DELAY OF REINFORCERS IN A CONCURRENT-CHAIN SCHEDULE: AN EXTENSION OF THE HYPERBOLIC-DECAY MODEL

MICHAEL DAVISON

UNIVERSITY OF AUCKLAND, NEW ZEALAND

Six pigeons were trained in concurrent-chain schedules with equal aperiodic initial links and delays to reinforcers in the terminal links. The terminal links always lasted 30 s. In Experiment 1, two reinforcers were delivered in each terminal link, with the first reinforcer delivered either 1 s (Experiment 1A) or 5 s (Experiment 1B) after choice. In these experiments, the delay between the first and second reinforcers in one terminal link was 10 s, and the delay between the first and second reinforcers on the other key was varied. This variation produced little change in preference. In Experiment 1C, the first and second delays on one key were 10 s, and on the other key they were varied within the restriction that the sum of delays was 20 s. Preference for the varied terminal link increased as the first delay was decreased. A hyperbolic model of the value of reinforcer delay provided a good description of the data from Experiment 1. In Experiment 2, a single reinforcer was delivered in each terminal link after a delay of either 0.2 or 19.8 s, and these delays were reversed between conditions. The initial-link schedule providing terminal-link access was varied from means of 5 s to 480 s. As the initial-link duration was increased, preference for the shorter delay became less extreme. An extension of the hyperbolic-decay model, in which the decay constant was a hyperbolic function of the initial-link duration, described the results well. Differences between the procedure used here (constant-duration terminal links) and that used in conventional concurrent-chain research precludes use of the model as a general account of concurrent-chain performance.

Key words: delay of reinforcement, concurrent-chain schedules, preference, hyperbolic decay, key peck, pigeons

Mazur (1984, 1986) introduced and tested a quantitative model of the effects of delayed reinforcers in a choice situation. In this model, the value of a choice is given by the sum of the hyperbolic decays between the choice response and each subsequent delayed reinforcer. Thus, the reinforcing value of alternative i is given by:

$$V_i = \sum_{j=1}^n \frac{1}{1 + KD_{2j}}, \quad (1)$$

where n is the number of differing delays that follow the choice response, D_{2j} is the duration of each delay, and K is a constant. In a series of experiments, Mazur (1984, 1986, 1987) has shown convincingly that the summated hyperbolic-decay model fitted his data well, though he (1987) briefly entertained a power-

hyperbolic model. He has, however, tested the model in only one particular type of experimental procedure in which choices are made by emitting single responses in the choice phase. This procedure provides forced trials to prevent preference from becoming exclusive, and the intervals to reinforcers for one choice change as a function of the degree of preference to titrate toward indifference in preference between the outcomes. Under these conditions, the value of the constant K has usually seemed close to 1.0, though Mazur, Snyderman, and Coe (1985) reported a best fitting K of 1.3.

Given the ability of this model to describe choice indifference between delayed reinforcers, it is important to determine whether the model might be able to account for preference in the more standard concurrent-chain choice procedure. In this procedure, performance on concurrent variable-interval (VI) schedules replaces the single-response choice phase, no forced trials are programmed, and instead of titrating preference toward indifference, the preference between delayed reinforcers is measured as the relative numbers of responses (or the relative time spent responding) in the choice phase. A second difference between the two

I thank the New Zealand University Grants Committee for equipment grants that allowed this research to be conducted, and the Masters and Doctoral students and staff who helped conduct this experiment. I also thank Brent Alsop for commenting on a draft of this paper. Reprints may be obtained from Michael Davison, Department of Psychology, University of Auckland, Private Bag, Auckland, New Zealand.

procedures is that instead of subjects spending fixed and equal times in the outcome phases as in the Mazur (1984) procedure, concurrent-chain schedules usually (but not invariably) arrange for the outcome phase to end when a number of reinforcers (usually one) has been delivered. Thus, the outcome phase duration is perfectly correlated with the outcome delay to reinforcers. Mazur (1984) was clear that the hyperbolic model could not, as it stood, account for concurrent-chain performance because the model did not predict the decrease in preference between constant outcomes that occurs when the initial links are lengthened (see Davison, 1987). Mazur et al. (1985) were also certain that the model should and could be extended to concurrent-chain performances. The present research is an attempt to do this.

If Mazur's (1984) model can be extended to concurrent-chain performance, it comes into competition with various existing models of concurrent-chain performance (see review by Davison, 1987). The most frequently cited model is the delay-reduction hypothesis (Fantino & Davison, 1983; Squires & Fantino, 1971) in which the value of an alternative is a function of the decrease in the expected time to reinforcement signaled by terminal-link entry. The delay-reduction hypothesis has no free parameters. However, its domain of application is limited. First, it is applicable to arrangements that use VI schedules in the terminal links, but not to those that use fixed delays or fixed-interval schedules (Davison, 1987; Fantino & Navarick, 1974). Second, it is probably not generally applicable when terminal-link entries are arranged on dependent concurrent VI VI schedules (Fantino, 1981), although it may predict accurately when preferences are not extreme (Fantino & Royalty, 1987). Third, because delays after reinforcers in the terminal links of concurrent-chain schedules affect preference (Gentry & Marr, 1980; Poniewaz, 1984; Shull & Spear, 1987), the delay-reduction hypothesis is probably applicable only to procedures in which the terminal links end after reinforcement. Mazur's delay-of-reinforcement model has been supported only in situations in which there are fixed delays to reinforcers in the terminal links, in which relative terminal-link entry frequency is controlled (albeit normally by forced trials; but see Davison & Smith, 1986), and

in which the times spent in the terminal links are equalized by arranging delays after reinforcers until the next presentation of the choice phase. Because the goal of the present research was to begin to assess the Mazur model's applicability to concurrent-chain schedule performance, we used the three techniques mentioned above that Mazur has used. Thus, the data collected here probably constitute an unfair test of Fantino's delay-reduction hypothesis.

Davison and Smith (1986) reported a concurrent-chain experiment in which pigeons chose on equal concurrent VI VI schedules between immediate and delayed 30-s periods of access to VI schedules of reinforcement. When the reinforcer frequencies in these periods were varied, choice-phase preference changed, but it was always biased toward the more immediate reinforcement period. Davison and Smith showed that Mazur's (1984) hyperbolic model (but using arithmetic, rather than hyperbolic, average delays) accounted very well for their data.

Experiment 1 reported here was an investigation of whether Mazur's hyperbolic model could account for preference (rather than indifference) in a more conventional concurrent-chain schedule, but one using equal-duration terminal links as in Mazur (1984, 1986, 1987) and in Davison and Smith (1986). The choice phase consisted of concurrent VI VI schedules, and each outcome consisted of two delays to reinforcers within a fixed time. In Experiments 1A and 1B, the delays in the left-key terminal link were kept constant, as was the first delay in the right-key terminal link. The second delay in the right-key terminal link was varied systematically. In Experiment 1C, the left-key terminal-link delays were kept constant, and both right-key terminal-link delays were varied with the restriction that they summed to 20 s.

