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A COMPARISON OF DELAYS AND RATIO REQUIREMENTS IN SELF-CONTROL CHOICE

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In a discrete-trial procedure, pigeons could choose between 2-s and 6-s access to grain by making a single key peck. In Phase 1, the pigeons obtained both reinforcers by responding on fixed-ratio schedules. In Phase 2, they received both reinforcers after simple delays, arranged by fixed-time schedules, during which no responses were required. In Phase 3, the 2-s reinforcer was available through a fixed-time schedule and the 6-s reinforcer was available through a fixed-ratio schedule. In all conditions, the size of the delay or ratio leading to the 6-s reinforcer was systematically increased or decreased several times each session, permitting estimation of an "indifference point," the schedule size at which a subject chose each alternative equally often. By varying the size of the schedule for the 2-s reinforcer across conditions, several such indifference points were obtained from both fixed-time conditions and fixed-ratio conditions. The resulting "indifference curves" from fixed-time conditions and from fixed-ratio conditions were similar in shape, and they suggested that a hyperbolic equation describes the relation between ratio size and reinforcement value as well as the relation between reinforcer delay and its reinforcement value. The results from Phase 3 showed that subjects chose fixed-time schedules over fixed-ratio schedules that generated the same average times between a choice response and reinforcement.

Key words: self-control, amount of reinforcement, delay of reinforcement, fixed ratio, adjusting procedure, key peck, pigeons

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We speak of self-control in situations that involve choice between large, delayed reinforcers and smaller, more immediate reinforcers (Ainslie, 1974). Thus, an animal is said to behave impulsively if it forgoes a larger reinforcer by choosing the reinforcer that is less delayed but smaller. Conversely, it is said to demonstrate self-control if it chooses the reinforcer that is larger but more delayed.

We begin with the assumption that an animal's behavior in a self-control situation depends on the relation between a reinforcer's delay and the resulting reinforcement value (i.e., effectiveness in sustaining instrumental responding). A number of different functions relating reinforcement delay and value have been proposed (see Ainslie, 1975). For example, Chung (1965) proposed a negative exponential function, whereas Baum and Rachlin (1969) proposed a reciprocal function. The empirical findings that served as a basis for these speculations were obtained primarily with concurrent-chains procedures in which the initial links of the chains consisted of variable-interval (VI) schedules, and the terminal links were simple delays. An advantage of this type of concurrent-chains procedure is that responding in the initial links can be used as a measure of relative preference. However, a disadvantage is that relative response rates in this type of procedure have been shown to vary with factors unrelated to the terminal-link schedules (Snyderman, 1983), including the length of the initial links (Fantino, 1969).

In an attempt to avoid some of the difficulties of the usual concurrent-chains procedure, Mazur (in press) used a variation of this procedure in which the initial links were kept as brief as possible. In this discrete-trial procedure, a pigeon's single key peck constituted choice between two alternative situations. On each trial, a subject chose between a *standard alternative,* for which the contingencies (delay and amount) were constant within a condition, and an *adjusting alternative,* for which the delay repeatedly changed depending upon

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the subject's previous choices. The adjusting delay eventually stabilized around a value that was termed the indifference point—a delay at which the subject showed no preference between the two alternatives.

Mazur's (in press) results were most consistent with the following hyperbolic equation:

$$V_i = \frac{A_i}{1 + Kd_i}, \quad (1)$$

where V_i is the value of alternative i, A_i is monotonically related to the magnitude of the reinforcer, d_i is the delay between a choice response and reinforcement, and K is a free parameter. To arrive at this conclusion, Mazur defined the indifference point,

$$V_6 = V_2, \quad (2)$$

where the subscripts refer to 6-s and 2-s reinforcer durations. It follows from Equations 1 and 2 that at the indifference point,

$$\frac{A_6}{1 + Kd_6} = \frac{A_2}{1 + Kd_2}. \quad (3)$$

Solving for d_6, we obtain,

$$d_6 = \frac{A_6 - A_2}{KA_2} + \frac{A_6}{A_2}d_2. \quad (4)$$

Equation 4 implies that if d_6 is plotted as a function of d_2, the resulting "indifference curve" should be linear, with a positive y intercept and a slope greater than 1.0 (inasmuch as A_6 is greater than A_2). Figure 1 illustrates the type of results predicted by Equation 4 when d_2 is varied across conditions. In contrast, Figure 1 shows that an exponential equation of the form $V_i = A_i e^{-Kd_i}$ predicts a linear function with a positive y intercept but with a slope of 1.0 regardless of the reinforcer magnitudes. A simple reciprocal function of the form $V_i = A_i/Kd_i$ predicts a linear function with slopes other than 1.0 but with a y intercept of 0. Mazur's results were consistent with the predictions of Equation 4, but not with those of the exponential or reciprocal equations.

