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PREFERENCE FOR MULTIPLE VERSUS MIXED SCHEDULES OF REINFORCEMENT

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Five pigeons were trained in a concurrent-chain procedure. In the initial links, equal nonindependent variable-interval schedules were available concurrently on two keys. Completing the schedule on either key led to exclusive presentation of one of two further variable-interval schedules for a fixed period of time. During these terminal links, as many reinforcers as were scheduled could be obtained. If the response producing this terminal link occurred on one key, differential stimuli signaled which variable-interval schedule had been produced. If the response producing the terminal link occurred on the other key, no such differential stimuli were available. Once the fixed period of time elapsed, the initial links were reinstated. In Experiment 1, the period of time for which the terminal links were available was always 10 s and the absolute duration of the initial links was varied. Subjects preferred the alternative leading to the multiple schedule when the initial-link duration was short, but preferred the alternative leading to the mixed schedule when the initial-link durations were longer. In Experiment 2, both the initial-link duration and the duration of the terminal links were varied. The effect of initial-link duration was identical to that in Experiment 1 and there was no systematic effect of varying the terminal-link duration.

Key words: concurrent chain, multiple schedule, mixed schedule, preference, key peck, pigeon

Studies of preference for mixed versus multiple schedules of reinforcement have encompassed a variety of experimental approaches. Typically, those using free-operant techniques have employed either the observing-response procedure or the concurrent-chain procedure. In the observing-response procedure (e.g., Branch, 1973; McMillan, 1974), a mixed schedule of reinforcement is arranged on one operandum (A). Responses on a second operandum (B) produce, for some specified period of time, a stimulus that is differentially correlated with that component of the mixed schedule currently in effect. Thus, by emitting a response on operandum B, the subject can change the mixed schedule on operandum A into a multiple schedule. Preference is measured as the relative amount of session time the subject spends in the presence of the multiple-schedule stimuli (e.g., Branch, 1973; McMillan, 1974).

In the concurrent-chain procedure, two variable-interval (VI) schedules are available concurrently (initial links), each leading to mutually exclusive schedules of primary reinforcement (terminal links). Once the reinforcer is obtained, the initial links are reinstated. In studies of preference for mixed versus multiple schedules, completing either initial-link VI schedule leads to the exclusive presentation of one of two further schedules, both terminating in a reinforcer. When the response leading to the presentation of a terminal link occurs on one alternative, each particular schedule of reinforcement produced is accompanied by a distinct stimulus—in effect, one component of a multiple schedule becomes available. When the response leading to a terminal link occurs on the other alternative, there are no differential stimuli signaling which of the two reinforcement schedules has been produced—in effect, one component of a mixed schedule becomes available. This procedure has the advantage of separating the measure of preference (initial-link performance) from the conditions between which the subjects choose (the mixed- and multiple-schedule components). Furthermore, the relative amount of time the subject is exposed to the two terminal-link schedules, and the number of reinforcers obtained in each, can be easily controlled. Therefore, any observed preference for one of these schedules during the initial links can be attributed primarily to the differing stimulus relations of the mixed- and multiple-schedule terminal links.

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Studies employing a concurrent-chain procedure have typically focused on features of the terminal links, such as the probabilities with which the two components comprising the mixed and multiple schedules are presented (Fantino & Moore, 1980; Green & Rachlin, 1977) or the differing rates of reinforcement within the mixed- or multiple-schedule components (Hursh & Fantino, 1974). Such experiments have demonstrated that subjects consistently prefer the alternative leading to the multiple-schedule components.

However, experiments using simple concurrent chains to investigate preference between two single schedules of reinforcement have found that initial-link choice was not dependent solely on the terminal-link consequences. Additionally, the duration of the initial links appears to have an effect (e.g., Davison, 1983; Fantino, 1969; Fantino & Davison, 1983). Typically, as the duration of the initial-link schedules relative to the terminal-link schedules is increased, so choice responding in the initial links moves in the direction of indifference (Davison, in press; Fantino, 1969). Hursh and Fantino (1974) presented an analogous finding using mixed and multiple schedules as the terminal links. Concurrent VI 15-s VI 15-s initial links resulted in large preferences for the alternative leading to the multiple-schedule components. Increasing the initial-link duration to concurrent VI 60 s VI 60 s led to a dramatic decrease in the degree of preference for the multiple schedule.

The present experiment provides further parametric data on the effect of initial-link duration on preference for mixed versus multiple schedules of reinforcement. Experiment 1 examined changes in the relative response rate during the initial links as the two equal initial-link schedules were increased in duration and the terminal-link schedules were held constant. There was one major difference between the concurrent-chain procedure employed in this study and those used in previous research (Fantino & Moore, 1980; Green & Rachlin, 1977; Hursh & Fantino, 1974): The mixed or multiple components did not terminate once the reinforcer was obtained; rather, the terminal links were of fixed duration. This meant that in Experiment 1 the subjects received 10-s access to either a mixed- or multiple-schedule component during a terminal link; then the initial links were reinstated irrespective of the number of reinforcers obtained during this period. This procedure served to keep approximately equal the amount of time the subjects were exposed to the various components of the mixed and multiple schedules, as is common practice when using standard mixed or multiple schedules. In Experiment 2, both the initial-link duration and this terminal-link component duration were varied, while preferences for the mixed versus multiple schedules were examined.

EXPERIMENT 1

METHOD

Subjects

Five homing pigeons, numbered 31, 32, 33, 35, and 36, were maintained at 85% ± 15 g of their free-feeding body weights. All subjects had previous histories of responding in free-operant procedures, but had no prior exposure to concurrent-chain schedules. Water and grit were freely available in their home cages at all times.

Apparatus

Solid-state experimental control equipment and impulse counters, situated remote from the experimental chamber, controlled all experimental events and recorded the data. The chamber, 33 cm high, 33 cm wide, and 31 cm deep, was fitted with an exhaust fan to provide ventilation and to help mask external noise. The chamber contained three response keys, 2 cm in diameter, 11 cm apart, and 25 cm above the grid floor. The left and right keys could be transilluminated white, and the center key could be transilluminated white, red, or green. When lit, the keys were operated by pecks exceeding about 0.1 N, which produced clicks of a relay. Pecks on darkened keys were ineffective and were not counted.

