EFFECTS ON PREFERENCE OF REINFORCEMENT DELAY, NUMBER OF REINFORCERS, AND TERMINAL-LINK DURATION

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Three experiments used concurrent-chains procedures to examine the effects of reinforcement delay, number of reinforcers, and terminal-link duration on preference. In Condition 30 of Experiment 1, food was delivered after 30 seconds in each 150-second terminal link, with four additional food deliveries occurring at 30-second intervals in one of the links. In Condition 5, food was delivered after 5 seconds in each 25-second terminal link, and the four additional reinforcers were delivered at 5-second intervals. Preferences for the multiple-food chain were greater in Condition 30. In Experiment 2, the terminal link(s) providing only one reinforcer terminated immediately after delivery of the reinforcer. Preferences for the multiple-food chain were smaller than in Experiment 1. In Condition 5 of Experiment 3, food was delivered after 5, 75, 100, 125, and 150 seconds in one 150-second link and after 5 seconds in the other. Condition 50 differed only in that the first (or only) reinforcer in each link was delivered after 50 seconds instead of after 5 seconds. Preferences for the multiple-food chain were greater in Condition 50. Results of Experiments 1 and 2 do not correspond to results obtained by Moore (1979).

Key words: choice, concurrent chains, conditioned reinforcement, number of reinforcers, delay of reinforcement, terminal-link duration, rate of reinforcement, key peck, pigeons

A concurrent-chains procedure may be used to determine preferences for different arrangements of primary reinforcers in the terminal links. When this procedure is used with pigeons, initial-link stimuli are simultaneously presented on two response keys. Identical variable-interval (VI) schedules are typically used in each initial link such that a key peck to an initial-link stimulus occasionally leads to a terminal-link stimulus and delivery of some number of primary reinforcers. A higher rate of key pecking on one of the initial-link stimuli indicates that the terminal link which follows that stimulus is the preferred one. Degree of pref-

erence is then measured by the relative rate of initial-link key pecking, the number of pecks on the preferred stimulus divided by the number of pecks on both stimuli.

Although the delay to the first primary reinforcer and the relative rate of reinforcement have been emphasized as the primary determiners of schedule preferences (Autor, 1969; Davison, 1968; Herrnstein, 1964; Hursh & Fantino, 1973), other variables also seem to be effective. Both Fantino and Herrnstein (1968) and Squires and Fantino (1971) reported evidence suggesting that pigeons prefer the longer terminal link when it provides more primary reinforcers even when the rate of reinforcement is the same in each terminal link. Note that in this case the duration of the terminal link and the number of food deliveries are necessarily confounded. Fantino and Herrnstein (1968) delivered different numbers of primary reinforcers in each terminal link on a VI 15-s schedule. They reported that the degree of preference for the longer terminal link increased as its duration (and thus also the number of primary reinforcers) increased.

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Squires and Fantino (1971) obtained indirect evidence for this same effect. They employed different VI schedules within each pair of initial links. A single primary reinforcer was delivered in each of the two terminal components followed by a return to initial-link (choice) conditions. The birds responded more on the stimulus that accompanied the richer initial-link VI. In other conditions the terminal link that followed the sparser initial link was lengthened so that multiple primary reinforcers were delivered during the terminal link. The relative rate of pecking during the sparser initial link was greater when multiple primary reinforcers followed this link than when only one primary reinforcer followed.

On the other hand, Moore (1979) conducted the most extensive investigation of the effect of terminal-link duration on preference, and reported no effect of number of primary reinforcers. In one comparison, VI 20-s schedules were in effect in both terminal links and VI 240-s schedules were in effect in both initial links. One terminal link lasted for 180 s (average of nine primary reinforcers) and the other lasted for 20 s (average of one primary reinforcer). In a second comparison, VI 60-s schedules were in effect in both terminal links. One lasted for 180 s (average of three primary reinforcers) and the other lasted for 60 s (average of one primary reinforcer). In both comparisons, initial-link pecking rates were approximately the same on each key despite the greater number of primary reinforcers gained by entry into the longer terminal link. It is not clear why the results obtained by Moore are discrepant from other findings (Fantino & Herrnstein, 1968; Squires & Fantino, 1971). The present experiments were designed to provide data relevant to this question.

In Moore's (1979) second experiment, relative rate of initial-link key pecking was also affected by the interval between successive primary reinforcers. In his procedure one terminal link provided a single primary reinforcer on an FI 30-s schedule followed by a return to initial-link (choice) conditions.

