A QUANTITATIVE ANALYSIS OF CHAIN-SCHEDULE PERFORMANCE

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Six pigeons were trained with a chain variable-interval variable-interval schedule on the left key and with reinforcers available on the right key on a single variable-interval schedule arranged concurrently with both links of the chain. All three schedules were separately and systematically varied over a wide range of mean intervals. During these manipulations, the obtained reinforcer rates on constant arranged schedules also frequently changed systematically. Increasing reinforcer rates in Link 2 of the chain increased response rates in both links and decreased response rates in the variable-interval schedule concurrently available with Link 2. Increasing Link-1 reinforcer rates increased Link-1 response rates and decreased Link-2 response rates. Increasing reinforcer rates on the right-key schedule decreased response rates in Link 1 of the chain but did not affect the rate in Link 2. The results extend and amplify previous analyses of chain-schedule performance and help define the effects that a quantitative model must describe. However, the complexity of the results, and the fact that constant arranged reinforcer schedules did not necessarily lead to constant obtained reinforcer rates, precluded a quantitative analysis.

Key words: chain schedules, variable-interval schedules, response rate, reinforcer rate, key peck, pigeons

In a two-link chain schedule, responding on one schedule in the presence of one discriminative stimulus (Link 1) contingently produces a second schedule and another discriminative stimulus (Link 2). Responses are reinforced in Link 2 according to the Link-2 schedule, and following reinforcement, Link 1 is reinstated. The importance of the chaining operation is that it parallels and amplifies the reinforcement operation itself. Some researchers have suggested that the terminal-link stimulus comes to act as a reinforcer through its association with a more "primary" reinforcer (Kelleher & Gollub, 1962), whereas others have suggested that any transition to a situation in which "primary" reinforcers become more likely is naturally reinforcing (Baum, 1974a). Whichever explanation is correct, it is important for models of behavior to know at least the direction in which a particular manipulation (say, increasing the mean interval in Link 1) affects behavior in both Link 1 and Link 2, and, better, the amount of behavior change engendered by a manipulation of a given

amount. The first is an ordinal or qualitative analysis of chain-schedule performance, the second is a quantitative analysis. As we will show, the former is needed to guide the latter toward an effective model.

The present research focuses on the simplest type of chain schedule, a two-link chain. Further, it is concerned only with chains comprising variable-interval (VI) schedules. Data on the qualitative analysis of chain schedules were summarized by Kelleher and Gollub (1962), whose discussion of chain VI VI schedules relied mainly on the data of Findley (1962). In one experiment, Findley studied rats pulling chains in the dark on a VI 240-s schedule that turned on a light and started various VI schedules of food reinforcers for lever pressing. The Link-2 VI schedules were varied over conditions from VI 30 s to VI 480 s. Link-1 performance (chain pulling) was a direct, but apparently concave downward, function of the Link-2 reinforcer rate (Findley's Figure 3 shows response rate as a function of the mean arranged VI schedule). Link-2 performance was rather little affected by the schedule of reinforcement in Link 2, although a small trend toward higher response rates with higher reinforcer rates is evident (Findley's Figure 4). In a second experiment, less directly relevant here, Findley trained pigeons on a chain VI (white key) fixed-interval (FI) 60-s (green key) sched-

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ule and varied the mean Link-1 VI interval from 60 s to 1,200 s. Response rate in Link 1 of the chain was a direct function of the rate at which responding produced Link 2 (which we shall term the Link-1 reinforcer rate, the reinforcer being Link-2 production). Responding in Link 2 was a clear, inverse, function of the Link-1 reinforcer rate—that is, as the Link-1 schedules were lengthened, Link-2 response rate increased (Findley's Figure 6). If the FI data are also representative of VI data, then we can summarize Findley's results by noting that Link-1 response rates are a direct function of both Link-1 and Link-2 reinforcer rates, and that Link-2 response rates are a rather minor direct function of Link-2 reinforcer rates and a strong inverse function of Link-1 reinforcer rates. But one problem with Findley's data should be noted here: The data from his two experiments were displayed as a function of arranged reinforcer rates, and it is clear from chain-schedule research that obtained Link-1 reinforcer rates can deviate very markedly from those arranged.

Davison (1974) attempted a quantitative analysis of data from pigeons working on chain FI FI schedules. In the three parts of the experiment, he kept the Link-2 schedule at FI 60 s and varied the Link-1 schedule, kept the Link-1 schedule at FI 60 s and varied the Link-2 schedule, or varied both schedules keeping the sum of the intervals at 120 s. Davison noted that the generalized matching law provided a good description of a closely related procedure (multiple schedules), and fitted that quantitative model to his chain FI FI data:

$$\frac{B_1}{B_2} = c \left(\frac{R_1}{R_2} \right)^a \quad (1)$$

where Subscripts 1 and 2 refer to Links 1 and 2 respectively, B denotes response rates, and R denotes reinforcer rates (R_1 is the rate of Link-2 production). The parameter c is called bias, and it measures a constant proportion of behavior allocated to one or other component. The parameter a is sensitivity to reinforcement, and it measures the rate of change of the behavior allocation when the initial-to-terminal link reinforcer-rate ratio is changed.

Davison (1974) fitted Equation 1 in logarithmic form to his data, and reported that chain FI FI schedule performance was strongly biased against Link 1 (i.e., response rates were

higher in Link 2), and that sensitivity to the Link-1/Link-2 reinforcer frequency ratio, a , was 0.19. He related this sensitivity value to the similar value obtained by Barron and Davison (1972) for multiple FI FI performance. However, Davison noted that not all his data fitted the logarithmic straight-line version of Equation 1 and that Equation 1 was not an adequate descriptor of conditions with long terminal links. Findley's (1962) results suggest an explanation: The model expressed in Equation 1 is inappropriate. Given that the relation between terminal-link response and reinforcer rates increases only at a low rate, Findley's data suggest that Link-1 to Link-2 response-rate ratios should be a strong positive function of Link-1 reinforcer rates and a minor but positive function of Link-2 reinforcer rates. If this were the case, forcing chain-schedule data into the constraints of Equation 1 would provide totally erroneous results. Davison did not provide sufficient data to investigate this possibility, and one aim of the present experiment was to collect enough data to test whether Equation 1 was the appropriate form.

Moore (1982) provided considerable data on performance in chain VI VI schedules when another VI schedule (the common schedule; see Lobb & Davison, 1977) was always available on a second key. Moore reported that, under these conditions, the behavior ratio between Link 1 of the chain and the single VI was lower than might be expected from the overall reinforcer rates on the two keys and that the behavior ratio between Link 2 and the single VI was greater than expected. Moore's procedure provided not only a chain schedule on one key, but also two concurrent schedules—in Link 2, concurrent VI VI schedules of food reinforcement, and in Link 1, concurrent schedules of food reinforcement and terminal-link production. Moore's results appear to be compatible with Davison's (1974) analysis because a bias away from Link-1 responding would produce Moore's results. But Moore's results may not rest solely on such a bias. Moore reported a higher rate of responding in Link 2 relative to Common 2 than predicted by the relative rate of reinforcers in these components, which might, as Moore suggested, indicate a type of within-chain contrast effect or a greater sensitivity to the Link-2/Common-2 behavior distribution to the reinforcer rates in these components than occurs

on standard concurrent VI VI schedules. Moore's results cannot be reanalyzed to answer such questions because he measured the common VI schedule food-reinforcer rates separately in the presence of Link 1 and Link 2 in only six conditions for each of 2 birds and did not carry out sufficient parametric manipulations of the independent variables for a quantitative analysis. Thus, the present experiment used a design similar to Moore's to collect parametric data on chain VI VI schedule performance when a VI schedule was also concurrently available. It was hoped that such data would allow performance in chain VI VI schedules to be quantified in much the same way as performance in multiple VI VI schedules (McLean & White, 1983).

A chain VI VI schedule was arranged on one response key. Link 1 was signaled by this key being lit red, and a green light signaled Link 2. The other key was lit white in the presence of both Link 1 and Link 2 and provided reinforcers on a single VI schedule (the common schedule). During the experiment, all three VI schedules (Link 1, Link 2, and the common schedule) were varied parametrically. These variations included many conditions in which the arranged values of two of the three schedules were kept constant while the other was varied.

METHOD

Subjects

Six homing pigeons were maintained at $85\% \pm 15$ g of their free-feeding body weights. They had considerable experience working on concurrent schedules.

Apparatus

The subjects worked in an experimental chamber (340 mm deep, 330 mm high, and 310 mm wide). On one wall of the chamber were three 20-mm diameter response keys set 115 mm center-to-center and 260 mm from the grid floor. Only the two outer keys were used in this experiment. A magazine aperture was located beneath the central key 110 mm from the floor. During reinforcement the keys were darkened, the magazine aperture illuminated, and the subject was given access to wheat for 3 s. The chamber was situated inside a sound-attenuating box remote from the solid-state equipment that controlled all experimen-

tal contingencies. All data were collected on impulse counters.

Procedure

Sessions commenced with the illumination of the keylights and ended in blackout either when 40 reinforcers had been obtained or when 45 min had elapsed, whichever event occurred first. Following daily experimental sessions, the subjects were returned to their home cages where water and grit were always available. At this time, they were fed the amount of mixed grain necessary to maintain their designated body weights.

A chain VI VI schedule was arranged on the left key. When Link 1 was in effect, this key was red. After the Link-1 VI timer had completed timing, a single response on this key turned it green, signaling that Link 2 was in effect and starting the Link-2 VI timer. When this had completed timing, a single response produced 3-s access to wheat. This reinforcer was followed by the presentation of the red Link-1 conditions. A single VI schedule (the common schedule) was arranged on the right key, which was lit white, during both Link 1 and Link 2 of the chain on the left key. Responses on this key also aperiodically produced 3-s magazine presentations. Responses on either key, when they were lit, produced an audible relay click.

As in Moore's (1982) procedure, food reinforcers for responses on either key could be obtained only after a fixed time had elapsed since the subjects commenced responding on that key, after responding on the other key. We used a 1-s delay, whereas Moore used 2 s. This changeover delay (Herrnstein, 1961) was arranged to minimize the possibility that a reinforcer for a response on one key would affect responding on the other key. Note that the changeover delay requirement did not apply to the response on the left key that produced Link 2. It is unclear whether Moore arranged his procedure in a similar way. A further contingency operated only when Link 2 of the chain was in effect: Food reinforcers were dependently arranged (Stubbs & Pliskoff, 1969) such that if a reinforcer had been arranged on one key, the reinforcer schedule on the other key (Link 2, or the common schedule during Link 2) ceased timing until that reinforcer had been obtained. If, for example, the common schedule arranged a reinforcer

Table 1

Sequence of experimental conditions and the number of training sessions carried out in each. All times are in seconds. The red left key signaled the first link of the chain, and the green left key signaled the second link of the chain.

