SENSITIVITY OF TIME ALLOCATION TO AN OVERALL REINFORCER RATE FEEDBACK FUNCTION IN CONCURRENT INTERVAL SCHEDULES

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Six pigeons were trained on concurrent variable-interval schedules in which feedback functions arranged that the overall reinforcer rate either (a) was independent of preference, (b) decreased with increasing absolute preference, or (c) increased with increasing absolute preference. In Experiment 1, the reinforcer rate in an interreinforcement interval was determined by the absolute time-allocation ratio in the previous interval. When arranged reinforcer ratios were varied, there was no evidence of control over preference by overall reinforcer rate. In Experiment 2, the feedback function arranged that reinforcer rates were an inverse function of absolute preference, and window durations were fixed times. In Phase 1, using schedules that provided a four-to-one reinforcer ratio, the window duration was decreased from 20 s to 5 s over four conditions. Then, in Phases 2 and 3, the arranged reinforcer ratios were varied. In Phase 2, the reinforcer rate in the current 5-s time window was determined by preference in the previous 5-s window, and in Phase 3, the window durations were 20 s. Again, there was no indication of control by obtained overall reinforcer rate. These data call into question theories that suggest that the process underlying matching is one of maximizing overall reinforcer rates, or that preference in concurrent aperiodic schedules is controlled to any extent by overall reinforcer rate. They also question the notion that concurrent-schedule preference is controlled by molecular maximizing.

Key words: concurrent schedules, variable-interval schedules, generalized matching, molar maximizing, molecular maximizing, overall reinforcement rate, feedback function, key peck, pigeons

The empirical phenomenon of matching is well known. On concurrent variable-interval (VI) VI schedules, the log of the ratio of responses emitted on two alternatives (or time spent responding) is a linear function of the log of the ratio of reinforcers obtained on the two options. This relation is known as the generalized matching law (Baum, 1974), and algebraically it is written as

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

where B refers to response counts, R to reinforcer counts, and the subscripts 1 and 2 refer to the two alternatives. The parameter a is called sensitivity to reinforcement (Lobb & Davison, 1975) and measures the sensitivity with which log response ratios change with

variation in log reinforcer ratios. Log c is called bias, and it measures a constant proportional preference for one alternative over the other when R_1 and R_2 are varied. Generally, the value of a is on average about 0.8 for response measures and 1.0 for time measures in concurrent VI VI schedule performance (Baum, 1979; Taylor & Davison, 1983; Wearden & Burgess, 1982).

A number of theories have been suggested to account for the empirical finding of matching as described by Equation 1. For instance, one account suggests that animals simply change their behavior in order to minimize deviations from strict equality of response and reinforcer ratios (e.g., matching theory as discussed by Vaughan, 1981; see also Rachlin, 1973). A second account, melioration, focuses on the possibility that animals may modify the time spent responding on the alternatives, increasing the time spent in the higher reinforcer-rate alternative. If allowed by the contingencies, this dynamic process can result in the equalization of the two or more obtained local reinforcer rates (i.e., the number of reinforcers per time spent responding on an alternative). A third account, molar maximizing (Rachlin, Battalio, Kagel, & Green, 1981; Staddon &

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Motheral, 1978) notes that, mathematically, a strict equality between response and reinforcer ratios occurs when the overall obtained reinforcer rate is greatest. Other accounts have focused on maximizing processes that may occur at more molecular levels. In particular, Silberberg and Ziriax (1982, 1985) have suggested that "animals allocate the times they spend responding to the schedules . . . so as to maximize the reinforcer rates that these interchangeover times produce" (1985, p. 84).

Molar maximizing is the subject of the present research, in which we asked whether concurrent VI VI schedule performance is sensitive to dynamic changes in overall reinforcer rates in a general sense, even though molar maximizing theory predicts strict, rather than generalized, matching. There has been a previous demonstration that, statistically at least, overall reinforcer rate does not contribute to behavior allocation on concurrent VI VI schedules. Hunter and Davison (1982) showed that concurrent VI VI schedule performance was not more efficiently described if a further parameter embodying overall reinforcer rate was included in Equation 1. However, in contrast, Alsop and Elliffe (1988), using a wider range of overall reinforcer rates, did show that sensitivity to reinforcement (a in Equation 1) increased with increasing overall reinforcer rates. This static demonstration does not show, however, whether animals will dynamically seek out higher reinforcer rates by varying their behavior allocation, as is required by molar maximizing theory.

At a more dynamic level, Vaughan (1981) used feedback functions that related concurrently available reinforcer rates to the relative time spent responding by the subjects. He showed that relative time allocations fell in parts of such feedback functions in which local reinforcer rates were equal. Vaughan's stable-state results were compatible with both melioration and minimizing-deviations-from-matching accounts and incompatible with molar maximizing (see Davison & McCarthy, 1988, p. 137). The fact that changes in conditions took behavior through parts of the feedback function in which deviations from matching were great led Vaughan to conclude that neither were deviations from matching controlling preference. However, Vaughan's results did not indicate *no* control by overall reinforcer rates, just that there was more control by other independent variables. It remains pos-

sible that some control by overall reinforcer rates could be demonstrated in situations in which it was not pitted diametrically against other sources of control. Vaughan used 4-min windows for his feedback function; that is, preference over a 4-min period changed the arranged relative and overall reinforcer rates during the next 4 min. Silberberg and Ziriax (1985) replicated Vaughan's experiment, but compared performance with a 6-s window duration with that using a 4-min window. When the 6-s window was in effect, they reported an effect of the feedback function on performance.

A second dynamic experiment that called into question a molar maximizing account of behavior was reported by Vaughan and Miller (1984). In their Experiment 1, Vaughan and Miller arranged single schedules that provided an inverse relation between response rate and reinforcer rate, and showed that their pigeons responded at a rate considerably greater than that required to maximize their obtained reinforcer rates. In Experiment 2, they arranged such schedules concurrently. Again, the pigeons responded at a considerably higher rate than that which would maximize the obtained reinforcers, and Equation 1 with a between 0.44 and 1.29 ($M = 0.81$) described the results. Although these results show that responding was not exclusively or overwhelmingly controlled by overall obtained reinforcer rate, the lack of appropriate controls does not allow the conclusion that there was *no* contribution by this independent variable to the control of behavior.

EXPERIMENT 1

The logic of the approach taken here was to arrange concurrent VI VI schedules in combination with an absolute feedback function that determined a reinforcer rate in the next time window as a function of the preference in the present window. The *relative* reinforcer rate was not changed by the feedback function. Preference was measured by the time-allocation ratio. In Experiment 1, Phase 1 consisted of conventional concurrent VI VI schedules, and the arranged reinforcer ratio was varied over five levels. In Phase 2, a feedback function arranged a maximum of two reinforcers per minute for time ratios approximating equal preference, and for increasing absolute preferences for either key the overall reinforcer rate was decreased progressively to 0.37 reinforcers

per minute for an absolute preference (i.e., toward either key) of 9:1 or greater. Phase 3 was similar to Phase 2, except that the minimum reinforcer rate occurred for approximately equal preference, and maximum reinforcer rates occurred for absolute preferences of 9:1 or greater. Again, in both Phases 2 and 3, the arranged reinforcer ratio was varied over five levels. We reasoned that, if relative performance was controlled by overall reinforcer rates, then the value of a in Equation 1 should be greater in Phase 3 than in Phase 2, with conventional concurrent-schedule performance (Phase 1) providing an intermediate a value. In Experiment 1, the feedback-function window was each interreinforcement interval—that is, the time-allocation ratio in the current interreinforcement interval affected the reinforcer rate (hence, the expected duration) of the next interreinforcement interval.