The food magazine contained wheat and was situated beneath the center key, 12 cm from the grid floor. During reinforcement, a nominal 3-s access to this grain, the hopper was illuminated and the keylights were extinguished. There were no other sources of illumination in the chamber.

Table 1

Sequence of experimental conditions, VI schedules in the initial and terminal links, terminal-link component duration, number of entries per session, number of sessions per condition, and experiments in which the data were analyzed are shown for each condition. VI schedule times are in seconds.

Condition	Initial links	Terminal link (Red)	Terminal link (Green)	Component duration	Entries	Sessions	Experiment
1	12	60	60	10	125	23	1
2	12	34	240	10	125	40	1
3	60	34	240	10	75	35	1
4	28	34	240	10	100	22	1, 2
5	72	34	240	10	50	22	1, 2
6	4	34	240	10	150	22	1, 2
7	44	34	240	10	75	30	1
8	72	34	240	10	50	33	1
9	4	34	240	10	150	28	1
10	12	60	60	10	125	22	1
11	28	34	240	30	70	26	2
12	72	34	240	5	60	26	2
13	4	34	240	30	60	21	2
14	28	34	240	5	75	20	2
15	72	34	240	30	55	31	2
16	28	34	240	60	30	24	2
17	4	34	240	5	150	31	2
18	72	34	240	60	30	37	2
19	28	34	240	10	75	37	2
20	4	34	240	60	40	24	2
21	4	34	240	10	125	27	2

Procedure

Because the pigeons were experienced with free-operant procedures, no initial shaping was necessary and the subjects were placed directly on the first experimental condition (Table 1). The general procedure used in the experiment is shown in Figure 1. During the concurrent initial links, the center key was dark and both side keys were transilluminated white, and each was correlated with a nonindependent VI schedule. These two initial-link schedules were arranged by a single arithmetic VI timer. As each interval timed out, the timer stopped and the terminal-link entry was assigned to either the left or the right key with a probability of .5, in the manner of Stubbs and Pliskoff (1969). The next response on the appropriate key immediately produced the terminal-link schedule. This procedure ensured that the numbers of terminal-link entries obtained on the two alternatives were approximately equal.

When a response on a side key produced a terminal link, both side keys were extinguished, the center key was lit, and there was 10-s access to one of two VI schedules (Figure 1). A probability gate set at .5 determined which of these schedules was presented at each terminal-link entry. During this period, subjects could obtain as many reinforcers as were arranged by the particular VI schedule while the terminal-link was in effect. When the ter-

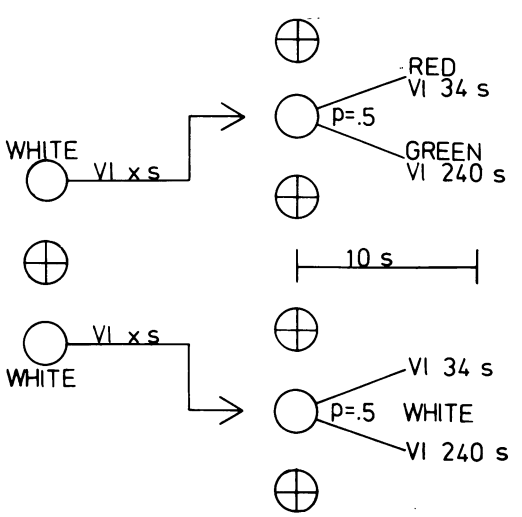

Fig. 1. A diagram of the general experimental procedure (see text).

Table 2

Relative numbers of responses and terminal-link entries during the initial links (multiple/multiple + mixed), relative numbers of responses and obtained reinforcers during the terminal links (multiple/multiple + mixed), and relative response rates in the multiple components (red/red + green) for each subject and each condition in Experiment 1.

Condition	Relative initial link		Relative terminal link		Relative multiple responses
	Responses	Entries	Reinforcers	Responses	
Bird 31					
1	.47	.52	.51	.48	.50
2	.37	.53	.51	.48	.58
3	.19	.52	.46	.47	.61
4	.24	.52	.53	.47	.63
5	.19	.54	.46	.50	.65
6	.60	.52	.48	.53	.80
7	.30	.52	.50	.52	.67
8	.17	.45	.51	.51	.74
9	.63	.48	.49	.50	.71
10	.40	.55	.46	.48	.55
Bird 32					
1	.45	.59	.51	.50	.60
2	.64	.57	.48	.51	.72
3	.51	.38	.49	.48	.60
4	.47	.48	.50	.52	.77
5	.45	.54	.48	.52	.47
6	.53	.53	.52	.49	.64
7	.41	.37	.45	.51	.82
8	.21	.39	.52	.50	.65
9	.45	.42	.52	.50	.77
10	.49	.48	.54	.51	.58
Bird 33					
1	.45	.50	.50	.51	.39
2	.62	.42	.53	.49	.65
3	.48	.43	.50	.53	.77
4	.53	.45	.54	.51	.74
5	.20	.47	.36	.48	.61
6	.53	.46	.48	.50	.79
7	.36	.43	.59	.49	.79
8	.50	.41	.52	.47	.69
9	.56	.42	.52	.49	.76
10	.35	.51	.48	.52	.47
Bird 35					
1	.37	.55	.49	.51	.46
2	.30	.53	.48	.51	.54
3	.14	.54	.39	.50	.69
4	.19	.51	.47	.49	.72
5	.10	.50	.56	.51	.66
6	.59	.55	.53	.47	.68
7	.16	.49	.44	.50	.70
8	.19	.44	.41	.49	.71
9	.60	.51	.49	.51	.63
10	.37	.49	.46	.52	.48
Bird 36					
1	.48	.60	.55	.45	.49
2	.71	.56	.62	.50	.68
3	.38	.44	.45	.46	.66
4	.46	.49	.49	.51	.71
5	.36	.44	.50	.53	.73
6	.65	.51	.49	.49	.62
7	.34	.48	.51	.52	.75
8	.22	.57	.45	.44	.62
9	.62	.57	.54	.51	.65
10	.56	.56	.53	.50	.49

Table 2 (*Continued*)

minal-link entry was obtained by a response on the left key, then the center key was transilluminated green if one VI-schedule component was available, or red if the other VI-schedule component was available; that is, one component of a multiple schedule was presented. If the terminal-link entry was obtained by a response on the right key, then the center key was transilluminated white, irrespective of which of the two VI schedules was available; that is, one component of an equivalent mixed schedule was presented. Once the 10-s access time to the terminal-link schedule had elapsed, the initial links were reinstated, even if no reinforcer had been obtained, and the timer for that terminal-link VI schedule was halted until the next presentation of the terminal link.