The value of K (Equation 1)—in s^{-1} —found by Davison and Smith (1986) ranged from 0.10 to 1.08 across 6 subjects and averaged 0.30. They noted that these values, obtained with concurrent VI 30-s VI 30-s initial-link schedules, were considerably lower than the range for the single-response procedure (0.4 to 2.6) reported by Mazur (1984). It thus seemed likely that the value of K in the hyperbolic-decay model (Equation 1) might be

a decreasing function of the duration of the choice phase. Experiment 2 arranged a constant pair of (single) delays to reinforcers in the outcome phase and manipulated systematically the duration of the (equal) schedules in the choice phase in order to discover the relation between the value of K and the choice-phase schedules.

GENERAL METHOD

Subjects

Six homing pigeons, numbered 31 to 36, were maintained at $85\% \pm 15$ g of their free-feeding body weights by providing them with mixed grain immediately after daily training sessions. Water and grit were freely available in their home cages. These subjects had extensive prior experience in performing on concurrent-chain schedules. Bird 31 died after completing Condition 41.

Apparatus

The experimental chamber, which was 330 mm high, 330 mm wide, and 310 mm deep, was fitted with an exhaust fan that provided ventilation and some masking of external noise. The chamber contained three response keys, 20 mm in diameter, 110 mm apart, and 250 mm above the grid floor. The center key was not used in this experiment. The left and right keys could be illuminated white, red, or green. When these keys were white, pecks on them exceeding about 0.1 N operated the keys and produced a relay click and the brief offset of the keylights. Pecks on red, green, or dark keys had no consequences and were not counted.

The food magazine contained wheat and was situated beneath the center key and 120 mm from the floor. During reinforcer delivery, the food hopper was illuminated and all keylights were extinguished. There was no other illumination in the chamber.

General Procedure

Subjects were placed in the darkened experimental chamber, and sessions ended in blackout after 40 reinforcers had been obtained or after 45 min had elapsed, whichever event occurred first. Sessions commenced with the left and right keylights illuminated white, and an interval from a VI schedule commenced timing. When this interval had elapsed, an

outcome-phase entry was arranged for a response on the left or right keys with a probability of .5. This procedure (Stubbs & Pliskoff, 1969) ensures approximately equal entries into the two outcome phases. If a left-key outcome was arranged, the next response on the left key extinguished the white keylights and resulted in the left key being illuminated red. When the left key was red, one or more reinforcers were delivered after fixed periods of time, independently of responding. Then, after 30 s (inclusive of reinforcer durations), both keys again became white, another interval from the VI schedule commenced timing, and the choice phase restarted. If a right-key outcome was arranged at the end of a choice-phase period, the next response on the right key turned this key green, extinguished the left key, and again one or more reinforcers were delivered, independently of responding, in a 30-s period before the choice phase was again presented.

The VI-schedule intervals arranged in the choice phase were selected randomly, without replacement, from a 14-interval set calculated from a constant-probability distribution (Cattania & Reynolds, 1968). When all 14 intervals had been used, all again became available for selection.

All experimental contingencies were controlled by a remotely placed 6809 computer programmed in SLAVIC (slave BASIC); this computer was one of eight controlled via a bus by a master 6809 computer running XBASIC. The data collected were the numbers of responses emitted on the two keys in the choice phase, the time spent responding on the two keys in this phase (from the first response on one key to the first response on the other), the numbers of changeovers between keys, and the number of reinforcers obtained on each key in the outcome phases.

Each experimental condition remained in effect until the behavior of all birds had reached a defined stability criterion five, not necessarily consecutive, times. The criterion was that the median relative number of left and right choice-phase responses over five sessions was not more than .05 different from the median of the five sessions prior to these. Thus, a minimum of 14 sessions was required for stability. Typically, once each bird had met this criterion, preference remained stable until experimental conditions were changed.

Table 1

Experiment 1: Sequence of experimental conditions, delays to reinforcers in seconds in the outcome phase, and the number of sessions training arranged for each condition. Conditions 8 to 10 used varied reinforcer durations, and the data are not reported here.

Condi- tion	Left key		Right key		Ses- sions
	First	Second	First	Second	
Experiment 1A					
1	1	10	1	10	38
2	1	10	1	20	25
3	1	10	1	4	22
4	1	10	1	15	17
5	1	10	1	2	16
6	1	10	1	6	25
7	1	10	1	0.2	27
11	1	10	1	6	21
Experiment 1B					
12	5	10	5	10	20
13	5	10	5	19	23
14	5	10	5	4	19
15	5	10	5	15	21
16	5	10	5	2	20
17	5	10	5	6	19
18	5	10	5	0.2	21
Experiment 1C					
19	10	10	10	10	19
20	10	10	15	5	23
21	10	10	5	15	23
22	10	10	18	2	24
23	10	10	2	18	37
24	10	10	0.2	19.8	28

EXPERIMENT 1

There were three parts to Experiment 1 (Table 1). In all three parts, the overall terminal-link entry frequency was set at two per minute using a VI 30-s schedule that allocated terminal-link entries with a probability of .5. In Experiments 1A and 1B, the delay to the first outcome-phase reinforcer was constant and the same on both keys. In Experiment 1A this delay was 1 s, and in Experiment 1B it was 5 s. In most conditions of Experiments 1A and 1B, the second delay on the left key (i.e., from the end of the first reinforcer to the commencement of the second) was 10 s, and the second delay on the right key was varied from 0.2 to 19 or 20 s. Conditions 8 to 10 used varied reinforcer durations; the data are not reported here.

In Experiment 1C, both left-outcome-phase delays were 10 s (i.e., the second reinforcer commenced 23 s after choice-phase entry)

throughout. The two delays on the right key were varied from 0.2 to 19.8 s under the restriction that the two delays summed to 20 s.

RESULTS AND DISCUSSION

The Appendix shows the numbers of responses emitted, seconds spent responding, and reinforcers obtained on both keys, and the number of changeovers for each subject and condition. These data have been summed over the final five sessions of each condition. Figure 1 shows the frequency of left-key choice-phase responses relative to all choice-phase responses for each individual subject in Experiment 1A as a function of the delay to the second reinforcer on the right key. As this delay was increased, so in general did preference increase marginally for most subjects. However, none of the individual subject trends were significant on a nonparametric trend test (Ferguson, 1965), nor was the group trend significant (Figure 4). Time-allocation data showed a similar nonsignificant trend. The data obtained from Experiment 1B were similar (Figure 2) in that no subject showed a significant trend, although the overall trend for response measures across individuals was statistically significant ($z = 2.39$).

The results of Experiments 1A and 1B accorded well with the general concurrent-chain finding that terminal-link reinforcers subsequent to the first have only small effects on preference (Davison, 1968; Hursh & Fantino, 1973); they also generalize this finding to performance in concurrent chains with dependently scheduled initial links and terminal-link delays to reinforcers (rather than fixed-interval or mixed-interval schedules).