METHOD

Subjects

Six naive homing pigeons were housed individually and were maintained at $85\% \pm 15$ g of their ad-lib body weights by providing postsession feeding of mixed grain.

Apparatus

Experimental contingencies were controlled by a 6809® computer, placed remote from the experimental chamber, using SLAVIC (a locally written control version of BASIC) software. The experimental chamber was 33 cm deep, 33 cm high, and 31 cm wide, and it was situated in a sound-attenuating box with an exhaust fan attached. Three circular keys were situated on one wall of the chamber, centered 26 cm from the grid floor and 7 cm apart. A magazine aperture, its center 13.5 cm from the floor, was located beneath the center key. During reinforcement, the keys were darkened, the magazine raised and illuminated, and the subject was allowed to eat wheat for 3 s. Only the outer keys were used in the experiment. When these were illuminated white, responses to these keys exceeding about 0.1 N were counted and could be reinforced. The only sources of illumination in the chamber were the key and magazine lights.

Procedure

The subjects were deprived of food and trained to eat from the food magazine (containing wheat) when it was presented. Key

Table 1

Experiment 1: Sequence of experimental conditions, number of training sessions given in each condition, and the phase of the experiment to which each condition contributed.

Condition	$p(\text{left})$	Sessions	Phase
1	.5	25	1
2	.9	24	1
3	.1	23	1
4	.5	28	2
5	.9	28	2
6	.1	30	2
8	.3	33	2
9	.7	32	2
10	.5	27	2
11	.5	28	3
12	.9	18	3
13	.3	27	3
14	.7	25	3
15	.1	22	3
16	.5	27	3
17	.3	27	1
18	.7	26	1
19	.5	31	1

pecking was then autoshaped on the left key lit white, and following this the schedule was increased progressively to VI 30 s. The right key was then introduced, with a VI 30-s schedule, concurrently with the left key. Then, over the next 20 sessions, a changeover delay (Herrnstein, 1961) was introduced and progressively increased to its final value of 3 s. The changeover delay ensured that a reinforcer, even if it was currently arranged on a key, could not be obtained until at least 3 s had elapsed since the animal started responding on that key after responding on the other key. Reinforcement was 3-s access to the hopper containing wheat.

The concurrent VI VI schedules were arranged on the left and right keys (illuminated white) of the experimental chamber. The birds were placed in the experimental chamber in blackout. When the session started, the two keys were illuminated, the computer selected at random and without replacement one interval from a VI 30-s progression with 14 intervals arranged according to a constant-probability distribution, and the reinforcer at the end of this interval was allocated, according to a set probability level, to the left or right keys. The probability levels used are shown in Table 1. In Phase 1, subsequent intervals were selected and reinforcers allocated according to this procedure. However, in Phases 2 and 3,

Fig. 1. Experiment 1. A graph of the feedback function used in Phases 2 and 3, showing how the local relative time allocation within an interreinforcer interval controlled the average reinforcer rate in the next interval.

the selected intervals were modified, before they were used, according to the feedback functions shown in Figure 1. This was accomplished using a table that provided a constant, according to the time-allocation ratio in the previous interval, that was used to multiply the value of the next-selected interreinforcement interval. The next reinforcer was then randomly allocated, according to a set probability level, to one of the two alternatives.

Sessions terminated in blackout after a maximum of 44 min or after 40 reinforcers had been obtained, whichever event occurred first. The measures taken were the number of responses emitted on the two keys, the cumulated time (exclusive of reinforcement time) spent responding from the first peck on a key to the first peck on another key, the numbers of reinforcers obtained on each key, and the number of changeovers between the keys.

Performance was considered stable when it reached our usual stability criterion. In this, the median relative number of responses over five sessions was compared with the median from the five sessions preceding these. When this difference was less than .05 on five occasions, the stability criterion had been reached. This criterion requires a minimum of 14 sessions per condition. When all 6 subjects had met this criterion, the experimental conditions were changed for all 6 subjects. Typically, once a subject reached the criterion, performance continued to satisfy the criterion.

The sequence of experimental conditions is

Fig. 2. Experiment 1. The overall rate of reinforcers per minute obtained in Phases 1, 2, and 3 as a function of the average relative time allocation across the last five sessions of each experimental condition. The data have been averaged over the 6 subjects, and data from replicated conditions have also been averaged.

shown in Table 1. The data from Condition 7 are not reported because of computer problems.

RESULTS

The numbers of responses emitted, response rates, relative response rates, seconds spent responding, reinforcers obtained, and changeovers between the keys summed over the last five sessions of each experimental condition are shown in the Appendix. To demonstrate the operation of the feedback function, Figure 2 shows the obtained reinforcer rates (averaged across subjects) in Phases 1, 2, and 3 plotted as a function of the obtained relative time allocation. In Phase 1, the obtained rate of reinforcers remained constant with changing relative reinforcer rates at a value a little below the arranged maximum reinforcer rate (two per minute). In Phase 2, the maximum obtained reinforcer rate (about one reinforcer per minute) occurred in conditions producing equal preference, and the minimum rate (about 0.55 reinforcers per minute) occurred in conditions producing the most extreme preference. In Phase 3, the maximum reinforcer rate (about 1.3 reinforcers per minute) occurred in conditions producing the most extreme preference, and the minimum reinforcer rate (about 0.52 per minute) occurred in conditions producing equal preference. Figure 2 shows that the feed-

Fig. 3. Experiment 1. Log response ratios (B rows) and log time ratios (T rows) as a function of log obtained reinforcer ratios for each phase. The straight lines showed the locus of the best fitting equation (see Table 2 for the parameters of these equations). The data plotted are those given in the Appendix.

back functions shown in Figure 1 operated correctly at an ordinal level. As Figure 2 also shows, the variations in *mean* time allocation across conditions did not produce overall reinforcer rates as high as those set at the higher points of the feedback functions, nor did they produce reinforcer rates as low as those arranged at the lower points of the feedback functions. This is due to two factors. First, the subjects did not always obtain reinforcers when they were arranged. Second, and more important, in the feedback-function conditions, a dis-

tribution of local relative time-allocation measures is naturally produced. The obtained overall reinforcer rates are aggregates of the local overall reinforcer rates produced as outputs from the feedback functions (Figure 1). Hence, the obtained molar overall reinforcer rates for molar relative time allocations will be regressions toward the mean of the arranged feedback function.