Condition	VI schedules and keys			Sessions
	Right	Left red	Left green	
1	60	30	30	26
2	60	14	46	26
3	60	46	14	17
4	60	6	54	29
5	60	54	6	15
6	120	30	30	22
7	120	14	46	24
8	120	46	14	26
9	120	6	54	34
10	120	54	6	21
11	120	10	50	38
12	120	50	10	18
13	60	10	50	36
14	60	50	10	17
15	180	10	50	39
16	180	46	14	18
17	180	30	30	31
18	180	14	46	22
19	180	54	6	15
20	180	6	54	30
21	180	50	10	15
22	240	10	50	37
23	240	46	14	22
24	240	30	30	24
25	240	14	46	22
26	240	54	6	14
27	240	6	54	42
28	240	50	10	15
29	240	10	10	15
30	240	54	10	19
31	240	14	10	14
32	240	46	10	14
33	240	6	10	20
34	60	50	10	28
35	60	10	10	22
36	60	54	10	16
37	60	14	10	25
38	60	46	10	17
39	60	6	10	34
40	60	30	10	18
41	60	6	14	27
42	60	6	20	27
43	60	6	24	29
44	60	6	30	34
45	60	54	30	25
46	60	50	30	22
47	60	46	30	17
48	60	30	30	26
49	60	14	30	27
50	60	10	30	28
51	60	54	24	24
52	60	54	20	15
53	60	54	14	19
54	60	54	10	16
55	240	10	50	27
56	60	50	10	22

prior to the Link-2 schedule arranging one, the Link-2 schedule stopped timing until the common-schedule reinforcer had been obtained, at which point it continued timing. When a reinforcer was arranged by the Link-2 schedule, the common schedule stopped timing until that reinforcer had been obtained, at which point Link 1 was reinstated and the common schedule continued timing. Thus, reinforcers arranged by the common schedule did not affect the timing of the schedule in Link 1 of the chain. This procedure was used to ensure that the relative reinforcer rate between Link 2 of the chain schedule and the right-key VI schedule remained at the value set by the schedules. The dependency did not apply to Link-1 to Link-2 transitions.

The following data were collected: responses on the left and right keys in the presence of both Link 1 and Link 2 of the chain; the numbers of food reinforcers obtained on the left key (which equaled the number of transitions from Link 1 to Link 2) and on the right key in the presence of Link 1 and Link 2 of the chain; and the time spent responding on the left and right keys in the presence of both Link 1 and Link 2 of the chain, measured from the first response on one key to the first response on the other. Time-allocation measures ceased during reinforcer presentations, but all schedules started at the end of reinforcers or immediately on Link 1 to Link 2 transition.

The sequence of experimental conditions for all subjects is shown in Table 1. Four different common-schedule reinforcer rates were arranged: VI 60 s, VI 120 s, VI 180 s, and VI 240 s. Nine sets of conditions, comprising at least six conditions each in which the schedules in one or other part of the chain were varied with a particular common schedule, can be discerned: Part 1, right key VI 60 s, left key VIs sum to 60 s (Conditions 1 to 5, 13, 14, 34 [replicates 14], 48 [replicates 1], and 56 [replicates 14 and 34]); Part 2, right key VI 120 s, left key VIs sum to 60 s (Conditions 6 to 12); Part 3, right key VI 180 s, left key VIs sum to 60 s (Conditions 15 to 21); Part 4, right key VI 240 s, left key VIs sum to 60 s (Conditions 22 to 28 and 55 [replicates 22]); Part 5, right key VI 60 s, Link 2 VI 10 s, Link 1 varied (Conditions 14, 34 [replicates 14] to 40, 54 [replicates 36], and 56 [replicates 14 and 34]); Part 6, right key VI 240 s, Link 2 VI 10 s, Link 1 varied (Conditions 28 to 33); Part 7,

Fig. 1. Part 1. Obtained reinforcer rates as a function of arranged Link-2 reinforcer rates, and response rate as a function of obtained Link-2 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The sum of the mean VI schedules in Links 1 and 2 was 60 s, and VI 60 s was arranged on the right key during both links.

right key VI 60 s, Link 2 VI 30 s, Link 1 varied (Conditions 1 and 44 to 50); Part 8, right key VI 60 s, Link 1 VI 6 s, Link 2 varied (Conditions 4, 39, and 40 to 44); and Part 9, right key VI 60 s, Link 1 VI 54 s, Link 2 varied (Conditions 5, 36, 45, and 51 to 54 [replicates 36]). Other groupings, with fewer than six conditions, can also be discerned. These sets of conditions were arranged to provide a wide range of parametric manipulations of both the proportion of reinforcers delivered in the common schedule and the links of the chain, and also of the overall reinforcer rates provided by the schedules.

The pigeons were trained on each condition until the performance of each had reached a stability criterion five times, not necessarily on consecutive sessions. The criterion required that the median relative time allocation on the chain (Link-1 time divided by total time in the chain) over five sessions did not differ by more than .05 from the median of the five sessions immediately preceding these. When all subjects had met this criterion five times, the experimental contingencies were changed for all subjects. The number of sessions to reach this stability criterion is shown in Table 1.

RESULTS

The number of responses emitted, time spent responding, and reinforcers obtained, in each component of the chain schedule and in the two components of the common schedule defined by the state of the chain, are shown for each condition in the Appendix. These data have been summed over the last five sessions of each experimental condition. Before commencing analysis of these data, it is important to note that in this data set (as in that reported by Moore, 1982) constant arranged schedule values do not necessarily imply constant obtained values. This is because response rates in the first link of the chain, and also on VI schedules that operated in the presence of other VI schedules that made high reinforcer rates available, were not sufficiently high to produce the maximum rate of reinforcers available. The data in the Appendix show that the reinforcer rates in both Link 1 of the chain and on the right key during Link 2 of the chain were frequently very much lower than those arranged. Thus, in the figures that follow, we have plotted both obtained reinforcer rates as a function of arranged maximum reinforcer rates and response rates as a function of ob-

Fig. 2. Part 2. Obtained reinforcer rates as a function of arranged Link-2 reinforcer rates, and response rate as a function of obtained Link-2 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The sum of the mean VI schedules in Links 1 and 2 was 60 s, and VI 120 s was arranged on the right key during both links.

tained reinforcer rates. This makes plain (a) the extent to which the manipulation of a schedule did change the reinforcer rate obtained on that schedule and (b) whether reinforcer rates on other constant *arranged* schedules also varied as a function of the manipulation.

Figures 1 to 4 show the reinforcers obtained as a function of the reinforcers arranged in Link 2, and the responses emitted as a function of the reinforcers obtained, in the four components of the concurrent VI chain VI VI schedule for the sets of conditions in which the mean VI intervals in the chain summed to 60 s (i.e., Parts 1 to 4). Figures 1 to 4 show, respectively, the data when the VI schedule on the right key was VI 60 s, VI 120 s, VI 180 s, and VI 240 s. Both the grouped data averaged over all 6 subjects and the individual data from Birds 121 and 125 are shown. (These two birds were selected as, respectively, providing the least and the most noisy data.) Changes in response and reinforcer rates in the components were assessed using nondirectional non-parametric trend tests (Ferguson, 1965) with p set at .01 using the individual-subject data averaged over the last five sessions of each con-

dition (Appendix). Because replicated conditions often provided different obtained reinforcer rates, response-rate trend tests used the data from all conditions. Reinforcer-rate trend tests used data averaged over replications, and hence were based on a smaller number of data. The results of trend tests carried out on data obtained in each part of the experiment are summarized in Table 2.

The reinforcer-rate data in Figures 1 to 4 are plotted as a function of the arranged reinforcer rate in Link 2 of the chain, with the mean VI schedule in Link 1 always being 60 minus the mean VI schedule in Link 2. The response-rate data are similarly plotted as a function of the obtained reinforcer rate in Link 2 of the chain.

In the conditions comprising Part 1 of this experiment (Figure 1, VI 60-s common schedule), increasing the Link-2 arranged reinforcer rate (and complementarily decreasing the Link-1 arranged reinforcer rate) led to generally monotonic increases in obtained Link-2 reinforcer rates (but see Bird 125, Figure 1), and this increase was significant ($z = 6.81$). As Figure 1 shows, there were nonsignificant changes in the obtained reinforcer rates in Link

Fig. 3. Part 3. Obtained reinforcer rates as a function of arranged Link-2 reinforcer rates, and response rate as a function of obtained Link-2 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The sum of the mean VI schedules in Links 1 and 2 was 60 s, and VI 180 s was arranged on the right key during both links.

1 (although the arranged schedule was changed) and in the Common-1 and Common-2 components. Figure 1 also shows that response rates increased significantly in both Link 1 and Link 2 of the chain ($z = 4.93$ and 5.15 , Table 2), although rates remained low in Link 1. Response rates also decreased significantly ($z = 7.27$, Table 2) in the common schedule arranged concurrently with Link 2 (i.e., Common-2 schedule).

When the common schedule was VI 120 s (Part 2, Figure 2), varying the schedules in the two links of the chain again significantly increased only the obtained reinforcer rate in Link 2 ($z = 6.81$). Response rates significantly increased in Link 1 ($z = 5.21$) and in Link 2 ($z = 5.46$) and significantly decreased in Common 2 ($z = 5.58$). When VI 180 s was arranged as the common schedule (Part 3, Figure 3), increasing the arranged reinforcer rates in Link 2 (and decreasing them in Link 1 complementarily) significantly increased the obtained reinforcer rates in Link 2 ($z = 7.42$) and in Common 2 ($z = 2.76$) and decreased them in Link 1 ($z = 2.64$). This last effect is clearly seen in the data from Bird 125 (Figure 3). When the mean interval in Link 1 was small

(and the interval in Link 2 large), this subject quickly completed Link 1. Birds 124 and 126 also showed the same effect. Response rates significantly increased in Link 1 ($z = 4.35$) and in Link 2 ($z = 5.33$; but see the large response-rate decrease for Bird 125 at the highest Link-2 reinforcer rate in Figure 3) and significantly decreased in Common 2 ($z = 5.58$). Finally, in Part 4 (Figure 4, common schedule VI 240 s), increasing Link-2 reinforcer rates and decreasing Link-1 reinforcer rates significantly decreased Link-1 obtained reinforcer rates ($z = 4.11$), increased Link-2 reinforcer rates ($z = 7.54$), and increased Common-2 reinforcer rates ($z = 4.97$), though only a small amount in absolute terms. Response rates increased significantly in Link 1 ($z = 4.29$) and in Link 2 ($z = 5.91$) and decreased significantly in Common 1 ($z = 2.58$) and in Common 2 ($z = 5.10$).