Figure 3 shows the data from Experiment 1C plotted as a function of the second right-key delay value (recall that the first right-key delay was 20 s minus the second delay). When both delays to reinforcers on the right key were varied complementarily, there were strong changes in both relative response and time allocation. Nonparametric trend tests showed that the changes were significant for all 6 subjects on response measures and for 5 of the 6 subjects on time measures (excluding Bird 35). Across subjects, the trends were significant for both measures ($z = -5.59$ and -5.91 for responses and time, respectively).

Figure 4 shows the left-key response-measured preference averaged over the 6 subjects

Fig. 1. Experiment 1A. The relative frequency of left-key responses in the initial links as a function of the duration of the second delay to reinforcement in the right-key terminal link. The delay to the first reinforcer in both terminal links was 1 s, and the delay to the second reinforcer in the left terminal link was 10 s.

Fig. 2. Experiment 1B. The relative frequency of left-key responses in the initial links as a function of the duration of the second delay to reinforcement in the right-key terminal link. The delay to the first reinforcer in both terminal links was 5 s, and the delay to the second reinforcer in the left terminal link was 10 s.

for Experiments 1A, 1B, and 1C. There were no differences in this measure of preference between the conditions in which the first delays were both 1 s (Experiment 1A) and when they were 5 s (Experiment 1B). In both cases there was a barely discernible (but nonsignificant) trend toward greater preferences with increasing second right-key delays. Experiment 1C, on the other hand, produced monotonically decreasing preferences as the second right-key delay was increased (and, thus, as the first right-key delay was decreased). Time-allocation measures of preference showed a closely similar trend, but, except in Condition 23, relative time-allocation measures were smaller than relative response measures. Because this difference was independent of whether preference was greater than or less than .5, the implication is that time measures were biased toward right-key choice-phase responding.

Because there was very little systematic variance in the data from Experiments 1A and 1B, it was not possible to fit Mazur's (1984) hyperbolic model to these data. One of the major reasons for doing Experiment 1C was to provide data with considerably more systematic variance. Thus, in order to assess the applicability of Mazur's model to these concurrent-chain data, we fit the model to the data from Experiment 1C and then determined how well the model described the data from Experiments 1A and 1B. Thus, we fit Equation 1 to the data from Experiment 1C using a nonlinear iterative curve-fitting procedure (Killeen,

personal communication) to estimate the two parameters K in Equation 1 and c , or left-right bias, in the fitting equations:

$$\frac{B_l}{B_l + B_r} = \frac{cV_l}{cV_l + V_r}, \quad (2)$$

where B is choice-phase responding on the left (l) and right (r) keys, and V is the value of the outcome-phase entry as defined by Equation 1. The results of these fits are shown in Table 2.

In general, the fits of the model to the data were reasonably good, with more than 80% of the variance accounted for for 5 of the 6 birds. Bird 35's data fit poorly; the reason for this can be seen in Figure 3—only this subject showed an upwardly concave function. The fit to the grouped data (Figure 4) was excellent. K values ranged from 0.10 to 0.90, a range very similar to that reported by Davison and Smith (1986), even though they used choice-phase schedules that were half as long as those used here. The mean K value was 0.22, lower than Davison and Smith's value of 0.30. However, if longer choice-phase durations decrease K , then this interexperiment comparison is in the correct direction. Bias (c) was, overall, close to 1.0, but was substantially toward the left key for Birds 33 and 36 and toward the right key for Bird 35.

The estimated parameters for the group data from Experiment 1C for Equations 1 and 2 (Table 2) were used to predict the group data trends; these are shown in Figure 5. For all

Fig. 3. Experiment 1C. The relative frequency of left-key responses in the initial links as a function of the duration of the second delay to reinforcement in the right-key terminal link. The delays in the left-key terminal link were 10 s and 10 s, and those in the right-key terminal links summed to 20 s.

Fig. 4. The relative frequency of left-key responses in the initial links as a function of the duration of the second delay in the right-key terminal link. The data have been averaged over all 6 subjects, and the results of all three parts of Experiment 1 are shown.

three experiments, the data trends and levels were closely predicted (cf. Figure 4). The preferences predicted by the model for Experiments 1A and 1B were very similar; therefore it was not surprising that the obtained data (Figure 4) for these two experiments were indiscriminably different. The model, therefore, seems to describe these three sets of data very well.

In summary, Mazur's (1984) hyperbolic model of the effects of reinforcer delay described well the data from Experiment 1. It predicted very little change in preference in Experiments 1A and 1B (Figure 5), and very little was found (Figures 1 and 2). It predicted very little difference in the preferences obtained in Experiments 1A and 1B (Figure 5), and no clear difference was found (cf. Figures 1 and 2). Finally, it predicted decreasing left-key preference as the first delay on the right key was decreased and the second delay was increased complementarily (Figure 5), and this result was found (Figures 3, 4, and 5). Estimates of the constant K in Equation 1 were of reasonable values and comparable to those found by Davison and Smith (1986). They were, however, lower than those reported by Mazur (1984, 1986) and by Mazur et al. (1985). As Davison and Smith reported, the hyperbolic-decay model seems to be well able to describe performance in choice situations in which the choice phase is extended in time, at least under the restriction that the terminal links last equal periods of time.

EXPERIMENT 2

Experiment 2 was designed to investigate the effect of initial-link length on preference between terminal-link delays to reinforcers. There is considerable literature that shows that, in conventional concurrent-chain schedules with unequal delays to reinforcers or schedules of reinforcement, shorter initial links give larger preferences for shorter delays (Fantino, 1969; Wardlaw & Davison, 1974; see the summary by Davison, 1987). In terms of Mazur's (1984) model, this implies that K in Equation 1 should fall as initial links are lengthened. Mazur's model itself also implies that the maximum initial-link response ratio attainable should equal the ratios of immediacies of reinforcers (the reciprocal of the delay ratio) when delays are of fixed duration. This implication is not tenable in the face of considerable data that show that preference can be greater than the immediacy ratio under two different conditions: (a) when the terminal-link delays are long (e.g., Davison & Temple, 1973; Duncan & Fantino, 1970; MacEwen, 1972), and (b) when the initial links are short (Wardlaw & Davison, 1974). However, the procedures used by Mazur and by Davison and Smith (1986) were different from those used in conventional concurrent-chain experiments. Mazur and Davison and Smith used constant and equal times in the terminal links, whereas the conventional procedure uses terminal-link dura-

Table 2

The results of nonlinear regression analyses of the data obtained in Experiment 1C according to Equations 1 and 2. VAC is the percentage of data variance accounted for, and Average deviation is the mean deviation of the data from the predictions.

Subject	K	c	VAC	Average deviation
31	0.19	0.91	83.7	0.03
32	0.15	1.07	82.9	0.04
33	0.27	1.61	88.4	0.03
34	0.90	0.97	95.3	0.03
35	0.10	0.72	65.9	0.03
36	0.14	1.52	91.6	0.02
Group	0.22	1.10	99.5	0.01

tions that are perfectly correlated with terminal-link delays.

