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CHOICE BETWEEN SINGLE AND MULTIPLE DELAYED REINFORCERS

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Pigeons chose between alternatives that differed in the number of reinforcers and in the delay to each reinforcer. A peck on a red key produced the same consequences on every trial within a condition, but between conditions the number of reinforcers varied from one to three and the reinforcer delays varied between 5 s and 30 s. A peck on a green key produced a delay of adjustable duration and then a single reinforcer. The green-key delay was increased or decreased many times per session, depending on a subject's previous choices, which permitted estimation of an indifference point, or a delay at which a subject chose each alternative about equally often. The indifference points decreased systematically with more red-key reinforcers and with shorter red-key delays. The results did not support the suggestion of Moore (1979) that multiple delayed reinforcers have no effect on preference unless they are closely grouped. The results were well described in quantitative detail by a simple model stating that each of a series of reinforcers increases preference, but that a reinforcer's effect is inversely related to its delay. The success of this model, which considers only delay of reinforcement, suggested that the overall rate of reinforcement for each alternative had no effect on choice between those alternatives.

Key words: number of reinforcers, delay of reinforcement, adjusting procedure, key peck, pigeons

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Previous research on choice between single and multiple reinforcers has produced a variety of results. Some studies have found that subjects slightly prefer the alternative that delivers more reinforcers (e.g., Fantino & Herrnstein, 1968; Shull, Spear, & Bryson, 1981; Squires & Fantino, 1971). For instance, Fantino and Herrnstein used a concurrent-chains procedure to measure preference, and they varied the number of reinforcers during a single terminal link between 1 and 10. Initial-link responding was influenced by the number of reinforcers in the terminal links, but it was by no means proportional to the number of reinforcers. On the other hand, Moore (1979) reported several studies with the concurrent-chains procedure in which the numbers of reinforcers had little or no effect. A study by McDiarmid and Rilling (1965) produced mixed results: In one condition, subjects preferred the alternative with more reinforcers, but in two others, they chose the alternative that delivered fewer reinforcers but with shorter delay to the first reinforcer.

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Theoretical analyses of multiple delayed reinforcers are also diverse. In proposing a modification of Fantino's (1969) delay-reduction hypothesis, Squires and Fantino (1971) suggested that choice proportions in the initial links of a concurrent-chains procedure are related to both the reduction of delay to reinforcement and the rate of reinforcement. They asserted that adding multiple reinforcers to one terminal link (e.g., by continuing the terminal link until several reinforcers are collected on a fixed-interval schedule) should affect preference only to the extent that this manipulation increases the average rate of reinforcement for that alternative.

A different hypothesis was offered by Moore (1979, 1982). He suggested that the main variable that determines preference in a concurrent-chains procedure is the delay to the first reinforcer of each terminal link. Moore proposed that additional reinforcers have no effect on choice, and some of his results were consistent with this view. However, Moore did find a preference for multiple reinforcers when they were delivered in rapid succession (e.g., when delays of only a few seconds separated one reinforcer from the next). To account for this preference, Moore suggested that when several reinforcers occur close together, this can be treated as an increase in the amount of reinforcement rather than in the number of reinforcers. Of course, amount of reinforcement is known to affect choice (e.g., Catania, 1963). Moore claimed that if multiple reinforcers are widely spaced, they will be no more effective than a single reinforcer.

A third approach to multiple-reinforcer effects was suggested by McDiarmid and Rilling (1965). They proposed that every reinforcer, not only the first, has its own impact on choice behavior, but this impact is inversely proportional to its delay, as described by the following equation:

$$V = \sum_{i=1}^{n} \frac{p_i}{t_i}. \quad (1)$$

V is the value of a series of reinforcers, n is the total number of potential reinforcers in the series, p_i is the probability that reinforcer i will be delivered on a given trial, and t_i is the delay to reinforcer i. It is important to recognize that t_i is not the interval between reinforcers but rather the total time between a choice response and the delivery of reinforcer i. In a choice situation, a subject will choose whichever alternative has the larger value, V.

In summary, three different hypotheses about multiple reinforcers have been proposed: (1) Multiple reinforcers alter preference because they change the rate of reinforcement (Squires & Fantino, 1971). (2) When closely spaced, multiple reinforcers alter preference because they change the amount of reinforcement; when widely spaced, multiple reinforcers exert no cumulative effect, and choice is determined by the delay to the first reinforcer (Moore, 1979). (3) The effects of multiple reinforcers are cumulative, but the contribution of each reinforcer is diminished as a function of its delay (McDiarmid & Rilling, 1965).

