENT 1

This study initially determined whether preference for a schedule involving a sequence of two fixed ratios, which together yielded two food deliveries per 100 responses, was affected by the values of the individual fixed ratios. Subsequent manipulations assessed whether established preferences for the schedule with the shorter initial FR could be shifted by (1) increasing the ratio requirement in the second FR of the preferred schedule, and (2) decreasing the ratio requirement in the second FR of the non-preferred schedule.

METHOD

Subjects

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

Apparatus

Three Lehigh Valley Electronics (BRS/LVE) 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. Each key could be illuminated in white, red, or blue. A minimum force of 0.2 N was required for key operation. An aperture horizontally centered on the same wall 7.5 cm above the floor allowed access to a hopper filled with mixed grain when the hopper was raised. The hopper, when raised, was illuminated by a 7-W white bulb. A 7-W white bulb centrally mounted 33 cm from the chamber floor provided continuous ambient illumination, and 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 software (SUPERSKED[®]) obtained from State Systems, Inc.

Procedure

Subjects were initially exposed to a forward-pairing autoshaping procedure similar to that described by Brown and Jenkins (1968). Under this procedure, one of the two side keys was lighted either blue or red for 5 s. At the end of this period the key was darkened and the food hopper was raised and illuminated for 5 s. Food delivery was independent of responding. A variable inter-trial interval (ITI) averaging 30 s followed each food delivery. Each session contained 30 trials, and the color and position of key illumination (i.e., left or right) was random.

Once key pecking was reliably established for both keys and colors under the autoshaping procedure, the subjects were exposed to a discrete-trial procedure in which sequences of two FR schedules were arranged. Each session contained 16 forced-exposure trials followed by 20 choice trials. In forced-exposure trials, either the left or the right key was illuminated blue or red. (In each block of 4 trials, each position and color was presented once.) Early in training, in each forced-exposure trial the first response simultaneously darkened the key and produced 3-s access to grain (i.e., an FR 1 was in effect). The same key was then re-

lighted the same color and a single response again produced 3-s access to grain, followed by a 15-s ITI during which neither key was illuminated.

Choice trials were initiated with left and right keys lighted simultaneously. Randomization of position and color was achieved in a fashion similar to forced-exposure trials, except that a position and color combination could occur twice within a block of 4 trials. During initial choice trials, the first response on either key darkened both keys for 3 s and produced 3-s access to food. The previously pecked key then relighted the same color while the other key remained dark. A second response on the lighted key again darkened the keylight and produced 3 s of food delivery. After a 15-s ITI, in which neither key was illuminated, another trial was initiated. Across sessions, ratio requirements were gradually increased until the sequence FR 50 FR 50 was in effect during both blue-stimulus and red-stimulus trials. Then the contingencies correlated with the two were differentiated and, across blocks of sessions, choice was assayed under conditions where the sequence FR 50 FR 50 was compared to the sequences FR 10 FR 90, FR 30 FR 70, FR 70 FR 30, and FR 90 FR 10.

For all birds each comparison was made on two occasions, with the order of exposure irregular across subjects. During one of the two comparisons for each pair of sequences, red-key illumination was correlated with the FR 50 FR 50 sequence and blue-key illumination with the alternative (e.g., FR 10 FR 90); the relation of key color to schedule sequence was reversed during the other comparison. Each sequence compared to the FR 50 FR 50 was in effect until the percentage of initial choice responses to that schedule was stable (i.e., deviated no more than 10% across three consecutive sessions). Throughout the study the first response on either key during choice trials terminated the opportunity to respond on the other key until the next trial was begun. Subjects P1, P2, and P3 completed the first phase of Experiment 1 in 169, 99, and 128 sessions, respectively.

