ESTIMATION OF INDIFFERENCE POINTS WITH AN ADJUSTING-DELAY PROCEDURE

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In a series of conditions, pigeons chose between 1.5 s and 3 s of access to grain, each preceded by some delay. The delay that preceded the small reinforcer was constant throughout a condition. The delay that preceded the large reinforcer was increased or decreased a number of times each session in order to estimate an "indifference point," a delay at which the subject chose each alternative about equally often. The experiment was designed to determine whether variations in any of four features of this adjusting-delay procedure would systematically alter the estimated indifference points. The four features were the total trial duration, the number of center-key responses necessary to begin a trial, the number of choice trials that preceded each change in the adjusting delay, and step size—the size of each increment and decrement in the delay. Manipulation of the first three features had no systematic effects on the indifference points. As step size was increased from 0.5 s to 6 s, within-session variability of the adjusting delay steadily increased, and the 6-s step size produced larger indifference-point estimates for some subjects. The results suggest that, within certain limits, these procedural features can be altered without affecting the indifference-point estimates, but that the use of a large step size can distort the estimates. Some theoretical implications of the relative constancy of indifference points across these procedural variations are discussed.

Key words: adjusting procedure, delayed reinforcement, amount of reinforcement, key peck, pigeons

Procedures for studying choice can be divided into two general categories—those that measure the degree of preference for one alternative over another and those that measure indifference between two alternatives. Measures of preference are essential for testing theories that predict a specific distribution of responses or time between the two alternatives, such as the matching law (Herrnstein, 1961). However, in developing and testing theories of choice that make specific, quantitative predictions, it is also frequently useful to find an indifference point—a pair of alternatives that a subject selects equally often in a choice situation.

Indifference points can be estimated in several ways. For example, suppose one alternative consists of a small amount of food delivered 3 s after the subject makes a choice. If the other alternative consists of twice as much food, what delay will produce an indifference point—a delay-amount combination that is chosen just as often as the first alternative?

One way to answer this question is to measure preference with several different delays (e.g., 2, 4, 6, 8, and 10 s) in succession, and then interpolate to estimate the delay at which the larger reinforcer would be chosen 50% of the time (e.g., Logan, 1965). The main disadvantage of this technique is that it is time consuming. A second technique is to use a titration procedure in which the delay is changed every few sessions in an attempt to narrow in on the indifference point (see Navarick & Fantino, 1972). This procedure also takes considerable time, because each new delay must remain in effect for enough sessions to assess the subject's preference accurately. A third method is to adjust the large-reinforcer delay in small steps every few trials, increasing it when the subject chooses the large reinforcer and decreasing it when the subject chooses the small reinforcer (see Lea, 1976). Once relative stability of performance is reached, the mean large-reinforcer delay can serve as a measure of the indifference point.

In a series of experiments, I have used an adjusting-delay procedure to estimate indifference points between alternatives that differed in their delay to reinforcement and along some other dimension (Mazur, 1984, 1985, 1986b; Mazur & Coe, 1987; Mazur, Snyderman, & Coe, 1985). In this procedure, a subject

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chooses between a *standard* alternative, for which the delay is constant within a condition, and an *adjusting* alternative, for which the delay can change after each block of four trials. In the usual procedure, the first two trials of a block are forced trials, in which the subject is required to choose each alternative once. The second two trials are choice trials. The adjusting delay is increased by 1 s if the adjusting alternative is chosen on both choice trials, and it is decreased by 1 s if the standard alternative is chosen twice. If each alternative is chosen once, the adjusting delay remains unchanged. When subjects are exposed to this procedure for the first time, the adjusting delay typically exhibits large fluctuations, but after several sessions the range of these fluctuations decreases. At this point, and once certain stability criteria are satisfied, the mean adjusting delay across a few sessions is treated as an estimate of the indifference point.

The indifference points obtained with this procedure are usually quite orderly, enough so that simple equations (employing no free parameters) can account for about 90% of the variance across conditions (e.g., Mazur, 1984, 1986b). Nevertheless, a question that is frequently asked about this technique is whether some arbitrary feature of the procedure (e.g., the use of 1-s increments and decrements in the adjusting delay, or the use of two choice trials per block) influences the obtained indifference points. The purpose of the present experiment was to collect some data relevant to this question.