Given the results reported by Mazur (1984, 1986, 1987) and by Davison and Smith (1986), it is conceivable that preference in the conventional procedure is controlled also by the immediacy with which the initial links are reinstated after terminal-link entry, and that this added reinforcer value increases preference measures. Shull and Spear (1987) raised this possibility and provided data from single-chain procedures that supported it. Poniewaz (1984) also reported data indicating that total terminal-link duration in a concurrent chain (i.e., inclusive of detention time after reinforcers) affected initial-link preference. Finally, Mazur et al. (1985) also reported a clear, but small, effect of detention time after reinforcement in the titration procedure. All these results suggest that there is a source of control in conventional concurrent-chain procedures that is attenuated or removed when terminal links are arranged to be equal in duration. When such procedures have been used in concurrent-chain schedules (Gentry & Marr, 1980), preference ratios did not reliably exceed reinforcer immediacy ratios even when the terminal-link durations were 128 s (cf. Duncan & Fantino, 1970). However, it is worthwhile noting that Gentry and Marr's results could be attributable, in whole or part, to their use of reinforcers delayed in blackout in the terminal links. Nondifferentially signaled terminal links do decrease preference, as was shown by Williams and Fantino (1978). However, Williams and Fantino, using nondifferentially signaled terminal links that ended af-

Fig. 5. Relative left-key initial-link responses (predicted from Equations 1 and 2) for the group data of Experiment 1 as a function of the second right-key terminal-link delay. The parameters used were those shown in Table 2.

ter reinforcers, also showed that preference still exceeded the ratio of terminal-link reinforcer immediacies. This discussion therefore suggests that the hyperbolic model is a serious contender for describing concurrent-chain procedures that use equal terminal-link durations. Under these conditions, the model does predict an increase in preference as the terminal-link delays are increased, and the available data (Gentry & Marr, 1980) suggest that, consistent with the model, preference does not exceed the terminal-link reinforcer immediacy ratio.

Experiment 2 addressed the second problem, mentioned above, in applying the hyperbolic model to concurrent-chain performances. The model cannot, as it stands, describe the usual decrease in preference between constant terminal-link delays when the initial links are lengthened. Thus, Experiment 2 arranged concurrent VI VI initial-link schedules that provided terminal-link entries in the range of once per 5 s to once per 480 s. For each entry rate, both terminal-link delays of 0.2 versus 19.8 s and the reversal of these delays between keys were arranged. Within Mazur's (1984) model, such a reversal allows the values of K and c (Equations 1 and 2) to be calculated algebraically.

METHOD

Subjects, Apparatus, and Procedure

The subjects and apparatus were the same as in Experiment 1.

Table 3

Experiment 2: Sequence of experimental conditions, delays to reinforcers in seconds in the outcome phase, and the number of training sessions arranged for each condition.

Condition	Left key	Right key	Schedule (s)	Sessions
25	0.2	19.8	30	28
26	19.8	0.2	30	28
27	0.2	19.8	5	23
28	19.8	0.2	5	42
29	0.2	19.8	10	22
30	19.8	0.2	10	21
31	0.2	19.8	20	27
32	19.8	0.2	20	15
33	0.2	19.8	60	26
34	19.8	0.2	60	24
35	0.2	19.8	120	25
36	19.8	0.2	120	21
37	0.2	19.8	240	28
38	19.8	0.2	240	29
39	0.2	19.8	480	36
40	19.8	0.2	480	31
41	0.2	19.8	30	24
42	19.8	0.2	30	17

The procedure was the same as described in the General Procedure; the sequence of experimental conditions is shown in Table 3. Terminal-link entry rate commenced at two per minute and was then set successively at 12, 6, 3, 1, 0.5, 0.25, and 0.125 per minute. Finally, the data obtained at two entries per minute were replicated. At each terminal-link entry frequency, the left- and right-key delays were initially set at 0.2 and 19.8 s, respectively, and in the subsequent condition the delays were 19.8 and 0.2 s.

RESULTS

The numbers of responses emitted, time spent responding, and reinforcers (terminal-link entries) on each key and the number of changeovers for each subject and condition are shown in the Appendix. These data have been summed over the final five sessions of each condition. Figure 6 shows the relative number of left-key responses emitted in all conditions as a function of the obtained duration of the initial links, according to whether the longer delay was arranged in the left or right terminal link. Clearly, preferences moved toward indifference as the initial links were lengthened, as expected. Time data showed very similar effects. In 8 of the 11 cases (no Condition 42

for Bird 31), the data obtained in Conditions 25 and 26 (VI 30-s initial links) were somewhat less extreme than those obtained in the replication Conditions 41 and 42; this difference was also shown for the grouped data. Because performance in Conditions 25 and 26 could have been affected by prior exposure to other conditions in Experiment 1, the data from Conditions 25 and 26 were excluded from subsequent analyses. There also was a problem in the performance of Bird 33 in Conditions 25 to 32, in which the choice between the terminal links was much closer to indifference than is indicated by the subsequent data, and by the replication of the VI 30-s conditions. The data from Conditions 25 to 32 for this bird were therefore not used in subsequent analyses.

Figure 7 shows the calculated values of K for the group data obtained in Experiment 2 as a function of the arranged time in the initial links. Figure 8 shows the same data for individual subjects. It was necessary to use arranged initial-link times in Figure 7 because the algebraic calculation of K from Equation 1 requires that, if there is any effect of initial-link length on K , the initial links are the same value in both conditions used to calculate K . The values of K fell, apparently hyperbolically, and with only a single reversal for the group data, as the terminal-link entry frequency was decreased.

However, the assumption of equal initial links between a condition and its reversal, made in plotting Figure 7, was not usually true. For instance, in Conditions 39 and 40 (VI 480-s initial link), the obtained mean initial-link times were unequal (529 and 494 s, respectively) averaged across subjects. This effect, for individual subjects, can be seen clearly in Figure 6. Because of this, the relation between the value of K and initial-link time, shown in Figure 7, is misleading. The exact relation may be obtained, as in Experiment 1, by fitting a model to the data.