The other provided five primary reinforcers on the following sequence of FI schedules: FI 30-s, FI x , FI x . FI x , FI x . The value of x ranged from 3 to 20 s in different conditions. Different keylight stimuli were present during each terminal link. Pigeons preferred the terminal link with five primary reinforcers when the interval between reinforcers was brief. Indifference prevailed for two of the birds when this interval was 12 s or longer and at 20 s for the third. Note that because the shorter terminal link was an FI 30-s schedule and x was never greater than 20 s, the maximum obtainable rate of reinforcement within a terminal link was always greater in the link providing five primary reinforcers. For example, when the last four primary reinforcers were delivered on an FI 12-s schedule, the maximum obtainable rate of reinforcement during the terminal link with five primary reinforcers was almost twice that of the other terminal link (1 per 15.6 s as compared to 1 per 30 s).

An experiment by Shull, Spear, and Bryson (1981) was also designed to determine if the interval between successive primary reinforcers affects preference. Birds could peck either a green key providing food on a VI 113-s schedule or a white key that changed the color of the food key to red. The rate of switching to red provided a measure of the degree of preference for the conditions during red relative to the value of the VI 113-s schedule during green. Birds were tested with several different sequences of food deliveries during red. Shull et al. reported that pigeons had a greater preference for red the shorter the interval between the first and second primary reinforcers during red. A similar but lesser effect of the interval between the second and third primary reinforcers was also obtained. However, they did not attempt to determine whether later primary reinforcers are ineffective if the interval between them exceeds some value (e.g., Moore, 1979).

The present series of experiments was designed to assess the effects of reinforcement delay, number of reinforcers, and terminal-link duration on the degree of

preference. All experiments had several common features. Different keylight stimuli (red or green) were present during each terminal link to facilitate effects of the differing contingencies. Sessions terminated after 72 primary reinforcers, which always consisted of 3-s access to food. In order to eliminate the effect of differential response requirements and to control time of reinforcer delivery more precisely, food was always delivered on fixed-time schedules (Zeiler, 1968), that is, after constant time intervals, independently of terminal-link responding. The use of fixed-time schedules (as distinct from varied-time schedules) also made it unnecessary to consider the proper method for averaging variable delays.

EXPERIMENT 1

Experiment 1 was designed to determine if the degree of preference for a stimulus signaling the higher rate of reinforcement is affected by the interval between successive primary reinforcers. Food was delivered after 30 s in each terminal link. Four additional primary reinforcers were provided at 30-s intervals in one of the links. Both terminal-link stimuli lasted for 150 s. In a second condition, food was delivered after 5 s in both links and the four additional food deliveries occurred at 5-s intervals. Both terminal-link stimuli lasted for 25 s. Note that Moore (1979) reported that pigeons were indifferent between terminal links providing different numbers of primary reinforcers when the interval between successive primary reinforcers was less than the longer (30 s) interval used here.

METHOD

Subjects

Subjects were four experimentally naive pigeons obtained from a local supplier. They were housed in individual cages with water and grit freely available and were maintained at 75 to 80% of their free-feeding weights. The colony room was under constant illumination.

Apparatus

Four sound-attenuating experimental chambers were used. Each chamber measured approximately 33 cm front to back, 38 cm side to side, and 31 cm in height. The centers of the two Gerbrands pigeon keys were 4.5 cm apart and 21 cm above the false floor. A minimum force of approximately 0.10 N was required to operate the response keys and produce an audible feedback click. A 4- by 5-cm aperture for the Lehigh Valley grain feeder was located equidistant from the two response keys and 4 cm above the false floor. A photocell, which could be used to monitor eating time, was mounted in the aperture. Two IEE stimulus projectors were used to present the various stimuli on the response keys. Each chamber was illuminated by a 6-W houselight located in the center of the chamber ceiling. The houselight was on at all times except during feeder presentation and at the termination of a session. Background noise of approximately 80 dB (scale C: re .0002 bar) was provided by a ventilating fan and white noise. Experimental events were controlled and recorded by a PDP 8/a minicomputer using SKED software (Snapper & Inglis, 1978).