The present experiment was designed to gain a better understanding of Equation 1 and to test its generality by substituting fixed-ratio (FR) schedules for the simple delays of Mazur's (in press) procedure. In Phase 1 of the experiment, the standard alternative was an FR schedule with a 2-s reinforcer, and the adjusting alternative was an FR schedule with a 6-s reinforcer. The size of the FR for the standard alternative was varied across conditions. One possible outcome is that the results could be described by a variation of Equation 4 in which ratio requirements replace delays. This would suggest that Equation 1 is applicable to response requirements as well as to simple delays. However, it is also possible that some other function describes the relation between FR size and value of a transition into the FR. In a similar experiment employing a concurrent-chains procedure, Schwartz (1969) obtained results consistent with a simple reciprocal relation between FR size and value.

A number of previous studies have suggested that simple ratio schedules might be evaluated in terms of their times to completion (Herrnstein, 1964b; Killeen, 1969; Neuringer & Schneider, 1968). That is, these studies suggested that the controlling variable in a ratio schedule is not the number of responses required, but rather, the time required to complete that ratio. For convenience, we will call this the *completion-time* hypothesis. If this hypothesis is correct, it might be possible to use Equation 4 without modification to describe the results of this experiment by using as d_i the time between a choice of an alternative and the completion of the ratio. The results of Phase 1 were used to make a preliminary test of the completion-time hypothesis, while the remaining phases of the experiment provided more stringent tests. In Phase 2, simple delays (or what may be called fixed-time [FT] schedules) were used instead of FR requirements, as in Mazur's (in press) experiment. This allowed within-subject comparisons of choices involving two FR schedules and those involving two FT schedules. In Phase 3, the standard alternative was an FT schedule leading to a 2-s reinforcer, and the adjusting alternative was an FR schedule leading to a 6-s reinforcer. According to the completion-time hypothesis, the time to complete the adjusting FR at the indifference point should be the same as if the choice involved two FT schedules (as in Phase 2). Finally, Phase 4 entailed conditions similar to those of Phases 1 and 2 to determine whether the order in which the conditions were presented might have affected the subjects' performances.

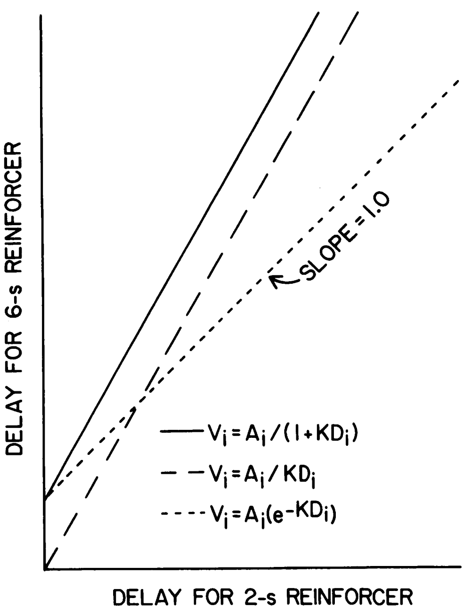

Fig. 1. For a choice between a delayed 2-s reinforcer and a delayed 6-s reinforcer, the types of indifference curves predicted by three different equations relating reinforcement delay (d_i) and reinforcement value (V_i).

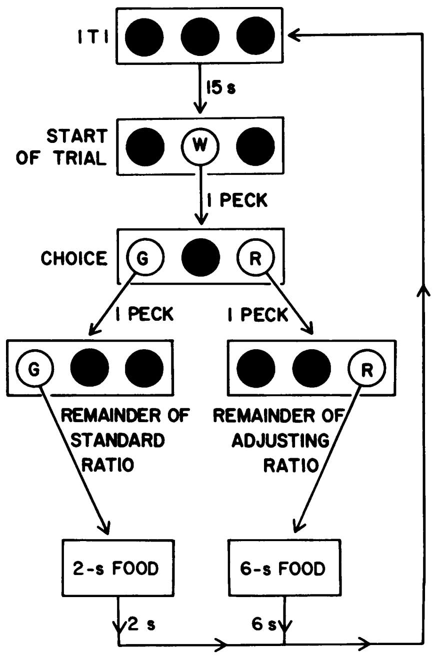

Fig. 2. A schematic diagram of the sequence of events on a free-choice trial in FR–FR conditions.

METHOD

Subjects

The subjects were 3 White Carneaux pigeons (numbers 268, 377, and 239) and 1 racing pigeon (number 331) maintained at 80% of their free-feeding weights. All had previous experience with a variety of experimental procedures.

Apparatus

The experimental chamber was 30 cm long, 32 cm wide, and 32 cm high. Three response keys, each 2 cm in diameter and 7 cm apart (center to center), were mounted on the front wall of the chamber, 24 cm above the floor. A force of approximately 0.10 N was required to operate each key, and each effective response produced a feedback click. A hopper below the center key, 5 cm above the floor, was equipped with two 6-W white lights, which were illuminated as the hopper was raised to make grain available. Four 6-W lights (two red and two green) were mounted above the wiremesh ceiling of the chamber near the front wall. A 6-W white houselight was mounted above the ceiling towards the back wall of the chamber and was illuminated throughout a session except when reinforcement was delivered. The chamber was enclosed in a sound-attenuating box that contained a speaker producing continuous white noise to mask extraneous sounds. A PDP®-8 computer in another room used a SUPERSKED® program to control the stimuli and to record responses.