Condition 1 (Table 1) was a baseline condition in that the two components comprising each terminal-link schedule were nondifferential. The initial-link schedules were concurrent VI 12 s VI 12 s and the two schedules comprising each terminal link were VI 60 s. Condition 10 was a replication of Condition 1.

In Conditions 2 to 7, the two schedules comprising each terminal link were always VI 34 s and VI 240 s. When the terminal-link schedule was produced by a response on the left key, the center key was green during the VI 240 schedule and red during the VI 34 schedule. Each condition employed equal initial links, but their absolute duration was varied (Table 1). The initial-link schedules ranged from concurrent VI 4 VI 4 (Condition 6) to concurrent VI 72 VI 72 (Condition 5).

In Conditions 8 and 9 the contingencies between initial-link responses and the production of the terminal links were reversed. Re-

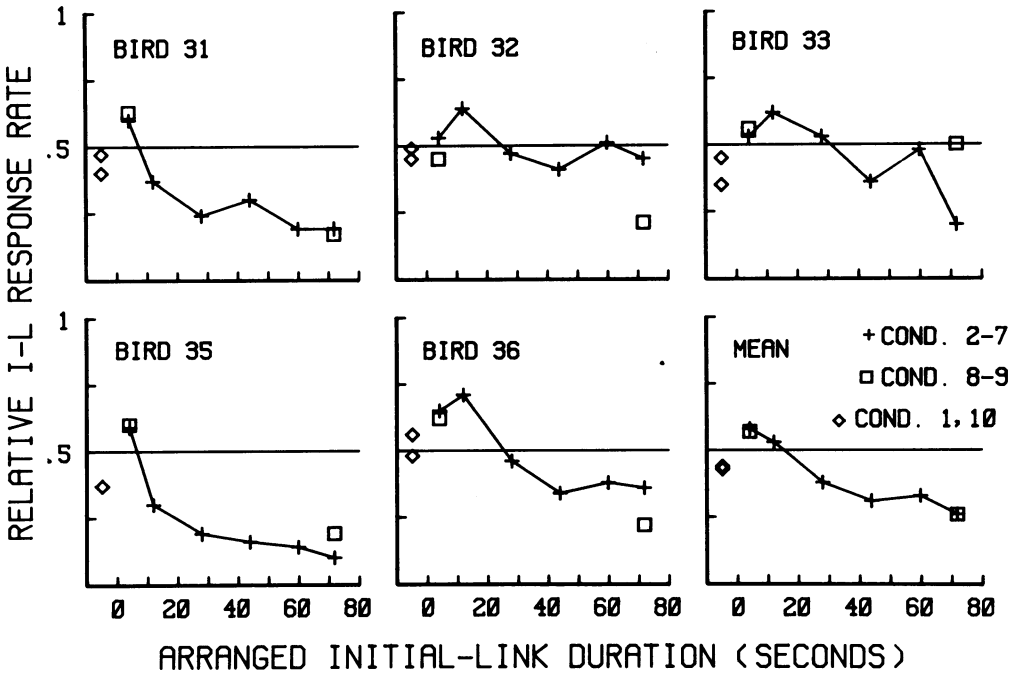

Fig. 2. The relative initial-link response rate (responses on key leading to the multiple-schedule terminal link as numerator) has been plotted as a function of the arranged initial-link VI schedules for each subject and condition in Experiment 1. During the baseline conditions (1, 10), the initial links were concurrent VI 12 s VI 12 s and both terminal-link VI schedules were VI 60 s. For all other conditions the terminal-link schedules were VI 34 s (red) and VI 240 s (green). The mean performance across subjects is also shown.

sponses on the left key produced one of the components of the multiple schedule as the terminal link, and responses on the right key produced one of the components of the mixed schedule as the terminal link. In all other respects, Condition 8 was a replication of Condition 6 and Condition 9 was a replication of Condition 5.

Sessions began in blackout and ended in blackout after approximately 45 min had elapsed or after a predetermined number of entries into the terminal links had been obtained, whichever occurred first. The number of entries required to end the session for each condition is shown in Table 1. At the end of each daily session, four sets of data were recorded: the number of responses on each key during the initial links, the number of entries into each terminal link, the number of responses on the center key during each terminal-link stimulus (green, red, or white), and the number of reinforcers obtained during each of these terminal-link stimuli. The pigeon was then returned to its home cage and was fed the amount of mixed grain necessary to maintain its designated body weight.

Each experimental condition remained in effect until all birds had reached a defined stability criterion five, not necessarily consecutive, times. This criterion was that the median relative initial-link response number over five sessions did not differ by more than .05 from the median of the five sessions prior to these. Typically, when a bird had met the stability criterion, preference remained stable until the experimental condition was changed.

Results

The sums of responses, reinforcers, and entries during the last five sessions in each condition for each subject were used in the analysis. These data are shown in the Appendix. Relative response rates during the initial links, during the mixed and multiple terminal links, and during the red and green components of the multiple schedule were calculated for each condition, as were the relative numbers of entries into the two terminal links and the relative terminal-link reinforcer rates. These data are shown in Table 2.