The data plotted in Figure 3 show log behavior and time-allocation ratios as a function of log obtained reinforcer ratios for Phases 1,

Table 2

Experiment 1: The results of least-squares linear regression analyses carried out on data of the last five sessions of each condition from Phases 1, 2, and 3. VAC is the percentage of data variance accounted for.

Subject	Phase	Slope (SD)	Intercept (SD)	VAC
Response measures				
11	1	0.78 (0.09)	-0.07 (0.14)	95
11	2	0.70 (0.04)	-0.13 (0.06)	98
11	3	0.70 (0.06)	-0.09 (0.09)	97
12	1	0.90 (0.09)	0.14 (0.14)	96
12	2	0.70 (0.09)	-0.02 (0.13)	93
12	3	0.68 (0.06)	-0.12 (0.09)	96
13	1	0.92 (0.10)	-0.02 (0.14)	96
13	2	0.72 (0.13)	-0.28 (0.18)	88
13	3	0.64 (0.04)	-0.12 (0.07)	98
14	1	0.74 (0.08)	0.15 (0.13)	96
14	2	0.82 (0.07)	-0.03 (0.10)	97
14	3	0.82 (0.05)	0.10 (0.07)	99
15	1	0.58 (0.11)	0.01 (0.15)	87
15	2	0.72 (0.09)	0.09 (0.15)	95
15	3	0.81 (0.13)	0.19 (0.20)	91
16	1	0.64 (0.05)	0.00 (0.08)	97
16	2	0.72 (0.05)	-0.11 (0.07)	98
16	3	0.63 (0.06)	-0.07 (0.09)	96
Time measures				
11	1	0.91 (0.10)	-0.05 (0.15)	95
11	2	0.76 (0.06)	-0.07 (0.09)	97
11	3	0.82 (0.06)	-0.07 (0.08)	97
12	1	0.91 (0.13)	0.00 (0.21)	92
12	2	0.71 (0.03)	0.02 (0.04)	99
12	3	0.80 (0.06)	0.03 (0.09)	98
13	1	1.07 (0.11)	-0.10 (0.16)	96
13	2	0.82 (0.05)	-0.05 (0.06)	99
13	3	0.80 (0.09)	0.02 (0.14)	95
14	1	0.79 (0.11)	0.07 (0.17)	93
14	2	0.86 (0.05)	0.06 (0.08)	99
14	3	0.88 (0.03)	0.07 (0.05)	99
15	1	1.15 (0.07)	0.09 (0.09)	99
15	2	1.01 (0.13)	0.25 (0.23)	94
15	3	0.98 (0.20)	0.22 (0.30)	86
16	1	0.68 (0.11)	-0.01 (0.17)	91
16	2	0.75 (0.05)	-0.10 (0.07)	98
16	3	0.73 (0.08)	-0.06 (0.10)	96

2, and 3 for each individual subject. This figure also shows the best fitting straight lines, by the method of least squares, for each subject and measure. The parameters of the fits (that is, the values of *a* and log *c* in Equation 1) are shown in Table 2 along with the standard errors of the fit and the percentage of total data variance accounted for by the fit. As Table 2 shows, the fits of the straight lines to the data were generally excellent.

If the overall reinforcer rate obtainable on the concurrent VI VI schedules controlled performance, we expected that the value of *a* in

Equation 1 would be greater for Phase 3 (in which overall reinforcer rates increased for more extreme preference) than for Phase 2 (in which overall reinforcer rates decreased for more extreme preference). If the *a* values shown in Table 2 for Phases 2 and 3 are compared, the *a* values in Phase 3 were greater than those in Phase 2 for 3 of the 6 subjects for both measures, showing no significant difference. We also expected that sensitivity values for Phase 1 would be intermediate between the Phase 2 and 3 values. A nonparametric trend test gave $\sum S$ values of -2 and 0 for response and time measures respectively, again showing no significant trend.

However, the overall *a* values may not be a sensitive measure of control by overall reinforcer rate. The highest reinforcer ratio arranged was 9:1, and for absolute preferences greater than 9:1 the feedback function (Figure 1) was flat. Thus, focusing on the 7:3 and 3:7 reinforcer ratios (Conditions 8, 9, 13, 14, 17, and 18) provides data from a portion of the feedback function in which the relation between overall reinforcer rate and preference had a steep slope. It is not, however, appropriate to compare directly the log preference ratios for these conditions because, as calculations from the data in the Appendix show, the obtained reinforcer ratios for these conditions in the three phases were not equal. Thus, for each condition with a 7:3 or 3:7 arranged reinforcer ratio, a point estimate of *a* was calculated using Equation 1 and assuming that log *c* was zero. This assumption was not always met (see Table 2), but the measure is at least directionally useful. If the values from Phases 2 and 3 are compared, the estimated *a* values decreased between Phases 2 and 3 for 9 of the 12 comparisons. On a one-tailed binomial test with *p* = .05, this result, in the direction opposite to that expected, is nonsignificant. If overall reinforcer rate were controlling preference, we would also have expected an increasing trend in these estimates of *a* between Phases 2, 1, and 3 (in that order). A nonparametric trend test showed a nonsignificant trend (*z* = -0.92) in the opposite direction to that expected.

DISCUSSION

The results of Experiment 1 gave no indication whatsoever that preference between concurrent VI VI schedules was controlled by

the overall reinforcer rate that the subject could obtain. Although the present result is clear cut, it is, of course, difficult to prove the null hypothesis. One major point needs to be made, however. The failure of overall reinforcer rate to control preference in this experiment makes it very difficult to see how such control could be exercised in conventional concurrent VI VI schedules (e.g., Phase 1). The slopes of the feedback functions used here in Phases 2 and 3 were much greater than those that would be expected in conventional concurrent VI VI performance, except if the arranged reinforcer rate was very high indeed (cf. Staddon & Motheral, 1978). Thus, subjects' performances are very unlikely to be sensitive to the marginal returns in overall reinforcer rates around strict-matching values in conventional concurrent VI VI schedules.

The present results thus support and extend Vaughan's (1981) conclusion. Under both Vaughan's procedure and the present procedure, subjects did not change preference to maximize overall reinforcer rates. Preferences did not show even a minor tendency to be biased toward areas in the feedback function providing greater overall reinforcer rates. This finding has been obtained when feedback-function windows were either 4 min (Vaughan) or the duration of the interreinforcement interval (the present results). Also, as Herrnstein and Vaughan (1980) have shown, matching occurs on concurrent VI VI schedules even when there is no local maximum overall reinforcer rate at the point at which response ratios equal reinforcer ratios.

