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HUMANS' CHOICE IN A SELF-CONTROL CHOICE SITUATION: SENSITIVITY TO REINFORCER AMOUNT, REINFORCER DELAY, AND OVERALL REINFORCEMENT DENSITY

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Human subjects were exposed to a concurrent-chains schedule in which reinforcer amounts, delays, or both were varied in the terminal links, and consummatory responses were required to receive points that were later exchangeable for money. Two independent variable-interval 30-s schedules were in effect during the initial links, and delay periods were defined by fixed-time schedules. In Experiment 1, subjects were exposed to three different pairs of reinforcer amounts and delays, and sensitivity to reinforcer amount and delay was determined based on the generalized matching law. The relative responding (choice) of most subjects was more sensitive to reinforcer amount than to reinforcer delay. In Experiment 2, subjects chose between immediate smaller reinforcers and delayed larger reinforcers in five conditions with and without timeout periods that followed a shorter delay, in which reinforcer amounts and delays were combined to make different predictions based on local reinforcement density (i.e., points per delay) or overall reinforcement density (i.e., points per total time). In most conditions, subjects' choices were qualitatively in accord with the predictions from the overall reinforcement density calculated by the ratio of reinforcer amount and total time. Therefore, the overall reinforcement density appears to influence the preference of humans in the present self-control choice situation.

Key words: choice, self-control, sensitivity to reinforcer amount and delay, overall reinforcement density, concurrent-chains schedule, screen touch, humans

Much research on human choice has focused on procedures in which both reinforcer amounts and reinforcer delays differ between the choice alternatives. Such procedures are interesting, in part, because they seem to be analogous in some respects to everyday situations that prompt people to speak of behaving impulsively or in a self-controlled manner (e.g., Logue, King, Chavarro, & Volpe, 1990; Logue, Peña-Correal, Rodriguez, & Kabela, 1986; Millar & Navarick, 1984). In the standard laboratory procedure, preference for a smaller, more immediate reinforcer over a larger, more delayed reinforcer has been called *impulsiveness*; preference for a larger, more delayed reinforcer is sometimes seen as analogous to *self-control* (cf. Logue, 1988; Rachlin & Green, 1972). Human choice has been studied with concurrent and concurrent-chains schedules designed to resemble as closely as possible procedures used with nonhumans (e.g., Belke, Pierce, & Powell, 1989; cf. Matthews, Shimoff, Catania, & Sagvolden, 1977), and much of the data obtained in these procedures can be dealt with by the following generalized matching equation (Baum, 1974):

$$\frac{R_1}{R_2} = k\left(\frac{A_1}{A_2}\right)^{S_a}\left(\frac{D_2}{D_1}\right)^{S_d}, \tag{1}$$

where A is reinforcer amount, D is delay to reinforcement, R is the number of responses to that alternative, and k, S_a, and S_d are empirical constants. These parameters can be estimated by the logarithmic linear transformation of the following form:

$$\log\left(\frac{R_1}{R_2}\right) = S_a\log\left(\frac{A_1}{A_2}\right) + S_d\log\left(\frac{D_2}{D_1}\right) + \log k. \tag{2}$$

A bias is present when k is less than or greater than 1.0. The parameters S_a and S_d represent the sensitivity to variations in reinforcer amount and delay, respectively.

Humans' self-control and impulsiveness shown in a self-control choice situation have been affected by several factors such as qualitative differences in reinforcers (e.g., Logue et al., 1986, points; Millar & Navarick, 1984,

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video game playing; Navarick, 1982, noise reduction), the presence or absence of a consummatory response (e.g., King & Logue, 1990), changeover-delay duration (e.g., King & Logue, 1987), difference in choice procedures (e.g., Ito, Nakamura, & Kuwata, 1997; Logue et al., 1990), and reinforcement density (e.g., Flora & Pavlik, 1992).