The results show that the use of dependent scheduling in the initial links was effective in

keeping the number of obtained entries into the mixed and multiple schedules approximately equal (Table 2). However, although the numbers of entries were equal, the relative obtained reinforcer rates (multiple/multiple + mixed) were also dependent on the subjects' behavior during the terminal links (Table 2). For the baseline conditions (Conditions 1 and 10), the relative reinforcer rates were approximately .50. In Conditions 2 to 9, Bird 31 received slightly more reinforcers from the mixed schedule, but across subjects and conditions there were no consistent differences in the reinforcer rates in the two terminal links (the mean relative reinforcer rate was .49, SD = .05). More importantly, there was no systematic trend in the relative obtained-reinforcer rates as the duration of the initial links was increased in Conditions 2 to 7.

Figure 2 shows the relative initial-link response rate for each subject (Table 2) and the mean relative response rate across subjects, for each of the 10 conditions. Each relative rate was calculated using responses to the key leading to the multiple schedule as the numerator. During the baseline conditions (Conditions 1 and 10), the subjects preferred the alternative that led to the mixed-schedule terminal link (mean relative initial-link response rate .44, SD = .07). There were no systematic differences in the relative initial-link response rate between the two baseline conditions.

When the initial-link duration was increased (Conditions 2 to 7), there was a consistent change in the subjects' preference (Figure 2). With the shortest initial-link duration, all subjects slightly preferred the alternative leading to the multiple-schedule terminal link. However, as the initial-link duration was increased, the performance moved toward indifference; as the duration was increased further, the subjects displayed substantial preferences for the alternative leading to the mixed-schedule terminal link. The trend across subjects was significant on a nonparametric trend test (Ferguson, 1965; SS = 30, z = 4.87; $p < .01$).

This trend was most evident in the data of Birds 31, 35, and 36 (Figure 2). Their preferences for the alternative leading to the multiple schedule with concurrent VI 4 VI 4 initial links (relative response rates of .60, .59, and .59, respectively) steadily changed as the initial links were increased. When the longest initial-link schedules were employed (concurrent VI 72 VI 72), all 3 subjects strongly preferred the alternative leading to the mixed schedule (relative response rates of .19, .10, and .36, respectively). The results of Conditions 8 and 9, in which the initial-link contingencies were reversed, demonstrated that this strong preference for the mixed schedule at the longer initial-link durations did not result merely from a right-key bias.

Although the data from Birds 32 and 33 were less orderly than those of the other 3 subjects, they revealed a similar pattern. The relative response rates from Bird 32 differed little from .50 across Conditions 3 to 7. However, the results from the initial-link key reversals (Conditions 8 and 9) suggest a strong left-key bias and a preference for the mixed-schedule terminal link with the concurrent VI 72 VI 72 initial links. Bird 33 also preferred the mixed schedule at the longer initial-link durations, even when the strong right-key bias indicated by Conditions 8 and 9 is taken into account (Figure 2).

Comparison of performance in the mixed versus the multiple schedules required calculation of the relative terminal-link response rates (multiple/multiple + mixed). The data, shown in Table 2, ranged from .37 (Bird 32) to .57 (Bird 36), with a mean of .48 (SD = .06). Bird 31 usually responded at a higher rate during the multiple schedule, Bird 33 usually responded at a higher rate during the mixed schedule, and Bird 35 showed some evidence of a monotonic trend from multiple to mixed as the initial-link duration was increased. However, for all subjects the relative response rate differed little from .50 and when the subjects were considered as a group, there were no systematic deviations.

Comparison of performances in the two components of the multiple schedule required calculation of the relative multiple-schedule response rate (red/red + green). These data, also shown in Table 2, are plotted in Figure 3. For the baseline conditions (1 and 10), where the reinforcement schedules were equal for the two components, Birds 31 and 33 responded at slightly higher rates during the red component, and the other birds responded at slightly higher rates during the green component. The mean relative response rate for the 5 subjects across both conditions was .50 (SD = .06). In Conditions 2 to 9, the red and

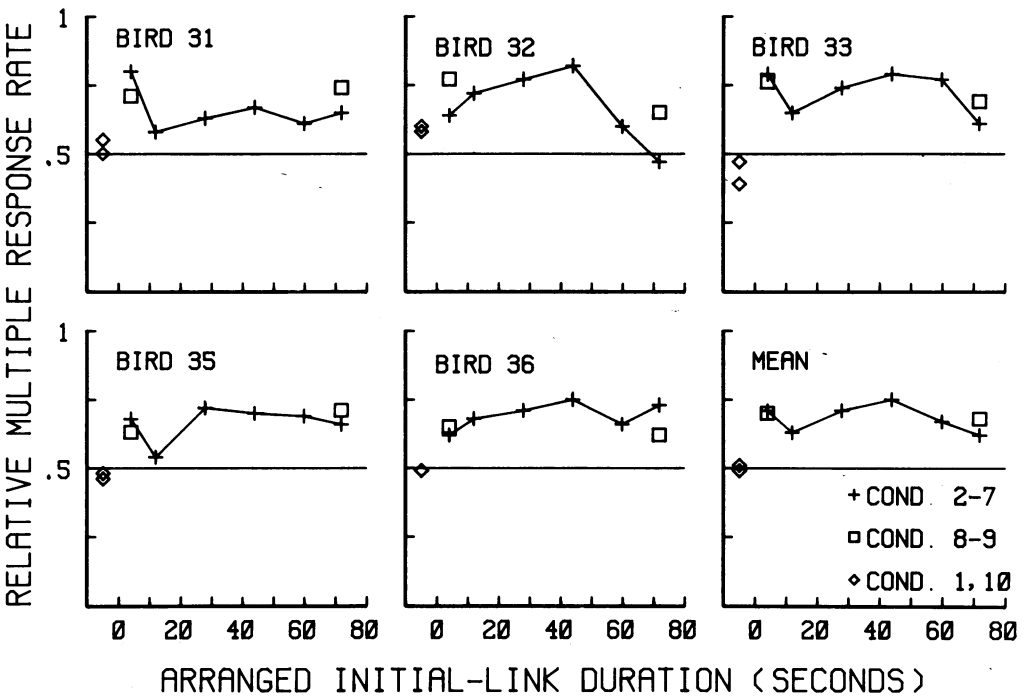

Fig. 3. The relative multiple-schedule response rate (red/red + green) has been plotted as a function of the arranged initial-link VI schedules for each subject and condition in Experiment 1. During the baseline conditions (1, 10), the initial links were concurrent VI 12 s VI 12 s and the terminal-link schedules were both VI 60 s. For all other conditions the terminal-link schedules were VI 34 s (red) and VI 240 s (green). The mean performance across subjects is also shown.