However, Silberberg and Ziriax (1985) argued that the 4-min window used by Vaughan (1981) was "well beyond extant demonstrations of pigeon memory for prior choices and their consequences" and suggested that a short-duration window would overcome this possible problem. In terms of data, Silberberg and Ziriax reported average slopes of 0.68 for both response- and time-allocation a values for a 4-min window procedure. These values replicated the results reported by Vaughan, and they are consistent with the results obtained here. However, with a 6-s window, they found lower slopes for all 4 subjects, with average a values of 0.38 and 0.27 for response and time measures, respectively. As Silberberg and Ziriax noted, the latter pair of data were quite unrepresentative of the usual values for a for

concurrent VI VI schedules (which have modal a values of about 0.8 for response measures and 1.0 for time measures; Baum, 1979; Taylor & Davison, 1983; Wearden & Burgess, 1982). The data from the 6-s window were also unrepresentative of the usual finding that time-allocation sensitivity is greater than response-allocation sensitivity (Taylor & Davison, 1983). In the present experiment, all 6 birds had time-sensitivity values greater than response-sensitivity values in Phases 1 and 2, with 4 of the 6 subjects showing the same differential in Phase 3 (Table 2). Although Vaughan's results argue strongly against molar maximizing with a 4-min window, Silberberg and Ziriax's results were, in fact, consistent with the notion that subjects maximized overall reinforcer rates with the 6-s window. Thus, their argument concerning the effective delay between behavior and its consequences could apply equally to control by dynamic changes in overall reinforcer rates. If the overall reinforcer rate changes that occurred soon after performance did control preference, one implication would be that, in conventional concurrent VI VI schedules, sensitivity to reinforcement would be greater with higher overall reinforcer rates, as was shown by Alsop and Elliffe (1988).

The molecular maximizing theory favored by Silberberg and Ziriax (1985) suggests that "animals allocate the times they spend responding . . . such that they maximize the reinforcement rates these interchangeover times . . . produce" (p. 84). This principle appears to make clear predictions for Phases 2 and 3 of the present experiment. For example, in Phase 3, when the probability of a left-key reinforcer was .5, a change in the time allocation away from an equality between the keys (toward either key) would increase the local interchangeover-time reinforcer rate on *both* keys. Such a time-allocation change should thus be maintained. Molecular maximizing predicts the same time-allocation changes for the 7:3 and 3:7 reinforcer ratios in Phase 3. The opposite change in time allocation can be derived for Phase 2. Because the feedback functions used in the present experiment did not produce variations in relative reinforcer rates, the molecular maximizing theory makes the same directional predictions here as does the molar maximizing theory. Evidently, neither is correct. However, the present results are

compatible with matching theory and with melioration theory, with the proviso that each must be able to predict deviations from matching in the direction of a values less than 1.0.

Experiment 2 continued the search for control by overall reinforcer rate by investigating control by an overall reinforcer rate feedback function using shorter windows. It remains possible that, in line with Silberberg and Zirrax's (1985) suggestion of memory failure mentioned above, maximizing overall reinforcer rate could occur, or occur more strongly, if the consequences of a local time allocation followed its emission more quickly.

EXPERIMENT 2

Experiment 2 was designed to generalize the results obtained from Experiment 1. The major change from Experiment 1 was that fixed windows, during which time allocation was measured and the overall reinforcer rate feedback function was applied, rather than variable interreinforcement intervals, were used. In view of the previous results reported by Vaughan (1981) and by Silberberg and Zirrax (1985), the focus of the experiment was on the variation of the fixed-time window from 5 s to 20 s. The results of Silberberg and Zirrax are consistent with the expectation that choice performance could be more sensitive to an overall reinforcer rate feedback function with a 5-s window than with a 20-s window, and that both of these performances might be more sensitive to the feedback function than when the feedback-function window was longer and variable (Experiment 1). A single overall reinforcer rate feedback function was used throughout Experiment 2 in which more extreme time-allocation ratios progressively decreased arranged overall reinforcer rate. The experiment commenced with a variation of the window from 20 s to 5 s over four conditions (Phase 1), with a constant reinforcer ratio, then the reinforcer ratio was varied over five levels with a 5-s window (Phase 2), and finally the same manipulation was carried out with a 20-s window (Phase 3).

METHOD

Subjects and Apparatus

The same 6 subjects at the same level of deprivation as in Experiment 1 were used in Experiment 2.

The experimental chamber was the same as used in Experiment 1, and all keylight, reinforcer, and other arrangements were the same as in Experiment 1. The contingencies of reinforcement were arranged by a PDP® 11/73 computer using SKED-11® software.

Procedure

Every second, the computer set up a reinforcer with a probability u , and arranged reinforcers were allocated to the left and right keys with a probability q . The probability per second of the first reinforcer was .032 (1.92 reinforcers per minute). Subsequent probabilities of reinforcers per second depended on the time-allocation ratio in the previous time window according to the following equation. If $|T_{i-1}|$ is the absolute time-allocation ratio (that is, the larger allocated time divided by the smaller allocated time) in window $i - 1$, p is the maximum reinforcer probability per second, and s is the slope of the feedback function, then the probability of reinforcement in the next (i th) window was

$$u_i = p + s(1 - |T_{i-1}|),$$

with $|T_{i-1}| = 9$ if $|T_{i-1}| > 9$. With $s = 0.002$, this equation provided a maximum probability of reinforcement, u , of .032 per second if the time-allocation ratio in the previous window was 1 (equal preference) and a minimum of .016 per second if the absolute time-allocation ratio was greater than or equal to 9. Because SKED-11® uses integers in the range 1 to 1,000 for probabilities, the feedback function used in Experiment 2 had 16 discrete steps on each side of the input time-allocation ratio of 1.0. It is graphed in Figure 4.

The sequence of experimental conditions is shown in Table 3. Condition 20 was used to develop an appropriate running program for the new computer. Because some minor modifications were made during this condition, the data are not reported here. In each condition, a maximum probability of reinforcement per second of .032 was arranged with a feedback-function slope of 0.002. In the first condition the window was 20 s, and the probability of reinforcement on the left key was .5. Then, in Condition 22 the left-key probability of reinforcement was .8, and the window was 20 s. Over Conditions 22 to 25, the window was decreased from 20 s through 15 s, 10 s, to 5 s. Conditions 25 to 29 varied the probability of

Fig. 4. Experiment 2. A graph of the feedback function used in Phases 1, 2, and 3, showing how the local relative time allocation within the time window controlled the average reinforcer rate in the next time window.

Fig. 5. Experiment 2. The overall number of reinforcers per minute obtained in Phases 2 and 3 as a function of the average relative time allocation across the last five sessions of each experimental condition. The data have been averaged over the 6 subjects.

left-key reinforcers from .1 through .2, .5, .8, to .9 with a window of 5 s. In Conditions 30 to 33 the window was 20 s, and the left-key reinforcer probabilities were again varied over the same range. Conditions 21 and 22 also contributed to this last data set, and Condition 32 was a replication of Condition 22.

The same stability criteria were used as in Experiment 1.

Table 3

Experiment 2: Sequence of experimental conditions, window duration, probability of a left-key reinforcer ($p(\text{rft}/L)$), sessions to stability, and the phase to which each condition contributed. The maximum probability of reinforcement was .032/s, and the slope of the feedback function was 2.

Condition	Window (s)	$p(\text{rft}/L)$	Sessions	Phase
21	20	.5	22	3
22	20	.8	19	1, 3
23	10	.8	28	1
24	15	.8	21	1
25	5	.8	27	1, 2
26	5	.1	23	2
27	5	.5	23	2
28	5	.9	21	2
29	5	.2	26	2
30	20	.9	28	3
31	20	.2	21	3
32	20	.8	21	3
33	20	.1	21	3

RESULTS

The numbers of responses emitted, seconds spent responding, reinforcers obtained, and number of switches are shown for each subject in the Appendix. These data were averaged over the final five sessions of each condition.