Table 2 provides a summary of the trends in all parts of this experiment. This table shows that the data from Parts 1 to 4 always provided increasing obtained reinforcer rates in Link 2 when the arranged rate was increased and also gave increasing response rates in Link 2. In contrast, when the Link-1 arranged reinforcer

Fig. 4. Part 4. Obtained reinforcer rates as a function of arranged Link-2 reinforcer rates, and response rate as a function of obtained Link-2 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The sum of the mean VI schedules in Links 1 and 2 was 60 s, and VI 240 s was arranged on the right key during both links.

rates were concomitantly decreased, the obtained rates increased nonsignificantly when the common schedule was VI 60 s, decreased nonsignificantly when the common schedule was VI 120 s, and decreased significantly when the common schedules were VI 180 s and VI 240 s. Thus, lowering the arranged common-schedule reinforcer rates increased the likelihood of obtained Link-1 reinforcer rates following arranged Link-1 reinforcer rates, but Link-1 response rates always changed in the same direction as the Link-2 arranged and obtained reinforcer rates and, when the common-schedule reinforcer rates were low, in a direction opposite to the changes in Link-1 obtained reinforcer rates. Decreasing common-schedule reinforcer rates made it more likely that obtained Common-2 reinforcer rates would be positively correlated with Link-2 reinforcer rates. Both Common-1 reinforcer and response rates fell nonsignificantly within each set of common-schedule conditions, except when the common schedule was VI 240 s, when the response rate decrease was significant. Common-2 reinforcer rates increased significantly only when the common schedule provided reinforcers on VI 180 s and VI 240 s,

but Common-2 response rates *fell* significantly with increases in the Link-2 arranged and obtained reinforcer rates for all common-schedule values.

Looking now across the changes in right-key (common-schedule) reinforcer rates in Figures 1 to 4 for each pair of conditions in which the same chain schedules were arranged, decreasing right-key arranged reinforcer rates significantly decreased the obtained reinforcer rates in Common 1 and Common 2 ($z = 5.26$ and 4.49 , respectively) and significantly increased the obtained reinforcer rates in Link 1 and Link 2 ($z = 5.01$ and 3.98 , respectively). (The trend tests in this section were carried out on group data, with seven comparisons containing four data each.) The same manipulation significantly increased responding in Link 1 of the chain ($z = 4.75$), did not affect responding in Link 2, and increased response rates in both common-schedule components ($z = 4.75$ and 4.24 , respectively).

Figure 5 shows the data obtained when the right-key schedule was VI 60 s, the VI schedule in Link 2 was VI 10 s, and the VI schedule in Link 1 was varied (Part 5). Figure 6 shows

Table 2

Results of trend tests carried out in each part of the experiment. A plus sign indicates an increase, and a negative sign indicates a decrease. Signs in parentheses indicate the direction of a nonsignificant trend, and a zero indicates no trend. All trends were assessed against positive increases in arranged reinforcer rates (for obtained reinforcer rates) or in obtained reinforcer rates (for changes in response rates), and the component on which the data were ordered is italicized.

Part	Link 1		Common 1		Link 2		Common 2	
	Reinforce- ment	Response	Reinforce- ment	Response	Reinforce- ment	Response	Reinforce- ment	Response
1	VI x s		VI 60 s		VI (60 - x) s		VI 60 s	
	(+)	+	(-)	(-)	+	+	(-)	-
2	VI x s		VI 120 s		VI (60 - x) s		VI 120 s	
	(-)	+	(-)	(-)	+	+	(+)	-
3	VI x s		VI 180 s		VI (60 - x) s		VI 180 s	
	-	+	(-)	(-)	+	+	+	-
4	VI x s		VI 240 s		VI (60 - x) s		VI 240 s	
	-	+	(-)	-	+	+	+	-
5	VI x s		VI 60 s		VI 10 s		VI 60 s	
	+	+	(-)	(-)	(-)	-	+	+
6	VI x s		VI 240 s		VI 10 s		VI 240 s	
	+	+	-	(-)	(-)	-	(+)	+
7	VI x s		VI 60 s		VI 30 s		VI 60 s	
	+	+	(+)	(+)	(-)	(-)	(+)	(+)
8	VI 6 s		VI 60 s		VI x s		VI 60 s	
	+	+	(-)	(-)	+	+	+	-
9	VI 54 s		VI 60 s		VI x s		VI 60 s	
	+	+	-	(-)	+	+	(0)	-

the data from the same chain-schedule manipulation when the right-key schedule was VI 240 s (Part 6). For both data sets, Link-1 obtained reinforcer and response rates increased significantly as the arranged Link-1 reinforcer rates were increased (reinforcer rates, $z = 6.68$ and 6.83 , respectively; response rates, $z = 6.10$ and 4.53 , respectively). The changes in obtained Link-1 reinforcer rates were both absolutely greater and more linear when the common schedule provided VI 240-s food (Figure 6) than when it provided VI 60-s food (Figure 5). Link-2 obtained reinforcer rates did not change significantly in either part, but Link-2 response rates decreased significantly as Link-1 reinforcer rates were increased ($z = 2.59$ and 3.15 , respectively). Common-1 obtained reinforcer rates did not change significantly in Part 5, but decreased significantly ($z = 4.68$) (but only to a small extent in absolute terms; see Figure 6) in Part 6 when the lower common-schedule reinforcer rate was arranged. Common-1 reinforcer rates decreased significantly only when VI 240 s was arranged on the right key ($z = 4.68$). Both Common-2 obtained reinforcer rates and re-

sponse rates increased significantly in Part 5 with increasing Link-1 reinforcer rates ($z = 2.64$ and 4.78), but the significant response-rate increase in Part 6 ($z = 2.68$) was not accompanied by a significant increase in obtained reinforcer rates.

Comparing the changes in response rates in Parts 5 and 6 (Figures 5 and 6), the proportions of Link-1 to Link-2 response rates changed much more when the common schedule was VI 240 s than when it was VI 60 s. Most of this change was produced by the greater changes in Link-1 response rates in the presence of the VI 240-s common schedule. Common-schedule response rates were naturally higher on the VI 60-s schedule than on the VI 240-s schedule. In the six pairwise comparisons that could be made between equivalent conditions, common-schedule obtained reinforcer rates were always lower in Part 6 than in Part 5, but both Link-1 and Link-2 obtained reinforcer rates were always higher in Part 6. Link-1 response rates were always higher in Part 6, and both common-schedule response rates were always lower.

Figures 7 and 8 show the obtained reinforc-

Fig. 5. Part 5. Obtained reinforcer rates as a function of arranged Link-1 reinforcer rates, and response rate as a function of obtained Link-1 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The VI schedule in Link 1 was varied, the schedule in Link 2 was VI 10 s, and VI 60 s was arranged on the right key during both links.

Fig. 6. Part 6. Obtained reinforcer rates as a function of arranged Link-1 reinforcer rates, and response rate as a function of obtained Link-1 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The VI schedule in Link 1 was varied, the schedule in Link 2 was VI 10 s, and VI 240 s was arranged on the right key during both links.

Fig. 7. Part 8. Obtained reinforcer rates as a function of arranged Link-2 reinforcer rates, and response rate as a function of obtained Link-2 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The VI schedule in Link 1 was VI 6 s, the schedule in Link 2 was varied, and VI 60 s was arranged on the right key during both links.

er and response rates emitted when the right-key schedule was VI 60 s, the Link-2 reinforcer rate was varied, and the Link-1 schedule was either VI 6 s (Part 8) or VI 54 s (Part 9). Link-2 obtained reinforcer rates increased significantly with increases in Link-2 arranged reinforcer rates in both parts ($z = 6.67$ and 6.21 , respectively), although this increase was generally clearer when Link 1 was VI 6 s. Link-1 reinforcer rates also increased significantly with increases in Link-2 arranged reinforcer rates in both parts ($z = 6.06$ and 3.61 , respectively), although the absolute amount of increase was much greater when the Link-1 schedule was VI 6 s (Figure 7) than when it was VI 54 s (Figure 8). Common-1 obtained reinforcer rates fell significantly with increases in Link-2 reinforcer rates when the Link-1 schedule was VI 54 s (Part 9, Figure 8, $z = 2.84$) but not when the Link-1 schedule was VI 6 s. On the other hand, Common-2 reinforcer rates increased significantly with increasing Link-2 reinforcer rates when Link 1 was VI 6 s (Part 8, Figure 7, $z = 3.30$) but not when Link 1 was VI 54 s. Link-2 response rates significantly increased in both parts ($z = 3.91$ and 4.48 , respectively), as did Link-1 response rates ($z = 6.21$ and 3.13 , respectively).

Common-1 response rates showed no significant changes in Parts 8 and 9. However, Common-2 response rates decreased significantly with increasing Link-2 reinforcer rates in both parts ($z = 4.83$ and 4.48 , respectively).

Comparing the results from Parts 8 and 9 (Figures 7 and 8) over the five available group comparisons, decreasing Link-1 arranged reinforcer rates always decreased Link-1 obtained reinforcer rates but always increased Common-2 obtained reinforcer rates. Both Common-2 and Link-2 response rates were always higher in Part 9 than in Part 8, but Common-2 reinforcer rates were always lower.

Figure 9 shows the obtained reinforcer and response rates in all four components when the right-key schedule was VI 60 s, the schedule in Link 1 was varied, and that in Link 2 was VI 30 s (Part 7). The obtained Link-1 reinforcer rate increased significantly with arranged Link-1 reinforcer rates ($z = 3.25$), although to a small absolute extent, and no other reinforcer rates changed significantly. The response rate in Link 1 significantly increased with Link-1 reinforcer rate ($z = 3.69$), but Figure 9 shows that the increase was very small. The significant increase was caused by Birds 121 and 122 showing strong (but in the case

Fig. 8. Part 9. Obtained reinforcer rates as a function of arranged Link-2 reinforcer rates, and response rate as a function of obtained Link-2 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The VI schedule in Link 1 was VI 54 s, the schedule in Link 2 was varied, and VI 60 s was arranged on the right key during both links.

of Bird 121, very small) individually significant trends. There was no other significant response-rate change. In comparison with Figure 5 (Link 2 VI 10 s), in each of the five group comparisons Link-1, Link-2, and Common-2 reinforcer rates were lower when Link 2 was VI 30 s (Part 7) than when it was VI 10 s (Part 5). Link-1 and Link-2 response rates were also lower in Part 7 than in Part 5, but Common-2 response rates were always higher. It is also noticeable from the comparison between Figures 5 and 9 that varying the Link-1 reinforcer rate with a longer VI schedule in Link 2 led to a truncated change in the Link-1 reinforcer rates. This was caused by the low Link-1 response rates and hence by the Link-1 schedule not being completed when the schedule had arranged a transition.