One purpose of the present experiment was to evaluate these three interpretations, using a special case of a concurrent-chains procedure in which the initial links of the chain were kept as brief as possible. In the typical concurrent-chains procedure, the initial links are variable-interval (VI) schedules, and therefore both the initial links and the terminal links contribute to delays before reinforcement. Fantino (1969) has shown that the sizes of the VI schedules in the initial links affect choice, and that preference shifts toward indifference as the durations of the initial links are increased. The logic behind the procedure used in the present experiment was that if the initial links are so short that their contribution to the total delay before reinforcement is negligible, choice will be determined almost entirely by the schedules in the terminal links. This experiment therefore used a discrete-trial procedure in which a pigeon chose between two alternatives by making a single key peck. This briefer choice period might make the procedure more sensitive to small differences in reinforcer value than the typical concurrent-chains procedure.

A second purpose of this study was to test a model of delayed reinforcement that is similar, but not identical, to that of McDiarmid and Rilling (1965). Notice that Equation 1 describes a simple reciprocal relation between t_i and V, but this is only one of many possible relations. In several studies, Mazur (1984, in press; Mazur, Snyderman, & Coe, 1985) has obtained results consistent with the following hyperbolic equation:

$$V = \frac{1}{1 + Kt}, \quad (2)$$

where K is a free parameter. Extrapolating to alternatives that include more than one reinforcer, in the manner of McDiarmid and Rilling, we obtain

$$V = \sum_{i=1}^{n} \frac{p_i}{1 + Kt_i}. \quad (3)$$

Mazur's results (1984, in press) were consistent with Equations 2 and 3. However, these results did not rule out the possibility that in the most accurate equation relating delay and value, it might be necessary to raise t_i to some power, B, other than 1.0. If so, Equation 3 would become

$$V = \sum_{i=1}^{n} \frac{p_i}{1 + Kt_i^B}. \quad (4)$$

The present experiment provided a situation for evaluating Equation 4 in comparison to the simpler Equation 3. To see why, consider a situation in which a subject must choose between one alternative that provides two reinforcers delivered after x seconds and $2x$ seconds, respectively, and a second alternative that delivers one reinforcer after y seconds. In this experiment, the first was called the *standard alternative,* because the delays to the two

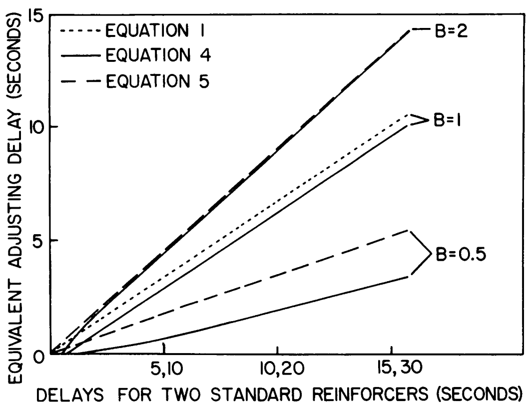

Fig. 1. Indifference points predicted by Equations 1, 4, and 5 for a choice between a standard alternative that delivers two reinforcers at x and $2x$ seconds and an adjusting alternative that delivers one reinforcer. (Equation 4 is equivalent to Equation 3 when $B = 1.0$.)

reinforcers were constant within a condition. The second was called the *adjusting alternative,* because the delay y was systematically increased and decreased in 1-s increments many times in each session. These adjustments permitted estimation of an indifference point, or a value of y at which the subject chose the standard and adjusting alternatives about equally often. Several indifference points were estimated by varying the duration of x across conditions, and together these indifference points were used to estimate an "indifference curve." The obtained indifference points could then be compared to those predicted by the above equations. The procedure for calculating the predicted indifference points is simple. Using Equation 3 as an example, let us set $K = 1.0$. We can now calculate the value of the standard alternative for any duration of x, the delay to the first standard reinforcer. Assuming that the values of the standard and adjusting alternatives are equal at an indifference point, Equation 3 can now be used to solve for y, the predicted delay to the single reinforcer of the adjusting alternative.

The solid curves in Figure 1 show the various types of indifference curves that are predicted for this situation by Equation 4 with different values of B (which is equivalent to Equation 3 when $B = 1.0$). The parameter K was set equal to 1.0, the value that provided the best fit for Mazur's (1984) results. As can be seen, all of the predicted indifference curves are nearly linear, but their slopes vary markedly depending on the value of the exponent B. This feature of the indifference curves makes them a particularly sensitive way of testing whether B is different from 1.0.

The dotted line in Figure 1 shows the predictions of Equation 1, the simple reciprocal equation proposed by McDiarmid and Rilling (1965). The predictions of Equation 3 (i.e., Equation 4 with $B = 1.0$) approach those of Equation 1 as the value of K increases and approaches infinity. In other words, for all values of K between 1.0 and infinity, the predictions of Equation 3 would lie between those displayed in Figure 1 for Equation 1 and for Equation 4 with $B = 1.0$.