Figure 7 suggests that the relation between K and the initial-link duration is hyperbolic. To describe this relation, we can write (for a single terminal-link delay):

$$K = \frac{1}{1 + K'D_1}, \quad (3)$$

where K is the constant in Equation 1, and D_1 is the time spent in the initial link. This is the

Fig. 6. Experiment 2. Relative left-key responses in the initial links as a function of the obtained mean initial-link duration for individual subjects. Squares denote data obtained when the left and right terminal-link delays were 0.2 and 19.8 s, respectively, and triangles show the data obtained when these delays were reversed. Filled data points indicate data not used in subsequent analyses (see text). Joined points show the predictions of Equations 2 and 4 using the best fitting parameter estimates for each subject (Table 4).

approximate relation shown in Figure 7, and it implies that $K = 1$ when no time is spent in the initial links. This implication appears to be valid for the group data (Figure 7). It is the same value as that reported by Mazur (1984, 1986), although Mazur et al. (1985) found that a value of 1.3 was preferable for their data set. A value of $K = 1$ may be too low for some individual subjects (e.g., Birds 33, 34, and 36 in Figure 8). Although these cases could easily be handled by an additional constant in the numerator of Equation 3 (that is, a nonunit value of K in Equation 1), the simplest case will be assumed here. If Equation 3 is used to replace the value of K in Equation 1, we obtain:

$$V_i = \frac{1}{1 + \frac{D_2}{1 + K'D_1}}. \quad (4)$$

Equation 4 makes it clear that the value associated with a particular terminal-link delay (D_2) is increased by increasing the time spent in the initial links (D_1), as it is also by decreasing the delay in the terminal links (D_2). The value of the delay is thus a function of

the context in which the delay occurs, and the equation operates in a way that is similar conceptually to Fantino's delay-reduction hypothesis, in which choice is an undefined function of the difference between the overall and terminal-link times to reinforcers. Instead of choosing according to the decrease in the expected times to reinforcement for the two options (delay-reduction hypothesis), Equation 4 suggests that subjects choose according to the terminal-link delays discounted hyperbolically by the time spent choosing.

Equation 4 was fit to the data from Experiment 2 in combination with Equation 2 using nonlinear regression. The conditions mentioned in the discussion of Figure 6 were not used in these fits. Results of these regressions are shown in Table 4. The fits of the data to Equation 4 were excellent for all subjects, with more than 94% of the data variance accounted for and an average deviation of the data from the predictions of .07 or better. Bias (c) values were close to 1.0 (no bias), except for Birds 31 and 32, who showed large biases but in opposing directions. The values of K' appear to be reasonable, but because this constant has units of s^{-1} , it may be easier to conceptualize the reciprocal of K' , which is the half-life of

Fig. 7. Experiment 2. Algebraic estimates of K (Equation 1) as a function of arranged initial-link duration. The data used to calculate K were averaged across individual subjects.

the hyperbolic decay in seconds (i.e., the time delay at which K reaches half its value at a 0-s terminal-link delay). For the group data, the half-life was 20.3 s; the half-life for the individuals ranged from 8.8 to 56.8 s. The predicted relative response rates based on these fits are shown as joined points in Figure 6. Both the data trends and levels were well described by Equation 4.

The delay-reduction hypothesis (Fantino & Davison, 1983; Squires & Fantino, 1971) makes clear predictions for Experiment 2, though we noted above its possible inapplicability to the present procedure. It predicts infinite preference with the 5-s initial-link schedule (Conditions 27 and 28), but, because terminal-link entries were dependently arranged in these experiments, it was impossible for preference to be this extreme. More important, the delay-reduction hypothesis predicts that preference falls more steeply with increasing initial-link schedule durations than was observed in Experiment 2. For example, it predicts relative left-key response rates of .58 and .42 in Conditions 33 and 34 (VI 60-s initial links). As Figure 6 shows, preferences were much more extreme. Clearly, the delay-reduction hypothesis does not describe the present data.

GENERAL DISCUSSION

Results from Experiments 1A and 1B showed that when two delays to reinforcers

Fig. 8. Experiment 2. Algebraic estimates of K (Equation 1) as a function of arranged initial-link duration for each individual subject.

followed choices, the value of the second delay exerted little effect on preference (Figures 1 and 2). Such a small effect is clearly predicted by Mazur's (1984, 1987) description of the value of delayed reinforcers as the summation of hyperbolically decremented values for each delay. However, the very small systematic variance both within each of Experiments 1A and 1B and between the results of these experiments precluded the fit of Mazur's model to these data. In Experiment 1C, the first and second of two reinforcer delays for choice of the right key were varied complementarily. As shown in Figure 3, preference for the left key decreased as the second right-key delay was increased (and, hence, the first right-key delay was decreased). Because Experiment 1C provided a reasonable amount of systematic variance over six conditions, Mazur's hyperbolic model was fit to these data. As shown in Table 2, the model fit the data well in terms of the average deviation of the data from the model predictions. However, presumably because the initial-link schedule arranged that terminal-link entries could be obtained only once every 30 s on average, the values of K , the constant in Equation 1, were lower than the values reported by Mazur, who used single-response initial links. These values were, however, comparable to those reported by Davison and Smith (1986), who arranged terminal-link entries once every 15 s on average.

In Experiment 2, single reinforcers were arranged in each terminal link with different delays. The initial-link schedule was varied from VI 5 s to VI 480 s, and, at each initial-link value, the delays were reversed between

the keys. As the initial-link schedule was increased, preference between the constant different delays decreased toward indifference (Figure 6). These data provided considerable systematic data variance and showed that within Mazur's (1984) hyperbolic model, the value of K is determined by the duration of the initial link. Under the assumption that K in the hyperbolic model is itself a hyperbolic function of initial-link duration, a new, double-hyperbolic, model was fit to the data of Experiment 2. This model naturally requires the obtained, rather than arranged, initial-link durations, and these were used. The fits to the model (Table 4) were very good, and the predictions of relative response rates (shown in Figure 7) were also good. We can conclude, then, that Mazur's hyperbolic-decay model for delayed reinforcers can be extended to procedures in which choosing between the delays takes a substantial period of time, and that the appropriate extension is Equation 4.

This conclusion must modify some of the detailed parameter estimates reported by Mazur (1984). If choice-phase duration affects choice between delayed reinforcers, the parameters estimated by Mazur may err, at least a little, on the side of being too small because choice in a single-response procedure necessarily takes some time. Depending on the value of K' , even a 1-s delay could change the estimate of K . Moreover, the latency of choice is affected systematically by the delays to reinforcers arranged, with longer delays producing longer latencies (Shull, Spear, & Bryson, 1981). As a result, K measured in Mazur's titration procedure may change as a function of the size of the delays, although no data seem to have been collected to assess the constancy of K as a function of absolute delay.

It must be stressed that the model proposed in Equation 4 may not have generality beyond the present procedure and that used by Mazur (1984). The procedure used here ensured that the terminal links were entered equally often by arranging dependent concurrent VI VI initial links. Mazur's (1984) titration procedure attempts to keep terminal-link entries equal by arranging forced trials to both terminal links. In many ways it is surprising, and gratifying, that the same model applies to both procedures. Neither Mazur's model nor the extension of it proposed here addresses the effects of allowing unequal terminal-link entries.

Table 4

The results of nonlinear regression analyses of the data obtained in Experiment 2 to Equations 2 and 4. K' has units of s^{-1} . VAC is the percentage of the data variance accounted for, and Average deviation is the mean deviation of the data from the predictions.