Qualitative differences in reinforcers are likely to affect the occurrence of humans' self-control and impulsiveness. For example, Logue et al. (1986), using points exchangeable for money as a reinforcer, found that human subjects chose the larger, more delayed reinforcer over the smaller immediate reinforcer. On the other hand, Millar and Navarick (1984), using video game playing as a reinforcer, found that human subjects tended to choose the smaller, immediate reinforcer when a delay was imposed before the larger reinforcer in a self-control choice situation. Humans' impulsiveness was also shown in the context of negative reinforcement. Navarick (1982), using noise reduction as a reinforcer, found that humans' preference for the smaller immediate reinforcer increased as the delay preceding the larger reinforcer increased. These results are consistent with those obtained by Belke et al. (1989), who compared pigeons' choices reinforced by food with humans' choices reinforced by points in a concurrent-chains procedure. They showed that immediately consumable reinforcers such as food generated high sensitivity to delay, whereas conditioned reinforcers such as points generated low sensitivity to delay. Taken together, it seems that secondary reinforcers such as points that are later exchangeable for money tend to produce self-control, whereas primary reinforcers such as food, video game playing, or noise reduction tend to produce impulsiveness in a self-control choice situation. However, a recent study by Forzano and Logue (1994), using an adjusting-delay procedure (cf. Mazur, 1988), provided inconsistent data, showing that in human subjects a higher sensitivity to reinforcer amount relative to reinforcer delay was evident irrespective of the difference in the type of reinforcers (juice vs. points) and also that subjects did not differ in their degree of self-control between two different reinforcers that were delivered at the end of the session. These results suggest that the difference in the time of delivery of reinforcers (i.e., consumable during a session or at the end of a session) may in part explain the different effects of primary and secondary reinforcers on self-control choices.

Further, impulsive choice has also been obtained in situations using secondary reinforcers when the so-called impulsive choice produced a greater reinforcement density than the so-called self-control choice would have produced. For example, Flora and Pavlik (1992) revealed that in a discrete-trial procedure using points as a reinforcer, self-control was observed in all but one condition without postreinforcer delays when the impulsive choices produced a higher reinforcement density. In their study, reinforcement density for an alternative was defined as the amount of reinforcement per trial divided by the total time between reinforcements (i.e., prereinforcer delay, reinforcer access period, and postreinforcer delay).

According to the generalized matching equation, reinforcer amounts and delays are assumed to be combined multiplicatively to determine preference for two alternatives; that is, the ratio of reinforcer amount and delay (i.e., A/D) is taken to represent a reinforcing value for each alternative in the generalized matching equation. In contrast, some versions of molar maximization hold that preference is based on the total time (T) rather than prereinforcer delay (D) alone; total time is defined as the sum of the choice phase duration, prereinforcer delay, reinforcer access period, and postreinforcer delay (timeout period). The ratio of reinforcer amount and total time (i.e., A/T) is taken to represent a reinforcing value for each alternative according to molar maximization. In either view, reinforcement density (i.e., number of reinforcements per unit time) is supposed to determine preferences in a self-control choice situation. The ratio of reinforcer amount and delay (A/D) represented by the matching law is referred to as local reinforcement density, whereas the ratio of reinforcer amount and total time (A/T) represented by molar maximization is referred to as overall reinforcement density.

In general, models with free parameters, such as the generalized matching law, can provide a post hoc description but cannot derive predictions in advance of an experiment because these parameters are estimated from the data after the experiment has been conducted. However, one way to circumvent this shortcoming of Equation 1 (or models with free parameters in general) is to derive predictions by using parameters that have been obtained in a different situation. Only a few studies have examined the validity of this approach (e.g., Logue et al., 1990).

The present study, using a concurrent-chains schedule and points as a reinforcer, investigated more systematically whether human choice in a self-control choice situation is predicted by local reinforcement density (LRD) as shown in Equation 1 or by overall reinforcement density (ORD), and whether sensitivity values of Equation 1 obtained in a different situation can be used in predicting human choice in a self-control choice situation. In Experiment 1, humans' sensitivity to variations in reinforcer amount and delay was determined for each subject. Using sensitivity values obtained in Experiment 1, Experiment 2 assessed the predictions of the LRD and ORD in a self-control choice situation in which reinforcer amounts and delays were varied together so as to make different predictions from the two different views.