In different parts of this experiment, four features of the adjusting-delay procedure were varied. First, step size, or the size of the increments and decrements in the adjusting delay, was varied from 0.5 s in some conditions to 6 s in others. Second, some conditions were divided into blocks of four trials (two forced and two choice), whereas others were divided into blocks of eight trials (two forced and six choice). Because changes in the adjusting delay were made only at the end of a trial block, this manipulation doubled the number of trials between each possible change in delay, so only half as many changes could occur in a single session. Each of these first two manipulations therefore varied the speed at which changes in the adjusting delay might occur. Based on results from a related procedure (Weiss & Laties, 1959), such changes might be expected to

alter both the variance and mean duration of the adjusting delay. A third variable manipulated in this experiment was trial duration—the time between a choice response and the start of the next trial. If a subject's choice on a given trial were controlled in part by the change in the adjusting delay that would result on subsequent trials, increasing the trial duration should weaken this control. Fourth, the number of responses on a center key that were required to start each trial was varied from 1 to 30. In previous experiments with this procedure, one center-key response was required to make it more likely that the subject's head was about equally far from each choice key when the choice period began. However, if the time required to make the center-key responses is treated as a part of the total delay to reinforcement, the durations of both the standard and adjusting delays will be longer (and therefore the indifference point might shift) when many center-key responses are required. In summary, there are reasons to expect that manipulation of each of these four variables might produce systematic variations in the estimated indifference points.

METHOD

Subjects

The subjects were four White Carneau pigeons 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, were mounted on the front wall of the chamber, 24 cm above the floor. A force of approximately 0.1 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 wire mesh ceiling of the chamber near the front wall. Two 2-W white houselights were mounted above the ceiling towards the back wall of the chamber. 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 Super-SKED® program to control the stimuli and to record responses.

Procedure

The experiment consisted of 19 conditions. To counterbalance for the order of exposure to the different experimental manipulations, the conditions were presented in one order for Subjects 1 and 2 and in a different order for Subjects 3 and 4. For convenience, the conditions will be referred to by the order in which they were presented to Subjects 1 and 2. The order of presentation for all subjects is shown in Table 1. The procedure for Condition 1 will be described in detail, and then the variations used in the other conditions will be discussed.

Condition 1. Each session lasted for 64 trials or 80 min, whichever came first. Each block of four consecutive trials consisted of two forced trials followed by two choice trials. Figure 1 diagrams the sequence of events on a 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. A center-key peck darkened this key and illuminated the two side keys, one green and one red. The locations (left key or right key) of these colors were varied randomly from trial to trial to control for position preferences.

Throughout the experiment, the red key represented the standard alternative and the green key the adjusting alternative. In Condition 1, a peck on the red key extinguished both side keys and initiated the standard delay of 8 s, during which the red houselights were lit instead of the white houselights. At the end of the standard delay, a 1.5-s reinforcement period began during which all houselights were extinguished and the lights above the grain hopper were lit. After reinforcement, the white houselights were again lit, and an intertrial interval (ITI) began. The start of the next trial occurred 60 s after the choice response of the preceding trial. If the green key were pecked during the choice period, both side-key lights were extinguished and the adjusting delay began, during which the green houselights were lit. The adjusting delay was followed by a 3-s reinforcement period and then the ITI. As with

the standard alternative, the next trial began 60 s after the preceding choice response.

The procedure on forced trials was the same as on 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 alternate, darkened key had no effect. Of every two forced trials, one involved the red key and the other the green key. The order of these two types of trials varied randomly.

After every two choice trials, the delay for the adjusting key might be changed. If a subject chose the adjusting key on both 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 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 8 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.

Condition 1 lasted for a minimum of 15 sessions (to familiarize the subjects with the adjusting procedure), and all other conditions lasted for a minimum of 10 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 32-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: (a) Neither the highest nor the lowest single-block mean of a condition could occur in the last six blocks of the condition. (b) The mean adjusting delay across the last six blocks could not be the highest or the lowest six-block mean of the condition. (c) 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).