Procedure

Prior to the actual experiment, all subjects were trained on FR schedules of gradually increasing response requirements. During this training, the color of the illuminated key was varied randomly from trial to trial to deter a color preference from developing before the experiment began. The duration of reinforcement was varied randomly between 2 s and 6 s.

The experiment consisted of 16 conditions. Throughout the experiment, a green key accompanied the standard alternative, and the reinforcer for this alternative was always 2 s in duration. A red key accompanied the adjusting alternative, and the reinforcer for this alternative was always 6 s in duration. Each experimental session ended after 60 trials or 60 min, whichever came first. The 60 trials were divided into six blocks of 10 trials. Within

Table 1

Order of experimental conditions and number of sessions per condition.

Phase	Condition	Standard schedule	Adjusting schedule	Number of sessions per subject #268	#377	#239	#331
1	1	FR 20	FR	18	34	18	32
	2	FR 5	FR	16	21	28	16
	3	FR 40	FR	31	20	31	21
	4	FR 10	FR	17	17	19	18
2	5	FT 0.88 s	FT	24	15	23	14
	6	FT 15.73 s	FT	16	19	14	22
	7	FT 2.26 s	FT	15	25	20	16
	8	FT 8.24 s	FT	14	21	17	22
	9	FT 20.00 s	FT	15	16	20	14
3	10	FT 20.00 s	FR	15	20	19	14
	11	FT 8.24 s	FR	14	14	14	14
	12	FT 15.73 s	FR	14	19	14	15
4	13	FR 40	FR	14	16	14	14
	14	FT[a]	FT	21	15	19	22
	15	FR 40	FR	18	16	17	17
	16	FT[a]	FT	20	25	14	23

[a] In Condition 14, the standard-key delays for the 4 subjects were, respectively, 14.50 s, 18.69 s, 17.89 s, and 12.88 s. In Condition 16, the standard-key delays were, respectively, 15.48 s, 15.91 s, 17.31 s, and 13.27 s.

each block, the first two trials were forced-choice trials and the next eight were free-choice trials, as described below.

Phase 1: FR–FR choices (Conditions 1–4). Figure 2 diagrams the sequence of events on a free-choice trial. After a 15-s intertrial interval (ITI) during which only the white houselight was lit, a trial began with the illumination of the white center key. A peck on this key was required so that the subject's head would not be close to one of the side keys when the choice period began. A center key peck darkened this key and illuminated both side keys, one red and one green, with the positions of these colors randomized across trials to control for any position preference. As soon as the pigeon pecked one of the two colored keys, it was committed to its choice; the light on the other key immediately extinguished, and the pigeon was required to complete the ratio on the chosen key before another trial began. Completion of the ratio resulted in the darkening of the keylight and the white houselight, and the presentation of grain. After reinforcement, the next ITI began.

The procedure on forced-choice trials was the same as on free-choice trials, except that only one side key was illuminated, either red or green, after a center key peck, and the subject was required to complete the ratio on this key. Of the two forced-choice trials in each block, one involved the red key and the other the green key. The order of presentation of these two colors varied randomly across blocks.

In the four conditions of Phase 1, four different FR schedules were presented as the standard alternative, as shown in Table 1. The FR schedule for the adjusting key could change after each block of 10 trials, depending on the pigeon's eight free choices. If the bird chose the red key fewer than three times in a given block of eight choices, the adjusting ratio decreased by five responses in the subsequent block (to a minimum of FR 5). If the bird chose the red key more than five times in a given block, the ratio subsequently increased by five responses. If the adjusting key was chosen between three and five times, the ratio remained unchanged for the subsequent block of 10 trials. These rules for adjusting the ratio held both within sessions and across them, from the last block of one session to the first block of the next day's session. In the first session of the experiment, the adjusting-key FR was initially set at FR 5.

Each condition lasted a minimum of 14 sessions and was terminated when three stability criteria were met: (1) Neither the highest nor the lowest single-session mean adjusting-key ratio could occur in the last five sessions of a condition; (2) the mean adjusting-key ratio of the last five sessions could not be the highest nor the lowest five-session mean of the condition; (3) the mean adjusting-key ratio of the last five sessions could not differ by more than 10% from the mean ratio across the preceding five sessions.

Phase 2: FT–FT choices (Conditions 5–9). The conditions of this phase were similar in all respects to those of Phase 1 except that FT schedules replaced the FR schedules. That is, after a single response on the green key, both keylights were extinguished, and the standard delay began. During this delay, the white houselights were off, and the green houselights were lit. At the end of the standard delay, the green houselights were extinguished and grain was presented for 2 s. Similarly, after a single response on the red key, both keylights were extinguished, the adjusting delay began, and the red houselights were lit. At the end of the adjusting delay, the red houselights were extinguished and grain was presented for 6 s.