The effects found here (Table 2) can be summarized in this way. First, varying *arranged* food reinforcer rates always produced strongly correlated changes in *obtained* food reinforcer rates. Changing the arranged rate of terminal-link entry (the Link-1 schedule) usually produced a correlated change in the obtained rate of entry, but only (a) when the terminal-link schedule was constant or (b) if

the terminal-link schedule covaried inversely, only if a low rate of reinforcers was available from the common schedule (see Parts 3 and 4, Table 2). Second, increasing obtained Link-1 reinforcer rates increased Link-1 response rates (Parts 5, 6, and 7) if Link-2 arranged reinforcer rates did not covary inversely or, perhaps, if common-schedule reinforcer rates were high (Part 1). This variation also decreased Link-2 response rates (Parts 5 and 6), at least if the Link-2 schedules were VI 10 s but not if they were VI 30 s (Part 7). Increasing Link-1 reinforcer rates had little effect on responding in Common 1 but tended to increase both reinforcer rates (Part 5) and response rates (Parts 5 and 6) in Common 2, given the Link-2 schedules provided a high reinforcer rate (cf. Part 7). Third, increasing Link-2 reinforcer rates decreased Common-2 responding significantly (Parts 1 to 4 and 8 to 9), even when a significant *increase* in Common-2 obtained reinforcer rate occurred (Parts 3, 4, and 8). Fourth, on the common right-key schedule, increasing right-key reinforcer rates always increased right-key response rates (Figures 1 to 6). Finally, in terms of interactions between the chain and the single schedule, increasing right-key

Fig. 9. Part 7. Obtained reinforcer rates as a function of arranged Link-1 reinforcer rates, and response rate as a function of obtained Link-1 reinforcer rate, in the two links of the chain schedule and on the right key concurrent with these links. The VI schedule in Link 1 was varied, the schedule in Link 2 was VI 30 s, and VI 60 s was arranged on the right key during both links.

reinforcer rates did not affect response rates in Link 2 of the chain (Figures 1 to 4) but did decrease response rates in Link 1 of the chain (Figures 1 to 6).

DISCUSSION

The data obtained in the present experiment directly replicate those reported by Findley (1962) despite the fact that Findley plotted his data as a function of arranged, rather than obtained, reinforcer rates. As shown in Figures 1 to 9, obtained reinforcer-rate changes followed arranged reinforcer-rate changes, except in Part 7 (Figure 9) when, in comparison with Parts 5 and 6, a lower Link-2 reinforcer rate was arranged. But we also found instances in which changing the Link-2 schedule also affected the rate at which Link 1 was completed, although the arranged schedule in Link 1 was constant (Parts 8 and 9). Because changing the Link-1 schedules did sometimes change Link-2 response rates (Parts 5 and 6; Table 2), an analysis of single-chain performance as a function of *arranged* reinforcer rates is likely to be misleading.

In the chain schedule, increasing Link-2 reinforcer rates increased both Link-1 and Link-2 response rates (Figures 7 and 8). Increasing Link-1 reinforcer rates increased Link-1 response rates and decreased Link-2 response rates, at least when Link 2 provided a high reinforcer rate (Figures 5, 6, and 9). Similar effects of Link-1 schedule values on Link-2 response rates were reported by Fantino (1982). These results show clearly that Equation 1 (Davison, 1974) cannot be correct. In that equation, changing Link-1 and Link-2 reinforcer rates should have symmetrical effects. The present data show that they do not.

The lack of generality of Equation 1 is best shown by fitting it separately to the data for the nine parts of this experiment. Thus, using the data shown in the Appendix, we fitted log Link-1/Link-2 response-rate ratios to log Link-1/Link-2 reinforcer-rate ratios using linear regression, and the results are shown in Table 3. In Table 3, the slope of the relation is the estimate of a , and the intercept is an estimate of $\log c$. Percent-variance-accounted-for measures are provided in Table 3, but they are of marginal use because this measure is

Table 3

Results of linear regressions between log response-rate ratios and log reinforcer-rate ratios according to Equation 1.

Part	Slope (SD)	Intercept (SD)	VAC (%)
Link 1/Link 2			
1	-0.88 (0.84)	-1.78 (0.51)	12
2	-1.04 (0.27)	-1.66 (0.22)	75
3	-0.37 (0.13)	-0.76 (0.13)	60
4	-0.21 (0.11)	-0.55 (0.12)	39
5	0.56 (0.08)	-0.32 (0.07)	85
6	0.52 (0.05)	-0.04 (0.04)	97
7	0.61 (1.31)	-0.81 (0.25)	3
8	2.59 (0.76)	-0.36 (0.38)	74
9	0.41 (0.76)	-0.63 (0.25)	5
Link 2/Common 2			
1	1.22 (0.15)	0.03 (0.13)	90
2	1.42 (0.06)	-0.19 (0.05)	99
3	1.63 (0.19)	-0.35 (0.12)	94
4	1.89 (0.13)	-0.67 (0.08)	97
5	1.37 (0.40)	-0.12 (0.09)	59
6	3.08 (0.51)	-2.00 (0.06)	90
7	1.29 (0.48)	-0.05 (0.04)	55
8	1.06 (0.10)	0.02 (0.04)	96
9	1.04 (0.34)	0.14 (0.13)	66

positively correlated with the slope of the function. Thus, for example, the data for Part 4 were fitted well by Equation 1 (small standard deviations of the parameter estimates), but variance accounted for was low.

Table 3 shows that there was a clear change in both a and $\log c$ in Parts 1 to 4 as the common-schedule reinforcer rate was decreased. First, the estimates of a for Parts 1 to 4 were all negative, although the estimate for Part 1 was not more than two standard deviations from zero. This resulted from response rates increasing proportionally more in Link 1 than in Link 2 when Link-2 reinforcer rates were increased (and Link-1 rates decreased). Second, as the common-schedule reinforcer rates were decreased over Parts 1 to 4, the standard deviations of the a estimates fell and, bearing in mind the poor estimate for Part 1, the absolute a values became smaller. This indicates that the lower the reinforcer rate obtained for responding on the common-schedule alternative to the chain, the less sensitive to reinforcer-rate variations (these occurred mainly in the terminal link; see Figures 1 to 4) was the distribution of behavior between Link 1 and Link 2. The decreasing negative intercepts with decreasing common-

schedule reinforcer rates show that high alternative reinforcer rates have more effect on Link-1 than on Link-2 performance. This intercept change can also be seen in the comparison between the fits for Parts 5 (common VI 60 s) and 6 (common VI 240 s) in Table 3. However, in Parts 5 and 6, differing common-schedule reinforcer rates did not affect the value of a . It seems, therefore, that the sensitivity of the distribution of behavior within the chain was more strongly affected by terminal-link reinforcer-rate changes (Parts 1 to 4) than it was by initial-link changes. Parts 7, 8, and 9 gave poor estimates of both slopes and intercepts and are of little interest, although comparison of Parts 5 and 7 indicates that the systematic description of behavior by Equation 1 was lost when the longer terminal link was arranged.

Equation 1 is clearly unable to describe the present results with single a and $\log c$ parameters. In Parts 1 to 4, both parameters varied. Comparing Parts 5 and 6, the slopes were similar but the intercepts were considerably different. Davison's (1974) findings are supported in only one way: There was always a bias toward responding in Link 2 compared with Link 1 (a negative $\log c$), although the estimates were not significantly different from (i.e., more than two standard deviations away from) zero in Parts 6 and 8. Davison, however, did not arrange any explicit reinforcers as an alternative to the chain-schedule reinforcers, and any extraneous reinforcers (Herrnstein, 1970) that were available were probably reasonably constant over the course of the experiment. Davison's data are thus seen to be of limited generality given the effects demonstrated in Parts 1 to 4.

Table 3 also shows generalized-matching fits (Baum, 1974b) for the concurrent reinforcer schedules arranged as Link 2 and Common 2. As the common-schedule reinforcer rates were decreased over Parts 1 to 4, concurrent-schedule sensitivity increased substantially, and a large bias developed toward responding in Common 2. This finding is supported by the results of Parts 5 and 6. Despite poorly estimated slopes, sensitivity increased from 1.37 to 3.08, and the intercepts changed from -0.12 to -2.00 when the common schedule was changed from VI 60 s to VI 240 s. Because the obtained reinforcer rates were used in these fits, these results do not reflect changes in

Link-2 or Common-2 reinforcer rates and must be the result of some interaction from the Link-1 reinforcer or response rates, because the former was the major manipulated variable in Parts 5 and 6. It appears that making the Link-1 schedule relatively richer than alternative reinforcer sources may increase Link-1 responding (see the Link-1/Link-2 analysis in Table 3) and simultaneously decrease Link-2 responding. However, the role of the Link-1 schedule itself is unclear because there were no differences between the results of Part 8 (Link 1 VI 6 s) and Part 9 (Link 1 VI 54 s) (Table 3). The controlling variable for this effect thus appears to be simply the common-schedule reinforcer rate concurrently available with Link 1. Notice that it is difficult to derive these behavior-distribution changes from the absolute response and reinforcer rates in Figures 1 to 4. As we showed in Table 2, in Parts 1 to 4 there was a positive relation between response and reinforcer rates in Link 2, but in Parts 3 and 4, when reinforcer rates significantly increased in Common 2, response rates in Common 2 significantly decreased. This seems to imply a positive, rather than the obtained negative, bias (a decreasing Link-2/Common-2 reinforcer ratio, coupled with an increasing Link-2/Common-2 response ratio).

The present results extend those reported by Moore (1982). He arranged two different common VI schedules (VI 120 s and VI 480 s for one pair of subjects and VI 120 s and VI 240 s for another pair), and for each common-schedule value he arranged one to four different chain schedules. Moore reported that relative Link-1/Common-1 response rates were lower than relative *overall* chain/common obtained reinforcers, and that relative Link-2/Common-2 response rates were greater than the same independent variable. Because Moore measured the obtained reinforcers separately in the two common-schedule components for only 2 of the 6 subjects, he was unable to relate relative behavior in pairs of components to relative obtained reinforcers in those components. The present data permit this more detailed analysis, and they also show relatively low Link-1 response rates and relatively high Link-2 response rates. Moore also reported that relative obtained Link-2/Common-2 response rates were greater than relative arranged Link-2/Common-2 reinforcer rates. Although it may not initially appear so, this

finding is compatible with the Link-2/Common-2 generalized matching analyses shown in Table 3. Despite the strong biases toward Common-2 relative to Link-2 responding (Table 3), such biases in combination with a sensitivity to reinforcement (a) value greater than one can easily produce relative behavior allocations that are greater than relative obtained reinforcer rates. For example, in Part 4 (Table 3), any Link-2/Common-2 obtained log-reinforcer ratio greater than .75 (i.e., 6:1) will produce greater relative Link-2/Common-2 response than reinforcer rates. If the generalized matching results shown in Table 3 also describe Moore's results (there are insufficient data available from Moore's experiment to check this), the two apparently conflicting findings are, in fact, consonant.