Procedure

Pretraining. Birds were first given one session of feeder training with the response keys covered by gray tape. Autoshaping with the horizontal and vertical stimuli was started on the next session (Brown & Jenkins, 1968). Each of these stimuli appeared 14 times on each key for a total of 56 trials per session. The stimulus remained on the key until the pigeon pecked that key or until 10 s had elapsed. In either case food presentation followed. Autoshaping continued until the bird either pecked the key on all 56 trials in one session or pecked on at least 49 of 56 trials in three not necessarily consecutive sessions.

Birds were next given three sessions of concurrent VI training with immediate food deliveries. The mean duration of the intervals was 15, 30, and 60 s across these three sessions. A 3-s changeover delay (COD) was

introduced with the concurrent VI 60-s schedule. In the COD procedure used here, key pecks were ineffective until 3 s after the first peck on the new key. Phase 1 was instituted at the start of the next session. Birds were usually tested 6 days per week.

Preferences were assessed by means of a concurrent-chains procedure that is presented schematically in Figure 1. A single constant-probability VI 30-s schedule was used for both initial links. Every 0.12 s there was a .004 probability that terminal-link entry would become available on one of the keys. Terminal-link entry was then assigned such that a randomly selected four of every eight assignments would follow an effective peck on each initial-link stimulus. Therefore each initial link was a VI 60-s schedule. The VI 30-s timer stopped as soon

Fig. 1. Procedure for one bird in Experiment 1. The sequence of events leading to five primary reinforcers is shown in the left panel. The sequence of events leading to the single primary reinforcer is shown in the right panel. Red or green stimuli were present throughout a terminal link. The particular initial-link and terminal-link stimuli correlated with the richer schedule were different for each bird so that there was complete counterbalancing across birds. The value of x was 5 s in one condition and 30 s in the other.

as terminal-link entry was set up. The use of such an interdependent procedure guarantees an equal number of entries into each terminal link (Stubbs & Pliskoff, 1969). Each initial link was signaled by a different keylight stimulus, either three horizontal or three vertical black bars on a white background. The two keylights were always red during the terminal link with five primary reinforcers, and green during the other terminal link. A peck on a particular initial-link stimulus always produced the same terminal-link stimuli for a particular bird. Initial-link stimuli were counterbalanced across birds such that pecks on horizontal produced red for two birds and green for the others. Individual assignments of stimuli and schedules are presented with the results in Table 1.

Each subject was tested with the same two pairs of schedules. The fixed-time interval was 30 s in one pair of schedules and 5 s in the other. Within each pair of schedules the delay to the first primary reinforcer and the duration of each terminal-link stimulus were the same, but the rate of reinforcement was not. In the 30-s condition, food was delivered after 30, 60, 90, 120, and 150 s in one terminal link and after 30 s in the other. The terminal-link stimuli (either both red or both green, depending on which terminal link was entered) lasted for 150 s, followed by a return to initial-link (choice) conditions. Thus, the green terminal-link stimuli were present for an additional 120 s following the single food delivery. Terminal-link durations are exclusive of reinforcement time except as noted.

In the 5-s condition, food was delivered after 5, 10, 15, 20, and 25 s in one terminal link and after 5 s in the other. The terminal-link stimuli were on for 25 s.

The sequence of conditions is shown in Table 1. Preference was first determined in the 30-s condition. Following determination of preference (see stability criteria below), both the contingencies and stimuli were reversed from the left to the right key. Thus a peck on the same initial-link stimulus produced the same terminal-link stimulus and

Table 1
Total key pecks and relative rate of key pecking from the last five sessions of each phase in Experiment 1

Bird	Fixed-Time Interval	Vertical Stimulus	Sessions	Initial-Link Key Pecks		Relative Rate	Combined Relative Rate	Changeovers
				5-Food Key	1-Food Key			
1	30	L	15	4143	746	.85		405
	30	R	15	2829	860	.77	.81	745
	5	L	15	2590	853	.75		252
	5	R	66	1309	1946	.40	.57	409
	30	L	15	4737	496	.91		236
	30	R	36	1480	750	.66	.83	338
2	30	R	19	5432	664	.89		344
	30	L	18	4128	1043	.80	.85	488
	5	R	15	7130	1206	.86		288
	5	L	16	6251	1640	.79	.82	176
	30	R	19	13310	1067	.93		314
	30	L	16	6916	1067	.87	.90	439
3	30	R	18	10443	858	.92		928
	30	L	15	9016	975	.90	.91	868
	5	R	16	5426	2767	.66		122
	5	L	24	5387	1872	.74	.70	561
	30	R	15	11125	1288	.90		464
	30	L	15	13072	690	.95	.92	544
4	30	L	20	5929	985	.86		706
	30	R	17	8220	894	.90	.88	620
	5	L	21	9586	1677	.85		427
	5	R	17	6064	1655	.79	.82	417
	30	L	16	23415	1022	.96		834
	30	R	15	12267	1292	.90	.94	1199

schedule as before reversal, but the initial-link stimulus now appeared on the other key. Initial-link stimuli were also switched when the fixed-time interval was changed.