EXPERIMENT 1

The purpose of Experiment 1 was to examine humans' sensitivity to variations in reinforcer amount and delay. Previous studies used only one condition (except for the baseline condition) of reinforcer amount and delay to estimate sensitivity values for reinforcer amount and delay (e.g., Logue et al., 1986, 1990). To increase the generality of sensitivity values obtained, the present experiment used three conditions (four conditions including baseline) for each reinforcer dimension (i.e., amount and delay). The values of S_a and S_d for each subject were used to predict the subjects' choices in a self-control choice situation arranged in Experiment 2.

Method

Subjects

The subjects were 6 adult undergraduate students (3 males and 3 females) between 18 and 22 years of age. They were recruited for participation from an introductory psychology class. None of the subjects was a psychology major.

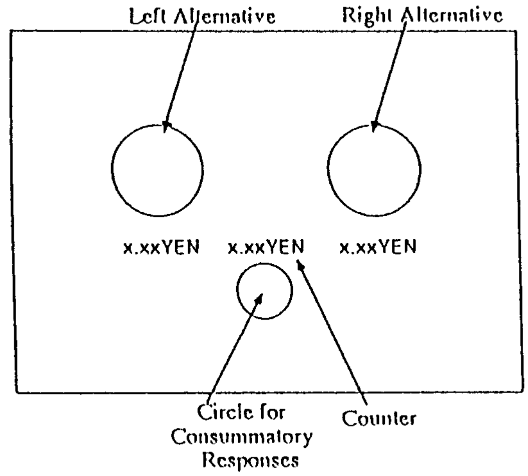

Fig. 1. A display of the monitor used in the present experiments.

Apparatus

The experiment was conducted in a small room (3.6 m by 2.8 m). A 14-in. color CRT monitor with a touch panel (MicroTouch Systems Inc.) was placed on the desk, and was separated by a large panel from a personal computer (NEC PC-9801U2) and the experimenter. The touch panel consisted of a capacitance screen. The minimum detectable response duration was 15 ms, and the maximum number of responses that could be detected per second was 44. A touch to the circles presented on the screen of the monitor was defined as a response. A personal computer, programmed to present stimuli (i.e., colored circles and counters) on the screen of the monitor, controlled the experiment and recorded events.

The screen of the monitor contained three colored circles and counters (see Figure 1). Two colored circles, 5.0 cm in diameter, were located in the center of the screen and 11 cm apart (from center to center). A small colored circle was located 7.0 cm below the center and 13.5 cm from the sides. A counter was located below each of the large circles and above the small circle. A touch to the circles produced a brief beep as response feedback.

Procedure

Each subject was seated before the monitor and required to remove all metal objects (i.e., watches and jewelry) to minimize interference with the touch panel during the session. The subject was then given the following minimal instructions (in Japanese):

> Please read repeatedly until you understand. Do not ask for additional instructions. You may play a game. Your task is to earn as much money as you can. Money will be accumulated on the counter and you will receive the total amounts of money accumulated on the counter at the end of the session. Each session is 20 min in duration. You may touch anything on the screen to earn money, but you have to touch with a forefinger. A brief beep sound will be provided if a response is effective. The session will begin when three white circles come on.