Calculations from Moore's (1982) data also show that his 2 pigeons (for which data are available) always obtained a greater reinforcer rate in Common 1 (indeed, up to three times the rate) than that arranged in Common 1—a seemingly impossible result that will be explained shortly. The same finding was made here, although the extent of the reinforcer-rate excess was not as great. Figure 10 shows, for all parts of the experiment, the difference between the obtained and arranged reinforcer rates in the two common-schedule components. Positive values show an increase over the arranged rate, and negative values a decrease. In the group-average data, there were some very consistent differentials between the reinforcers per minute arranged in the common-schedule components and some quite evident trends. In Parts 1 to 4 (when both chain schedules were varied within each part, and the common schedule was varied over parts) when the common schedule was VI 60 s (Part 1), the subjects obtained approximately the arranged reinforcer rates in Common 1 but a considerably lower reinforcer rate in Common 2. There were no clear trends as the chain schedule was varied. As the common-schedule reinforcer rate was decreased from VI 60 s (Part 1) to VI 240 s (Part 4), there was perhaps a slight decrease in obtained reinforcer rates in Common 1, but Common-2 reinforcer rates increased until (in Part 4) they were equal to or higher than those arranged, and there was a clear trend toward higher obtained Common-2 reinforcer rates as Link-2 reinforcer rates were increased. How might these ef-

fects have occurred? In Part 4, the low common-schedule reinforcer rate was associated with a higher Link-1 response rate than in Part 1 (see Figures 1 and 4). This higher response rate produced, perhaps through direct interactions, a lower Common-1 response rate. Thus, because there was no dependency between reinforcers in the initial link, it was possible to enter a terminal link with a common-schedule reinforcer available. A dependency did exist in the terminal link, so held-over reinforcers would need to be taken before the Link-2 reinforcer became available. It appears that the longer Link 1 was on average (moving to the right of Figure 4), the more likely it was that the common-schedule time was depleted in the presence of Link 1 and the arranged reinforcer was obtained in Link 2. Although we might have expected the opposite effect in Part 1, it simply did not occur, perhaps because of the lack of a dependency in the initial links. These considerations suggest that the specific results of the present experiment depend on the provision of reinforcer dependencies versus nondependencies and on the fact that a single common-VI schedule was arranged. Rather than detracting from the results, they highlight the contingencies that are operative in research of this type. If explicit reinforcers are reallocated between the links of a chain schedule in this way, how will reinforcers implicit in such an experiment be reallocated? Notice, by the way, that common-schedule reinforcers were not simply allocated as inverse functions of either response or reinforcer rates on the chain schedules.

Parts 5 and 6 (chain VI $\times$ s VI 10 s, Figure 10) showed a similar effect to Parts 1 to 4 in that decreasing common-schedule reinforcer rates from VI 60 s to VI 240 s increased Common-2 obtained reinforcer rates above the value arranged, but Common-1 reinforcer rates were also decreased below the value arranged. In Part 6 (common VI 240 s) higher reinforcer rates in Link 1 of the chain also progressively decreased obtained Common-1 reinforcer rates. As Figure 6 showed, Link-1 response rates increased substantially, and Common-1 response rates decreased, with increasing Link-1 reinforcer rates.

Parts 5 and 7 (Link-2 VI 10 s and VI 30 s, respectively) showed clear differences. Obtained Common-2 reinforcer rates were lower

when Link 2 was VI 30 s than when it was VI 10 s. We expected higher Common-2, and lower Link-2, response rates in Part 7 than in Part 5, and this was the case (Figures 5 and 9). The finding highlights another effect that occurs with the present contingencies. If the subject favors responding on Common 1 during Link 1, switches to Link 2 only after a common-schedule reinforcer, and then favors Link 2 over Common 2, a greater proportion of the common-schedule *timing* will be done during Link 2, but a heightened common-schedule reinforcer rate may be obtained during Link 1. In Part 5 (Figure 5), because of the higher common-schedule reinforcer rate the response-rate differential between Link 1 and Common 1 was much smaller, so the terminal link was entered when it was arranged. This analysis is completely supported by the Link-1 obtained reinforcer rates shown in Figures 5 and 9. In Part 5, changing the Link-1 schedule strongly changed the Link-1 obtained reinforcer rate. In Part 7, the change was much smaller (although significant). Again, these results show that alternative reinforcers are not reallocated inversely to obtained reinforcers. Sometimes, as in the comparison between Parts 5 and 7, a lower reinforcer-rate schedule can result in lower rates of alternative reinforcers being taken. Presumably, such an effect would be amplified if no dependency had been arranged between reinforcers in Link 2.

Finally, the comparison between Parts 8 and 9 (Link-1 VI schedules of VI 6 s and VI 54 s) shown in Figure 10 is comparatively uninteresting. It appears that the longer Link-1 schedule decreased Common-2 obtained reinforcer rates from those arranged, perhaps again because the subjects entered the terminal link only following a common-schedule reinforcer. In Part 8 (Figure 7), the rate of terminal-link entry (which was arranged to be 10 per minute) covaried strongly with the Link-2 reinforcer rate, perhaps explaining the upward trend in Common-2 obtained reinforcer rates in Figure 10 (if the subjects were entering the terminal link when it was arranged, the Common-2 reinforcer rate would move toward that arranged). In contrast, in Part 9 (Figure 8), although both Link-1 and Link-2 reinforcer rates significantly increased, a covariation between these reinforcer rates was much less evident, and in general the Link-1 obtained rein-

Fig. 10. The difference between obtained and arranged reinforcer rates in Common 1 and Common 2 as a function of the arranged reinforcer rates in Link 1 or Link 2 for all parts of the experiment. Group-average data were used. A positive value indicates that obtained rates were higher than arranged rates, and a negative value indicates that obtained rates were lower than arranged rates. The horizontal line shows the equality of obtained and arranged rates.

forcer rate remained below the level set (1.11 entries per minute; but see Bird 125 for a relatively high Link-1 obtained reinforcer rate).

The behavior produced in the present experiment was thus particularly complex in comparison with that seen on chain schedules without alternative reinforcers present (e.g., Findley, 1962). It is possible that some of the complexity was caused by the contingencies that we arranged. The point to be made, however, is that the complexity of performance on

chained schedules demonstrated here is inherent in performance on simple chains. In simple chains, alternative reinforcers *are* available (Herrnstein, 1970) but are simply unmeasured. The schedules on which these alternative reinforcers are available are unknown, the contingencies that operate between the defined and the alternative reinforcers are also unknown, and the nature of the alternative reinforcers is unknown (are they, for instance, complements or substitutes for the defined

reinforcers?). Avoiding or ignoring inherent complexities does not benefit an experimental analysis of behavior. An additional complexity may be that exposure to particular experimental conditions, with perhaps the development of a behavioral strategy suitable for that condition, may be carried over into the next condition and be maintained superstitiously. This might explain some poorly replicated data in the present experiment. Such effects could presumably be eliminated by using changeover delays in the first link of the chain as well as in the second, but (like the terminal-link dependency) the procedure becomes more artificial. The alternative view is that such procedures anchor the limits of an experimental analysis more firmly.

By distributing their behavior between the common-schedule components, the subjects redistributed their obtained reinforcers between the components. Such an effect is known to increase the disparity between multiple-schedule component response rates when the redistribution is inversely related to the component reinforcer rates (Hinson & Staddon, 1978; McLean & White, 1983). An effect perhaps analogous to an inverse redistribution was seen quite clearly in Parts 1 and 7 to 9, but when it occurred, the amount of redistribution was constant rather than a function of the reinforcer rates in the chain. Such an effect is likely to be the mechanism for the apparent contrast in Link-1 versus Link-2 responding noted by Moore (1982) and discussed in detail by him (see also Wilton & Gay, 1969). Notice, however, that in Parts 3 and 4 (Figure 10), the reallocation of common-schedule reinforcers was directly correlated, rather than inversely correlated, with the concurrently available chain-schedule reinforcer rates.

By analogy, the same mechanism of reinforcer redistribution discussed above may operate in single-chain schedules. When no explicitly reinforced alternative response is available and no reinforcer dependencies exist, the extraneous reinforcers (Herrnstein, 1970) available to experimental subjects should also be reallocated between links. The degree of reallocation will depend on the schedule of extraneous reinforcement. If this schedule is more like a ratio schedule than an interval schedule (Pear, 1975), then the degree of reallocation, and hence the contrast, could be enhanced. A similar argument (but for multiple-

schedule performance) has been advanced by Elliffe and Davison (1985).

How might a quantitative analysis of chain-schedule performance proceed? One possibility is to modify an existing model of multiple-schedule performance (McLean & White, 1983) that was developed explicitly to deal with successively arranged schedules in the presence of concurrently available alternatives. This model takes reinforcer redistribution into account if these reinforcers can be measured. However, the model cannot be applied to the present data because it assumes that concurrent-schedule performance in one component is unaffected by the schedules in the alternated component. As we showed above, the generalized matching analysis of the concurrent schedule comprising Link 2 and Common 2 was strongly affected by the value of the common schedule (Parts 1 to 4 and 5 and 6). Presumably this is because the value of the transition from Link 1 to Link 2 of the chain (i.e., the reinforcer amount following this transition) depends on a number of factors. If the response rate in Link 1 is taken as an ordinal index of this value, the present results suggest that the chain-transition value is directly related to (a) increasing Link-2 reinforcer rates (Table 2, Parts 8 and 9 particularly); (b) increasing Link-1 to Link-2 transition rates (Parts 5, 6, and 7); and (c) decreasing common-schedule reinforcer rates (comparing Parts 1 to 4 and 5 and 6). It may be, of course, that some of these results (particularly the last) do not indicate a change in reinforcer value but rather a simple redistribution of a constant behavioral output (Herrnstein, 1970; McLean & White, 1983), or even a combination of this and value changes. However, even the first two possibilities, in which response rate will likely be a nonlinear function of the controlling variables, make a quantitative analysis difficult. When, as here, independent variables that are arranged to be constant change systematically with the values of manipulated variables, a quantitative analysis cannot make initial progress by modeling a series of partial effects in isolation. It must deal with the variation of all controlling variables simultaneously. We assessed various models, based on the one offered by McLean and White, in which the value of the transition was a function (linear or nonlinear) of the above variables. None was satisfactory.

One way out of this impasse is, instead of arranging fixed schedule values, to change dynamically the values of schedules so as to maintain fixed *obtained* schedules in the components other than that in which a manipulation is carried out. This might be of some value because it would minimize uncontrolled redistribution of reinforcers between components and uncontrolled variation of obtained reinforcer frequencies in constant arranged schedules. This procedure would not, however, eliminate such effects because, by definition, there can be no control over extraneous reinforcers and behaviors. "Leisure," grooming, and so on may be reallocated between the links of the chain and may even be reallocated outside of the experimental period. Although this may be a useful approach and may help to define performance in a theoretical chain with no extraneous reinforcers, a full understanding of chain-schedule performance also demands an investigation of performance when extraneous reinforcers can be reallocated to various different degrees between components. From such a research program, it may become possible to infer the nature of the feedback function describing the amount of, and reallocation of, extraneous reinforcers between chain-schedule components. But this function will be subject-idiosyncratic as well as dependent on the parameters of the chain.