Table 1 shows the standard delay for each condition. The particular delays chosen for Conditions 5 to 8 corresponded to the average times previously taken to complete the standard FR schedules in Conditions 1 to 4. More precisely, the geometric mean of the times between a choice response and reinforcement on the standard key during the last five sessions of a condition was calculated for each subject. The delays in Conditions 5 to 8 are the group means of these four geometric means.

After each block of 10 trials, the adjusting-key delay might be incremented or decremented by 1 s according to the same rules used during Phase 1. Each condition lasted for a minimum of 14 sessions and was terminated when the three stability criteria used in Phase 1 (but applied to the adjusting-key delays instead of ratios) were met.

Phase 3: FT–FR choices (Conditions 10–12). In Conditions 10, 11, and 12, the consequences of choosing the standard key were the same as those of Conditions 9, 8, and 6, respectively: A fixed delay with a green houselight was followed by a 2-s reinforcer. The adjusting alternative was an FR schedule, as in Phase 1. The criteria for changing the size of the adjusting FR and for terminating each condition were identical to those of Phase 1.

Phase 4: FR–FR choices and FT–FT choices (Conditions 13–16). Conditions 13 and 15 were identical to Condition 3, with an FR 40 schedule as the standard alternative. Conditions 14 and 16 included FT schedules as both the standard and adjusting alternatives, as in Phase 2. In Condition 14, the standard delay for each subject was set equal to the geometric mean of that subject's times to complete the FR 40 schedule in the last five sessions of Condition 13. Similarly, the standard delays in Condition 16 were set to the geometric means of the completion times in Condition 15. In all other respects, these conditions were identical to those of Phases 1 and 2, respectively.

RESULTS

The right side of Table 1 lists the number of sessions needed for each subject to satisfy the stability criteria in each condition. All analyses were based on the last five sessions of a condition, and the average value of the adjusting ratio or delay in these five sessions was used as a measure of the indifference point for that condition. In all conditions, subjects usually pecked at the center key and then at a side key within a few seconds after these keys were lit. For each subject, geometric means of the response latencies on the choice keys were calculated for both the standard and adjusting alternatives in every condition. In 113 of 128 cases, the latencies were less than 2 s. All 15 cases with average latencies greater than 2 s involved conditions in which the standard-key schedule was either FR 20 or FR 40. In other words, the longest choice latencies occurred in conditions in which the large ratios were in effect.

Figure 3 presents the mean adjusting-key ratios for each subject and for the group mean from Conditions 1 to 4, plotted as a function of the size of the FR on the standard key. Without exception, adjusting-key ratios increased monotonically with increasing standard-key ratios. The lines fitted to the data points are the best fitting regression lines, and the equations for these lines are shown in each panel along with the percentages of variance accounted for by them. The results for each subject are well described by these lines, all of which have intercepts greater than 0 and slopes greater than 1.0.