During the second phase of this study, the red stimulus was initially correlated with the sequence FR 50 FR 50 and the blue stimulus with the sequence FR 10 FR 90. Across blocks of sessions, the sequence FR 50 FR 50 was then compared to the sequences FR 10 FR 110, FR 10 FR 130, and FR 10 FR 170, arranged in that order for all birds. Each sequence remained in effect until choice responding was stable according to the criterion described above, or until 2 of the 3 subjects failed to complete a session within two hours on two consecutive sessions. Schedule values higher than FR 10 FR 170 were not examined because at that value birds frequently failed to complete sessions within the allotted time. When the second FR of the varied schedule (i.e., the alternative to FR 50 FR 50) was 110, the FR 50 FR 50 sequence was correlated with the blue stimulus; at 130, with the red stimulus; and at 170, with the blue stimulus. With the exception of the ratio values studied, choice and forced-exposure trials were identical in both phases of Experiment 1. Subjects P1, P2, and P3 completed the second phase of this study in 29, 26, and 33 sessions, respectively.

RESULTS

The data of interest involve the percentage of initial choice responses allocated to the alternative to the FR 50 FR 50 sequence (i.e., to the varied schedule). Initial choice responses are of particular significance under the conditions of the present study, because the first (initial) response emitted during a choice trial eliminated the opportunity to respond to the other alternative.

As shown in the left column of panels of Figure 1, over 90% of each bird's initial choice responses were allocated to the key correlated with the varied schedule when that schedule was an FR 10 FR 90 or an FR 30 FR 70. However, the key correlated with the FR 50 FR 50 sequence controlled over 90% of initial choice responses when the alternative sequence was FR 90 FR 10 or FR 70 FR 30. Thus, in Phase 1 of Experiment 1, subjects strongly preferred the schedule sequence with the shorter initial FR value.

Fig. 1. Percentage of initial choice responses directed by each bird (P1, P2, P3) to the varied schedule sequence when the alternative was an FR 50 FR 50 sequence. The left frames depict performance when the varied schedule sequence was FR 10 FR 90, FR 30 FR 70, FR 70 FR 30, or FR 90 FR 10. The right frames depict performance when the varied schedule sequence was FR 10 FR 90, FR 10 FR 110, FR 10 FR 130, or FR 10 FR 170. The three data points shown for each condition represent choice responding during the final three sessions of exposure to the condition, when responding was stable. All food deliveries in this experiment were 3 s in duration, and the first (initial) choice response directed toward one or the other sequence terminated the availability of the alternative for the balance of the trial.

As shown in the right column of panels of Figure 1, which presents data for Phase 2 of Experiment 1, over 90% of each bird's initial choice responses were allocated to the key correlated with the varied schedule when that schedule sequence was FR 10 FR 90, FR 10 FR 110, FR 10 FR 130, or FR 10 FR 170.

DISCUSSION

Previous data have indicated that when choice is arranged between differently valued FRs that repeat throughout the session, responding is almost exclusively allocated to the key associated with the lower FR value (Herrnstein & Loveland, 1975; Neuringer, 1967). In contrast, when concurrent FR values are equal, "responding may be maintained by either schedule, with shifts from one schedule to the other occurring from time to time" (Catania, 1966, p. 230). The first phase of the present study combined features of both equally and unequally valued concurrent FR schedules: Initial FR components were of different values, but the overall response requirement of each FR FR sequence was equal. If the mean number of responses per reinforcer were the primary determinant of choice, one would expect choice response allocation to be similar to that produced by equally valued concurrent FRs; that is, pigeons would be indifferent to the choices arranged in Phase 1 of this study. However, this did not occur; choice responding was controlled almost exclusively by the initial FR value.

Results of Phase 2 further indicate that initial FR values in FR FR sequences are the primary determinant of choice responding. Here, under conditions of greater overall response requirements in the varied schedule sequence, pigeons continued to prefer the sequence containing the shorter initial FR. This is interesting, considering the birds could have earned an equal amount of food with less effort by choosing the alternative (i.e., FR 50 FR 50) sequence.

Although increases in the value of the second FR of the varied schedule failed to

alter choice in Phase 2 of Experiment 1, it was unclear whether other kinds of parametric changes would affect preference. Experiment 2 evaluated the role of another variable, reinforcer magnitude (duration of food delivery), as a determinant of preference for FR FR sequences.