Subject	K'	c	VAC	Average deviation
31	0.114	0.71	96.0	0.05
32	0.068	1.31	94.2	0.07
33	0.018	1.18	99.4	0.02
34	0.033	1.01	99.3	0.02
35	0.064	0.96	96.5	0.05
36	0.058	1.06	97.9	0.04
Group	0.049	1.07	99.6	0.02

Similarly, if the delays to reinforcers are both zero (concurrent VI VI schedules), Equation 4 predicts no effect of unequal initial-link schedules, which is clearly wrong. However, Equation 4 is a model of the value of entering the terminal links, and, as such, it would not be expected to describe the effects of changing the relative frequencies with which these values were obtained. Clearly, like the delay-reduction hypothesis (Fantino & Davison, 1983; Squires & Fantino, 1971), it needs to be concatenated with a model of reinforcer-frequency effects for the case of unequal terminal-link entries or for 0-s delays in both terminal links (concurrent VI VI schedules). Suitable models include the generalized matching law (Baum, 1974) or the contingency-discriminability model (Davison & Jenkins, 1985). Future research will be needed to find out whether this suggestion is correct.

With the suggestion above, Equation 4 is a contender for a general account of conventional concurrent-chain schedule performance. It describes the general finding (see Davison, 1987, for a review) that preference decreases as initial links are increased in duration, and it also predicts that preference between a constant ratio of delays will increase as the delays are increased. The initial-link preference ratio is predicted, by Equation 4, not to exceed the ratio of reinforcer immediacies, and it did not do so in the present results (although the ratio was very extreme, 99:1 or, in relative terms, .99). It is evident, then, that although the Mazur model as extended here can account in a directional sense for some concurrent-chain effects, it fails to account for the size of some of

Table 5

The results of nonlinear regression analyses of the data obtained in Experiment 1C according to Equations 2 and 4. VAC is the percentage of data variance accounted for, and Average deviation is the mean deviation of the data from the predictions. Also shown is the variance accounted for and average deviation when the best fitting parameters from Experiment 2 (Table 4) were used to describe the data from Experiment 1C.

Bird	Best fit				Table 4 parameters	
	K'	c	VAC	Average deviation	VAC	Average deviation
31	0.129	0.91	83.6	0.03	48.0	0.07
32	0.174	1.07	83.0	0.04	54.9	0.05
33	0.084	1.61	88.2	0.03	0	0.10
34	0.004	0.97	95.0	0.03	91.1	0.04
35	0.291	0.72	66.5	0.03	0	0.06
36	0.187	1.52	91.9	0.02	0	0.12
Group	0.108	1.10	99.5	0.01	85.1	0.03

the effects. This “failure” may not be a problem with procedures using equal-duration terminal links (see Gentry & Marr, 1980; Poniewaz, 1984; and the introduction to Experiment 2).

The suggestion that, in the conventional procedure, the necessarily shorter duration of the higher reinforcer rate terminal-link schedule (hence, the more immediate production of reinforcers on subsequent trials) could add to the reinforcing value of that outcome (Mazur et al., 1985; Shull & Spear, 1987) is supported by the apparently clear different asymptotic levels of choice in the constant terminal-link duration procedure (Gentry & Marr, 1980; and the present experiment) compared with the procedure in which terminal-link delays and durations are perfectly correlated (Davison & Temple, 1973; Duncan & Fantino, 1970; Williams & Fantino, 1978). The real possibility is that, with the added reinforcement of returning to the initial link equalized between the choices, modeling concurrent-chain performance will be simplified considerably. Then, models of the more complicated, conventional procedure may be easier to develop.

The model proposed here on the basis of Experiment 2 allows values of K' (Equation 4) to be obtained for the results of Experiment 1C. These values will naturally be different from the K values obtained from the fit of Equations 1 and 2 to those data because K' takes into account the obtained initial-link durations. The benefit of fitting Equations 2 and 4 to the data from Experiment 1C is that the invariance of K' values across procedures can

be assessed. The fits of Equations 2 and 4 to the data of Experiment 1C are shown in Table 5. Also shown in this table is the fit of Equations 2 and 4 to these data using the best fitting parameter values from Experiment 2. The parameters obtained from Experiment 2 provided (in terms of the average deviation of the data from the predictions) generally poorer accounts for 5 of the 6 individuals. But for 4 of the 6 birds, the average deviations were as small or smaller than the largest deviation in Table 4 (0.07). Given that there was not a great deal of systematic data variance obtained from Experiment 1C, the descriptions of those data by the best fitting Experiment 2 parameters were reasonable. However, a more interesting question is whether the data from Experiment 1C, when fit to Equations 2 and 4, gave similar parameter estimates as when the equations were fit to the Experiment 2 data. A comparison of Tables 4 and 5 shows that K' was estimated to be greater in Experiment 1C than in Experiment 2 for all the subjects except Bird 34. For the group data, K' was estimated to be about twice as large in Experiment 1C as in Experiment 2. Although this difference is not statistically significant, the apparent lack of invariance in K' is certainly worrying. However, it should be borne in mind that the amount of data variance in Experiment 2 was considerably greater than in Experiment 1C, and hence the Experiment 1C parameter estimates may be imprecise. Bias values were also somewhat different between Experiment 1C and Experiment 2 (see data for Birds 32, 33, and 36). These results may

indicate problems with the hyperbolic-decay model and the way in which it sums multiple delays following single choices. Only further, more detailed research will answer this question.

Finally, it should be noted that the present report (and that of Davison & Smith, 1986) used arithmetic-mean obtained initial-link times in Equation 4. The spirit of Mazur's (1984) model suggests that each individual time to terminal-link entry should be summed hyperbolically before it is used in the model. This could not be done here because the individual times were not recorded. The arithmetic-mean interval is monotonic with the hyperbolically calculated mean, but when exponential schedules (Catania & Reynolds, 1968) are arranged, the two types of mean do not map one-to-one onto each other. With $K = 1$, hyperbolic means for VI 5 s to VI 480 s fall from 3.4 s to 124 s, and smaller values of K further truncate the range. Clearly, if hyperbolic means are appropriate, the values of K' reported here are underestimated. Additional research is needed to determine whether the arithmetic mean or the hyperbolic mean is appropriate.

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Received December 16, 1987
Final acceptance May 6, 1988

APPENDIX

Responses emitted, seconds spent responding, and number of changeovers (c/o; from the left to the right key) in the choice phase of the concurrent-chain schedule, and the numbers of reinforcers obtained in the two outcome phases. Conditions 8 through 10 were not used in this experiment.