Figure 4 compares the results from the FR

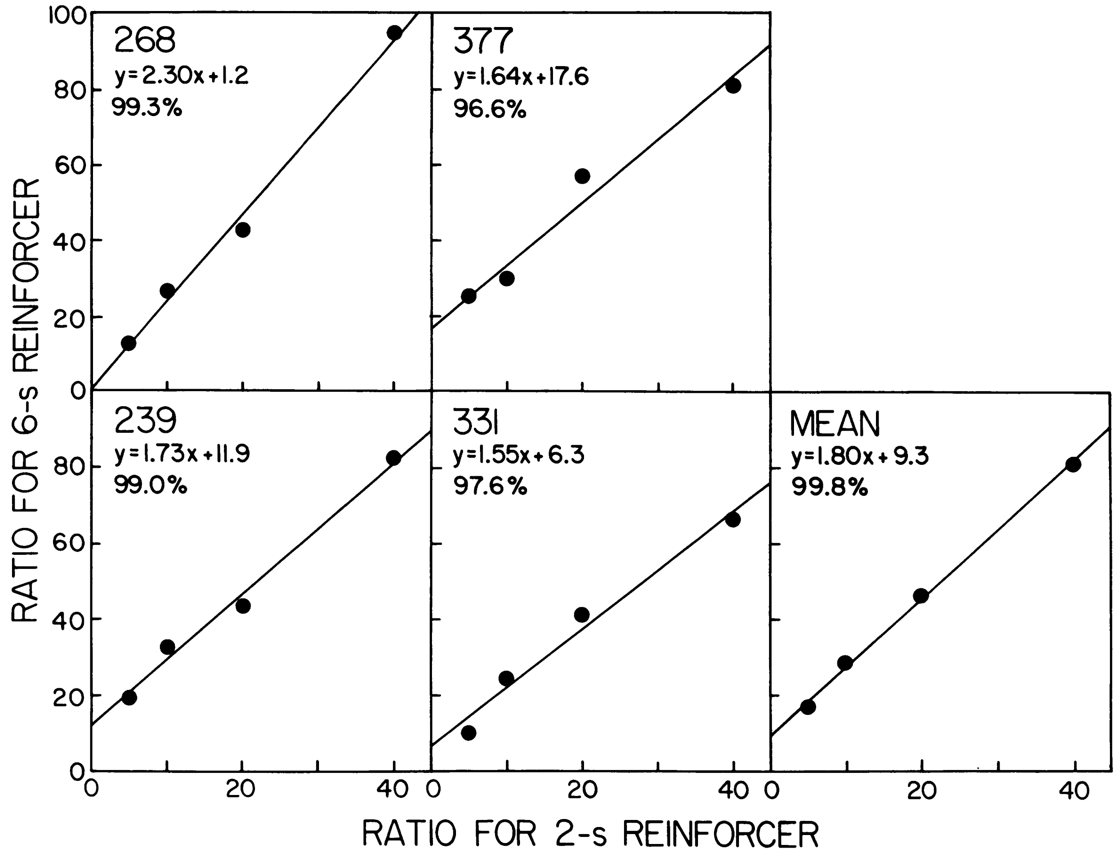

Fig. 3. Mean adjusting-key ratios are plotted as functions of standard-key ratios for the four FR–FR conditions of Phase 1. The lines are the best fitting regression lines. Each panel shows the linear equation and the percentage of variance it accounts for.

schedules of Phase 1 and the FT schedules of Phase 2 by plotting the average times between a choice response and the delivery of the reinforcer. Geometric means were used to calculate these and all other average durations presented in this article. This was done to minimize the influence of occasional trials that included unusually long times to complete the ratio requirements (which might occur, for instance, if a subject stopped responding for some period of time in the middle of a ratio). The *x* axis shows the average time between a choice response and the 2-s reinforcer, and the *y* axis shows the average time between a choice response and the 6-s reinforcer. The filled circles are from the FR conditions, and the solid lines are the best fitting regression lines for these data. The open circles and dashed lines show the results and regression lines from the FT conditions of Phase 2. The indifference points from both phases were well described by the regression lines, and in all cases the *y* intercepts were positive. The delays for the first four FT conditions were chosen to be the same as the mean completion times in the FR conditions, so that the group means could be easily compared. Figure 4 shows that there were virtually no differences between the group results from the FR and FT conditions. However, the results from individual subjects did exhibit differences, albeit inconsistent, between the FR and FT conditions. The slopes of the regression lines were higher in the FR conditions for Subjects 268 and 239, but they were lower for Subjects 377 and 331 (although the two regression lines for Subject 331 were very similar).

The three conditions of Phase 3 used the same standard-key FT schedules as three of the conditions of Phase 2, but the adjusting