Variations in the number of choice trials per block (Conditions 1 through 5 and 14). In three of these six conditions, including Condition 1, each 64-trial session consisted of 16 blocks of trials—two forced trials followed by two choice

Table 1

Order of experimental conditions, number of sessions per condition, and estimated indifference points for each subject. Each adjusting delay is the mean across the six half-session blocks that satisfied the stability criteria described in the text. (All durations are in seconds.)

Condition	Stand. delay	Step size	ITI	Choice trials	Center key FR	Subject 1 ^a	
						Sess.	Adj. delay
1	8	1	60	2	1	15	28.50
2	8	1	60	6	1	13	25.54
3	3	1	60	6	1	12	15.21
4	3	1	60	2	1	10	16.71
5	8	1	60	2	1	10	23.67
6	8	2	60	2	1	13	27.67
7	8	0.5	60	2	1	13	28.98
8	3	0.5	60	2	1	10	15.00
9	3	2	60	2	1	13	16.46
10	8	1	40	2	1	11	22.69
11	8	1	100	2	1	10	25.88
12	3	1	100	2	1	13	14.59
13	3	1	40	2	1	12	9.52
14	8	1	60	6	1	11	22.25
15	3	1	60	2	10	12	13.29
16	3	1	60	2	1	15	12.27
17	3	1	60	2	30	16	13.44
18	8	6	60	2	1	13	24.38
19	3	6	60	2	1	11	14.88

^a The order of conditions for Subjects 1 and 2 was the same as the condition number shown in the extreme left column of the table.

Fig. 1. A schematic diagram of the two possible sequences of events that could occur on a choice trial, depending on which key was pecked.

trials. In the other three conditions, a session consisted of eight blocks of eight trials each—two forced trials followed by six choice trials. As in Condition 1, all changes in the adjusting delay were made at the end of each trial block. In conditions with six choice trials, if the adjusting key was chosen on between zero and two choice trials, the adjusting delay was decreased by 1 s. If it was chosen on three trials, the adjusting delay was not changed. If it was chosen on between four and six choice trials, the adjusting delay was increased by 1 s. There were therefore only eight possible changes in the adjusting delay per session with six choice trials per block, compared to 16 possible changes per session with two choice trials per block. Of the three conditions employing each procedure, two used a standard delay of 8 s and the other used a standard delay of 3 s.

Variations in the step size for the adjusting delay (Conditions 6 through 9, 18, and 19). The procedure, two used a standard delay of 8 s as in Condition 1, except that the adjusting delay was increased or decreased in steps of 0.5 s, 2 s, or 6 s rather than 1 s. Each step size was used in two conditions, one with a standard delay of 3 s and the other with a standard delay of 8 s.

Table 1 (Continued)

Subject 2 ^a			Subject 3			Subject 4		
Sess.	Adj. delay	Order	Sess.	Adj. delay	Order	Sess.	Adj. delay	
18	16.82	2	13	16.98	2	17	15.65	
12	19.50	1	15	17.58	1	16	10.54	
17	11.96	4	23	10.25	4	17	12.71	
12	9.42	3	16	10.40	3	12	10.46	
16	16.64	14	17	19.52	14	15	16.19	
11	18.46	7	19	15.46	7	13	20.29	
15	17.71	6	12	20.68	6	15	20.81	
12	6.02	9	12	5.92	9	10	9.43	
15	6.92	8	14	8.58	8	10	13.58	
10	18.71	11	16	19.02	11	12	21.65	
12	14.71	10	17	14.90	10	12	22.32	
11	7.73	13	13	6.90	13	12	10.07	
13	8.98	12	20	8.42	12	12	8.78	
11	15.71	5	12	25.79	5	22	18.41	
11	10.98	—	—	—	16	29	9.52	
11	6.82	—	—	—	15	11	11.24	
10	6.86	—	—	—	17	20	11.57	
14	21.13	15	15	21.25	18	15	25.83	
13	12.88	16	11	10.25	19	14	20.13	

Variations in trial duration (Conditions 10 through 13). The procedure in these conditions was the same as in Condition 1, except that the time from a choice response to the start of the next trial was 40 s in two conditions and 100 s in the other two. One condition with each trial duration used a standard delay of 3 s, and the other used a standard delay of 8 s. These conditions were compared with those employing a 60-s ITI (Conditions 1, 4, 5, and 16), which have already been described.