green components were unequal schedules of reinforcement (VI 34 and VI 240, respectively). There was some variation in relative response rate as the initial links were varied in Conditions 2 to 9 (Figure 3). However, a Friedman analysis of variance (Siegel, 1956) showed no consistent variations across subjects and conditions. The mean relative response rate taken across subjects in Conditions 2 to 9 was .68 (SD = .07). This demonstrates that even with only 10-s periods of access to the two components, the subjects were sensitive to the differences between the two reinforcer rates.

EXPERIMENT 2

METHOD

Subjects, Apparatus, and Procedure

The subjects, apparatus, and general procedure were identical to those employed in Experiment 1. During the initial links, responses on the left key occasionally produced one component of the multiple schedule, and responses on the right key occasionally produced one component of the mixed schedule. In all conditions, the red component of the multiple schedule accompanied a VI 34-s schedule and the green component accompanied a VI 240-s schedule of reinforcement. The mixed schedule comprised the same two VI schedules presented on a white key. Table 1 shows the order, number of training sessions, and set values of each condition.

In Conditions 17, 14, and 12, the initial-link schedules were concurrent VI 4 s VI 4 s, concurrent VI 28 s VI 28 s, and concurrent VI 72 s VI 72 s, respectively. However, in these conditions a terminal-link entry produced only 5-s access to the component of the mixed or multiple schedules. In Conditions 13, 11, and 15, the initial-link schedules were concurrent VI 4 VI 4, concurrent VI 28 VI 28, and concurrent VI 72 VI 72, respectively. In these conditions, a terminal-link entry produced 30-s access to the component of the mixed or multiple schedules. In Conditions 20, 16, and 18, the initial-links were again concurrent VI 4 VI 4, concurrent VI 28 VI

Table 3

Relative numbers of responses and terminal-link entries during the initial links (multiple/multiple + mixed), relative numbers of responses and obtained reinforcers during the terminal links (multiple/multiple + mixed), and relative response rates in the multiple components (red/red + green) for each subject and each condition in Experiment 2.

Condition	Relative initial link		Relative terminal link		Relative multiple
	Responses	Entries	Reinforcers	Responses	responses
Bird 31					
11	.32	.49	.51	.46	.78
12	.19	.49	.34	.48	.61
13	.59	.46	.43	.45	.72
14	.30	.50	.49	.54	.67
15	.20	.46	.52	.55	.67
16	.33	.43	.50	.54	.72
17	.62	.41	.67	.48	.70
18	.23	.41	.52	.57	.71
19	.25	.44	.59	.48	.71
20	.58	.41	.44	.47	.68
21	.54	.48	.50	.51	.67
Bird 32					
11	.44	.50	.48	.55	.76
12	.36	.42	.55	.50	.56
13	.50	.50	.45	.48	.77
14	.32	.39	.57	.52	.91
15	.20	.46	.52	.55	.67
16	.33	.49	.50	.56	.67
17	.41	.50	.63	.51	.81
18	.25	.57	.52	.42	.89
19	.24	.44	.41	.50	.77
20	.53	.56	.52	.45	.83
21	.55	.56	.46	.52	.82
Bird 33					
11	.48	.45	.50	.53	.78
12	.28	.43	.68	.53	.71
13	.58	.53	.50	.46	.73
14	.35	.45	.51	.52	.74
15	.22	.43	.48	.53	.67
16	.35	.50	.50	.43	.74
17	.43	.47	.47	.49	.70
18	.20	.46	.54	.38	.84
19	.33	.47	.52	.50	.70
20	.64	.43	.47	.49	.60
21	.38	.49	.51	.48	.59
Bird 35					
11	.24	.50	.55	.48	.61
12	.11	.45	.47	.46	.87
13	.56	.52	.49	.49	.63
14	.19	.49	.61	.52	.73
15	.14	.45	.50	.53	.71
16	.24	.50	.52	.53	.72
17	.54	.49	.60	.51	.74
18	.09	.48	.47	.49	.64
19	.18	.45	.42	.49	.72
20	.63	.49	.54	.49	.73
21	.53	.48	.49	.47	.64

Table 3 (*Continued*)

Condition	Relative initial link		Relative terminal link		Relative multiple
	Responses	Entries	Reinforcers	Responses	responses
Bird 36					
11	.42	.49	.49	.46	.71
12	.21	.51	.40	.50	.57
13	.69	.51	.44	.52	.75
14	.37	.55	.43	.48	.62
15	.21	.52	.52	.48	.63
16	.27	.52	.51	.46	.66
17	.33	.53	.53	.50	.67
18	.31	.46	.42	.49	.57
19	.29	.51	.45	.49	.53
20	.62	.49	.45	.50	.69
21	.59	.53	.57	.49	.59

28, and concurrent VI 72 VI 72, respectively. A terminal-link entry produced 60-s access to a component of the mixed or multiple schedules. The results of Conditions 6, 4, and 5 from Experiment 1 were included in the analysis; these were conditions with comparable initial-link durations, but with 10-s access to the mixed- or multiple-schedule components as the terminal links. Condition 19 was a replication of Condition 6 and Condition 21 was a replication of Condition 5.

Results

The raw data summed over the last five sessions of each condition for each subject are shown in the Appendix. The same relative values were calculated from these data as in Experiment 1 and are shown in Table 3. There were no systematic differences in the subjects' performance for those conditions that were replications of Experiment 1 conditions; hence the mean performance was calculated and used in the subsequent analyses.