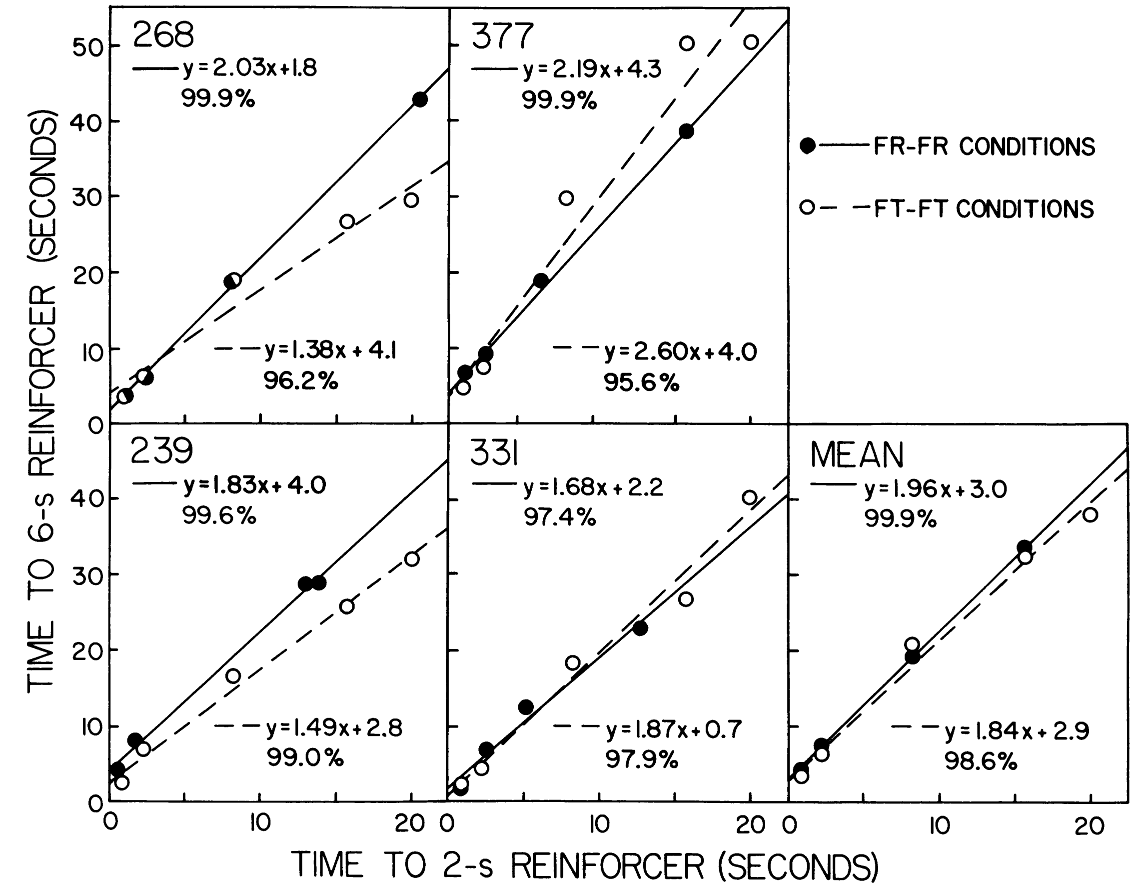

Fig. 4. Geometric means of the times between a choice response and reinforcement in the FR–FR conditions of Phase 1 and the FT–FT conditions of Phase 2. The lines are the best fitting regression lines for Phase 1 (solid lines) and Phase 2 (dashed lines). Each panel shows the equations for both lines and the percentages of variance they account for.

schedule was an FR rather than an FT. Figure 5 presents the results from Phase 3. The filled circles show the mean times to complete the adjusting FR (which produced a 6-s reinforcer) as a function of the FT schedule on the standard key (which produced a 2-s reinforcer). The open circles in Figure 5 repeat the results from the three corresponding FT–FT conditions. The lines in each panel are the best fitting regression lines. If the imposition of a ratio requirement in place of an FT schedule decreased the value of the adjusting alternative, this would result in shorter times to the 6-s reinforcer in Phase 3 than in Phase 2. Figure 5 shows that the mean times to the 6-s reinforcer were shorter in 11 of 12 cases, but the sizes of these decreases varied considerably among subjects. The decreases were substantial for Subjects 377 and 331, but not for Subjects 268 and 239. Overall, Figure 5 shows that the replacement of simple delays with ratio requirements usually led to reductions in the times to the larger reinforcer, and these reductions tended to be larger with longer delays on the standard key.

The conditions of Phase 4 were included to provide temporally adjacent comparisons of FR and FT conditions that involved long delays between a choice response and reinforcement. The results from individual subjects in Figure 4 suggested that there might be differences in the slopes of the indifference curves from FR and FT conditions. However, because the FR conditions were all in Phase 1 and the FT conditions were all in Phase 2, the discrepancies between these conditions