EXPERIMENT 2

This study examined whether preference could be shifted from the sequence FR 10 FR 90 to the sequence FR 50 FR 50 by (1) increasing the duration of food delivery in the second FR 50 of the FR 50 FR 50 sequence, (2) decreasing the duration of food delivery in the FR 10 of the FR 10 FR 90 sequence, and (3) increasing the duration of food delivery in the first FR 50 of the FR 50 FR 50 sequence.

METHOD

Subjects and Apparatus

Subjects and apparatus were the same as in Experiment 1.

Procedure

The basic procedure was the same as in Experiment 1. At the beginning of the first phase of this study, the red stimulus was correlated with the sequence FR 50 FR 50, the blue stimulus with the sequence FR 10 FR 90. These sequences remained constant throughout the study, although the key colors were interchanged at various points as indicated below. Across blocks of sessions, the duration of food delivery in the second FR 50 of the FR 50 FR 50 sequence was sequentially increased from 3 s to 6 and 9 s; duration of food delivery for all other FRs remained at 3 s. At 6-s food delivery, the FR 50 FR 50 sequence was correlated with the blue key; at 9-s, with the red key. Duration of food delivery was increased only when choice responding was stable, as defined in Experiment 1. Subjects P1, P2, and P3 completed the first phase of this study in 36, 22, and 24 sessions, respectively.

Phase 2 of the experiment began with the

red stimulus correlated with the FR 50 FR 50 sequence, the blue stimulus with the FR 10 FR 90 sequence. Across blocks of sessions, the duration of food delivery in the FR 10 of the FR 10 FR 90 sequence was sequentially decreased from 3 s to 1.5 and then to 0.75 s; all other food deliveries were 3 s. Duration of food delivery was decreased only when choice responding was stable according to the criterion used in Experiment 1. The blue stimulus was correlated with the FR 10 FR 90 sequence when duration of food delivery in the FR 10 component of that schedule was 3 s (the initial condition of this phase) and 0.75 s. In the other condition of interest (1.5-s food delivery in the FR 10 component), the red stimulus was correlated with the FR 10 FR 90 sequence. Subjects P1, P2, and P3 completed this phase of the study in 37, 44, and 47 sessions, respectively.

During Phase 3, duration of food delivery in the initial FR 50 of the FR 50 FR 50 sequence was systematically increased across blocks of sessions from 3 s to 6, 9, and 12 s. All other food deliveries remained constant at 3 s. The FR 50 FR 50 sequence was correlated with the blue stimulus when food delivery in the initial FR 50 was 3 and 9 s, and with the red stimulus when this value was 6 and 12 s. Duration of food delivery was increased only when choice responding was stable as defined in Experiment 1. Subjects P2 and P3 completed this phase of the study in 32 and 24 sessions, respectively. Pigeon P1 rapidly gained weight when, exposed to the final conditions of this phase, and failed to reach criterion after 28 sessions of exposure to it.

RESULTS

As seen in the left column of panels of Figure 2, over 90% of each bird's initial choice responses were allocated to the key associated with the FR 10 FR 90 sequence regardless of the duration of food delivery in the second FR 50 of the FR 50 FR 50 sequence.

As indicated in the middle column of panels of Figure 2, all birds also allocated

more than 90% of initial choice responses to the key correlated with the FR 10 FR 90 sequence when duration of food delivery in the FR 10 was 3 or 1.5 s. However, when duration of food delivery in the FR 10 was decreased to 0.75 s, P1 and P2 chose the FR 10 FR 90 sequence on no more than 5% and 10% of the trials, respectively; P3 emitted fewer than 35% of initial choice responses on the FR 10 FR 90 key under this condition.

The right column of panels of Figure 2 shows that 90% or more of P2's and P3's initial choice responses, and 80% or more of P1's initial choice responses, were allocated to the FR 10 FR 90 sequence regardless of duration of food delivery in the first FR 50 of the FR 50 FR 50 sequence.