Figure 5 shows the group average obtained feedback function for Phases 2 and 3 of Experiment 2 as a function of the obtained relative time allocation. It is evident that the same feedback function produced much more change in overall reinforcer rates in Phase 3 (20-s window) than in Phase 2 (5-s window). The reason for this is that the instances of relative time allocations put into the feedback function would have had a much wider distribution with a 5-s window than with a 20-s window (Staddon, 1988; Vaughan, 1987a, 1987b). This cannot be shown directly, because the relevant data were not collected. However, the switching rates in Phase 3 were very similar to those in Phase 2 (Figure 6). They ranged from 2.5 (with a left-reinforcer probability of .5) to less than 1 (left-reinforcer probabilities of .1 and .9) switches per minute. The former rate implies an interchangeover time of 12 s, about half the feedback-function window in Phase 3 and more than twice the window in Phase 2. Thus it is evident that most 5-s windows in Phase 2 would have contained exclusive time-

Fig. 6. Experiment 2. The overall number of switches per minute from the left to right keys as a function of the relative time spent responding on the left key. The data have been averaged over the 6 subjects.

allocation measures, and hence the obtained reinforcers per minute (Figure 5) remained asymptotically low with variations in the reinforcer ratio.

Phase 1

Figure 7 shows the way in which both response- and time-allocation ratios changed as the window size was changed in Phase 1 from

Fig. 7. Experiment 2. Log response and time-allocation ratios as a function on the feedback-function window duration in Phase 1. The data have been averaged over the 6 subjects.

Fig. 8. Experiment 2. Log response ratios (upper panels) and log time ratios (lower panels) as a function of log obtained reinforcer ratios in Phase 2. The straight lines show the locus of the best fitting equation (see Table 4 for the parameters of these equations). The data plotted are those given in the Appendix.

5 s to 20 s (using grouped data). Trend tests showed that there was no significant directional change in these measures.

Phase 2

Figure 8 shows log response- and time-allocation ratios as a function of log obtained reinforcer ratios when the probability of reinforcement for a left-key response was varied from .1 to .9 in Phase 2. The lines on these graphs show the best fitting line by the method of least squares, and the values of the slopes and intercepts (a and $\log c$ in Equation 1) are shown in Table 4. The values of a and $\log c$ were similar to those found in Experiment 1, and in five of the six cases, time-allocation sensitivity was greater than response-allocation sensitivity (the exception was Bird 14). If the overall reinforcer rate produced by the feedback function was affecting preference, then following the logic outlined in Experiment 1 and taking into account the shape of the feedback function, we would have expected either lowered sensitivity values or an ogival

Table 4

Experiment 2: The results of least-squares linear regression analyses carried out on data of the last five sessions of each condition from Phases 2 and 3. VAC is the percentage of data variance accounted for.

Subject	Phase	Slope (SD)	Intercept (SD)	VAC
Response measures				
11	2	0.77 (0.03)	-0.08 (0.06)	100
11	3	0.83 (0.06)	-0.05 (0.11)	98
12	2	0.73 (0.03)	0.03 (0.05)	100
12	3	0.73 (0.07)	0.08 (0.13)	97
13	2	0.66 (0.05)	-0.06 (0.08)	98
13	3	0.67 (0.10)	-0.05 (0.16)	93
14	2	0.63 (0.07)	0.12 (0.13)	97
14	3	0.80 (0.02)	0.13 (0.04)	100
15	2	0.45 (0.01)	0.11 (0.02)	100
15	3	0.45 (0.05)	0.10 (0.07)	96
16	2	0.65 (0.03)	-0.03 (0.06)	99
16	3	0.70 (0.02)	0.01 (0.04)	100
Time measures				
11	2	0.92 (0.02)	-0.01 (0.04)	100
11	3	0.96 (0.07)	0.03 (0.13)	98
12	2	0.90 (0.05)	0.03 (0.08)	99
12	3	0.83 (0.06)	0.01 (0.12)	98
13	2	0.82 (0.10)	-0.10 (0.17)	95
13	3	0.99 (0.07)	-0.08 (0.12)	98
14	2	0.66 (0.06)	0.01 (0.12)	98
14	3	0.87 (0.05)	0.00 (0.08)	99
15	2	0.99 (0.06)	0.09 (0.09)	99
15	3	0.91 (0.11)	0.04 (0.17)	94
16	2	0.74 (0.06)	0.07 (0.10)	98
16	3	0.85 (0.08)	0.07 (0.13)	97

deviation from a straight line function between log preference and obtained log reinforcer ratios. (Sensitivity values were low for Bird 15, but this subject had also given the lowest response-allocation sensitivity in Experiment 1.) This deviation was expected to be concave upwards for log reinforcer ratios greater than zero and concave downwards for log ratios less than zero. As can be seen in Figure 8, the data showed no clear evidence of ogival deviations. An analysis of the deviations from the fitted lines between left-reinforcer probabilities of .1 and .2, and between .8 and .9, showed that only 3 of the 12 deviation differences were in the expected direction for response measures. Only one difference was in the expected direction for time measures. There was, therefore, no evidence that the feedback function applied with a 5-s window produced any differential control over preference. However, it must be noted that, as shown in Figure 5, the feedback function produced little change in molar obtained overall reinforcer rates as a

Fig. 9. Experiment 2. Log response ratios (upper panels) and log time ratios (lower panels) as a function of log obtained reinforcer ratios in Phase 3. The straight lines show the locus of the best fitting equation (see Table 4 for the parameters of these equations). The data plotted are those given in the Appendix.

function of mean preference. Three conditions arranged subsequent to Phase 3 used a considerably steeper feedback function (a maximum of six reinforcers per minute), with a 5-s window, in the hope of producing a wider variation in overall reinforcer rates. However, approximately one reinforcer per minute was obtained in each of the three probability of reinforcement conditions arranged (.1, .5, and .9). It is evident that the 5-s window duration simply did not allow the feedback function to control preference.

Phase 3

Figure 9 shows log response- and time-allocation ratios as a function of log obtained reinforcer ratios when the probability of reinforcement for a left-key response was varied from .1 to .9 in Phase 3. As in Figure 8, these graphs show the best fitting line by the method of least squares, and the values of the slopes and intercepts (a and $\log c$ in Equation 1) are shown in Table 4. The values of a and $\log c$ were again similar to those reported in Ex-

periment 1, and again Bird 15 showed an abnormally low response-allocation sensitivity value. Time-allocation sensitivities were greater than response-allocation sensitivities for all 6 birds. If overall reinforcer rate were affecting preference, the deviations of the data from the fitted lines would be in the same direction as in Phase 2, but an analysis of the deviations showed that only 4 of the 12 deviation differences were in the expected direction for both response and time measures. There is again, therefore, no evidence that overall reinforcer rate affected preference.