As in Experiment 1, the numbers of entries into the two terminal links were approximately equal throughout. The relative terminal-link obtained-reinforcer rate (multiple/multiple + mixed) differed little from .50 (overall mean = .50, SD = .06), and no systematic changes as a function of either initial-link duration or terminal-link component duration were found across subjects (Table 3).

Figure 4 shows the relative initial-link response rate (key leading to the multiple sched-

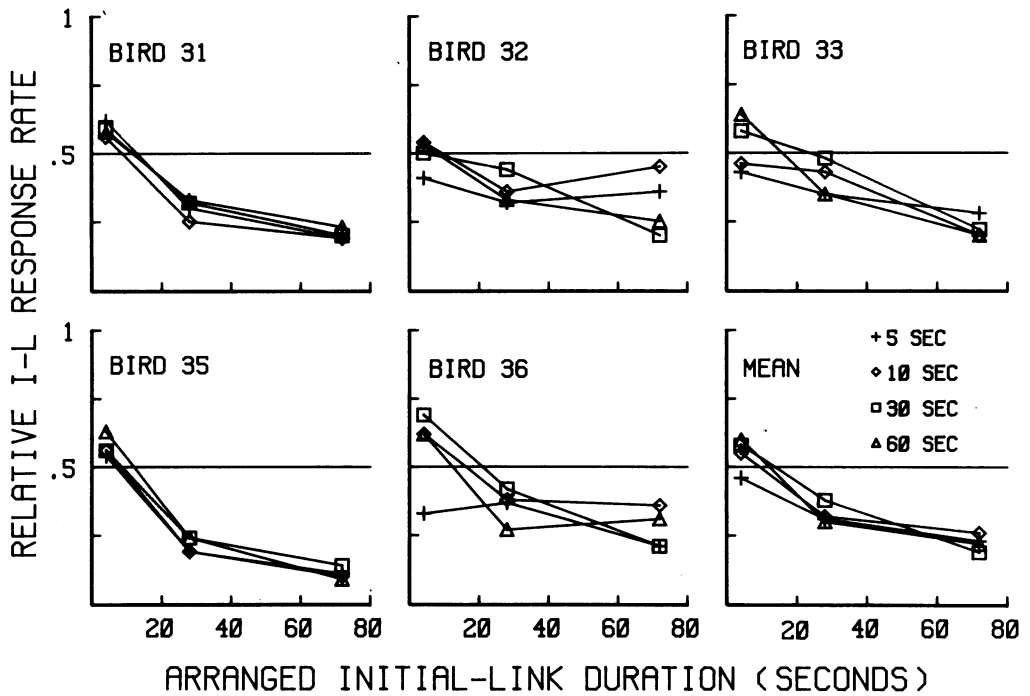

Fig. 4. The relative initial-link response rate (responses on key leading to the multiple-schedule terminal link as numerator) has been plotted as a function of the arranged initial-link VI schedules for Experiment 2. The data for each set of terminal-link component durations are shown separately for each subject. The mean performance across subjects is also shown.

ule as the numerator) plotted as a function of initial-link duration for each set of terminal-link component durations for each subject. The results of Experiment 1 were clearly replicated. At the shortest initial-link duration (concurrent VI 4 VI 4), subjects typically responded more on the alternative that led to the multiple-schedule terminal link. With the longer initial-link schedules, this preference was reversed and subjects responded more on the alternative leading to the mixed-schedule terminal link. Furthermore, preference appeared to be independent of the component duration of the mixed- and multiple-schedule terminal links; that is, there were no systematic differences in the relative initial-link response rates at any given initial-link duration across the four different component durations. There was some evidence for lower relative response rates than would be expected for Condition 17 (Birds 32, 33, and 36), when the initial-links were concurrent VI 4 VI 4 and the component duration was 5 s. This result, however, remained an anomaly, as neither the remaining conditions employing the same initial-link schedules but different component durations, nor those conditions employing the same component duration but different initial-link durations, provided further evidence of an effect.

Performances in the two terminal links were compared on the basis of relative terminal-link response rates (multiple/multiple + mixed). Table 3 shows that although 1 subject typically responded more during the mixed schedule (Bird 31), and another responded more during the multiple schedule (Bird 36), there were no consistent differences across the 5 subjects. Furthermore, there were no systematic changes as either the initial-link or terminal-link durations were varied. The mean relative terminal-link response rate across subjects and conditions was .48 (*SD* = .04), identical to that in Experiment 1.

Performances in the multiple schedule were assessed using the relative response rates from the two components (red/red + green). No systematic changes in relative multiple-schedule responding as a function of changes in either the initial-link or terminal-link durations were found (Table 3). The mean relative multiple-schedule response rate across sub-

jects and conditions was .71 (SD = .08), similar to that obtained in Experiment 1 (mean = .68, SD = .07). There was, however, considerable variability in the data, ranging from .91 (Bird 32, Condition 14) to .53 (Bird 36, Condition 19).

DISCUSSION

Concurrent-chain experiments measuring preference between two similar types of schedules; (e.g., Davison, 1983; Fantino, 1969) or between mixed versus multiple schedules (e.g., Hursh & Fantino, 1974) would predict that as initial-link duration increased, preference for the multiple schedule should decrease. This was clearly the case in this experiment. However, choice responding did not simply fall to indifference. Rather, Figures 2 and 4 show that at the longer initial-link durations, all 5 subjects preferred the alternative leading to the mixed schedule. In several cases these preferences were stronger than those shown for the multiple schedule at the shorter initial-link durations. Interpolating from Figures 2 and 4, the point at which there was indifference between the two terminal-link schedules fell between initial links of concurrent VI 10 VI 10 and concurrent VI 20 VI 20.

This change in preference was not merely a by-product of other changes in the experimental situation. The procedure used in the present study ensured that the number of entries into each terminal link and the number of entries into each component of a particular terminal link were approximately equal. The data showed that the rates of responding and the rates of reinforcement in each pair of terminal links also were approximately equal throughout. The differential rates of responding obtained in the two components of the multiple schedule during Experiment 1 demonstrated that the arranged differential reinforcer rates were discriminable even with only 10-s access time per entry. Furthermore, Experiment 2 showed that the change in preference with increasing initial-link duration was independent of the terminal-link component duration.