Just as Mazur (in press) suggested that an exponent other than 1.0 may be needed in Equation 4, others (Davison, 1969; Duncan & Fantino, 1970; Killeen, 1968) have suggested that it may be necessary to raise t_i in Equation 1 to some power other than 1.0. That is, they proposed that the following equation is appropriate:

$$V = \sum_{i=1}^{n} \frac{p_i}{t_i^B}, \tag{5}$$

where B sometimes differs from 1.0. In particular, Davison and Duncan and Fantino suggested that B can sometimes have a value of 6 or larger. These previous applications of Equation 5 each dealt with situations in which only one reinforcer was delivered in each terminal link. For terminal links with more than one reinforcer, it is not clear whether these authors would treat t_i as the interval between successive reinforcers or as the time from the onset of the terminal link to each successive reinforcer. For the present, however, we will adopt the latter strategy, which is consistent with the general approach to multiple delayed reinforcers proposed by McDiarmid and Rilling (1965). The dashed lines in Figure 1 show the predictions of Equation 5 for two different values of B. As with Equation 4, the slopes of these indifference curves vary markedly with the value of B, but in all cases the predicted functions are linear with y intercepts of zero. With the same value of B, the predictions of Equations 4 and 5 are fairly similar, especially when B is greater than 1.0. Inasmuch as the predictions of Equations 1 and 3 are also similar, this experiment can provide no further evidence on the need for the constant, 1.0, in the denominators of Equations 2, 3, and 4. The experiment can yield an estimate of the exponent *B*, however, regardless of whether or not the constant 1.0 is needed.

METHOD

Subjects

Three White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. All subjects had previously taken part in a variety of experiments. A fourth bird performed erratically during the first few conditions and was eliminated from the experiment.

Apparatus

The experimental chamber was 30 cm long, 30 cm wide, and 32 cm high. Three response keys, each 2.5 cm in diameter, were mounted in the front wall of the chamber, 20.5 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 provided controlled access to mixed grain, and when grain was available the hopper was illuminated with two 6-W white lights. Six 6-W lights (two white, two blue, and two orange) were mounted above the wiremesh ceiling of the chamber. The chamber was enclosed in a sound-attenuating box that contained an air-blower for ventilation and 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 record responses.

Procedure

The experiment consisted of nine conditions, which differed from one another only in the number and temporal placement of the reinforcers that followed a peck at whatever side key was transilluminated with red light. In all conditions, the red key was the standard key, and the consequences of a peck on this key remained constant throughout a condition. The other side key, illuminated with green light, was the adjusting key, and its delay to reinforcement was increased or decreased in steps of 1 s many times each session, depending on the subject's previous choices.

Throughout the experiment, sessions ended after 56 trials or 65 min, whichever came first. The duration of every reinforcer was 2 s. Each block of four consecutive trials consisted of

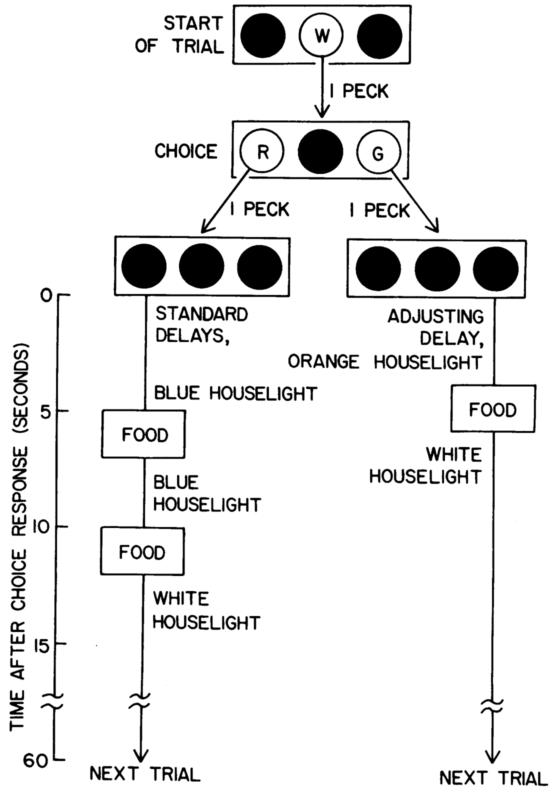

Fig. 2. The two possible sequences of events that could occur on a free-choice trial in Condition 1, depending on whether the red or green key was pecked.

two forced-choice trials followed by two free-choice trials. To illustrate the procedure of a typical condition, Figure 2 diagrams the sequence of events on a free-choice trial in Condition 1. At the start of the trial, the center key was illuminated with white light, the white houselights were on, and a single peck on the center key was required to begin the choice period. The purpose of this response requirement on the center key was to increase the likelihood that the subject's head was equally distant from the two side keys when the choice period began. A center-key peck darkened this key and illuminated the two side keys, one green and one red. The locations of these colors (left key or right key) varied randomly from trial to trial so as to control for any position preferences.