A concurrent-chains schedule was employed with two independent variable-interval (VI) VI schedules (i.e., choice phase). During the choice phase, the two larger circles and the smaller circle with its counter were presented on the screen of the monitor. Each circle was colored white (the background color of the screen was black). After entry into either of the terminal links (i.e., delay period), the large circle not selected was darkened and the other large circle was lit with either blue or yellow. Entry into either of the terminal links was arranged by two independent VI 30-s VI 30-s schedules (see Figure 2). Each interval of the VI tape was derived from the distribution of Fleshler and Hoffman (1962). As each interval in one of the VI schedules timed out, the timer stopped and reinforcement was assigned to the appropriate side. A 3-s changeover delay (COD) was used. In this COD procedure, 3 s had to elapse after a changeover response from the right to the left circle or vice versa before a subsequent response made it possible to enter into the delay period (cf. de Villiers, 1977). The next response on the appropriate circle initiated the delay period defined by a fixed-time (FT) schedule. After the delay, the reinforcer access period (3 s in duration) was in effect, in which the small circle was illuminated red and either the left or the right side counter was presented on the screen. Each response to the red circle accumulated a prescribed point (i.e., 1 point was worth 1 yen) on the respective side counter. Therefore, total reinforcer amount (points) per cycle depended on the number of consummatory responses emitted during the 3-s reinforcer access period. The center counter accumulated total points earned. The side counter was always reset at the start of the next cycle. A timeout period followed the shorter delay. Timeout periods were used to equate overall rates of reinforcement on the two alternatives. During timeout periods, the screen was darkened except for the center counter, and a touch to the screen produced no scheduled consequences and no feedback beep.

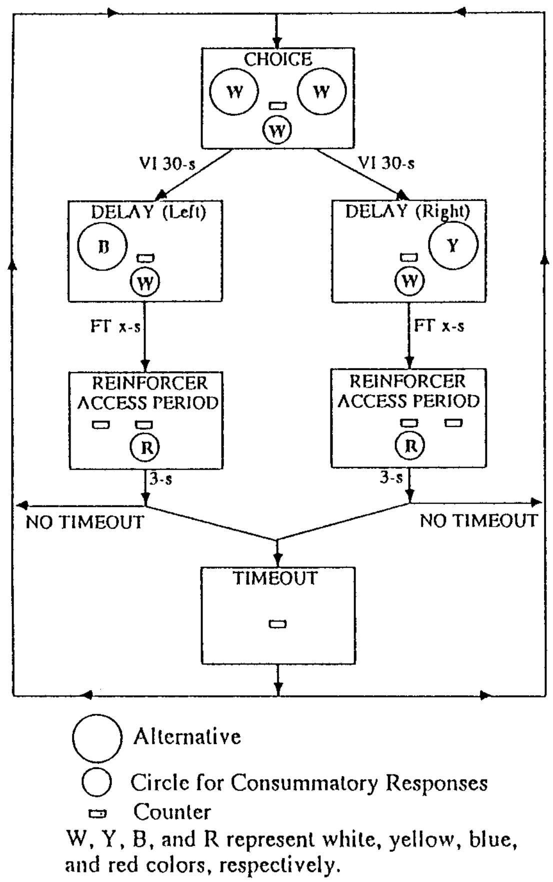

Fig. 2. A schematic diagram of the free-choice procedure used in the present experiments.

The experiment consisted of three conditions, that is, baseline, reinforcer amount, and reinforcer delay conditions. In baseline, reinforcer amount was 0.03 yen, and reinforcer delay was 5 s for both alternatives. For the reinforcer amount condition, three different pairs of reinforcer amounts of 0.03 and 0.15, 0.03 and 0.30, and 0.03 and 0.60 yen (for a consummatory response) were studied with equal delays of 5 s, and, for the reinforcer delay condition, different pairs of reinforcer delays of 5 s and 25 s, 5 s and 50 s, and 5 s and 100 s were studied with equal amounts of 0.03 yen. Each condition was presented once in a random sequence for the reinforcer amount condition. For the reinforcer delay condition, however, each condition was presented two to four times, depending on the delay values, to equate the total number of cycles (about 40 cycles) for each condition. The baseline condition was presented once, but it was replicated if the subject was not indifferent between two alternatives in the baseline condition. Indifference was defined as choice proportions ranging from .55 to .45. The order of the conditions is shown in Table 1. Each session was 20 min in duration, and four sessions were conducted per day. The experiment was conducted over 3 days. At the start of each session (except for baseline), the subjects were exposed to four forced cycles (trials) in which both alternatives were presented and the available terminal link was assigned quasirandomly, with equal probability (i.e., two right and two left alternatives), to the right or to the left. These forced cycles were not included in a 20-min session and were never used in data analysis. Each subject completed a questionnaire asking how he or she did during the experiment and received the money earned at the end of each session.