Comparing the results of Phases 2 and 3 shows that Phase 3 sensitivity estimates were greater than Phase 2 sensitivity estimates for 4 of the 6 subjects for both response- and time-allocation measures. Because this result is non-significant on a sign test, there therefore seemed to be no substantial differential effect of the duration of the feedback-function window, confirming the results of Phase 1 of Experiment 2.

GENERAL DISCUSSION

In the experiments reported here, we found no evidence of any control of preference by overall reinforcer rate. Preference did not move on the feedback functions in the direction of higher overall reinforcer rates. Second, short fixed-duration windows in which preference was measured that controlled reinforcer rates in the subsequent window did not potentiate control by the overall reinforcer rate feedback function. Third, we did not find differences between matching slopes for standard concurrent-schedule performance, variable-duration window performance (Experiment 1), or 20-s or 5-s fixed window durations (Experiment 2). On this basis, we can reject the theory (Rachlin et al., 1981; Staddon & Motheral, 1978) that animals distribute their behavior between alternatives so as to maximize, or even to increase, the obtained overall rate of reinforcers. We can also reject any notion that decreasing the time between choice behavior and its consequences affects control of choice by overall reinforcer rates.

The present data also allow us to reject Silberberg and Ziriax's (1985) molecular maximizing theory, which suggests that animals should emit interchangeover times that maximize the reinforcer rates in these times. In

Phases 2 and 3 of Experiment 1 and in Experiment 2, the subjects could increase their interchangeover-time reinforcer rates on *both* keys by changing preference away from one similar to the obtained reinforcer ratios. They did not do so.

Both melioration theory (Herrnstein & Vaughan, 1980; Vaughan, 1981) and matching theory described the present results. As it stands, melioration theory does not predict undermatching ($a < 1.0$) in concurrent VI VI schedules, and as a result it fails to describe both the present data and the general concurrent VI VI schedule results (Baum, 1979; Taylor & Davison, 1983; Wearden & Burgess, 1982). It does, however, provide predictions for these data that are directionally correct. For reasons extensively discussed by Vaughan (1987a, 1987b) and by Staddon (1988), it remains a tenable theory despite the results of Silberberg and Ziriax (1985). Matching theory, as described by Vaughan (1981), does not seem a tenable theory in light of Vaughan's results and those of Silberberg and Ziriax.

Finally, we return to the question that we posed earlier: Does overall reinforcer rate affect preference? Static results (Alsop & Elliffe, 1988) that report a relation between preference and overall reinforcer rate may chart a real relation, but one at a different level from that investigated here. There is a considerable difference between possibly changing preference to attain a higher reinforcer rate (as here) and showing a lesser preference between two differing schedules at lower overall reinforcer rates. The subjects in the Alsop and Elliffe experiment clearly had no choice about what reinforcer rates they received, unless it was to decrease them by not responding. If the effect that they reported operated in the present experiment, then any movement away from equal time allocation with U-shaped feedback functions should have been potentiated by an increasing a value. With inverted-U functions, any change should have been attenuated. Thus, the operation of their result implies exactly the sorts of change in sensitivity to reinforcement for which we have been looking and which we failed to find.

Behavior is typically under multidimensional, rather than unidimensional, control. Thus, the appropriate question to ask may not be which principle controls behavior allocation (i.e., which theory is correct), but (as in the

present research) how much do the various principles contribute to the control of choice. It appears from the present results that molar maximizing contributes nothing to concurrent-schedule performance, but this result cannot be generalized widely. However, research with concurrent-chain schedules shows that subjects do prefer higher reinforcer rates to lower reinforcer rates and more immediate reinforcers to less immediate reinforcers in some experimental procedures (see Davison, 1987). In other words, subjects change their preference between two alternatives toward that which produces the higher reinforcer rate. Thus, the appropriate question is: Under what conditions will preference be controlled by subsequent overall reinforcer rates? There is obviously a procedure, somewhere between the present procedure and the concurrent-chain schedule, in which overall reinforcer rate exerts some control. We have now commenced experiments to chart control by overall reinforcer rate in procedures in which preference in a discriminatively controlled choice phase determines reinforcer rate, via feedback function, in a subsequent outcome phase. It seems very likely that control will be found in such a procedure.

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APPENDIX

Numbers of responses emitted, overall responses per minute, relative response rates, times in seconds spent responding, reinforcers obtained, and changeovers from the left to the right keys summed over the last five sessions of each condition for each subject.

Condition	Responses		Responses/min		Rel- ative re- sponse rate	Seconds		Reinforcers		Change- over
	Left	Right	Left	Right		Left	Right	Left	Right	
Bird 11										
1	2,455	3,134	17.9	22.8	.44	3,321	4,915	102	98	350
2	3,802	782	31.2	6.4	.83	6,439	873	174	26	156
3	453	4,047	3.7	33.1	.10	560	6,784	10	190	78
4	3,756	4,653	18.7	23.2	.45	5,614	6,441	95	100	499
5	5,881	2,263	27.8	10.7	.72	10,348	2,360	111	17	319
6	1,207	7,180	5.7	33.8	.14	2,100	10,636	13	113	287
8	1,946	5,205	9.5	25.3	.27	3,717	8,634	62	123	377
9	3,761	2,579	18.3	12.5	.59	7,351	4,994	122	48	376
10	2,852	3,375	13.9	16.4	.46	5,259	7,080	90	89	352
11	2,332	2,305	11.7	11.5	.50	5,560	6,430	43	46	334
12	4,072	1,281	22.0	6.9	.76	9,034	2,055	170	25	200
13	1,934	4,278	9.2	20.3	.31	3,994	8,640	35	101	357
14	2,294	1,742	12.6	9.5	.57	6,611	4,355	81	31	242
15	671	4,385	4.4	28.4	.13	1,028	8,220	21	179	122
16	2,253	2,478	11.2	12.3	.48	6,132	5,981	58	45	313
17	1,134	3,705	7.8	25.6	.23	2,039	6,635	64	136	254
18	2,292	2,009	17.3	15.1	.53	4,442	3,527	126	74	386
19	2,295	2,181	17.2	16.4	.51	3,967	4,031	100	100	345
21	1,867	2,432	11.9	15.5	.43	4,387	5,053	94	106	358
22	3,411	1,536	19.2	8.6	.69	7,905	2,775	161	39	317
23	4,101	1,275	21.3	6.6	.76	8,710	2,848	153	38	248
24	4,703	871	26.3	4.9	.84	9,136	1,596	161	31	169
25	4,482	1,645	21.7	8.0	.73	9,501	2,871	143	36	281
26	614	5,021	3.0	24.3	.11	1,174	11,210	12	150	114
27	2,604	2,922	12.7	14.2	.47	5,659	6,690	86	92	440
28	3,547	648	17.4	3.2	.85	11,289	956	161	12	94
29	1,164	5,656	5.5	26.8	.17	2,187	10,462	26	138	183
30	4,445	723	21.3	3.5	.86	11,404	1,120	165	23	107
31	1,138	5,272	5.6	26.2	.18	2,260	9,834	39	157	175
32	4,471	1,662	22.8	8.5	.73	9,353	2,422	153	44	187
33	539	5,530	2.7	27.9	.09	889	11,015	9	166	91
Bird 12										
1	5,328	5,426	40.7	41.5	.50	4,197	3,655	93	107	483
2	10,200	749	84.9	6.2	.93	6,580	631	179	21	141
3	1,516	8,906	12.3	72.1	.15	863	6,547	13	187	200
4	10,636	7,043	54.9	36.4	.60	6,476	5,147	101	90	529
5	17,006	4,054	80.2	19.1	.81	10,562	2,157	103	11	290
6	4,690	16,173	22.1	76.1	.22	2,604	10,145	16	106	594
8	4,044	13,447	20.0	66.3	.23	3,904	8,258	49	140	703
9	12,708	8,662	67.2	45.8	.59	7,058	4,296	137	63	521
10	10,337	8,345	59.0	47.6	.55	6,220	4,300	110	81	541
11	9,325	12,322	43.5	57.5	.43	6,525	6,326	47	53	702
12	11,645	2,794	82.2	19.7	.81	7,497	1,008	185	15	225
13	6,736	11,244	31.7	53.0	.37	5,192	7,541	34	82	659
14	10,761	9,809	50.7	46.2	.52	8,606	4,141	85	42	575
15	1,467	11,125	9.4	71.6	.12	1,214	8,112	18	182	268
16	7,287	12,449	34.1	58.2	.37	5,242	7,598	46	58	669
17	4,714	8,016	34.7	59.0	.37	2,104	6,052	70	130	365
18	9,268	4,109	69.8	31.0	.69	5,138	2,826	136	64	486
19	6,339	4,479	48.2	34.0	.59	2,845	5,054	97	103	389
21	7,924	4,803	55.2	33.5	.62	3,391	5,215	89	111	536
22	9,661	2,783	54.2	15.6	.78	7,743	2,947	155	42	654