A peck on the red key extinguished both side keys and initiated the standard schedule, during which the blue houselights were lit instead of the white houselights. During each 2-s reinforcement period, however, all house-

Table 1

Order of experimental conditions and number of sessions per condition.

Condition	Number of standard reinforcers	Delay(s) to standard reinforcer(s)	Number of sessions		
			Sub. 309	Sub. 310	Sub. 400
1	2	5, 10 s	25	26	25
2	2	15, 30 s	26	25	27
3	2	10, 20 s	31	27	29
4	1	15 s	26	28	28
5	3	15, 22.5, 30 s	14	14	15
6	3	10, 15, 20 s	12	13	14
7	1	10 s	18	27	13
8	3	5, 7.5, 10 s	13	12	12
9	1	5 s	13	14	12

lights were extinguished and only the lights above the grain hopper were lit. In Condition 1, reinforcement periods began 5 s and 10 s after the choice response. After the final reinforcer of the standard schedule, the white houselights were again lit. The start of the next trial occurred 60 s after the choice response of the preceding trial. If the green key was pecked during the choice period, both side-key colors were extinguished and the adjusting delay began, during which the orange houselights were lit. The adjusting delay was followed by 2 s of access to grain and then the white houselights were lit. As with the standard alternative, the next trial began 60 s after the preceding choice response. The procedure in other conditions was the same except for the number of standard-schedule reinforcers and their temporal locations.

The procedure on forced-choice trials was the same as on free-choice trials except that only one side key was lit, red or green, and a peck on this key led to the appropriate delay. A peck on the opposite key, which was dark, had no effect. Of every two forced-choice trials, one involved the red key and the other the green key. The temporal order of these two types of trials varied randomly.

After every two free-choice trials, the delay for the adjusting key might be changed. If a subject chose the adjusting key on both free-choice trials, the adjusting delay was increased by 1 s. If the subject chose the standard key on both trials, the adjusting delay was decreased by 1 s unless it was already zero. If a subject chose each key once on the two free-choice trials, no change was made in the adjusting delay. In all three cases, this adjusting delay remained in effect for the next block of four trials. At the start of the first session of the experiment, the adjusting delay was set at 5 s for all 4 subjects. For the start of every other session, the adjusting delay was determined by the above rules as if it were a continuation of the preceding session.

Table 1 lists the number of standard-schedule reinforcers and the delays between a choice response and the onset of each reinforcer in the nine conditions. In Conditions 4, 7, and 9, the standard alternative provided only one reinforcer, which was delivered after a delay of either 15 s, 10 s, or 5 s, respectively. The first standard reinforcer of the other six conditions also occurred after one of these three delays. Two standard reinforcers were delivered in Conditions 1, 2, and 3, and the delay to the onset of the second reinforcer was double the delay to the first. Three standard reinforcers were delivered in Conditions 5, 6, and 8. The delays to the second and third standard reinforcers were, respectively, 1.5 times and 2 times the delay to the first reinforcer.

The first four conditions each lasted for a minimum of 25 sessions (to familiarize the subjects with the adjusting procedure), and all other conditions lasted for a minimum of 12 sessions. After the minimum number of sessions, a condition was terminated for each subject individually when several stability criteria were met. To assess stability, each session was divided into two 28-trial blocks, and the mean delay on the adjusting key in each block was calculated. The results from the first two sessions of a condition were not used, and a condition was terminated when the following three criteria were met, using the data from all subsequent sessions: (1) Neither the highest nor the lowest single-block mean of a condition could occur in the last six blocks of the condition. (2) The mean adjusting delay across the last six blocks could not be the highest or the lowest six-block mean of the condition. (3) The mean delay of the last six blocks could not differ from the mean of the preceding six blocks by more than 10% or by more than 1 s, whichever was larger.