Stability criteria. Each phase was continued for a minimum of 15 sessions and until the bird had met the two stability criteria simultaneously. The first criterion required that relative rates on each of the last five sessions be within $\pm 5\%$ of the overall relative rate for those five sessions. The second criterion required that there be neither consistent increases nor consistent decreases in relative rates over the last four sessions.

RESULTS

Table 1 summarizes results from the last five sessions of each phase. Rates of key pecking are not given because obtained (as

opposed to programmed) initial-link durations were not recorded and it cannot be assumed that these two measures were equal, especially when preferences were extreme. With the exception of Bird 1 in Phases 4 and 6, all birds reversed preferences rapidly when the initial-link stimulus signaling the higher rate of reinforcement was switched to the other key.

Preferences would be expected to reverse rapidly because the stimuli signaling the terminal link providing five primary reinforcers were not changed between phases. Relative rates are computed for the initial-link stimulus followed by the five primary reinforcers. Combined relative rates were computed from the sums of the numbers of key pecks from the last five sessions of a particular phase with the reversal phase of that

condition—that is, Phase 1 with Phase 2, Phase 3 with Phase 4, etc. Phases were combined because position biases occasionally obscured the effects of schedule preferences. The extreme left-key bias seen in Bird 1 during Phase 4 was probably the result of intermittent operation of the right keylight in the terminal link providing the greater number of reinforcers during several sessions early in this phase. Combined relative rates were always greater than .5, indicating that the pigeons preferred the terminal link with the greater number of reinforcers (and higher rate of reinforcement) with each fixed-time interval. As can be seen in Table 1, in every case the degree of preference was greater when the fixed-time interval was 30 s than when it was 5 s.

DISCUSSION

Experiment 1 indicated that pigeons preferred the terminal link providing the greater number of reinforcers (and higher rate of reinforcement) with each fixed-time interval. Furthermore, these preferences were greater when this interval was 30 s than when it was 5 s. Both findings were surprising in view of Moore's failure to obtain a preference for the terminal link with the greater number of reinforcers (and higher rate of reinforcement) when the interval between primary reinforcers was greater than about 12 to 20 s.

Perhaps a partial explanation for these apparently discrepant results is that the ratio of the rates of reinforcement between terminal links was much greater in the present experiment (always five-to-one) than in Moore's. In his experiment, longer delays between successive primary reinforcers resulted in smaller proportional differences in the rate of reinforcement between terminal links. At his shortest interval (3 s), the programmed ratio of reinforcement rates was approximately three-to-one. At the longest interval (20 s), this ratio was less than two-to-one. These smaller proportional differences at the longer intervals may be important in view of Moore's first experiment in which pigeons were indifferent between terminal links pro-

viding different numbers of primary reinforcers when the rate of reinforcement was the same in both terminal links (but see Fantino & Herrnstein, 1968; Squires & Fantino, 1971). Therefore, Experiment 2 was conducted to determine the effects of the fixed-time interval on degree of preference for the greater number of reinforcers when the rate of reinforcement was the same for each terminal link.

EXPERIMENT 2

Conditions were similar to Experiment 1 except that the terminal links providing only a single primary reinforcer ended after delivery of that reinforcer—that is, after either 5 or 30 s.

METHOD

Subjects, Apparatus, and Pretraining

Four experimentally naive pigeons served. Maintenance conditions, apparatus, and pretraining were as described for Experiment 1.

Procedure

Preferences were again determined using a concurrent-chains procedure, as shown in Figure 2. As in Experiment 1, a peck on a particular initial-link stimulus (horizontal or vertical) always produced the same terminal-link stimulus (red or green) for a particular bird. Unlike Experiment 1, each initial-link stimulus appeared equally often on the left and right keys in every session. This change in procedure was intended to equalize the effects of possible position-related biases and made it unnecessary to reverse initial-link stimuli between series of sessions. With this procedure there were four possible combinations of the key on which an initial-link stimulus appeared and the terminal link that would be entered following an effective peck. These four combinations were randomly assigned so that each combination occurred twice in each block of eight trials. The same 3-s COD employed in Experiment 1 was used.