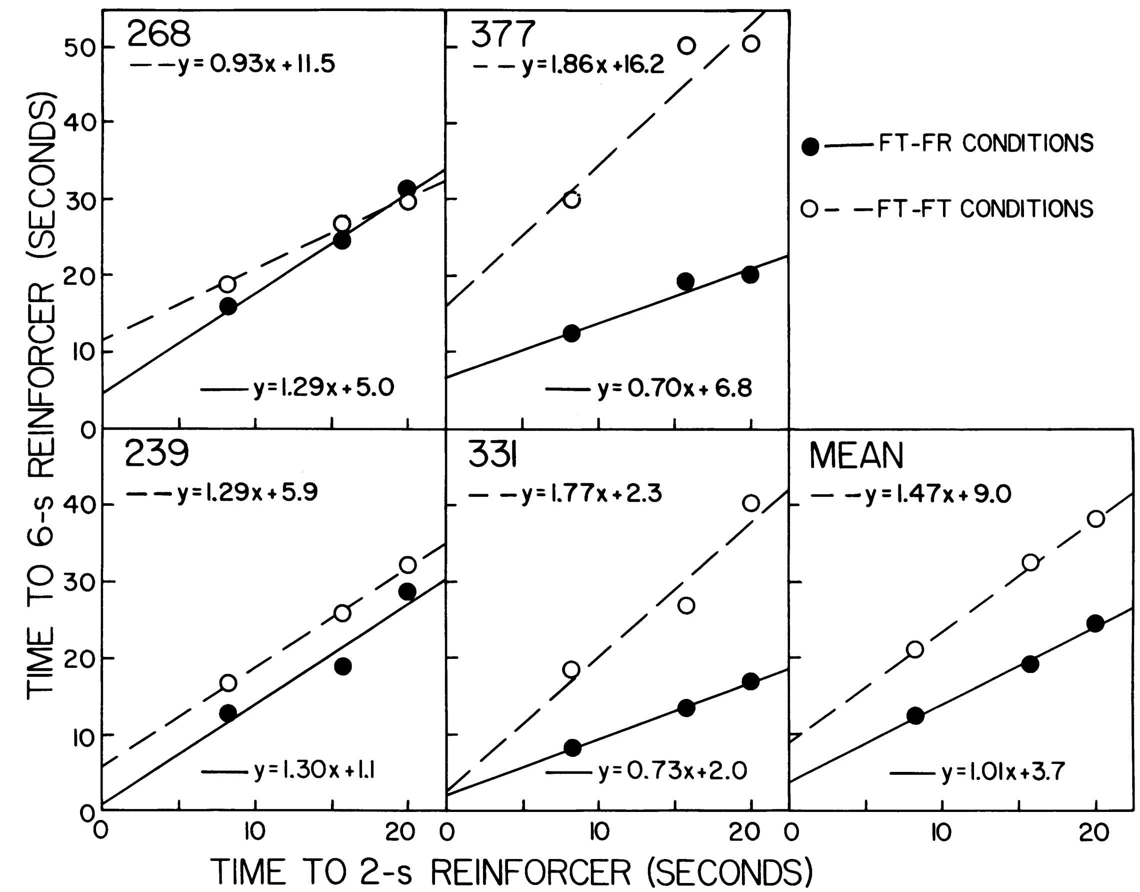

Fig. 5. The filled circles show the geometric means of the times between a choice response and reinforcement in the FT–FR conditions of Phase 3, showing choices between standard FT schedules and adjusting FR schedules. The open circles are the results from the three corresponding FT–FT conditions of Phase 2. The lines are the best fitting regression lines.

could be due to order effects. Table 2 presents the mean durations between a choice response and reinforcement from the two FR 40 conditions of Phase 4 and from the corresponding FT conditions. As in Figure 4, there was a slight tendency for these durations to be longer in FR conditions than in FT conditions. Of the eight comparisons of FR–FR and FT–FT conditions, the adjusting-key duration was longer for the FT schedules in six cases. For the group as a whole, the adjusting-key duration averaged 36.4 s in the FR 40 conditions and 32.2 s in the FT conditions. However, it is worth noting that for individual subjects, the discrepancies between FT–FT and FR–FR conditions were not necessarily in the same direction as in Figure 4. In summary, the results from Phases 1, 2, and 4 indicated that when the time between a choice response and the small reinforcer was long, the time to the large reinforcer tended to be slightly longer when the alternatives were two FR schedules than when they were two FT schedules. These differences were usually small, however, and they were often inconsistent across conditions for individual subjects.

DISCUSSION

The results of this experiment show that Equation 1 can be applied to choice in self-control situations that involve ratio schedules rather than scheduled delays before reinforcement. The results parallel those obtained by Mazur (in press) with simple delays. Regardless of whether the results of Phase 1 are plot-

Table 2

Times between a choice response and reinforcement in Phase 4. (Durations are geometric means, in seconds.)

Condition	Schedule	Reinforcer duration	Subject #268	Subject #377	Subject #239	Subject #331	Mean
13	FR 40	2	14.50	18.69	17.89	12.88	15.94
	Adjusting FR	6	32.88	44.61	44.63	25.50	36.91
14	FT	2	14.50	18.69	17.89	12.88	15.94
	Adjusting FT	6	29.07	40.83	35.07	21.40	31.59
15	FR 40	2	15.48	15.91	17.31	13.27	15.49
	Adjusting FR	6	35.10	33.80	42.77	31.87	35.89
16	FT	2	15.48	15.91	17.31	13.27	15.49
	Adjusting FT	6	38.00	37.70	32.37	22.87	32.74

ted in terms of the ratio requirements at the indifference point (Figure 3) or in terms of times to complete these ratios (Figure 4), the indifference points are well described by straight lines with positive y intercepts and slopes greater than 1.0. The results seem to rule out a simple exponential equation as a possible equation relating ratio size (or completion time) to the value of an alternative, because the exponential equation predicts that the indifference curve will have a slope of 1.0 irrespective of the durations of the two reinforcers (see Mazur, in press). The results also provide evidence against a simple reciprocal relation between ratio size and value (Schwartz, 1969), because the reciprocal equation predicts an indifference curve with a y intercept of 0. These findings therefore join those of several other studies (Mazur, 1984, in press; Mazur, Snyderman, & Coe, 1985) in suggesting that Equation 1 provides an accurate description of the relation between schedule size and reinforcing value of transitions into that schedule.

It is not clear whether the variable that actually controlled subjects' preferences in the FR–FR conditions was the size of a ratio schedule or the time needed to complete that ratio. Equation 1 provided about equally good descriptions of the FR–FR results regardless of which of these two measures was used. However, the results from Phases 2 and 3 provided evidence against the completion-time hypothesis, which states that time is the controlling variable in ratio schedules and that the number of responses is irrelevant (Herrnstein, 1964b; Killeen, 1969; Neuringer & Schneider, 1968). If this hypothesis were true, the indifference points in Phases 2 and 3 should have been identical, because the standard alternatives were identical FT schedules in three conditions from these two phases, and all that differed was whether the adjusting alternative was an FR schedule or an FT schedule. Yet Figure 5 shows that at indifference, the times to the large reinforcer were almost always shorter when that reinforcer was delivered on an FR schedule rather than an FT schedule. For example, the standard schedule was FT 20 s (for a 2-s reinforcer) in both Conditions 9 and 10. In Condition 9, the equivalent adjusting FT schedule (for a 6-s reinforcer) averaged 38 s for the group. In Condition 10, the equivalent adjusting FR schedule for the group required about 62 responses, which took an average of only 24 s to complete. However, Figure 5 also shows that the effects of the ratio requirement varied greatly among subjects.