RESULTS

The right side of Table 1 shows the number of sessions that were needed to meet the

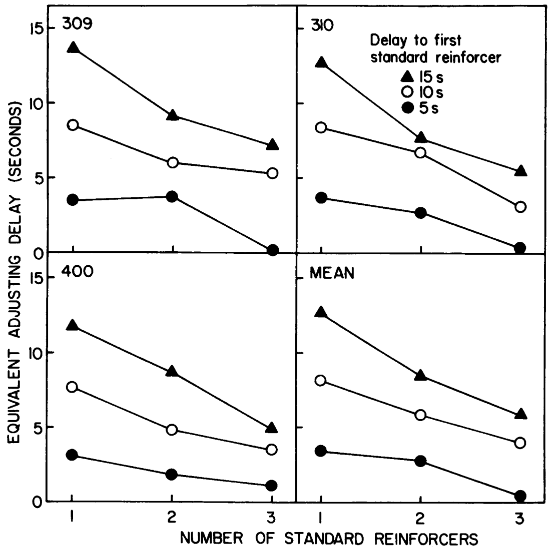

Fig. 3. For each subject and for data pooled (means) across subjects, the mean adjusting delay in the last six half-session blocks is plotted for each of the nine conditions.

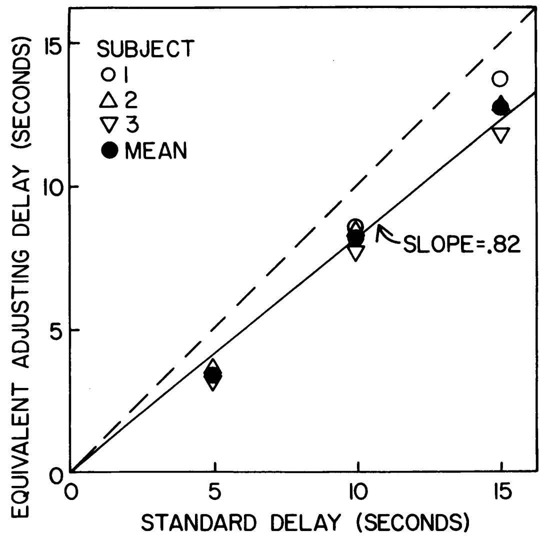

Fig. 4. Indifference points from the three conditions with a single standard reinforcer. With no bias for or against the adjusting key, the points would be expected to fall on the dashed line. The solid line, which was fitted to the group means, is the best fitting line with a y intercept of zero, according to a least-squares criterion.

stability criteria in each condition by each subject. The mean adjusting delay in the last six half-session blocks of a condition was used as an estimate of the indifference point. Without exception, the subjects completed all 56 trials of each session used to estimate an indifference point.

Figure 3 presents the results in a form that emphasizes the contribution of each additional standard reinforcer. For each subject and for the group mean, the x axis represents the number of reinforcers delivered by the standard schedule, and the y axis represents the mean adjusting delay. The lines in each panel connect the data points from conditions that had the same delay to the first standard reinforcer. With one minor exception (the lowest curve for Subject 309), the indifference points decreased monotonically as the number of standard reinforcers increased from one to three, as they should if each additional standard reinforcer increased the value of the standard alternative. A two-way, repeated-measures analysis of variance revealed highly significant effects both of the delay to the first standard reinforcer, $F(2, 4) = 288.58$, $p < .001$, and of the number of standard reinforcers, $F(2, 4) = 223.63$, $p < .001$. The delay-by-number interaction was also significant, $F(4, 8) = 6.00$, $p < .05$.

The three conditions with only one standard reinforcer were used to measure possible bias for or against the adjusting alternative. The indifference points from these conditions are replotted in Figure 4, and these points would be expected to fall on the dashed line if there were no bias. Inasmuch as the results from all three conditions are below the line, it appears that there was a bias toward the standard alternative (e.g., a 12.7-s delay on the adjusting key was equivalent to a 15-s delay on the standard key). This bias could not be the result of a position preference because the positions of the standard and adjusting keys varied randomly over trials. It might have been the result of a preference for the key color or delay-light color correlated with the standard schedule. In any case, the amount of bias was approximately proportional to the standard delay (as it was in the experiment of Mazur, 1984). For the group means, the solid line in Figure 4 is the best fitting straight line with an intercept of zero, as assessed by a least-squares criterion. The slope of 0.82 represents a bias of approximately 18% toward the standard key, and to compensate for this bias all predictions for the remaining six conditions were multiplied by 0.82.