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APPENDIX

Number of responses emitted, minutes spent responding, and number of reinforcers obtained, summed over the final five sessions of each experimental condition for each subject. R and L refer to the right and left keys, and the numerals 1 and 2 refer to Links 1 and 2, respectively.

Condi- tion	Responses				Time (minutes)				Reinforcers		
	R1	R2	L1	L2	R1	R2	L1	L2	R1	R2	L2
Bird 121											
1	8,229	452	73	1,500	147.7	5.9	5.4	19.5	145	12	41
2	7,434	798	47	2,035	145.4	10.0	3.1	22.5	146	21	33
3	3,938	368	257	2,660	77.1	4.5	17.2	24.0	92	19	89
4	7,967	677	28	2,055	156.8	9.1	4.2	21.6	144	27	28
5	4,986	117	595	1,845	65.8	1.6	34.3	13.1	89	17	94
6	3,595	691	242	5,408	106.2	12.4	23.8	53.3	62	27	109
7	5,235	987	113	5,760	132.0	15.0	9.5	53.1	76	25	85
8	5,542	351	692	3,578	70.6	4.9	41.4	34.7	51	23	126
9	2,933	1,542	113	7,119	65.6	38.0	19.0	79.6	40	50	110
10	3,885	68	1,211	1,945	53.7	0.9	77.8	15.6	63	9	128
11	7,400	910	82	4,740	139.2	21.1	17.1	40.1	79	21	66
12	4,399	318	1,309	3,025	59.2	3.8	66.2	26.4	51	20	129
13	5,490	1,220	56	2,925	104.3	20.1	3.9	29.5	121	28	51
14	2,793	257	652	2,053	47.9	4.1	39.4	19.2	85	16	99
15	3,162	1,239	217	6,375	85.4	31.0	25.7	81.2	40	28	114
16	3,376	112	1,368	4,524	51.5	3.6	78.8	41.8	40	14	146
17	1,884	942	1,069	5,390	46.4	21.0	51.9	63.4	30	25	145
18	2,326	1,121	539	6,613	79.3	27.4	30.4	85.6	35	31	128
19	2,753	82	2,272	2,558	54.0	1.1	95.7	19.3	39	14	147
20	4,473	1,137	306	7,130	97.3	21.7	16.4	72.1	45	21	93
21	2,046	59	2,240	3,240	44.4	0.8	87.8	25.8	45	8	147
22	4,040	1,333	736	8,121	99.7	25.4	18.8	76.8	33	23	111
23	3,023	142	2,004	4,954	53.5	2.0	81.2	39.6	35	9	156
24	2,232	1,022	1,267	7,883	40.2	18.5	56.1	69.1	20	24	156
25	3,763	1,231	855	7,193	95.7	24.7	22.8	73.7	34	20	117
26	2,654	50	2,678	2,647	41.9	0.5	113.8	19.6	36	8	156
27	3,526	1,511	540	8,021	91.4	30.7	17.0	84.7	31	22	117
28	2,033	43	2,719	3,390	49.1	0.5	97.7	29.1	37	6	157
29	65	120	1,884	2,921	2.9	2.1	31.6	36.3	1	18	181
30	2,939	65	2,422	2,939	54.3	1.8	103.5	30.1	38	10	152
31	175	132	2,041	3,084	3.5	2.2	45.9	35.5	0	19	181
32	1,540	69	2,777	3,515	42.9	1.3	101.2	31.9	24	11	165
33	0	112	1,188	2,923	0.0	1.7	20.3	34.5	0	14	186
34	3,992	67	709	1,954	72.0	0.7	30.7	16.2	109	9	82
35	2,579	211	764	2,207	46.7	3.6	18.6	23.2	63	25	112
36	5,004	37	720	1,409	80.6	0.4	28.4	13.6	119	1	80
37	3,178	93	587	2,271	60.3	1.5	17.9	21.0	84	14	102
38	4,489	90	579	1,920	84.9	1.1	20.2	15.9	112	9	79
39	1,252	371	928	2,504	25.8	5.0	14.7	29.0	35	34	131
40	3,022	81	801	1,636	64.7	0.9	24.2	17.8	99	8	93
41	2,357	418	632	2,265	47.9	6.8	14.8	28.7	63	28	109
42	5,229	426	319	1,646	110.4	6.8	6.7	18.8	124	18	58
43	5,807	28	18	161	189.5	0.4	0.8	2.1	192	2	6
44	8,661	223	50	748	172.4	3.5	3.3	8.6	179	4	17
45	8,126	258	71	1,305	155.1	4.0	4.1	12.5	163	9	28
46	7,221	360	85	1,816	131.7	5.8	5.1	17.5	146	15	39
47	9,892	238	87	1,496	145.5	3.8	4.1	16.4	160	9	31
48	7,756	256	71	1,385	149.9	3.7	3.0	13.3	164	8	28
49	9,046	129	73	1,873	145.2	2.0	3.4	18.1	162	6	32
50	7,179	187	155	1,697	129.0	3.9	5.1	21.6	141	14	45
51	7,722	229	308	2,638	104.9	3.3	10.4	25.9	124	16	60
52	7,284	212	193	2,156	102.7	3.2	12.2	23.7	121	15	64
53	6,237	166	600	2,200	83.6	15.2	18.9	20.0	114	10	76
54	4,812	88	622	1,885	72.8	1.0	26.7	16.9	109	8	83
55	3,730	1,619	1,008	7,698	84.9	34.6	19.9	77.6	27	27	128
56	3,836	148	1,050	2,299	55.9	1.5	32.5	19.4	89	16	95

APPENDIX (Continued)

Condi- tion	Responses				Time (minutes)				Reinforcers		
	R1	R2	L1	L2	R1	R2	L1	L2	R1	R2	L2
Bird 122											
1	9,585	140	12	457	190.4	1.4	0.7	4.2	191	1	8
2	11,614	537	31	1,482	165.9	8.1	2.2	11.5	169	9	22
3	8,890	191	128	1,783	138.6	2.5	4.8	14.4	142	10	48
4	10,157	85	3	82	196.2	1.5	0.4	0.7	195	2	3
5	10,807	0	1	7	205.7	0.1	0.2	0.0	199	0	1
6	8,346	415	58	1,611	184.7	6.6	4.8	17.7	95	8	37
7	4,758	840	45	2,090	178.3	13.2	4.8	23.7	87	17	41
8	4,149	123	148	1,975	201.0	2.0	10.2	19.3	98	6	69
9	4,943	1,167	44	2,210	163.2	23.6	4.9	22.9	85	15	43
10	4,746	6	372	1,626	157.8	0.1	20.2	11.3	91	1	108
11	4,644	1,166	56	2,433	163.7	20.3	6.1	29.9	92	14	53
12	4,715	99	291	3,123	154.1	2.1	18.9	21.1	89	9	102
13	10,160	526	14	640	180.1	6.8	0.8	7.2	179	7	14
14	8,003	144	136	1,839	135.0	2.4	7.1	13.0	132	13	55
15	4,661	1,434	94	5,274	140.3	21.2	12.8	55.3	50	22	78
16	4,116	148	860	4,949	99.1	2.2	40.8	36.1	51	7	142
17	3,821	1,076	497	5,747	112.1	16.4	31.8	53.9	57	14	131
18	2,217	926	327	9,158	76.3	14.7	33.8	100.1	33	35	124
19	3,235	54	1,688	3,203	54.1	1.4	95.1	19.7	40	12	148
20	695	709	119	6,390	84.5	15.6	32.9	89.5	28	36	89
21	1,995	78	1,897	3,529	64.4	1.4	89.6	28.2	47	13	140
22	721	568	281	7,221	73.1	10.6	32.0	110.5	17	32	106
23	1,485	109	2,045	5,152	25.6	2.2	107.3	51.4	22	21	157
24	889	429	1,776	7,221	13.2	6.8	77.1	91.9	14	31	155
25	409	808	860	7,272	11.1	16.0	41.0	129.9	8	37	155
26	2,135	50	1,883	2,634	56.9	1.2	102.8	22.2	33	10	157
27	751	1,009	544	8,735	51.3	20.5	22.4	122.6	17	34	140
28	2,016	84	2,045	3,444	57.1	2.6	91.9	32.5	30	17	153
29	23	145	1,273	3,909	0.4	2.4	33.9	36.3	1	18	181
30	3,044	64	2,651	3,458	61.6	1.7	89.5	30.5	34	11	155
31	249	127	1,539	3,310	3.2	2.9	42.3	34.7	5	17	178
32	2,026	77	2,940	3,679	31.8	1.6	99.0	31.9	29	12	159
33	5	144	712	4,257	0.2	2.0	21.6	34.6	0	18	182
34	3,770	171	1,201	2,681	50.2	2.3	40.1	20.4	80	21	99
35	1,010	544	618	3,608	13.7	6.1	18.9	26.1	25	34	141
36	3,995	246	1,365	2,522	51.7	2.8	39.6	18.0	85	19	96
37	1,368	481	802	3,393	18.2	6.8	21.4	25.3	34	29	137
38	3,951	236	1,097	2,341	60.3	2.6	27.2	17.2	89	15	96
39	1,785	335	451	3,097	30.9	4.2	13.0	24.1	43	29	128
40	3,034	235	664	2,719	56.3	3.3	22.8	20.3	78	21	101
41	1,060	669	347	3,860	25.7	9.2	14.1	32.0	32	39	129
42	2,938	602	222	3,087	73.4	8.9	7.9	27.8	86	26	88
43	4,045	490	147	2,538	120.4	6.6	4.9	23.3	117	24	59
44	4,343	522	104	1,924	135.2	7.1	3.9	19.1	141	17	42
45	5,735	500	129	1,626	131.9	7.2	4.9	18.0	145	16	39
46	5,623	212	45	830	163.1	3.2	3.5	10.8	166	10	24
47	4,537	473	148	1,871	126.4	8.6	5.5	20.7	139	13	48
48	4,948	520	103	1,576	136.0	6.7	4.6	19.6	139	19	42
49	6,949	334	53	658	161.6	5.8	2.8	9.7	172	5	23
50	5,232	515	81	1,173	138.2	9.3	4.0	17.0	144	20	36
51	5,242	279	62	651	162.7	4.7	5.4	9.0	167	10	23
52	4,609	64	12	159	190.1	1.2	7.2	3.7	188	1	10
53	4,610	128	53	615	158.5	1.9	5.6	7.8	164	5	31
54	4,080	30	120	403	159.8	0.5	6.2	6.6	166	3	31
55	2,085	33	5	222	194.5	1.3	12.7	3.0	48	0	5
56	3,992	6	25	150	190.1	0.2	3.0	2.7	185	0	15