DISCUSSION

Considerable research has indicated that, all other factors being equal, longer durations of food delivery are preferred to shorter (Catania, 1963; Fantino & Logan, 1979; Logan, 1965; Picker & Poling, 1982; Poling et al., in press; Schwartz, 1969; Ten Eyck, 1970; Young, 1981). Under the conditions of the present study, however, pigeons usually preferred the FR FR sequence with the shorter initial FR value, even when that sequence provided briefer overall access to food. Only when the duration of food delivery in the FR 10 of the FR 10 FR 90 sequence was 0.75 s did the pigeons consistently prefer the FR 50 FR 50 sequence. Direct observation of subjects indicated that 0.75-s food deliveries were too brief to allow for eating, although all other durations did so. Therefore, when food delivery in the FR 10 of the FR 10 FR 90 sequence was 0.75 s, the FR 50 FR 50 sequence actually led to more immediate primary reinforcement (food delivery). It is plausible that this factor, rather than overall duration of food delivery (6 s for the FR 50 FR 50 sequence, 3.75 s for the FR 10 FR 90 sequence), was the primary determinant of preference for the FR 50 FR 50 sequence.

Fig. 2. Percentage of initial choice responses directed by each bird (P1, P2, P3) to the FR 10 FR 90 sequence when the alternative was an FR 50 FR 50 sequence. The left frames depict performance when the second FR of the FR 50 FR 50 sequence yielded 3, 6, or 9 s of food delivery. The middle frames depict performance when the initial FR of the FR 10 FR 90 sequence yielded 0.75, 1.5, or 3 s of food delivery. The right frames depict performance when the initial FR of the FR 50 FR 50 sequence yielded 3, 6, 9, or 12 s of food delivery. The three data points shown for each condition represent choice responding during the final three sessions of exposure to the condition, when responding was stable. Except in the FR in which duration of food delivery was manipulated, all food deliveries in this study were 3 s in duration. The first (initial) choice response directed toward one or the other sequence always terminated the availability of the alternative for the balance of the trial. For Subject P1, no data are presented for the final condition shown in the right frame because the subject failed to reach stability under that condition.

GENERAL DISCUSSION

The present findings indicate 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. Many previous studies using other procedures have shown that choice is sensitive to duration of, and delay to, food delivery (e.g., Ainslie & Herrnstein, 1981; D'Amato & Buckiewicz, 1980; Deluty, 1978; Dziadosz & Tustin, 1982; Neuringer, 1967, 1969; Poling et al., in press; Schwartz, 1969). This raises the possibility that the parameters examined in the present studies simply were not extreme enough to influence behavior. Although this possibility cannot be dismissed entirely, previous investigations (e.g., Neuringer, 1967; Schwartz, 1969) have indicated that, under other conditions, choice is sensitive to differences in FR value and duration of food delivery of lesser magnitude than arranged in the present experiments.

Another 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).

Studies using concurrent chained schedules have also indicated, however, that the duration of the initial link influences preference. For example, in studies of concurrent chained schedules with VI schedules as terminal links, "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 responding occurs exclusively on the key leading to the shorter terminal link" (Abarca & Fantino, 1982, p. 119). This finding, like the results of the present studies, makes it clear that the initial component of a sequential schedule can in some cases be the primary determinant of choice.

It is of some interest that in the present experiments pigeons preferred the FR FR sequence with the shorter initial FR, even though relative to the alternative this sequence produced less overall access to food, or required more responses to produce equal access. The failure of pigeons to respond so as to maximize overall access to food in the present studies may appear counterintuitive, but it is by no means unique. Previous investigations have convincingly demonstrated that under some conditions pigeons prefer brief food deliveries delayed by short intervals over longer but more delayed ones (e.g., Green, Fisher, Perlow, & Sherman, 1981; Rachlin & Green, 1972). Other studies have also shown that pigeons may (1) prefer a schedule correlated with shorter delay to the first food delivery but a lower overall rate of food delivery (Shull, Spear, & Bryson, 1981), and (2) consistently emit a response that avoids an otherwise immediately forthcoming electric shock, even though such responding increases the total number of shocks delivered in the situation (Gardner & Lewis, 1977). These findings, like those of the present studies, demonstrate that the effects of temporally prior reinforcers can overshadow those of subsequent reinforcers, and appear to be incompatible with strong molar interpretations of operant behavior (e.g., Baum, 1973).

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