Variations in the center-key response requirement (Conditions 15 through 17). In all three of these conditions, the standard delay was 3 s. To begin each trial, one center-key response was required in Condition 16, 10 responses were required in Condition 15, and 30 responses were required in Condition 17. In all other respects, these conditions were identical to Condition 1. Subject 3 was not exposed to these three conditions.

RESULTS

Table 1 shows the number of sessions required for each subject to satisfy the stability criteria in each condition. The mean adjusting delays from the six half-session blocks that satisfied these criteria were used as estimates of the indifference points. Table 1 lists these indifference points for each subject and condition.

Three of the procedural variations were re-

peated in two separate conditions (Conditions 1 and 5, 2 and 14, and 4 and 16), thus providing a measure of replicability across conditions. In the eight cases that included an 8-s standard delay (4 subjects in two conditions), the average adjusting delay was 19.3 s, and the deviation between pairs of replications averaged 3.9 s. In the three cases that included a 3-s standard delay, the average adjusting delay was 11.2 s, and the deviation between pairs of replications averaged 2.6 s. Thus in both cases the deviations between replications averaged slightly over 20% of the adjusting delay. Another rough measure of replicability was obtained by calculating, for each subject, one standard deviation for the indifference points from the nine conditions with an 8-s standard delay and another from the 10 conditions with a 3-s standard delay. Since any effects of the procedural differences among conditions would increase these standard deviations, they can be considered upper limits to those that would be obtained from a series of identical conditions. The standard deviations averaged 2.9 s for conditions with an 8-s standard delay and 2.3 s for conditions with a 3-s standard delay.

Figure 2 presents the indifference points for each subject and for the group as a whole, in a way that facilitates assessment of the different procedural manipulations. The open circles indicate conditions with a 3-s standard delay, and the filled circles indicate conditions with an 8-s standard delay. The first column

Fig. 2. Indifference points from each condition are shown, and the vertical lines are standard deviations of the adjusting delay. The indifference points are based on the six half-session blocks that satisfied the stability criteria, and the standard deviations are based on these six plus the preceding six half-session blocks. See the text for additional explanation. In cases in which the same procedures were repeated in two conditions, the results were averaged across the two conditions. The results from the conditions with two choice trials per block in the left column reappear in the second column (60-s trial duration) and in the third column (1-s step size).

shows the results from conditions in which the number of choice trials was varied. The remaining columns show, from left to right, the effects of variations in trial duration, step size, and the number of center-key responses. In cases in which the same procedures were repeated in two conditions, the results in Figure 2 are averaged across the two replications. It should be noted that the results from the conditions with two choice trials per block in the left column reappear in the second column (60-s trial duration) and in the third column (1-s step size).

The vertical lines in Figure 2 are standard deviations that reflect the trial-to-trial variability in the adjusting delay within each condition. These standard deviations were calculated as follows. To obtain a larger sample of each subject's behavior, the results from 12 half-session blocks were used (the six blocks that satisfied the stability criteria plus the preceding six blocks). For each subject, the standard deviation of the adjusting-delay duration was calculated from these 12 half-sessions.

As Figure 2 shows, the size of the standard delay had a clear effect on the indifference points for all subjects. Across all conditions, the mean indifference point was 11.0 s with a 3-s standard delay and 20.3 s with an 8-s standard delay, and there was no overlap between group means from the 3-s and 8-s conditions. In comparison, the various experimental manipulations had relatively little effect on the indifference points. Examination of both individual results and group means shows that neither the number of choice trials per block nor the number of center-key responses had systematic effects on the estimated indifference points. The group means from the conditions with two and six choice trials per block differed by less than 1 s. The group means from conditions with different center-key response requirements differed by just over 1 s. In the latter case, this relative stability was found although the larger response requirements substantially increased the total time between the start of a trial and reinforcement. For the response requirements of 1, 10, and 30, the time between the lighting of the center key and completion of the ratio averaged 0.7 s, 4.2 s, and 14.1 s, respectively. (These durations are the means of the harmonic means of every subject's response times in each condition.) Indifference points from the conditions in which

trial duration was manipulated were more variable, but no systematic trends were evident. For instance, the indifference points for Subject 1 increased somewhat with the longer trial durations, whereas those for Subjects 2 and 3 decreased slightly and those for Subject 4 showed no systematic changes.