Fig. 2. Schematic representation of the terminal links in Experiment 2. The sequence of events in the terminal link providing five primary reinforcers is shown on the left and the sequence of events in the terminal link providing the single primary reinforcer is shown on the right. The particular stimuli in effect depended on the bird and condition (see text for details). The value of x was 5 s in one condition and 30 s in the other.

An A-B-A design was used. In the first phase, birds were given a choice between five primary reinforcers delivered at 5-s intervals and one primary reinforcer delivered after 5 s. Initial-link conditions were reinstated after the last food delivery, either 8 or 40 s after terminal-link entry (inclusive of reinforcement time). Analogous relationships were used for the procedure based on 30-s intervals.

Red and green stimuli were counterbalanced across birds; red always signaled the terminal link with five primary reinforcers for two birds and green always signaled this link for the others. Initial-link stimuli were also counterbalanced such that within each of these two sets of birds, a peck on horizontal produced red for one bird and green for the other.

Stability criteria were the same as those in Experiment 1 but the minimum number of sessions for a condition was increased from

the 15 in Experiment 1 to 20. Birds were usually tested 6 days per week.

RESULTS

Table 2 summarizes results from the last five sessions of each phase of training in the same manner as Table 1. Relative rates in Column 6 and throughout are computed for the initial-link stimulus followed by five primary reinforcers.

Inspection of Column 6 indicates that in each phase all pigeons preferred the terminal link with five primary reinforcers. There was no consistent effect of the duration of the fixed-time interval on the degree of preference as each bird demonstrated a different pattern of results with respect to this variable.

DISCUSSION

The results of Experiment 2 suggest that Moore's failure to obtain a preference for the greater number of primary reinforcers with all of the intervals he used cannot be ascribed entirely to smaller proportional differences in the rates of reinforcement at the longer intervals. In the present experiment preferences were always for the greater number of primary reinforcers even though the rate of reinforcement was the same in each terminal link. Other possible explanations for these discrepant results will be discussed later.

Second, preferences were consistently greater in the 30-s condition of Experiment 1 than in the 30-s condition of Experiment 2. This suggests that continuing a terminal link after the last primary reinforcer (as in the link providing only a single primary reinforcer in Experiment 1) decreases the value of the nonpreferred link and therefore increases the degree of preference for the multiple-food link. The trend for the 5-s condition is in the same direction but is small and unreliable. Results from the 30-s condition are consistent with Logan's (1965) finding that continuation of stimuli paired with primary reinforcers after delivery of those reinforcers affects preferences. In his experiment, rats preferred to enter a goal box from

Table 2
Total key pecks and relative rates of key pecking from the last five sessions of each phase in Experiment 2

<i>Bird</i>	<i>Fixed-Time Interval</i>	<i>Sessions</i>	<i>5-Food Key</i>	<i>1-Food Key</i>	<i>Relative Rate</i>	<i>Changeovers</i>
5	30	24	2728	1633	.63	378
	5	20	7299	5096	.59	534
	30	31	7687	4335	.63	317
6	30	26	1612	1009	.62	339
	5	20	2661	968	.73	308
	30	26	2892	1252	.70	196
7	30	24	4410	3416	.56	316
	5	24	5557	3348	.62	427
	30	25	4952	1991	.71	266
8	30	23	4373	1378	.76	270
	5	20	4192	1968	.68	251
	30	28	5096	2757	.65	242

which they were removed immediately after eating rather than one in which they were detained an additional minute. It should be noted that Shull and Spear (in press) have proposed a model that seems to account for the effects of terminal-link duration in terms of delay to the next terminal-link entry.

EXPERIMENT 3

Experiment 3 was designed to determine whether the same set of additional primary reinforcers would have less effect on the degree of preference when the delays to the first primary reinforcer were shorter. If the delay to the first primary reinforcer is decreased by the same time in each component, the absolute value of each terminal link should increase by equal increments. If the absolute value of each terminal link is increased by equal increments, the relative value of the preferred link should decrease.