Interestingly, the present experiment is the only one of its type published in which subjects consistently preferred the components of a mixed schedule over the components of a multiple schedule. However, no others have varied initial-link duration over such a wide range of values. For example, Hursh and Fantino (1974) used only two different initial-link durations, VI 15 s VI 15 s and VI 60 s VI 60 s. The results of the present experiment suggest that their data should have revealed a preference for the mixed schedule at the longer of these durations. With their 2 subjects and particular experimental procedure, a greater increase in the initial-link duration may have been required to produce this effect.

An unpublished study by Daniels (1971; cited by Catania, 1980, pp. 123–124) provides some support for this contention. The procedure was similar to that employed by Hursh and Fantino (1974). One terminal link was a mixed FI 10-s FI 40-s schedule and the other was a multiple FI 10-s FI 40-s schedule, each component terminating with a reinforcer. The initial links were varied from VI 0 s VI 0 s to VI 120 s VI 120 s. At VI 0 VI 0, the higher rate of responding was on the key producing the multiple-schedule terminal link; at VI 15 VI 15, the response rates on the two alternatives were approximately equal; and from VI 30 VI 30 to VI 120 VI 120, the higher rate of responding was on the key leading to the mixed-schedule terminal link. But, because independent concurrent initial links were used in that study, preference changes obtained were confounded with changing frequencies of entries into the terminal links. In the present experiment this difficulty was overcome by using dependent schedules in the initial links.

More generally, these results demonstrate that measure of preference between two schedules of reinforcement obtained from a concurrent-chain procedure must be treated with caution. It is already well established that the strength of a preference can depend on factors such as initial-link duration (e.g., Davison, 1983; Fantino, 1969). However, had the present experiment simply varied terminal-link component duration with only constant initial links of concurrent VI 4 VI 4, a relatively consistent preference for the multiple schedule would have been obtained. Conversely, had a comparable set of conditions been conducted with only constant initial links of concurrent VI 72 VI 72, subjects would have displayed a preference for the mixed schedule. Inasmuch as the preference between

two schedules reversed as a function of initial-link duration, the very nature of what is meant by a preference must be questioned. Obviously, preference cannot be viewed as an absolute. With context playing such an important role, the applicability of preference measures obtained in a particular concurrent-chain experiment to other experimental situations (even other concurrent chains) may be extremely limited. Therefore, if experimenters continue utilizing concurrent-chain procedures to investigate preferences, understanding the contribution of relatively innocuous procedural factors, such as initial-link duration, seems imperative.

REFERENCES

Branch, M. N. (1973). Observing responses in pigeons: Effects of schedule component duration and schedule value. *Journal of the Experimental Analysis of Behavior,* **20,** 417–428.

Catania, A. C. (1980). Freedom of choice: A behavioral analysis. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 14, pp. 97–145). New York: Academic Press.

Daniels, P. V. (1971). *The reinforcing value of information.* Unpublished doctoral dissertation, Columbia University.

Davison, M. (1983). Bias and sensitivity to reinforcement in a concurrent-chain schedule. *Journal of the Experimental Analysis of Behavior,* **40,** 15–34.

Davison, M. (in press). The analysis of concurrent-chain performance. In M. L. Commons, J. A. Nevin, & H. C. Rachlin (Eds.). *Quantitative analyses of behavior: Vol. 5. The effects of delay and intervening events.* Cambridge, MA: Ballinger.

Fantino, E. (1969). Choice and rate of reinforcement. *Journal of the Experimental Analysis of Behavior,* **12,** 723–730.

Fantino, E., & Davison, M. (1983). Choice: Some quantitative relations. *Journal of the Experimental Analysis of Behavior,* **40,** 1–13.

Fantino, E., & Moore, J. (1980). Uncertainty reduction, conditioned reinforcement, and observing. *Journal of the Experimental Analysis of Behavior,* **33,** 3–13.

Ferguson, G. A. (1965). *Nonparametric trend analysis.* Montreal: McGill University Press.

Green, L., & Rachlin, H. (1977). Pigeons' preferences for stimulus information: Effects of amount of information. *Journal of the Experimental Analysis of Behavior,* **27,** 255–263.

Hursh, S. R., & Fantino, E. (1974). An appraisal of preference for multiple versus mixed schedules. *Journal of the Experimental Analysis of Behavior,* **22,** 31–38.

McMillan, J. C. (1974). Average uncertainty as a determinant of observing behavior. *Journal of the Experimental Analysis of Behavior,* **22,** 401–408.

Siegel, S. (1956). *Nonparametric statistics for the behavioral sciences.* New York: McGraw-Hill.

Stubbs, D. A., & Pliskoff, S. S. (1969). Concurrent responding with fixed relative rate of reinforcement. *Journal of the Experimental Analysis of Behavior,* **12,** 887–895.

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APPENDIX

Responses on the key leading to the mixed schedule and on the key leading to the multiple schedule during the initial links, and responses and obtained reinforcers during the mixed schedule and the red and green components of the multiple schedule during the terminal links, summed over the last five sessions for each subject under each condition.