Results

Table 1 shows the number of responses to both left and right circles, choice proportions, the number of cycles, and the order of conditions for each subject. Mean number of consummatory responses per cycle and mean obtained reinforcer amount (points) per cycle are also shown in Table 1. For the reinforcer delay condition, data were combined across sessions. Choice proportions were obtained by dividing the initial-link responses for the right by the total initial-link responses. Choice proportions for the larger of two reinforcers or the shorter of two delays increased with increases in the ratio of the two reinforcers (i.e., reinforcer amount and delay). The mean number of consummatory responses per cycle did not differ substantially between the two alternatives for all conditions, although it ranged from 13 to 34 across conditions. The ratios of obtained reinforcer amounts between the two alternatives were similar to those of programmed reinforcer amounts (arranged as points per consummatory response). In the baseline and reinforcer delay conditions, the mean ratios of obtained reinforcers between the two alternatives, averaged over all subjects and across conditions, were 1.02 for the baseline and 1.03 for the reinforcer delay condition, which were close to the programmed ratio of 1.0. For the reinforcer amount condition, the mean obtained ratios of two reinforcer amounts, averaged over all subjects, were 5.2, 9.6, and 19.2 for the smallest to the largest ratio, corresponding to the programmed reinforcer ratios of 5, 10, and 20, respectively. The difference between the programmed and obtained reinforcer ratios can be expressed with a measure obtained by dividing the obtained reinforcer ratio by the programmed reinforcer ratio. This measure, averaged over all subjects and across conditions, gave a value of 1.01, indicating that the obtained reinforcer ratio was identical to the programmed reinforcer ratio in the present procedure.

Figure 3 shows the logarithm of the ratio of responses during the initial links as a function of the logarithm of the ratio of reinforcer amount or delay for each subject. The dashed lines show the locus of perfect matching between the response ratio and reinforcer amount ratio or reinforcer delay ratio. The solid lines show a least squares fit to the data. The value of r^2 is the coefficient of determination. A linear regression was applied to the log-transformed data.

For all but 1 subject (S82), the slopes of the function for the reinforcer amount condition were steeper than those of the function for the reinforcer delay condition. The values of the slope obtained ranged from 0.41 to 1.94 for the reinforcer amount condition and from 0.15 to 1.30 for the reinforcer delay condition. The percentages of data variance accounted for ranged from 64% to 98% for the reinforcer amount condition and from 80% to 99% for the reinforcer delay condition. A linear regression applied to mean data over all 6 subjects yielded the functions $y = 0.97x - 0.12$ ($r^2 = 0.92$) for the reinforcer amount condition and $y = 0.55x - 0.02$ ($r^2 = 0.99$) for the reinforcer delay condition. These results indicate that most of these hu-

Table 1

Sequence of conditions, number of initial-link responses, mean choice proportion, number of sessions, number of cycles per session, mean number of consummatory responses per cycle, and mean obtained points per cycle for each subject in Experiment 1.