Value refers here to a metric that summarizes the total effect of all variables that determine degree of preference. Relative preference would then be predicted from a model of the form:

$$r_{PL} = \frac{V_L}{V_L + V_R},$$

where r_{PL} represents relative preference for

the left key, and V_L and V_R represent the values of the left and right terminal links, respectively. Quantitative predictions obviously cannot be made from such a general model because the metric for value is not known. Additionally, this model fails to account for the effects of initial-link durations. However, it could be modified to do so by predicting that preferences are determined by the relative increment in reinforcing value produced by a shift from the initial to the terminal link, as Fantino (1977) and Baum (1973) have suggested. Nevertheless, this model suggests that preferences should be less strong when the delay to the first primary reinforcer is shorter.

Subjects, Apparatus, and Pretraining

Four experimentally naive pigeons served. Maintenance conditions, apparatus, and pretraining were as described for Experiments 1 and 2.

Procedure

Sessions were like those in Experiment 2 except for the terminal-link schedules, as illustrated by Figure 3. In Experiment 3, both the delay to the first primary reinforcer (either 5 or 50 s in different phases) and the duration of terminal-link stimuli (always 150 s) were the same within each pair of sched-

ules, but the rate of reinforcement was not. In one pair of schedules, food was delivered after 5, 75, 100, 125, and 150 s in one terminal link and after 5 s in the other (all times are exclusive of reinforcement time). In the other pair of schedules, food was delivered after 50, 75, 100, 125, and 150 s in one terminal link and after 50 s in the other. Thus, the two pairs of schedules differed only in the delay to the first food delivery.

The same color keylights (red or green) were always present during the terminal link with the higher rate of reinforcement for a particular bird. However, initial- and terminal-link stimuli were completely counter-balanced across birds, as in Experiment 2.

All birds were tested on both pairs of schedules. Two birds were tested first with the 5-s delay. Testing continued in a particular phase until the stability criteria used in Experiment 2 had been met. Birds were usually tested 6 days per week.

RESULTS

Table 3 summarizes results from the last five sessions of each phase in the same manner as Table 2. Relative rates of pecking the initial-link stimulus followed by the greater number of reinforcers (and higher rate of reinforcement) are shown in Column 6. Preference for the terminal link with the greater number of reinforcers (and higher rate of reinforcement) was greater when the delay to the first primary reinforcer was 50 s than when it was 5 s.

Column 6 also suggests that the first condition on which birds were tested affected preferences through all three phases. Birds 9 and 10 demonstrated little or no preference when the delay to the first primary reinforcer was 5 s (Phases 1 and 3), but Birds 11 and 12 exhibited a marked preference under these same conditions (Phase 2).

DISCUSSION

Preferences were greater in Experiment 3 when the delay to the first primary reinforcer was 50 s than when it was 5 s. This suggests that a longer delay to the first primary reinforcer contributed to the greater preferences obtained in Experiment 1 when the fixed-time interval was 30 s than when it was 5 s. That is, if the absolute value of a terminal link is determined primarily by the delay to the first food delivery, later primary reinforcers may have very little effect on preferences when the delay to the first primary reinforcer is short. This may have been the case in Experiment 1, even though later primary reinforcers in the 5-s condition were also closer to terminal-link onset. However, this interpretation implies that preferences also should have varied systematically with the fixed-time interval in Experiment 2, a result which was not obtained.

Finally the results in Experiment 3 are again contrary to expectations based on Moore's (1979) second experiment. In Experiment 3, all four pigeons preferred the terminal link with the greater number of reinforcers and the higher rate of reinforcement when the interval between successive

Fig. 3. Schematic representation of the terminal links in Experiment 3. The sequence of events in the terminal link providing five primary reinforcers is shown on the left and the sequence of events in the terminal link providing the single primary reinforcer is shown on the right. Food was delivered at either x or x' , depending on the phase of training. The particular stimuli in effect depended on the bird and phase (see text for details).

Table 3

Total key pecks and relative rates of key pecking from the last five sessions of each phase in Experiment 3

<i>Bird</i>	<i>Delay to First</i>	<i>Sessions</i>	<i>Initial-Link Key Pecks</i>		<i>Relative Rate</i>	<i>Changeovers</i>
			<i>5-Food Key</i>	<i>1-Food Key</i>		
9	5	29	3630	3525	.51	369
	50	20	7017	1333	.84	198
	5	20	4321	4170	.51	416
10	5	21	3203	3123	.51	272
	50	42	7541	1789	.81	250
	5	21	4468	4364	.51	198
11	50	21	6943	1741	.80	617
	5	20	5939	3660	.62	511
	50	20	7250	2085	.78	413
12	50	20	17409	1664	.91	535
	5	20	9898	3665	.76	372
	50	20	19469	848	.96	226

primary reinforcers was 25 s and the delay to the first primary reinforcer was 50 s. All three pigeons in Moore's experiment demonstrated no preferences when the interval between successive primary reinforcers was about 12 to 20 s.