	Initial-Link responses		Terminal-link responses			Terminal-link reinforcers		
Condition	Mult.	Mix.	Red	Green	Mix.	Mix.	Red	Green
Bird 31								
1	1,049	1,192	1,805	1,732	3,388	59	24	33
2	921	1,598	1,860	1,466	3,176	56	45	10
3	896	3,831	1,007	674	1,747	41	25	6
4	875	2,791	1,061	691	1,846	43	37	6
5	641	2,805	758	430	995	25	17	5
6	946	621	2,191	606	2,271	65	61	5
7	968	2,304	1,131	600	1,496	33	31	4
8	482	2,315	572	212	908	22	19	5
9	937	561	1,864	857	2,868	70	62	7
10	916	1,371	1,849	1,560	2,901	66	28	25
11	610	1,300	2,049	645	3,261	87	71	6
12	713	3,119	305	213	558	16	8	0
13	388	274	1,666	686	3,280	89	48	7
14	718	1,668	625	336	824	15	13	1
15	693	2,741	2,070	1,088	2,899	57	68	8
16	263	532	1,617	676	2,590	61	60	11

Appendix (*Continued*)

	Initial-Link responses		Terminal-link responses			Terminal-link reinforcers		
Condition	Mult.	Mix.	Red	Green	Mix.	Mix.	Red	Green
17	933	573	677	319	1,631	19	31	3
18	401	1,319	2,050	878	3,215	57	74	7
19	613	1,828	756	329	1,491	25	29	4
20	245	179	1,737	856	4,104	100	58	12
21	670	568	1,534	832	2,446	49	48	3
Bird 32								
1	915	1,123	3,623	2,391	4,138	58	29	33
2	2,085	1,185	3,595	1,475	3,663	59	47	10
3	1,410	1,366	916	662	2,775	28	24	1
4	1,199	1,373	2,146	690	2,743	48	42	10
5	1,038	1,262	1,054	1,305	1,833	22	20	2
6	1,005	884	2,621	1,599	3,990	65	56	10
7	1,020	1,493	1,376	330	2,819	39	32	2
8	712	2,635	827	496	2,050	21	20	3
9	785	964	3,056	986	5,572	67	60	11
10	962	998	2,492	1,818	4,416	52	30	35
11	818	1,039	3,640	1,245	3,916	78	76	13
12	1,379	2,495	651	543	1,677	12	11	4
13	355	360	2,344	737	3,378	77	54	5
14	897	1,940	971	105	1,568	13	17	2
15	693	2,741	2,070	1,088	2,899	57	68	8
16	329	675	2,412	1,275	3,087	57	59	13
17	807	1,145	2,101	543	2,677	21	32	4
18	533	1,596	3,480	483	4,051	92	70	2
19	688	2,219	1,337	423	2,244	34	20	4
20	216	193	3,808	854	4,402	100	79	10
21	689	574	2,580	631	2,292	50	42	5
Bird 33								
1	1,017	1,260	2,236	3,509	5,440	57	28	32
2	1,580	959	2,402	1,376	5,367	48	44	8
3	1,136	1,251	1,701	554	2,718	31	32	3
4	1,252	1,092	2,115	835	3,508	41	44	5
5	603	2,383	897	614	1,836	29	14	1
6	874	775	2,961	861	4,499	72	57	9
7	916	1,627	1,323	389	2,492	31	32	9
8	1,960	1,985	997	481	2,356	23	18	4
9	1,000	774	3,109	1,061	5,986	63	58	8
10	794	1,469	2,412	2,724	4,486	60	28	33
11	863	948	3,811	1,195	5,633	83	75	17
12	941	2,376	563	267	1,014	8	17	1
13	429	306	2,705	1,114	4,041	77	58	9
14	679	1,284	791	301	1,210	15	16	1
15	569	2,064	2,431	1,292	4,338	64	53	12
16	290	535	2,666	984	4,733	78	51	9
17	790	1,055	1,580	722	2,687	32	26	2
18	448	1,768	2,481	497	5,659	89	58	6
19	698	1,396	1,428	680	2,461	29	28	3
20	281	158	2,628	1,821	6,107	94	68	12
21	607	973	2,239	1,650	4,457	47	39	6
Bird 35								
1	867	1,459	1,879	2,228	3,213	60	30	29
2	842	1,921	1,852	1,681	2,996	56	45	9
3	680	4,063	1,648	803	2,041	40	22	4
4	718	3,139	2,067	862	2,923	48	34	6
5	446	3,834	882	491	1,364	17	19	3
6	868	601	2,964	1,507	4,139	68	61	7

Appendix (*Continued*)

	Initial-Link responses		Terminal-link responses			Terminal-link reinforcers		
Condition	Mult.	Mix.	Red	Green	Mix.	Mix.	Red	Green
7	674	3,547	1,494	684	2,201	37	25	5
8	550	2,276	871	395	1,649	25	16	1
9	913	598	2,452	1,523	3,657	68	59	9
10	814	1,365	1,704	1,808	3,448	61	21	35
11	630	2,033	2,641	1,879	4,824	85	75	19
12	603	5,090	534	86	878	17	12	1
13	383	301	2,406	1,462	3,692	69	54	10
14	530	2,294	625	252	874	12	16	4
15	523	3,125	2,464	1,082	3,772	59	61	6
16	243	774	2,858	1,220	3,687	68	74	11
17	825	692	1,353	529	1,889	23	34	1
18	243	2,364	2,639	1,542	4,590	70	46	14
19	493	2,223	1,176	489	2,081	34	22	2
20	255	153	3,282	1,298	5,110	87	88	10
21	690	604	1,637	982	3,123	51	40	4
Bird 36								
1	908	998	2,646	2,705	4,265	57	23	34
2	1,044	430	2,266	1,190	2,790	35	52	3
3	892	1,427	1,243	696	2,771	38	24	3
4	770	899	1,917	841	2,736	44	40	4
5	555	996	957	395	1,522	24	23	4
6	1,069	569	2,728	1,831	4,573	69	54	10
7	676	1,311	1,682	632	2,381	31	32	3
8	562	2,012	905	574	1,383	28	13	5
9	841	507	3,838	2,302	4,636	62	62	11
10	863	691	2,211	2,303	3,542	48	25	30
11	821	1,114	3,222	1,446	5,553	90	68	6
12	543	2,052	486	393	814	13	7	2
13	459	211	3,420	1,262	4,072	87	72	5
14	702	1,215	856	559	1,235	17	10	2
15	519	1,925	2,476	1,572	4,102	65	58	8
16	258	697	2,806	1,576	4,774	71	57	6
17	595	1,203	1,950	1,027	2,670	28	27	4
18	515	1,140	2,266	1,820	4,940	87	49	11
19	570	1,365	1,062	994	2,052	32	19	6
20	252	154	3,857	1,803	5,747	99	74	10
21	745	522	2,117	1,627	3,401	41	46	6