The indifference points from the conditions with different step sizes were the most variable, but if the results from conditions with a 6-s step size are ignored, the results exhibit no consistent trends. The two conditions with a step size of 6 s were added at the end of the experiment because the results with smaller step sizes showed no clear trends, and it was suspected that changes in the indifference points might be observed if the step size was large enough. As Figure 2 shows, the 6-s step size produced larger indifference points for Subjects 2 and 4, but not for the other 2 subjects. However, for all subjects the standard deviations of the adjusting delays were larger in the two conditions with a 6-s step size than in any other condition of the experiment.

To provide a clearer picture of how the different manipulations affected the trial-by-trial variability of the adjusting delay, the standard deviations in Figure 2 were averaged across subjects and plotted as points in Figure 3. Overall, standard deviations with the 3-s and 8-s standard delays were not substantially different, averaging 3.6 s and 4.1 s, respectively. Of the four independent variables, only step size had systematic effects. Standard deviations increased steadily from less than 2 s with a step size of 0.5 s to more than 6 s with a step size of 6 s. The larger standard deviations with larger step sizes were, in part, a statistical necessity. That is, if the adjusting delay fluctuated within the same range of values regardless of step size, larger standard deviations would nevertheless occur with the 6-s step size because of the absence of delay durations that were not multiples of 6 s. However, the observed increases in standard deviations with increasing step size were several times too large to be attributed entirely to this statistical artifact. Instead, the standard deviations were larger mainly because the adjusting delay fluctuated over a wider range of values with larger step sizes.

An examination of within-session changes in the adjusting delay provides additional support for this last statement. Figure 4 shows,

Fig. 3. Group means of the standard deviations in the adjusting delay are shown for each condition. In cases where the same procedures were repeated in two conditions, the results were averaged across the two conditions. The results from the conditions with two choice trials per block in the left panel reappear in the second panel (60-s trial duration) and in the third panel (1-s step size).

Fig. 4. For Subject 2, trial-by-trial changes in the adjusting delay are shown for the conditions with different step sizes. The data are from the same 12 half-sessions used to calculate the standard deviations in Figures 2 and 3. The beginning and end of individual sessions are indicated by breaks in the plotted functions.

for 1 subject, trial-by-trial changes in the adjusting delay from conditions with different step sizes. The data are from the same 12 half-sessions used to calculate standard deviations for Figures 2 and 3. Results from conditions with a 3-s standard delay are shown in the left column, and those from conditions with an 8-s standard delay are shown in the right column. It is clear that fluctuations in the adjusting delay were smallest with a step size of 0.5 s, intermediate with step sizes of 1 s and 2 s, and largest with a step size of 6 s. The effects of step size on within-session variability were similar for the other 3 subjects.

DISCUSSION

The main finding of this experiment was that variation of four different variables had relatively little effect on the indifference points estimated with this adjusting-delay procedure. Three of the variables—the number of choice trials per block, the center-key response requirement, and trial duration—had no systematic effects. Of course, it is possible that larger variations in any of these variables might produce systematic changes in the obtained indifference points. Nevertheless, we can conclude that, within limits, changes in these three variables do not produce greatly differing estimates of indifference. This conclusion means that the adjusting-delay procedure can be used for its intended purpose of obtaining reasonably accurate estimates of indifference points in considerably less time than would usually be required by the other two methods mentioned in the introduction.

Although total trial duration was varied by only a factor of 2.5, the actual range of ITI durations was larger (where ITI is defined as the time from the end of reinforcement to the start of the next trial), because trial duration included both the delay before reinforcement and reinforcer duration. For example, if the adjusting delay was 20 s, the ITI ranged from 17 s to 77 s (a factor of 4.5) as trial duration was varied. On the surface, the finding that ITI duration had no effect on choice may seem to be inconsistent with the results of Mazur et al. (1985), who found that indifference points varied as a function of the ITI that followed the standard alternative. However, both sets of results are consistent with the theory discussed by Mazur et al. (a theory also advocated

by McDiarmid & Rilling, 1965, and by Shull & Spear, 1987), which proposes that choice is determined by the delays to the next reinforcer and to subsequent reinforcers, with each delay being measured from the time of the current choice. In the present experiment, the total time from one choice to the start of the subsequent trial was always the same no matter which alternative was chosen. The times to reinforcers delivered on subsequent trials were therefore independent of the current choice, and therefore according to the theory they should not affect the indifference point. The results suggest that they did not.