Subject	Order	Points (yen) L/R	Delay (s) L/R	Initial-link responses L/R	Choice proportion R/(R+L)	Sessions	Cycles	Consummatory responses per cycle L/R	Obtained points per cycle L/R
S81	1	0.03/0.03	5/5	2,583/2,603	.502	1	46	22/22	0.66/0.66
	4	0.15/0.03	5/5	3,286/1,544	.320	1	39	21/22	3.15/0.66
	2	0.30/0.03	5/5	2,064/169	.076	1	37	24/28	7.20/0.84
	5	0.60/0.03	5/5	5,146/8	.002	1	32	21/20	12.60/0.60
	6	0.03/0.03	25/5	2,686/3,050	.532	2	53	21/22	0.63/0.66
	3	0.03/0.03	50/5	1,988/2,521	.559	3	52	16/18	0.48/0.54
	7	0.03/0.03	100/5	1,623/2,589	.615	4	42	20/23	0.60/0.69
S82	1	0.03/0.03	5/5	2,003/1,958	.494	1	42	13/14	0.39/0.42
	3	0.03/0.15	5/5	550/470	.461	1	42	21/22	0.63/3.30
	2	0.03/0.30	5/5	1,629/2,946	.644	1	42	18/18	0.54/5.40
	5	0.03/0.60	5/5	1,005/3,559	.780	1	41	23/24	0.69/14.40
	6	0.03/0.03	5/25	3,670/415	.102	2	42	21/19	0.63/0.57
	4	0.03/0.03	5/50	5,938/279	.045	3	46	23/19	0.69/0.57
	7	0.03/0.03	5/100	5,216/111	.021	4	37	22/15	0.66/0.45
S83	1	0.03/0.03	5/5	2,133/2,348	.524	1	37	18/18	0.54/0.54
	7	0.15/0.03	5/5	2,790/1,472	.345	1	44	18/16	2.70/0.48
	5	0.30/0.03	5/5	2,455/1,700	.409	1	44	15/16	4.50/0.48
	4	0.60/0.03	5/5	2,768/1,261	.313	1	43	19/20	11.40/0.60
	2	0.03/0.03	25/5	2,021/2,578	.561	2	54	20/21	0.60/0.63
	6	0.03/0.03	50/5	2,043/2,955	.591	3	50	17/18	0.51/0.54
	3	0.03/0.03	100/5	1,513/2,332	.607	4	40	18/20	0.54/0.60
S84	1	0.03/0.03	5/5	23/22	.489	1	20	25/24	0.75/0.72
	7	0.03/0.15	5/5	695/2,993	.812	1	43	23/24	0.69/3.60
	2	0.03/0.30	5/5	191/2,667	.933	1	32	34/27	1.02/8.10
	5	0.03/0.60	5/5	31/3,372	.991	1	31	21/25	0.63/15
	6	0.03/0.03	5/25	3,253/1,008	.237	2	48	24/23	0.72/0.69
	3	0.03/0.03	5/50	3,219/1,435	.308	3	45	23/23	0.69/0.69
	4	0.03/0.03	5/100	3,633/415	.103	4	38	25/21	0.75/0.63
S85	1	0.03/0.03	5/5	140/158	.530	1	34	18/17	0.54/0.51
	3	0.15/0.03	5/5	411/239	.368	1	37	19/17	2.85/0.51
	2	0.30/0.03	5/5	76/35	.315	1	26	18/16	5.40/0.48
	5	0.60/0.03	5/5	687/123	.152	1	29	15/17	9.00/0.51
	6	0.03/0.03	25/5	99/206	.675	2	41	18/17	0.54/0.51
	7	0.03/0.03	50/5	386/1,008	.723	3	44	17/17	0.51/0.51
	4	0.03/0.03	100/5	234/938	.800	4	37	18/16	0.54/0.48
S86	1	0.03/0.03	5/5	1,016/918	.475	1	44	13/12	0.39/0.36
	6	0.03/0.15	5/5	151/1,722	.919	1	37	19/19	0.57/2.85
	7	0.03/0.30	5/5	95/1,704	.947	1	37	20/21	0.60/6.30
	4	0.03/0.60	5/5	60/1,782	.967	1	34	32/21	0.96/12.60
	3	0.03/0.03	5/25	1,812/550	.233	2	47	19/23	0.57/0.69
	2	0.03/0.03	5/50	1,478/389	.208	3	47	17/15	0.51/0.45
	5	0.03/0.03	5/100	1,234/261	.175	4	40	20/21	0.60/0.63

man subjects were more sensitive to variations in reinforcer amount than to variations in reinforcer delay in the present choice situation.