APPENDIX (Continued)

Condition	Responses		Responses/min		Relative re- sponse rate	Seconds		Reinforcers		Change- over
	Left	Right	Left	Right		Left	Right	Left	Right	
23	14,356	5,198	82.0	29.7	.73	8,215	2,291	164	36	511
24	11,792	3,346	62.8	17.8	.78	9,087	2,184	159	39	372
25	13,734	6,485	67.8	32.0	.68	9,008	3,143	144	56	396
26	2,064	11,292	9.8	53.9	.15	1,671	10,904	15	157	462
27	8,892	9,443	45.3	48.1	.48	5,530	6,251	96	96	645
28	15,443	3,250	86.6	18.2	.83	9,344	1,360	164	22	250
29	5,458	12,641	27.1	62.7	.30	2,506	9,599	39	159	430
30	12,556	1,675	60.0	8.0	.88	11,472	1,091	169	10	249
31	3,719	11,146	17.8	53.5	.25	3,259	9,251	31	169	380
32	13,504	4,456	69.0	22.8	.75	9,420	2,328	159	41	281
33	1,641	8,993	8.3	45.3	.15	1,434	10,489	19	180	298
Bird 13										
1	4,128	3,760	31.7	28.9	.52	3,765	4,040	102	98	320
2	6,566	643	51.1	5.0	.91	7,136	576	181	19	114
3	1,039	7,360	8.6	60.7	.12	540	6,732	21	179	87
4	5,945	6,514	28.9	31.6	.48	6,889	5,462	104	87	570
5	7,583	2,151	35.6	10.1	.78	10,982	1,799	109	10	433
6	1,965	11,619	9.3	54.7	.14	2,210	10,534	18	114	495
8	1,801	7,833	8.6	37.5	.19	3,905	8,625	65	117	495
9	3,888	6,905	19.0	33.7	.36	7,946	4,351	128	57	556
10	3,087	6,871	17.5	38.9	.31	4,216	6,377	82	112	549
11	2,603	3,992	12.4	18.9	.39	6,378	6,265	43	51	494
12	4,016	914	31.5	7.2	.81	6,968	690	186	14	142
13	3,217	6,582	15.1	30.9	.33	4,869	7,900	33	92	472
14	4,923	4,569	23.2	21.5	.52	7,695	5,051	89	38	595
15	1,103	5,709	6.6	34.0	.16	1,751	8,319	22	178	253
16	2,302	3,962	10.8	18.6	.37	4,311	8,440	46	67	476
17	2,240	4,684	16.4	34.2	.32	2,104	6,114	52	148	368
18	4,003	2,879	31.0	22.3	.58	4,042	3,711	138	62	416
19	2,782	4,200	22.8	34.4	.40	2,836	4,491	99	101	310
21	2,648	5,291	19.9	39.7	.33	2,780	5,216	92	108	330
22	8,616	3,109	48.6	17.6	.73	8,627	2,001	161	39	308
23	7,931	2,450	41.2	12.7	.76	9,484	2,058	166	28	313
24	7,493	2,940	42.2	16.5	.72	8,259	2,407	151	48	340
25	7,090	3,515	33.9	16.8	.67	9,453	3,109	144	48	385
26	1,697	8,202	8.2	39.6	.17	1,647	10,786	17	174	268
27	5,682	5,084	27.2	24.3	.53	5,983	6,555	103	85	619
28	8,180	2,002	38.8	9.5	.80	10,549	2,085	161	13	292
29	2,554	9,145	12.2	43.6	.22	1,827	10,768	38	150	295
30	5,819	1,875	27.9	9.0	.76	10,739	1,792	181	19	192
31	2,724	6,631	13.0	31.7	.29	2,056	10,480	39	158	231
32	6,413	1,906	30.8	9.1	.77	10,048	2,464	158	42	290
33	1,721	8,034	8.8	41.0	.18	1,221	10,528	21	179	215
Bird 14										
1	7,880	4,418	62.8	35.2	.64	5,071	2,453	100	100	372
2	8,628	1,060	78.8	9.7	.89	6,027	541	188	12	131
3	2,411	10,532	19.0	83.1	.19	1,654	5,952	23	177	222
4	7,785	7,309	47.9	45.0	.52	5,394	4,359	99	101	470
5	14,385	2,225	67.4	10.4	.87	11,557	1,247	92	10	304
6	2,686	15,991	12.8	76.0	.14	1,695	10,928	10	106	238
8	4,281	14,606	21.2	72.2	.23	4,115	8,020	52	138	448
9	12,006	6,296	62.5	32.8	.66	7,810	3,707	136	48	514
10	6,615	6,293	42.5	40.4	.51	5,139	4,203	106	94	516
11	8,025	6,577	37.6	30.8	.55	7,604	5,199	60	57	545
12	11,716	1,535	87.0	11.4	.88	7,224	855	183	17	195

APPENDIX (Continued)