The discrepancy in indifference points for ratios and delays may have occurred because the presence of the response requirement made the FR schedules more aversive than the FT schedules, which required no key pecks after the choice response. The behavior patterns that occurred between a choice response and reinforcement were quite different on these two types of schedules. The predominant behavior on the FR schedules was, of course, key pecking. Although the number of key pecks during the FT schedules was not recorded in this experiment, occasional direct observations of the subjects indicated that very few pecks occurred during the delays before reinforcement.

(The response keys were dark during these delays.) Typical patterns of behavior during the delays included pacing from side to side, pecking in the vicinity of the food hopper, looking around the chamber, and standing still. For simplicity, we can call the behavior that occurred during the FT schedules *delay behavior.* One interpretation of the differences in results from Phases 2 and 3 is that key pecking was more aversive than the delay behavior (except for Subject 268). Although this line of reasoning cannot be tested with the present data, it does make at least one readily testable prediction: Preference for a simple delay over a ratio requirement with an equivalent completion time should become more and more pronounced as response effort is increased (e.g., by requiring greater force for an effective response, which would presumably make responding more aversive).

Prior to this study, an experiment by Neuringer and Schneider (1968) provided the most direct test of the completion-time hypothesis. These investigators found that postreinforcement pauses on an FR 15 schedule could be increased without increasing the response requirement if the interreinforcement interval were lengthened by inserting brief timeouts after each response. Conversely, they found no change in postreinforcement pause durations when the number of responses in a fixed-interval 30-s schedule was decreased by inserting similar timeouts after each response. Neuringer and Schneider concluded from these results that time, not the number of responses, may be the crucial variable controlling pause-termination behavior. However, there are at least two other possible reasons why the number of responses did not seem to make a difference in the Neuringer and Schneider study. First, because key pecking is not a very difficult response for pigeons, pecking and delay behavior may have been, by coincidence, about equally aversive for the subjects in that experiment. Second, the relatively few responses required per reinforcer may have obscured any preference between pecking and delay behavior, for in the present study, the largest differences between FR and FT schedules were found with long ratios and large delays.

Contrary to the findings of Neuringer and Schneider (1968), our results suggest that the completion-time hypothesis is incorrect, and that animals are not necessarily indifferent between schedules that require some operant response (e.g., ratio schedules) and those that simply impose a delay for an equivalent amount of time. It may be possible to obtain approximate indifference in such a choice if the operant response requires very little effort, but it seems likely that in these cases a preference for the simple delay over the ratio schedule would be revealed if the time to reinforcement were lengthened for both alternatives or if the effort involved in producing the response were increased. In other words, we propose that indifference between schedules that require responding and those that do not is the exception, not the rule (cf. Crossman, Heaps, Nunes, & Alferink, 1974).

Throughout this article, we have implicitly assumed that the measured indifference points were determined by the schedules correlated with each key color and not by arbitrary features of the adjusting procedure itself, but this assumption could be wrong. For instance, it is certainly possible that different results would have been obtained with a different mixture of free- and forced-choice trials, a different adjustment size, or a different ITI. There is evidence, however, that at least some of these features of the procedure did not strongly affect the results. Mazur (in press) obtained results very similar to those found in Phase 2 of the present study even though his procedure involved a different number of free-choice trials per block (two rather than eight) and a different ITI (60 s rather than 15 s). Nevertheless, the choice of 1-s adjustments for the time schedules and five-response adjustments for the ratio schedules may have had some effect on the comparisons between FR and FT schedules. For instance, the comparisons of FT–FT conditions and FT–FR conditions (Figure 5) might have had different outcomes if other adjustment increments had been used. This possibility could be tested by systematically changing the adjustment increments for both ratio and time schedules in conditions like those of Phase 3.

One additional factor that may have contributed to the differences between the delay and ratio conditions was the variability in completion times on the FR schedules. Whereas the delay between a choice response and reinforcement is constant over trials on an FT schedule, it varies on an FR schedule because subjects take longer to complete the ratio on some trials than on others. Because animals prefer schedules with variable rather than fixed time or response requirements (e.g., Davison, 1972; Herrnstein, 1964a; Killeen, 1968; Rider, 1983), the variable completion times of long FR schedules may have increased their values compared to the constant delays of long FT schedules. Because the longest completion times occurred on the adjusting key, any preference for variability per se might have produced shorter indifference points for the FR schedules than if completion times had been constant over trials. In future research, this factor could be controlled by using variable-time (VT) schedules instead of FT schedules, with the components of the VT schedules being matched to the actual completion times for a subject in a previous FR-FR condition. Another tactic to investigate the role of response effort would be to compare ratio schedules with several different effort requirements, to determine how progressive increases in response effort affect the choice between a small, proximal reinforcer and a large, more distant one.

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