Figure 5 compares the predictions of Equa-

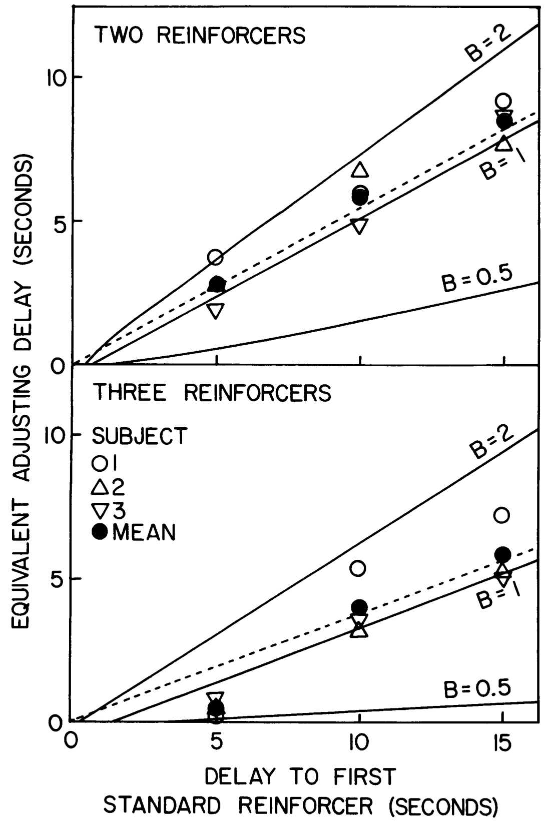

Fig. 5. Indifference points from the conditions with two or three standard reinforcers are compared to the predictions of Equation 1 (dotted lines) and Equation 4 (solid curves). The value of B is listed next to each curve generated by Equation 4.

tions 1, 3, and 4 to the results from the six conditions with multiple reinforcers. The top panel shows the predictions and results from the conditions with two standard reinforcers, and the bottom panel shows those from the conditions with three standard reinforcers. The solid curves show the predictions of Equation 4 (which is equivalent to Equation 3 when $B = 1.0$), with K set to 1.0 in all cases. The dotted lines show the predictions of Equation 1. As can be seen, the group means from all conditions are close to those predicted by both Equations 1 and 3. They are distinctly different from the predictions of Equation 4 with B equal to either 0.5 or 2.0. The predictions of Equation 5 are not shown in Figure 5, but as can be inferred from Figure 1, these predictions are similar to those of Equation 4.

For each subject, the harmonic mean latencies of pecks at the center key, the adjusting key, and the standard key were calculated from the six half-session blocks used to estimate the indifference point of every condition. The latencies for individual subjects are presented in the Appendix. Figure 6 shows the group means of these harmonic mean latencies. In several respects, these response latencies exhibited patterns that paralleled those of the indifference point estimates. First, for all three response keys, latencies tended to be longer with longer standard delays and with fewer standard reinforcers. In a three-way, repeated-measures analysis of variance, the effect of standard-key delay on response latencies failed to reach statistical significance, $F(2, 4) = 4.94$, $p = .08$, but the effect of number of reinforcers was significant, $F(2, 4) = 52.98$, $p < .002$. Second, latencies were consistently longer on the adjusting key than on either the standard key or the center key, and the effect of response key was also statistically significant, $F(2, 4) = 15.66$, $p < .02$. (None of the interactions among these three variables reached statistical significance.) The reason for the longer latencies on the adjusting key is not clear, but this result is consistent with the bias against the adjusting key exhibited in Figure 4.

DISCUSSION

The results show clearly that as the number of reinforcers delivered by one alternative increases, so does preference for that alternative. This increase in preference was evident in the shorter response latencies and, more importantly, in the shorter delays corresponding to indifference points for a single reinforcer of presumably equal value. The results of this discrete-trial experiment are therefore consistent with those of at least three studies that used more typical concurrent-chains procedures with VI schedules in the initial links (Fantino & Herrnstein, 1968; Poniewaz, 1984; Squires & Fantino, 1971).

The three hypotheses about multiple reinforcers described in the introduction can be evaluated in light of these results. First, let us consider Moore's (1979) suggestion that only the delay to the first reinforcer is important, and that additional reinforcers have no effect unless they occur so close to the first that they can be viewed as an increase in the amount of reinforcement. This hypothesis is difficult to