Condition	Responses		Responses/min		Relative re- sponse rate	Seconds		Reinforcers		Change- over
	Left	Right	Left	Right		Left	Right	Left	Right	
13	5,547	9,901	26.4	47.1	.36	3,876	8,726	39	115	466
14	12,423	3,409	68.6	18.8	.78	8,418	2,450	150	48	374
15	2,072	10,864	12.6	66.3	.16	1,382	8,453	21	178	191
16	10,727	6,377	50.4	29.9	.63	7,155	5,621	66	59	489
17	3,821	4,458	31.9	37.3	.46	2,218	4,958	61	139	345
18	8,967	2,407	72.3	19.4	.79	4,939	2,507	143	57	407
19	6,445	5,039	53.0	41.4	.56	3,295	4,008	99	101	342
21	7,766	5,557	55.3	39.6	.58	3,995	4,433	104	96	347
22	12,232	3,294	83.6	22.5	.79	6,287	2,494	155	45	305
23	13,920	3,864	82.5	22.9	.78	7,349	2,774	155	45	354
24	12,693	2,864	75.4	17.0	.82	7,700	2,405	161	39	279
25	13,702	3,300	70.7	17.0	.81	8,719	2,911	153	47	390
26	2,574	12,767	12.5	62.2	.17	1,638	10,687	8	174	160
27	10,204	7,520	54.2	40.0	.58	5,762	5,526	104	96	498
28	16,678	3,141	79.5	15.0	.84	10,457	2,123	176	13	367
29	5,038	11,648	24.2	56.1	.30	2,854	9,613	35	145	313
30	12,849	1,616	65.0	8.2	.89	10,453	1,416	179	18	216
31	3,252	8,457	17.0	44.2	.28	2,698	8,781	38	162	223
32	11,803	2,795	59.6	14.1	.81	9,489	2,393	157	43	257
33	2,553	10,977	12.2	52.6	.19	1,556	10,962	19	181	210
Bird 15										
1	4,678	7,069	37.8	57.1	.40	3,735	3,697	105	95	487
2	4,720	1,812	38.8	14.9	.72	6,642	655	172	28	142
3	862	3,777	7.0	30.6	.19	619	6,779	18	182	104
4	6,833	3,010	35.9	15.8	.69	5,339	6,090	102	82	500
5	4,087	376	20.2	1.9	.92	11,879	269	85	4	47
6	1,199	4,677	5.6	22.0	.20	2,154	10,617	10	105	390
8	3,824	8,570	19.0	42.6	.31	5,275	6,791	62	136	468
9	4,555	2,775	21.6	13.1	.62	10,388	2,279	81	42	321
10	5,477	3,820	26.1	18.2	.59	9,324	3,261	86	74	431
11	6,306	3,655	29.8	17.3	.63	8,539	4,154	75	65	464
12	5,648	716	42.6	5.4	.89	7,338	624	181	19	106
13	4,388	4,380	20.5	20.5	.50	7,150	5,673	20	76	539
14	5,691	1,820	27.1	8.7	.76	10,068	2,531	126	53	286
15	734	5,101	4.9	34.1	.13	655	8,324	20	180	88
16	6,937	3,887	32.5	18.2	.64	8,213	4,581	53	52	453
17	4,104	4,258	34.4	35.7	.49	2,359	4,804	65	135	411
18	4,690	2,456	35.5	18.6	.66	6,147	1,781	141	59	277
19	5,321	3,720	42.3	29.6	.59	4,883	2,656	106	94	385
21	6,027	3,632	37.8	22.8	.62	6,548	3,007	118	82	387
22	5,510	2,121	34.9	13.4	.72	7,614	1,867	152	48	231
23	5,977	3,547	31.0	18.4	.63	8,936	2,646	148	49	345
24	5,331	2,262	31.0	13.1	.70	8,526	1,799	168	32	235
25	5,108	2,060	24.3	9.8	.71	10,812	1,812	145	35	220
26	1,472	3,392	7.0	16.1	.30	1,350	11,283	14	159	195
27	5,563	4,306	27.1	21.0	.56	6,870	5,459	92	101	411
28	5,949	1,812	29.3	8.9	.77	10,911	1,269	164	20	178
29	3,380	4,488	16.3	21.7	.43	3,119	9,294	49	144	435
30	4,559	2,172	22.2	10.6	.68	9,672	2,651	157	32	253
31	2,477	3,673	11.9	17.6	.40	2,237	10,286	45	151	261
32	5,203	2,593	24.9	12.4	.67	9,165	3,357	151	49	251
33	1,658	3,590	8.4	18.1	.32	1,770	10,131	18	178	211
Bird 16										
1	5,203	5,125	33.7	33.2	.50	3,502	5,758	101	83	325
2	8,130	1,649	61.9	12.5	.83	6,752	1,133	179	21	178
3	2,014	8,259	16.2	66.5	.20	1,437	6,019	15	185	196

APPENDIX (Continued)

Condition	Responses		Responses/min		Rel- ative re- sponse rate	Seconds		Reinforcers		Change- over
	Left	Right	Left	Right		Left	Right	Left	Right	
4	5,841	7,903	29.5	40.0	.42	4,481	7,379	69	91	325
5	9,233	2,298	46.4	11.6	.80	9,865	2,063	101	9	198
6	1,788	12,019	8.7	58.4	.13	1,695	10,646	10	92	180
8	4,907	13,276	23.9	64.5	.27	3,205	9,139	46	97	405
9	11,659	7,596	56.6	36.9	.61	7,809	4,558	119	48	445
10	7,719	10,724	39.6	55.0	.42	4,956	6,748	82	116	442
11	6,457	7,851	30.5	37.1	.45	5,928	6,785	53	47	397
12	11,818	3,128	70.8	18.8	.79	8,339	1,670	175	24	261
13	5,510	11,381	26.1	53.9	.33	3,645	9,014	38	122	417
14	7,443	7,245	35.2	34.3	.51	6,549	6,140	79	42	331
15	2,682	11,265	17.1	72.0	.19	1,617	7,767	21	179	200
16	6,962	8,390	32.7	39.4	.45	5,635	7,150	61	52	454
17	3,939	8,521	31.7	68.6	.32	2,220	5,231	50	150	283
18	7,415	5,597	58.8	44.4	.57	4,602	2,964	129	71	398
19	6,026	6,907	46.2	53.0	.47	3,955	3,863	100	100	317
21	6,276	7,225	40.7	46.8	.46	4,529	4,724	90	110	327
22	10,570	4,780	60.3	27.3	.69	7,856	2,668	154	46	306
23	10,782	4,284	60.1	23.9	.72	8,548	2,225	165	35	281
24	10,778	3,391	65.4	20.6	.76	8,011	1,881	163	37	219
25	12,146	4,366	57.9	20.8	.74	10,342	2,247	147	36	281
26	3,575	13,830	17.5	67.9	.21	2,939	9,288	26	169	222
27	9,092	7,997	45.5	40.0	.53	6,864	5,123	111	87	379
28	12,768	2,433	63.9	12.2	.84	10,675	1,315	173	10	209
29	4,008	12,141	20.3	61.6	.25	2,705	9,125	32	167	291
30	12,284	2,670	59.5	12.9	.82	10,827	1,567	174	19	203
31	3,307	10,063	17.0	51.7	.25	3,361	8,322	30	167	215
32	10,814	4,358	51.8	20.9	.71	9,912	2,607	150	50	254
33	2,324	11,353	11.2	54.6	.17	1,439	11,047	20	180	160