Condition	Responses		Seconds		c/o	Reinforcers	
	Left	Right	Left	Right		Left	Right
Bird 31							
1	1,028	621	2,258	1,224	392	100	100
2	1,209	892	1,931	1,446	588	100	100
3	1,039	1,109	1,554	1,762	514	100	100
4	902	1,100	1,562	1,825	500	100	100
5	807	1,147	1,355	1,809	529	100	100
6	906	1,517	1,185	2,182	647	102	98
7	1,059	1,695	1,115	1,994	790	100	100
11	1,549	1,340	1,511	1,738	822	98	102
12	1,358	1,061	1,600	1,527	693	94	106
13	1,323	1,122	1,544	1,453	667	104	96
14	1,462	1,297	1,483	1,517	838	102	98
15	1,313	1,280	1,408	1,622	850	98	102
16	961	1,672	1,046	2,139	755	102	98
17	1,045	1,423	1,167	1,825	764	100	100
18	1,039	1,745	1,050	2,131	884	98	102
19	924	1,431	1,090	1,879	675	102	98
20	1,224	1,042	1,831	1,458	643	100	100
21	1,039	1,372	1,431	1,762	761	98	102
22	1,379	987	1,982	1,188	742	100	100
23	1,014	2,012	1,232	2,137	730	98	102
24	912	2,089	893	2,264	796	100	100
25	4,414	948	5,412	1,199	877	101	99
26	1,253	4,068	1,453	5,019	1,176	99	101
27	2,301	138	2,040	148	132	100	100
28	164	3,012	187	1,832	155	100	100
29	2,686	185	3,062	240	168	103	97
30	207	3,841	226	2,899	202	98	102
31	3,314	666	4,252	939	473	101	99
32	689	4,478	636	4,224	625	100	100
33	5,010	1,462	6,812	2,109	1,361	73	70
34	1,193	5,388	1,307	7,566	1,007	74	70
35	2,909	2,788	4,202	6,705	1,389	38	36
36	1,443	5,814	2,050	8,462	933	43	45
37	2,077	2,695	4,691	6,977	1,149	26	23
38	1,105	2,525	2,748	8,888	725	23	25
39	1,535	1,912	5,517	7,074	679	11	8
40	810	1,458	5,188	7,375	457	9	10
41	4,338	655	5,798	1,231	552	101	99
Bird 32							
1	1,612	2,102	1,511	1,528	876	98	102
2	1,471	1,695	1,755	1,475	1,180	100	100
3	1,340	1,517	1,565	1,322	1,154	104	96

APPENDIX (Continued)

Condition	Responses		Seconds		c/o	Reinforcers	
	Left	Right	Left	Right		Left	Right
4	1,923	1,131	1,952	1,037	842	98	102
5	1,456	1,461	1,681	1,293	998	102	98
6	1,270	1,541	1,522	1,459	1,015	96	104
7	1,387	1,831	1,580	1,497	1,266	102	98
11	1,153	1,654	1,466	1,773	1,074	96	104
12	1,437	1,516	1,709	1,521	1,257	102	98
13	1,265	1,454	1,488	1,590	1,137	102	98
14	1,318	1,554	1,595	1,675	1,186	98	102
15	1,259	1,209	1,740	1,254	1,005	100	100
16	1,012	1,441	1,425	1,451	911	98	102
17	1,378	1,414	1,783	1,616	1,189	102	98
18	1,288	1,254	1,756	1,399	1,132	100	100
19	1,304	1,071	1,991	1,375	927	102	98
20	1,249	814	2,204	813	757	102	98
21	1,106	1,590	1,510	1,705	982	100	100
22	1,145	1,003	2,291	1,092	882	94	106
23	965	1,571	1,254	2,008	890	100	100
24	965	1,572	1,154	1,992	911	98	102
25	3,126	1,419	5,044	1,525	1,227	97	103
26	1,452	5,235	1,699	4,693	1,423	101	99
27	2,638	115	2,369	164	112	100	100
28	221	4,222	187	1,738	125	100	100
29	4,199	304	3,460	276	219	100	100
30	202	4,577	223	3,749	160	101	99
31	7,632	432	5,514	390	290	97	102
32	402	6,105	472	4,713	391	97	103
33	7,945	1,774	7,475	1,631	1,354	66	72
34	2,860	5,861	2,948	5,955	2,709	72	71
35	8,384	2,619	8,148	2,330	1,705	44	47
36	2,927	4,858	4,294	6,318	2,643	45	40
37	7,977	2,243	9,654	2,027	1,832	23	27
38	2,572	5,748	5,293	6,375	2,124	29	21
39	4,221	2,625	9,921	2,553	1,123	9	13
40	2,085	3,711	5,171	7,042	1,479	12	14
41	7,864	210	8,389	259	185	74	75
42	1,717	3,293	2,108	4,151	1,636	100	100
Bird 33							
1	2,030	1,846	1,647	1,660	1,317	98	102
2	2,240	1,985	1,313	1,658	1,474	98	102
3	2,510	1,866	1,592	1,451	1,521	98	102
4	2,744	1,628	1,833	1,262	1,393	98	102
5	2,904	1,860	1,768	1,440	1,579	96	104
6	2,775	1,904	1,611	1,469	1,630	106	94
7	2,485	1,892	1,477	1,389	1,681	102	98
11	2,786	1,758	1,849	1,099	1,446	104	96
12	3,173	1,634	2,080	1,071	1,368	102	98
13	2,825	1,351	2,344	946	1,211	98	102
14	2,315	1,573	1,749	1,609	1,265	98	102
15	1,894	1,130	1,656	1,636	851	98	102
16	2,656	1,771	1,794	1,538	1,452	96	104
17	2,086	1,780	1,490	1,686	1,092	96	104
18	2,565	1,399	1,743	1,136	1,100	98	102
19	1,785	1,116	1,584	1,500	831	96	104
20	2,443	1,097	1,961	1,159	934	104	96
21	2,151	1,494	1,385	1,776	1,070	100	100
22	1,903	1,215	1,880	984	1,011	104	96
23	1,656	2,019	1,078	2,014	1,164	102	98
24	1,419	2,514	776	2,419	1,102	102	98
25	7,705	1,682	5,539	772	1,647	100	100

APPENDIX (*Continued*)