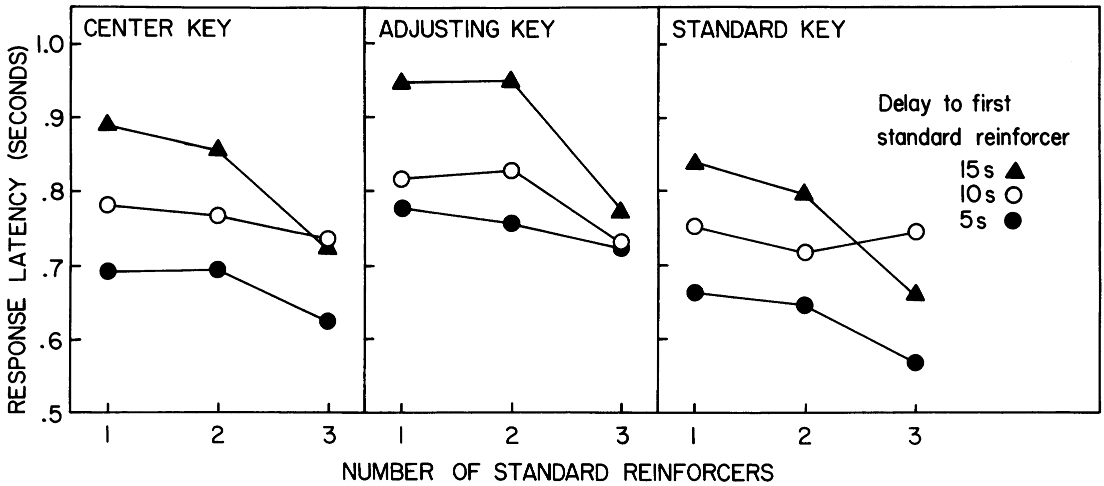

Fig. 6. The group means of each subject's harmonic mean response latencies on the center key, the adjusting key, and the standard key are plotted for each of the nine conditions.

evaluate because it makes no clear prediction about how close together multiple reinforcers must be before they should be treated as a change in the amount of reinforcement. From his data, Moore estimated that this duration varied from 9 s to 15 s for his 3 subjects. The results from the present experiment, however, suggest that an additional reinforcer can affect preference when it is separated by as much as 15 s from the previous reinforcer. For instance, in Condition 2 the two standard reinforcers were separated by 15 s, yet each subject reached an indifference point that was substantially shorter than the comparable condition with only one standard reinforcer (Condition 4).

Moore went on to say that, consistent with his hypothesis, the number of reinforcers produced a "two-state effect" in his experiment: Subjects showed either indifference or a constant, modest preference for the alternative with multiple reinforcers. Even for his own data, this conclusion is questionable (see Moore, 1979, Figure 3), but it is certainly not applicable to the present results. Figure 3 shows no evidence for stepwise shift from preference to indifference as the spacing between reinforcers increased. Such a shift would be suggested if, for example, the change from one to two standard reinforcers produced a decrease in the indifference points in the 5-s and 10-s conditions but no change in the 15-s conditions. Instead, the indifference points changed in a gradual fashion as the delays separating the multiple reinforcers increased.

Squires and Fantino (1971) proposed that two separate factors affect choice when multiple reinforcers are involved: the delay to the first reinforcer and the average rate of reinforcement for each alternative. However, for situations with very short choice periods such as those of the present experiment, their model predicts exclusive preference for whichever alternative offers the shorter delay to the first reinforcer (see their Equation 3). Thus, if it is applied without modification, the delay-reduction model cannot account for the present results. To be fair, however, it must be noted that this model was developed to deal with results from concurrent-chains procedures with longer initial links, not from single-response choice situations.

Instead of trying to decide how to modify the delay-reduction model to accommodate these data, we can consider the more general question of whether both delay and rate of reinforcement affect choice in this type of discrete-trial situation. Perhaps the strongest argument against this position is that there is simply no need to include the second factor, rate of reinforcement. A model such as that of McDiarmid and Rilling (1965), which includes only one independent variable—delay of reinforcement—can account for the results very well. As expressed in Equation 1, this model states that every reinforcer delivered by one alternative contributes to the value of that alternative, but a reinforcer's contribution is inversely proportional to its delay. As Figure 5 shows, this equation provided a good description of the results, and it accounted for 93.9% of the variance in the group means, using a least-squares criterion. Using Equation 5 instead of Equation 1 and allowing the exponent B to vary as a free parameter produced virtually no improvement in the fit to the data: The best fit was obtained with $B = 1.02$, with 94.0% of the variance accounted for. Therefore, there seems to be no justification either for including B as a free parameter or for including rate or reinforcement as an additional independent variable. The results are well described by Equation 1, which includes no free parameters and which does not consider rate of reinforcement at all.

As already noted, this experiment cannot distinguish between the two equations that have the additive constant of 1.0 in the denominator (Equations 3 and 4) and the two that do not (Equations 1 and 5), because the predictions of these two pairs of equations are similar. However, if we rely on the results of earlier experiments (Mazur, 1984, in press) and assume that the additive constant is necessary and that $K = 1.0$, the best fit of Equation 4 to the group means of the present experiment is obtained with $B = 1.10$, with 95.8% of the variance accounted for. If B is set equal to 1.0 (thereby reducing Equation 4 to Equation 3), the fit is nearly as good, with 92.2% of the variance accounted for. Thus, given the uncertainty inherent in the estimation of this parameter, we can conclude that B is either equal to or close to 1.0, regardless of which of the above equations is used.