GENERAL DISCUSSION

In two major respects the results of the present experiments differed from expectations based on the results obtained by Moore (1979). First, his pigeons were indifferent between terminal links providing different rates of reinforcement when the interval between successive primary reinforcers was greater than 12 to 20 s, depending on the bird. In all three of the present experiments, pigeons preferred the terminal component providing the higher rate of reinforcement and/or the greater number of primary reinforcers even when the interval between primary reinforcers was longer than 20 s.

Second, the results of Experiment 2 differed from Moore's (1979) finding of indifference between terminal links of different durations when the rate of reinforcement was the same for each alternative. However, the results of Experiment 2 are consistent

with the results of two other experiments (Fantino & Herrnstein, 1968; Squires & Fantino, 1971).

One procedural difference between the present experiments and Moore's (1979) is the use of fixed-time (as opposed to fixed-interval) schedules in the terminal links of the present experiment. However, this difference was probably not important, as Neuringer (1969) reported that pigeons were indifferent between fixed-time and fixed-interval schedules of equal duration.

Moore suggested that terminal-link duration had a different effect in his experiment because multiple primary reinforcers were occasionally delivered in the shorter terminal link as well as in the longer one in his procedure. This occurred in his experiment because terminal links were in effect for a fixed duration. When food is delivered on VI schedules, terminal links of a fixed duration result in variations in the number of food deliveries across trials. In the other experiments (including the present one), the number of primary reinforcers delivered during each terminal-link entry was held constant from trial to trial.

However, there is one finding that does not seem consistent with an interpretation

based on occasional presentations of multiple primary reinforcers in both terminal links. Fantino and Herrnstein (1968) obtained a preference for the greater number of primary reinforcers when multiple primary reinforcers (two versus three) were delivered in both links. Unfortunately, the substantial right-key bias demonstrated by their pigeons makes their findings difficult to interpret.

On the other hand, Moore's procedures simply may not have been sensitive enough for preferences to show up readily. For one thing, Moore did not use a changeover delay (COD). In simple concurrent schedules, relative rates of responding may be closer to indifference when no COD is used (see de Villiers, 1977, or Baum, 1982, for a more complete discussion of this issue). In this regard, the rather low absolute rates of initial-link key pecking in Moore's first experiment suggest that his pigeons may have been alternating between the two keys. Although CODs are not usually used with concurrent chains, there does not seem to be any reason to believe that a failure to employ a COD has different effects in the two types of procedures. However, neither Fantino and Herrnstein (1968) nor Squires and Fantino (1971) employed a COD when they obtained preferences for the longer terminal link providing more primary reinforcers. Additionally, Moore used VI 240-s schedules in the initial links of his first experiment. As Fantino (1977) has noted, sparser VI schedules in the initial links result in smaller preferences.

The present experiments were not designed to test any particular model of schedule preferences. However, none of the four major models (Davison & Temple, 1973; Killeen, 1982; McDiarmid & Rilling, 1965; Squires & Fantino, 1971) accurately predicts the results of all three of the present experiments. In fact, only the model proposed by Killeen allows for the effects of all three of the major factors that have been shown to affect schedule preferences. These factors are: (1) the precise temporal location of each primary reinforcer, (2) terminal-link duration, and (3) the initial-link schedules. A

complete discussion of these models is clearly beyond the scope of the present paper. On the other hand, an emphasis on mathematical models may even be premature at present. Perhaps what is first needed is a large, parametric investigation of the variables that affect schedule preference. One major problem with such an investigation is that these variables cannot always be independently manipulated. For example, in the third experiment reported here, delay to the first reinforcer is necessarily confounded with the delay between the first and second reinforcers. Similarly, number of reinforcers, rate of reinforcement, and terminal-link duration are also nonorthogonal. It is hoped that more advanced research designs will aid future investigators in making progress toward a systematic determination of the effects of those factors that affect schedule preferences and toward a quantitative summary of those effects.

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