APPENDIX (Continued)

Condi- tion	Responses				Time (minutes)				Reinforcers		
	R1	R2	L1	L2	R1	R2	L1	L2	R1	R2	L2
Bird 123											
1	4,955	598	144	4,171	91.2	9.3	7.8	32.8	109	23	68
2	7,785	779	35	2,314	149.1	8.1	2.9	19.0	157	14	29
3	4,663	394	264	3,745	99.0	3.1	10.3	20.0	109	17	74
4	6,986	1,391	36	2,931	137.7	13.5	3.2	22.9	138	26	36
5	3,644	190	930	2,654	45.1	1.6	50.4	13.5	82	15	103
6	6,112	1,446	501	8,903	80.5	11.3	24.5	57.0	52	32	116
7	6,338	1,819	129	7,649	124.6	15.2	10.3	61.3	76	26	92
8	4,723	506	901	5,084	57.1	4.1	49.1	31.8	62	11	127
9	4,261	2,347	111	7,033	100.1	22.2	11.1	68.4	65	31	91
10	4,656	123	1,351	2,789	58.6	1.2	67.6	15.9	58	11	131
11	5,519	1,619	92	5,070	143.6	15.8	8.3	53.7	80	29	75
12	4,001	221	1,388	2,518	62.6	1.9	66.7	24.1	64	10	126
13	5,080	1,224	48	2,323	116.7	18.0	3.8	25.3	129	24	47
14	3,528	299	1,403	2,448	61.6	3.0	34.5	16.7	96	13	91
15	3,641	2,141	927	8,662	86.5	25.2	21.4	90.0	41	31	125
16	4,236	240	4,312	4,303	61.2	2.9	73.6	35.9	47	8	145
17	4,581	876	3,373	7,493	94.5	8.2	40.4	67.4	47	19	130
18	3,904	1,339	433	8,010	119.7	10.9	15.0	77.4	47	20	104
19	3,940	52	5,918	3,086	51.3	0.4	90.0	16.8	46	6	148
20	7,162	1,250	92	4,111	180.0	11.0	5.7	34.4	63	17	48
21	3,976	123	5,712	4,334	52.7	1.0	74.8	26.7	41	9	150
22	5,301	1,149	1,170	6,508	142.0	12.3	8.7	54.5	43	13	72
23	4,008	107	6,468	6,278	46.6	0.8	78.1	42.8	29	12	159
24	6,075	583	3,962	8,962	96.3	4.2	41.8	73.0	42	12	145
25	7,416	1,167	2,044	6,966	139.9	12.3	15.0	59.5	42	13	84
26	6,024	57	9,627	3,499	52.0	0.4	91.5	18.5	34	8	158
27	3,002	3,035	1,080	7,364	54.5	35.7	17.7	99.4	21	33	136
28	3,180	138	10,265	4,424	32.3	1.0	97.5	29.6	27	12	161
29	389	346	5,280	4,298	4.8	2.5	29.0	34.9	4	14	182
30	3,581	174	11,932	4,456	43.9	1.4	96.9	29.5	29	14	157
31	824	181	6,874	4,228	10.6	1.6	36.0	32.5	7	15	178
32	2,683	75	10,189	4,520	41.6	0.5	81.2	28.5	36	8	156
33	311	223	4,135	3,463	5.6	1.7	19.3	34.4	2	13	185
34	3,506	191	3,281	2,896	50.5	1.2	37.8	18.5	91	16	93
35	2,525	282	2,456	2,683	49.7	1.8	14.9	21.5	69	16	115
36	3,619	150	2,755	2,469	63.4	1.0	30.8	15.4	103	8	89
37	2,141	291	2,331	2,657	27.3	1.9	20.5	25.3	52	26	122
38	4,066	222	3,401	2,512	46.7	1.4	34.7	17.8	88	15	97
39	2,035	504	2,298	3,221	21.1	2.6	13.2	26.1	39	23	138
40	3,182	424	4,368	3,010	36.0	2.2	34.2	20.3	72	15	113
41	1,949	906	1,906	3,356	36.3	7.7	12.1	26.9	45	36	119
42	2,923	815	1,512	3,567	61.0	7.9	9.5	32.3	72	33	95
43	4,157	847	955	2,728	78.8	10.7	6.7	25.3	96	24	80
44	4,955	770	672	2,823	94.2	8.8	5.0	26.9	111	26	63
45	5,778	499	668	3,597	99.5	4.0	9.6	29.6	127	12	61
46	4,910	900	2,508	4,252	64.1	9.0	22.9	32.9	98	26	76
47	4,523	1,070	2,056	4,007	60.8	14.1	22.3	31.0	89	35	76
48	3,949	961	1,609	4,026	52.8	9.8	19.4	38.1	87	29	84
49	4,077	1,034	825	4,267	56.4	12.2	10.9	34.4	81	30	89
50	4,112	1,201	998	4,917	56.8	13.8	9.8	35.2	78	33	89
51	4,775	641	2,550	4,419	61.9	6.2	27.9	30.5	95	24	81
52	4,860	381	2,571	4,017	62.6	3.4	28.9	28.5	100	17	83
53	4,572	371	3,158	3,633	60.3	2.7	30.9	21.4	95	19	86
54	3,388	122	4,097	3,270	50.8	0.9	39.3	18.1	97	9	94
55	3,120	1,620	1,712	9,981	95.6	18.8	16.7	77.5	26	24	104
56	4,366	232	2,668	2,925	54.7	1.6	31.8	16.5	96	9	95

APPENDIX (Continued)

Condi- tion	Responses				Time (minutes)				Reinforcers		
	R1	R2	L1	L2	R1	R2	L1	L2	R1	R2	L2
Bird 124											
1	2,229	405	143	3,556	79.2	8.6	15.1	42.2	95	30	75
2	3,149	503	79	3,742	92.3	8.4	8.7	47.5	115	24	61
3	1,305	50	144	2,725	96.4	0.9	19.5	22.6	115	7	78
4	2,483	1,333	62	3,420	81.6	22.7	5.4	42.5	103	38	59
5	1,921	16	329	1,591	98.5	0.6	18.3	9.9	115	2	83
6	3,780	888	449	4,949	77.3	13.0	25.3	58.5	57	23	120
7	2,097	722	210	7,169	71.9	14.1	15.0	84.9	52	34	114
8	2,130	61	1,443	5,016	40.1	1.5	68.6	42.9	45	20	135
9	2,333	1,725	147	7,857	39.0	24.1	14.1	81.4	26	52	122
10	1,963	41	1,557	2,196	39.7	1.0	87.8	20.0	54	13	133
11	2,075	1,281	345	7,869	48.5	29.6	16.6	92.3	31	47	120
12	4,001	221	1,388	2,518	62.6	1.9	66.7	24.1	64	10	126
13	1,661	905	135	5,088	48.3	21.5	12.9	70.6	66	55	79
14	1,743	183	1,818	3,118	31.9	2.9	57.8	27.8	68	32	100
15	1,184	1,265	2,018	8,297	25.4	28.8	26.1	110.1	11	44	145
16	1,450	151	2,581	5,347	33.5	4.6	92.1	58.6	30	23	147
17	764	446	2,097	6,659	25.3	16.2	60.1	87.6	22	29	149
18	1,435	963	1,191	7,823	46.0	26.4	28.1	110.6	27	35	136
19	934	60	3,085	3,055	25.1	3.0	121.9	26.6	31	18	151
20	854	1,836	627	7,447	19.6	42.3	15.1	100.0	10	45	145
21	1,548	116	3,210	2,919	28.9	2.5	98.4	35.8	31	19	150
22	1,154	840	1,094	8,226	30.0	23.7	20.7	121.2	9	38	153
23	680	131	3,678	4,179	13.4	4.8	112.4	55.3	18	24	158
24	666	813	2,380	5,816	20.3	27.3	63.4	68.0	14	27	159
25	593	1,456	1,471	7,280	13.8	40.5	33.6	98.3	6	38	156
26	830	81	4,727	1,971	17.7	2.0	127.1	22.5	23	17	160
27	1,800	1,317	768	7,670	49.8	34.1	15.8	108.5	15	35	146
28	1,142	98	4,228	2,915	24.0	2.1	114.9	34.5	24	15	161
29	20	100	1,466	2,414	0.7	3.6	31.4	41.5	0	18	182
30	1,201	79	4,774	2,241	25.2	2.2	119.1	34.5	27	14	159
31	6	81	1,884	2,135	0.1	3.4	43.6	37.2	0	18	182
32	1,269	50	4,540	2,380	20.9	1.9	106.5	32.9	24	10	166
33	25	48	1,004	2,038	0.5	2.7	19.8	36.1	2	13	185
34	1,753	155	1,924	1,874	31.9	4.0	52.1	20.5	81	17	102
35	199	164	845	2,352	6.7	5.9	23.7	37.3	14	42	144
36	1,755	126	1,656	1,936	33.0	3.2	56.3	23.0	79	21	100
37	778	199	772	1,811	19.6	7.5	26.3	30.4	42	25	133
38	1,760	244	1,582	2,171	28.5	5.4	53.6	24.2	65	29	106
39	375	120	888	2,294	11.9	5.8	15.9	33.9	27	26	147
40	1,357	84	1,271	1,860	38.9	3.9	31.3	26.8	67	25	108
41	519	246	868	2,365	18.6	9.3	15.9	41.9	26	41	133
42	1,462	284	734	1,998	49.3	8.9	12.0	37.2	73	25	102
43	1,392	275	542	2,053	53.2	9.3	11.6	45.5	75	29	96
44	1,922	330	410	1,885	90.9	10.3	8.2	36.1	108	24	68
45	1,681	223	661	1,789	74.9	8.0	25.9	39.7	104	26	70
46	1,659	254	527	1,255	79.0	8.6	18.7	43.6	103	28	69
47	2,132	305	723	1,562	71.6	9.1	20.6	52.5	96	31	73
48	1,585	268	651	2,134	61.4	9.7	19.0	47.6	89	28	83
49	1,452	538	639	2,160	47.2	15.6	15.9	46.4	79	31	90
50	2,125	406	391	1,468	82.5	11.7	9.2	38.9	104	25	71
51	1,819	210	908	2,092	73.5	9.1	24.1	36.0	106	21	73
52	2,256	133	1,138	1,866	65.1	5.7	27.4	29.7	105	13	82
53	2,151	137	1,541	2,194	49.5	3.8	43.4	32.0	85	23	92
54	1,977	86	1,668	1,364	49.4	3.0	44.4	27.1	86	20	94
55	833	1,167	1,241	6,306	18.5	28.9	23.9	125.6	8	36	156
56	1,724	92	1,303	1,241	47.0	3.5	40.5	25.9	88	16	96

APPENDIX (Continued)