The conclusions from this study might be questioned on the grounds that the adjusting-delay procedure is relatively novel, and several arbitrary features of the procedure (e.g., the size of the adjustments, the number of free- or forced-choice trials, or the variability in the adjusting delay) might have affected the indifference points. The importance of these factors cannot be determined without further research, but it is not obvious why any of them would produce the main result of this study—shorter indifference points in the conditions with more than one standard reinforcer. Furthermore, as already noted, there are now several studies with the more typical concurrent-chains procedure that found preference for terminal links with multiple reinforcers as opposed to a single reinforcer (Fantino & Herrnstein, 1968; Poniewaz, 1984; Squires & Fantino, 1971). The only published results suggesting indifference between terminal links with single and multiple reinforcers are those of Moore (1979). In fact, Moore did find a preference for the terminal links with multiple reinforcers when the times between successive reinforcers were short, but he obtained indifference when these durations were longer than about 9 to 15 s.

Several factors may have contributed to Moore's results. According to the McDiarmid-Rilling approach, the effects of reinforcers delivered after long delays should not be large to begin with. Their effects could be masked if the choice procedure is not sensitive to small differences in preference or if some other feature of the procedure counteracts the multiple-reinforcer effect. Both of these factors may have been at work in Moore's study. As already discussed, Moore used initial links that were much longer than in the present study, and Fantino's (1969) work has shown that choice shifts toward indifference as the duration of the initial links increases. In addition, the advantages of the terminal link with multiple reinforcers were partially offset in Moore's procedure by the shorter duration of the single-reinforcer terminal link: Immediately after the one reinforcer was delivered, the initial links were reinstated. As a result, the time to the start of the *next* terminal link was shorter, on the average, when the subject entered a single-reinforcer terminal link. Poniewaz (1984) found that preference for a multiple-reinforcer terminal link was less extreme with this sort of procedure than when the durations of the two terminal links were equal. This was especially true when long delays separated the multiple reinforcers. The combination of these factors might explain why Moore observed preference for the multiple-reinforcer terminal link with short interreinforcer intervals but not with longer ones.

Mazur et al. (1985) recently reported the results of a study that led them to the same conclusion about rate of reinforcement that has been proposed here. Their experiment also made use of a single-response adjusting-delay procedure, but what varied across conditions were the durations of the intertrial intervals that followed the standard and adjusting alternatives. The results were well described by Equation 3, and Mazur et al. therefore concluded that rate of reinforcement had little or no control over the subjects' choices. These results suggest that it may be worthwhile to make systematic comparisons between discrete-trial procedures and others (e.g., concurrent VI VI schedules) for which it has been hypothesized that rate of reinforcement is a controlling variable (e.g., Baum, 1973; Herrnstein, 1970). If rate of reinforcement does affect choice in some procedures but not in others, it will be important to discover why, and to understand when it will have an effect and when not. Another possibility, however, is that an analysis based on the cumulative effects of multiple delayed reinforcers can account for behavior in all of these situations, and that the molar variable, rate of reinforcement, is unneeded.

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APPENDIX

Harmonic mean response latencies for each subject (in seconds).

Condition	9	1	8	7	3	6	4	2	5
Delay[a]	5	5	5	10	10	10	15	15	15
Number[b]	1	2	3	1	2	3	1	2	3
Center-key latencies									
Subject 1	0.65	0.74	0.56	0.82	0.75	0.81	1.02	0.93	0.79
Subject 2	0.68	0.65	0.61	0.70	0.71	0.64	0.80	0.83	0.68
Subject 3	0.75	0.69	0.70	0.83	0.84	0.76	0.86	0.82	0.70
Mean	0.69	0.69	0.63	0.78	0.77	0.74	0.89	0.86	0.73
Adjusting-key latencies									
Subject 1	0.74	0.85	0.68	0.87	0.87	0.77	1.07	1.17	0.87
Subject 2	0.71	0.68	0.66	0.68	0.77	0.67	0.89	0.83	0.73
Subject 3	0.89	0.74	0.83	0.90	0.85	0.76	0.89	0.86	0.73
Mean	0.78	0.76	0.72	0.82	0.83	0.73	0.95	0.95	0.77
Standard-key latencies									
Subject 1	0.59	0.67	0.50	0.79	0.66	0.86	0.97	0.78	0.72
Subject 2	0.66	0.62	0.58	0.72	0.67	0.61	0.72	0.82	0.64
Subject 3	0.74	0.65	0.63	0.76	0.83	0.76	0.84	0.79	0.62
Mean	0.66	0.65	0.57	0.75	0.72	0.75	0.84	0.80	0.66

[a] Delay to the first standard reinforcer.
[b] Number of standard reinforcers.