Condition	Responses		Seconds		c/o	Reinforcers	
	Left	Right	Left	Right		Left	Right
26	2,646	5,447	1,246	5,342	2,072	101	99
27	3,611	134	2,223	100	129	98	102
28	1,175	1,405	492	699	346	102	98
29	2,904	819	1,727	448	766	99	101
30	1,847	2,447	863	1,277	758	100	100
31	5,336	1,618	3,634	728	1,564	101	99
32	3,903	4,600	1,719	2,469	2,002	100	100
33	11,389	1,018	8,678	523	923	67	65
34	1,090	10,310	709	8,372	864	64	72
35	9,847	1,727	9,498	1,099	1,446	44	43
36	1,351	8,551	1,295	9,252	985	44	43
37	9,044	2,057	10,495	1,573	1,641	20	17
38	1,583	8,135	1,493	10,243	1,319	21	27
39	6,313	1,611	8,516	3,872	1,016	14	12
40	3,580	7,877	3,311	8,959	2,332	17	13
41	9,536	313	7,312	218	299	97	91
42	717	8,506	660	6,386	612	101	97
Bird 34							
1	1,704	2,112	1,017	2,026	1,058	104	96
2	2,028	2,428	1,210	1,934	1,380	100	100
3	2,523	2,366	1,484	1,566	1,681	104	96
4	2,052	2,513	1,291	1,821	1,620	102	98
5	1,838	2,969	1,013	2,245	1,541	102	98
6	2,004	2,002	1,133	1,784	1,301	98	102
7	2,710	3,040	1,293	2,062	2,070	102	98
11	4,178	3,388	2,016	2,284	2,179	104	94
12	2,694	2,606	1,326	1,610	1,571	100	100
13	2,781	2,170	1,458	1,592	1,543	102	98
14	2,681	2,741	1,236	1,707	1,607	100	100
15	2,643	2,616	1,271	1,925	1,557	100	100
16	3,369	3,129	1,509	1,879	1,801	104	96
17	3,376	2,689	1,481	1,603	1,710	98	102
18	3,596	2,949	1,575	1,697	1,772	102	98
19	2,476	2,321	1,413	1,880	1,383	100	100
20	2,898	2,341	1,645	1,660	1,510	102	98
21	2,073	2,715	1,161	2,004	1,525	98	102
22	2,185	2,062	1,448	1,735	1,312	102	98
23	1,275	3,721	722	2,200	899	98	102
24	792	5,544	468	2,677	599	100	100
25	11,854	1,273	5,836	841	960	100	100
26	411	14,829	295	7,460	332	89	92
27	2,936	126	2,768	135	115	100	100
28	262	6,314	131	2,978	147	99	101
29	9,492	289	4,376	164	217	99	101
30	372	7,211	199	3,273	251	100	100
31	11,739	1,043	4,289	546	738	102	98
32	352	13,859	201	6,371	310	101	99
33	16,249	2,960	6,886	1,891	2,278	77	72
34	2,474	15,256	1,411	7,585	2,121	70	71
35	13,085	2,515	8,254	2,495	2,100	41	40
36	2,907	13,426	1,875	8,653	2,280	42	46
37	14,847	3,797	7,827	3,644	2,445	26	31
38	4,286	10,655	3,169	8,610	2,278	22	25
39	11,252	5,513	7,330	5,144	2,575	13	10
40	4,930	10,998	3,354	8,872	2,329	16	16
41	12,887	742	6,322	688	663	98	100
42	1,547	11,130	749	6,189	1,001	98	100
Bird 35							
1	1,638	1,541	1,721	1,561	746	92	108
2	2,561	1,153	2,192	1,254	533	96	104

APPENDIX (Continued)

Condition	Responses		Seconds		c/o	Reinforcers	
	Left	Right	Left	Right		Left	Right
3	1,827	1,880	1,839	1,754	617	96	104
4	1,708	2,032	1,584	1,506	740	100	100
5	1,418	1,950	1,413	1,574	898	106	94
6	1,369	2,104	1,765	1,693	908	98	102
7	1,543	2,172	1,559	1,676	925	100	100
11	1,582	2,789	1,281	1,938	822	102	98
12	1,591	2,201	1,293	1,907	826	98	102
13	1,800	2,214	1,384	1,797	909	102	98
14	1,357	3,105	1,022	2,083	744	104	96
15	1,593	2,479	1,211	1,919	778	100	100
16	1,274	2,041	981	1,664	668	98	102
17	1,542	2,270	1,159	1,940	840	106	94
18	1,746	2,743	1,200	2,012	788	96	104
19	1,422	2,574	1,112	2,044	760	102	98
20	1,772	2,446	1,565	2,983	987	98	102
21	1,435	2,437	1,280	1,763	748	102	98
22	2,334	1,980	1,701	1,497	885	96	104
23	1,303	2,544	991	2,450	773	98	102
24	1,140	2,322	871	2,210	648	102	98
25	7,564	1,728	4,829	1,584	1,083	102	98
26	1,352	5,431	1,378	5,090	863	98	101
27	1,954	176	1,553	190	174	100	100
28	239	2,672	308	2,214	170	102	98
29	3,226	421	2,279	366	361	100	100
30	336	3,703	441	3,218	204	100	100
31	7,181	568	4,409	520	536	96	104
32	294	6,804	419	5,297	243	100	100
33	9,148	1,754	7,160	1,799	1,213	69	72
34	964	7,932	1,218	7,706	839	70	72
35	8,851	2,571	7,590	2,936	1,773	43	46
36	2,494	6,873	2,789	7,886	1,606	39	44
37	4,255	3,366	6,385	5,247	1,711	25	23
38	3,510	5,601	4,608	7,179	1,821	26	21
39	2,894	2,803	7,243	4,939	1,364	13	15
40	3,055	3,924	5,353	7,058	1,576	13	13
41	9,148	425	6,922	450	412	99	97
42	1,290	4,563	1,404	5,133	995	99	101
Bird 36							
1	1,920	1,822	1,533	1,411	642	102	98
2	2,609	1,764	2,003	1,394	726	104	96
3	2,547	2,226	1,634	1,560	844	106	94
4	2,637	1,722	1,650	1,433	919	100	100
5	2,700	2,017	1,680	1,539	1,119	100	100
6	2,653	2,204	1,527	1,735	1,169	100	100
7	2,918	2,805	1,526	1,692	1,285	102	98
11	3,218	2,434	1,578	1,466	1,184	100	100
12	3,167	2,349	1,763	1,367	1,101	102	98
13	3,401	2,092	1,915	1,292	1,157	100	100
14	3,466	2,183	1,913	1,317	1,161	100	100
15	3,716	2,171	2,176	1,120	1,129	100	100
16	3,460	2,278	1,968	1,322	1,345	100	100
17	3,505	2,346	1,881	1,410	1,396	100	100
18	3,416	2,551	1,712	1,401	1,494	104	96
19	3,459	2,053	2,034	1,100	1,103	104	96
20	3,283	1,808	2,022	1,007	940	102	98
21	2,824	2,874	1,559	1,569	1,260	100	100
22	3,666	1,900	2,158	1,107	1,072	96	104
23	2,876	2,862	1,520	1,667	1,351	106	94
24	2,262	2,667	1,420	1,870	1,177	102	98
25	5,853	1,140	5,194	1,667	811	97	103
26	2,317	6,194	1,723	4,712	1,468	100	100

APPENDIX (Continued)

Condition	Responses		Seconds		c/o	Reinforcers	
	Left	Right	Left	Right		Left	Right
27	3,806	158	2,110	119	148	101	99
28	140	3,946	101	3,395	115	98	102
29	6,537	176	3,985	167	163	97	103
30	179	5,272	120	4,279	147	99	101
31	8,004	485	4,821	427	462	102	98
32	431	6,996	299	5,510	284	102	98
33	8,427	1,834	6,715	2,148	1,680	70	74
34	1,819	8,026	1,331	7,666	1,495	70	70
35	6,991	2,296	7,716	2,800	1,819	44	45
36	2,479	4,583	3,054	7,595	1,546	43	41
37	5,461	2,793	6,920	4,926	2,101	21	23
38	1,903	5,233	2,644	8,953	1,450	25	26
39	3,917	2,046	7,622	4,788	1,123	14	9
40	2,222	3,542	4,944	7,535	1,267	11	11
41	8,793	873	6,158	1,125	780	98	99
42	1,367	6,791	1,007	5,466	1,074	100	100