Discussion

The present experiment used four conditions (including the baseline condition) for each reinforcer to determine sensitivity to variations in reinforcer amount and delay, and found that the performance of most of these human subjects was more sensitive to reinforcer amount than to reinforcer delay, although the differences in the slope of the function between the reinforcer amount and

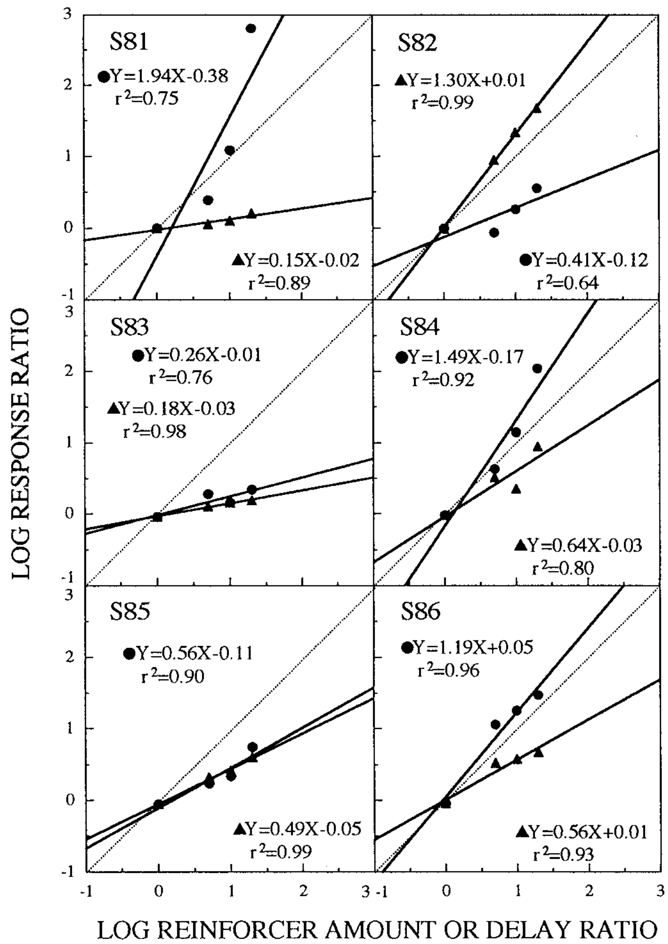

Fig. 3. The logarithm of the ratio of responses as a function of the logarithm of the ratio of reinforcer amounts or reinforcer delays. The dashed lines show the locus of perfect matching between the response ratio and reinforcer amount or delay ratio. The filled circles show the data from the reinforcer amount condition, and the filled triangles show the data from the reinforcer delay condition. The solid lines show a least squares fit to the data.

reinforcer delay conditions were relatively small for 2 subjects (S83 and S85). The present results are consistent with those of Logue et al. (1986), who used human subjects. They used a linear regression and multiple linear regression based on Equation 2 to examine the subjects' sensitivity to reinforcer amount and delay (only one condition for each experiment), and showed that the relative sensitivity values (S_a/S_d) were larger than 1.0 in the experiments in which reinforcer amount and delay were varied separately as well as in the experiments in which they were varied together (i.e., a self-control choice situation). Similar results were obtained by Logue et al. (1990), who examined humans' sensitivity by using a similar linear regression applied to the data obtained from conditions in which reinforcer amount and delay were varied separately. In their Experiment 1, similar to the present procedure, the values of sensitivity to reinforcer amount ranged from 0.5 to 2.0 across 4 subjects, and values to reinforcer delay ranged from 0 to 1.0, consistent with the degree of over- and undermatching obtained in the present experiment. However, the generality of these results (Logue et al., 1986, 1990) was limited because the regression analysis was based on a small number of points (one or two conditions). In this regard, the present study, using more than three points, confirmed and extended the previous findings.