The lack of an effect of the center-key response requirement has interesting theoretical implications. Some theories of choice, such as optimal foraging theory, predict that choice is determined by the total time required to obtain each reinforcer. Such theories predict that the time spent responding on the center key should be treated as part of the total delay to reinforcement, because it constitutes part of the "cost" of obtaining the reinforcer. If this were so, the indifference points should have increased substantially in the conditions with response requirements of 10 and 30. Notice that in all conditions in which the center-key requirement was one response, the adjusting delay at the indifference point was more than twice as long as the standard delay. This result, coupled with Mazur's (1987) finding that indifference curves for such delay-amount trade-offs are linear, suggests that for every additional second that is added to the standard delay, about 2 s must be added to the adjusting delay to maintain an indifference point. Because the response requirement of 30 added about 14 s to the total time before reinforcement for both the standard and adjusting alternatives, if this additional time is treated as part of each delay, the adjusting delay should have increased by an additional 14 s.

The failure to find any such increase in the adjusting delay suggests that subjects' choices were not affected by response requirements (and the accompanying passage of time) that occurred prior to the choice itself. This result is therefore inconsistent with theories that propose that the total time per reinforcer is the controlling variable in choice situations (e.g., Charnov, 1976; Schoener, 1971). On the other hand, the result is consistent with molecular theories that assume that a subject's choice is

determined by the schedule requirements in effect at the moment of choice (e.g., any remaining delay, or responses still to be completed), but not by schedule requirements that have already been met (e.g., Mazur et al., 1985; Shull & Spear, 1987; Vaughan, 1985).

This study found that changes in step size had large effects on within-session variability in the adjusting delay, and with the largest step size (6 s) larger indifference points were obtained for 2 subjects. This latter finding may appear to pose problems for interpreting the indifference points obtained with this procedure. Perhaps smaller variations in step size (e.g., between 0.5 s and 2 s) also have some effect on the measured indifference points, but this effect was obscured by random error in the present study. If indifference points estimated with this procedure actually vary continuously and systematically with step size, how can we decide which step size to use? Which indifference point should be accepted as the correct one?

There is a simple method for dealing with this problem, one that has been used in several previous studies (Mazur, 1984, 1986b; Mazur et al., 1985). The solution is to include several control conditions in which the two alternatives are identical in every way, except that the standard alternative has a fixed delay and the adjusting delay varies as in the present experiment. In different control conditions, the standard delay can be varied over a range of different durations. When this was done in the study of Mazur (1984), for instance, it was found that most subjects exhibited a bias toward the adjusting alternative, and that this bias was roughly proportional to the size of the standard delay. That is, for every duration of the standard delay, the adjusting delay at the indifference point was about 15% larger. It was a simple matter to correct for this bias in comparing the results with theoretical predictions, in making predictions for subsequent conditions, and in calculating bias-free estimates of the indifference points. This bias toward the adjusting alternative might be attributed to the variability in the adjusting delay over trials, because animals are known to prefer variable over fixed delays to reinforcement (Cicerone, 1976; Mazur, 1984; Rider, 1983). A problem with this interpretation, however, is that the amount of bias varied considerably across subjects in the Mazur (1984) study, and

a bias toward the standard alternative was found in another study (Mazur, 1986a). In any case, it does not matter whether this bias was due to the variability in the adjusting delay or to some other factor (e.g., the key color associated with the adjusting alternative). As long as this type of bias can be measured with some accuracy, it can be corrected for.

One unanticipated finding of this study was the low variability in the adjusting delay with a step size of 0.5 s. This finding was not explored further because the study was not specifically designed to seek ways to improve the adjusting-delay procedure. Nevertheless, it is possible that more reliable indifference-point estimates can be obtained with step sizes smaller than 1 s, the size used in previous studies with this procedure. The important but unanswered question is whether this lower within-session variability is accompanied by lower variability in estimated indifference points when the same standard and adjusting alternatives are repeated over several separate conditions.

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