Condi- tion	Responses				Time (minutes)				Reinforcers		
	R1	R2	L1	L2	R1	R2	L1	L2	R1	R2	L2
Bird 125											
1	3,795	2,261	272	2,292	55.3	19.7	16.9	49.7	65	48	87
2	2,970	2,382	74	1,656	103.0	19.2	8.5	38.6	114	32	54
3	3,176	428	135	780	106.3	4.4	13.7	22.6	119	13	68
4	3,871	1,482	46	1,563	128.4	25.5	4.8	30.5	130	29	41
5	3,450	556	428	843	107.2	11.7	12.2	21.0	111	10	79
6	4,741	1,185	270	2,056	122.1	16.4	17.2	50.0	72	20	94
7	5,413	2,505	142	1,953	139.2	28.2	10.0	51.0	77	23	75
8	5,870	334	1,693	3,581	73.2	3.8	39.0	38.0	55	15	130
9	4,868	4,320	169	6,262	83.0	34.6	12.8	74.6	46	50	103
10	8,856	85	2,620	1,177	66.8	1.5	61.3	24.0	62	6	132
11	3,039	4,924	222	7,262	43.9	39.2	11.7	83.4	23	55	122
12	6,449	131	5,010	3,442	42.4	1.8	75.2	30.5	49	17	134
13	2,867	2,618	111	2,512	82.5	32.1	6.6	35.7	94	43	63
14	4,367	425	3,541	2,496	40.3	5.4	51.0	22.6	69	29	102
15	2,023	5,449	1,484	9,213	22.7	41.2	24.0	97.0	8	48	144
16	4,765	549	5,608	4,612	40.4	6.0	82.5	40.1	33	17	150
17	5,188	2,874	3,260	7,315	40.5	20.8	46.5	67.6	24	30	146
18	2,827	3,884	1,236	9,477	23.4	33.9	25.7	89.1	16	38	146
19	4,244	75	7,364	1,324	38.5	1.2	102.6	27.3	43	9	148
20	511	5,181	1,360	11,291	5.7	45.3	16.0	102.0	3	49	148
21	4,495	228	6,777	3,102	33.1	2.1	88.2	30.8	40	12	148
22	2,496	3,027	1,239	7,816	46.5	37.1	21.4	106.0	12	35	146
23	4,369	209	6,472	4,657	31.1	2.4	90.6	44.5	25	16	159
24	3,739	2,115	3,841	8,486	33.2	19.4	54.5	68.3	21	22	157
25	1,566	4,125	2,144	9,875	16.8	43.1	28.6	89.2	10	32	158
26	3,631	52	6,783	2,527	31.0	1.0	117.0	22.0	29	12	159
27	2,203	5,651	893	10,311	31.9	47.5	15.5	103.3	10	39	151
28	4,460	137	8,263	3,447	32.8	1.5	101.4	32.2	31	11	158
29	11	312	4,769	3,207	0.1	2.5	30.8	38.2	0	17	183
30	3,789	122	10,681	4,668	31.2	1.7	113.5	33.7	27	16	157
31	655	224	4,599	2,625	6.2	2.5	38.2	39.6	8	15	177
32	3,905	75	6,660	3,217	30.2	1.1	98.0	34.4	30	10	160
33	32	199	2,595	2,386	0.5	1.9	19.5	43.7	0	15	185
34	4,959	157	2,072	1,493	68.1	2.2	24.8	22.5	93	16	91
35	1,178	702	3,103	2,792	11.5	6.5	18.5	33.0	23	34	143
36	5,330	239	3,861	2,671	48.5	2.8	39.0	21.3	88	15	97
37	2,537	235	2,669	3,147	29.8	2.3	17.1	27.7	51	22	127
38	6,266	395	3,194	2,791	53.4	3.1	30.1	20.5	82	19	99
39	1,846	577	1,733	2,849	19.3	4.8	10.5	28.6	35	25	140
40	4,615	260	2,572	1,907	37.7	1.9	26.9	26.6	70	16	114
41	1,609	1,112	1,269	2,249	20.0	13.6	9.7	34.8	35	34	131
42	2,648	1,089	894	3,379	39.6	13.3	8.0	36.7	55	32	113
43	2,599	1,531	973	3,717	39.4	16.4	7.8	37.4	61	35	104
44	1,766	1,520	836	2,536	46.4	28.4	6.8	39.1	66	37	97
45	6,015	1,203	983	3,289	87.6	10.4	12.7	30.0	111	24	65
46	3,832	1,283	1,448	3,116	72.9	12.7	15.3	36.8	97	28	75
47	4,424	1,007	334	2,659	91.5	9.1	8.2	29.8	111	23	66
48	3,682	1,442	1,198	3,104	64.5	12.0	11.0	33.9	90	28	83
49	2,888	1,606	957	3,607	57.8	16.6	9.3	38.0	76	34	90
50	2,470	1,674	1,070	3,420	43.3	23.1	9.5	34.6	65	36	99
51	4,325	806	978	2,524	87.5	6.7	11.8	27.2	109	20	71
52	4,460	677	1,329	2,901	78.2	5.4	19.3	26.3	107	16	77
53	4,532	286	2,742	1,986	69.2	2.8	28.9	23.9	104	14	82
54	5,105	138	3,105	2,082	68.9	1.3	29.3	19.1	103	10	87
55	2,700	3,654	2,173	10,280	35.0	34.9	20.7	107.8	13	35	152
56	5,389	157	2,318	2,944	55.3	1.3	31.8	19.1	86	16	98

APPENDIX (Continued)

Condi- tion	Responses				Time (minutes)				Reinforcers		
	R1	R2	L1	L2	R1	R2	L1	L2	R1	R2	L2
Bird 126											
1	4,302	2,783	568	5,240	40.6	20.3	19.3	36.3	51	50	99
2	4,579	3,868	348	5,341	61.7	32.2	8.5	40.9	57	57	86
3	6,275	779	1,179	3,085	53.4	5.7	29.3	24.8	80	22	98
4	5,260	3,878	97	3,444	67.1	42.5	5.0	30.4	80	54	66
5	6,022	110	2,071	1,816	48.2	1.0	45.7	12.4	94	8	98
6	4,863	2,037	1,176	6,892	47.0	16.4	32.4	55.7	37	32	131
7	4,369	4,599	224	6,750	52.4	42.3	12.2	66.0	29	50	121
8	6,123	231	2,937	3,173	55.9	2.2	51.8	35.8	58	13	129
9	4,630	4,227	141	7,348	59.2	40.3	10.1	77.7	43	41	116
10	6,993	65	3,936	2,196	53.1	0.6	74.3	15.8	61	7	132
11	911	3,770	812	6,569	13.5	48.1	17.9	75.2	13	58	129
12	4,471	111	4,803	3,082	43.0	1.6	70.2	27.7	50	17	133
13	1,795	3,561	648	4,854	18.8	41.5	11.9	50.9	21	84	95
14	4,202	70	2,512	2,495	47.2	1.5	40.7	20.9	86	16	98
15	1,194	2,875	1,314	7,314	19.4	50.7	20.2	85.4	10	44	146
16	4,639	247	5,081	3,994	54.2	3.5	71.3	39.7	40	13	147
17	2,839	1,870	3,768	5,439	34.3	26.3	50.2	60.6	21	31	148
18	1,825	2,208	1,377	9,339	25.2	30.3	25.2	98.1	12	45	143
19	4,404	65	7,956	1,820	44.4	0.6	98.7	19.2	41	9	150
20	450	2,760	870	8,014	7.7	44.6	14.2	94.9	4	49	147
21	2,496	127	7,168	2,305	30.9	1.6	94.6	29.4	40	12	148
22	1,410	2,788	1,706	5,461	28.7	46.4	21.6	93.8	11	33	156
23	1,712	1,448	6,470	2,367	25.3	6.8	98.8	37.0	26	13	161
24	1,328	732	3,399	2,385	33.4	22.6	55.1	73.8	21	23	156
25	474	2,423	2,415	2,416	8.7	65.5	32.0	78.7	4	38	158
26	1,513	80	7,585	846	22.2	1.9	119.2	24.8	30	11	159
27	850	3,619	904	7,796	13.7	52.9	17.0	99.6	5	35	160
28	2,068	138	6,208	2,060	29.1	2.0	105.4	29.9	30	9	161
29	48	430	2,102	2,124	0.4	5.4	31.0	31.5	0	17	183
30	1,964	133	6,603	2,033	20.8	1.6	118.7	29.5	35	7	158
31	149	330	2,721	2,489	1.4	3.9	40.8	33.8	2	18	180
32	2,254	161	5,527	1,901	22.4	2.0	98.4	29.6	29	15	156
33	44	181	1,044	2,361	0.4	2.4	20.2	35.8	0	17	183
34	4,121	176	2,888	1,305	35.5	2.2	48.4	20.3	83	15	102
35	1,107	567	1,205	2,193	9.0	6.1	18.6	28.7	21	37	142
36	4,590	264	2,647	1,606	42.3	2.9	42.9	18.7	80	21	99
37	1,793	430	1,544	2,294	15.3	4.2	20.8	27.5	33	29	138
38	4,766	255	2,500	1,792	39.2	3.0	37.8	22.4	67	29	104
39	718	598	1,051	2,375	6.3	6.1	12.1	27.7	18	28	154
40	3,185	298	2,224	2,075	26.2	2.8	32.9	23.2	62	17	121
41	778	1,100	819	2,938	7.1	11.9	10.3	29.9	18	38	144
42	1,450	1,438	580	3,480	17.5	14.9	7.9	37.2	20	49	131
43	3,471	1,845	591	2,815	39.5	17.7	8.0	35.2	45	46	109
44	2,559	1,512	458	2,802	37.9	19.4	6.8	37.4	52	45	103
45	6,035	916	763	1,888	76.1	11.6	13.5	30.4	104	23	73
46	5,136	704	841	2,086	68.6	9.4	16.5	34.9	92	31	77
47	5,308	1,110	1,510	2,489	56.9	12.2	24.5	35.0	90	31	79
48	3,963	1,157	1,151	2,412	51.8	16.2	17.4	37.3	74	38	85
49	3,074	1,395	598	3,086	36.2	15.8	11.5	42.8	54	45	101
50	3,374	1,658	553	2,881	37.3	18.0	8.2	41.3	57	43	100
51	5,882	673	635	2,131	83.6	6.3	10.9	26.9	106	20	74
52	6,675	580	1,302	2,171	75.7	4.8	20.7	25.3	106	17	77
53	5,674	413	1,881	1,841	50.2	3.9	35.5	24.9	84	22	94
54	4,041	244	2,863	1,655	40.4	2.6	44.6	22.1	74	27	99
55	764	4,351	1,715	6,289	6.0	56.3	22.6	86.2	3	39	158
56	5,433	93	2,125	1,443	59.4	0.9	32.3	19.3	97	12	91