EXPERIMENT 2

To examine whether human self-control choices can be predicted by local reinforcement density (LRD) or overall reinforcement density (ORD), Experiment 2 assessed the predictions of LRD and ORD in five conditions arranged in a self-control choice situation in which reinforcer amounts and delays were varied together so as to make different predictions from these different views. In addition, conditions with and without timeout periods (i.e., postreinforcer delay) that followed a shorter delay were arranged to see whether timeout periods affect human self-control choices. In conditions without timeout periods, overall reinforcement density for an alternative producing a smaller, less delayed reinforcer is relatively higher than in conditions with timeout periods. In contrast, local reinforcement density does not differ between conditions with and without timeout periods. Therefore, Experiment 2 determined the effects of presence and absence of timeout periods in relation to the LRD and ORD predictions.

METHOD

Subjects and Apparatus

The subjects were the same 6 undergraduate students who participated in Experiment 1. The same apparatus was used as in Experiment 1.

Procedure

The procedure was the same as that used in Experiment 1 except that reinforcer amount and delay were varied together, and in some conditions there was no timeout period that followed a shorter delay. The concurrent-chains schedule and the instructions were the same as those used in Experiment 1.

There were five conditions in which the reinforcer amounts and delays were combined so that the LRD and ORD views made different predictions. These five conditions were divided into two conditions with and three conditions without timeout periods following the shorter delay for each subject.

To derive the predicted choice proportions from the LRD (i.e., matching equation), the values of sensitivity obtained in Experiment 1 were used, and the bias parameter (k) in Equation 1 was assumed to be 1.0 for simplicity. For example, the value of the ratio of responses for two alternatives was calculated to obtain the predicted choice proportion based on Equation 1, $R_1/R_2 = (0.1/0.06)^{1.19}(6/20.6)^{0.56} = 1.03$, yielding a predicted choice proportion of .479 (i.e., indifference between two alternatives) for one condition for S86, given that $S_a = 1.19$, $S_d = 0.56$, $A_1 = 0.1$, $A_2 = 0.06$, $D_1 = 20.6$ s, and $D_2 = 6$ s.

The following four values were used to derive the predicted choice proportions based on the ORD view: (a) the sum of the prereinforcer delay, the reinforcer access period, and the postreinforcer delay (a timeout period) for the alternative producing the smaller, less delayed reinforcer; (b) the sum of the prereinforcer delay and the reinforcer access period for the other alternative producing the larger, more delayed reinforcer; (c) the mean initial-link duration; and (d) the reinforcer amount for each alternative. By using these values, overall reinforcement density can be calculated for each alternative. The predicted choice proportions for the larger, more delayed reinforcer were calculated by dividing the overall reinforcement density for the larger, more delayed reinforcers by the total reinforcement density for the two alternatives. For example, to obtain the predicted choice proportion based on the ORD for the abovementioned condition for S86, the mean initial-link duration was 15 s. Therefore, total time for the alternative producing the larger, more delayed reinforcer would be 15 + 20.6 + 3 = 38.6 s, and for the other alternative producing the smaller, less delayed reinforcer, this value would be 15 + 6 + 3 + 14.6 = 38.6 s. Then, reinforcement density was obtained by the ratio of the reinforcer amount and total time; that is, 0.1/38.6 and 0.06/38.6, yielding a predicted choice proportion of $(0.1/38.6)/(0.1/38.6 + 0.06/38.6) = .625$ (i.e., preference for the larger, more delayed reinforcer).

The following two conditions were arranged with timeout periods; in the first condition (labeled A), the LRD view predicted indifference between two alternatives differing in reinforcer amounts and delays, where-

Table 2

Sequence of conditions, number of initial-link responses, mean choice proportion, number of sessions, number of cycles per session, mean number of consummatory responses per cycle, and mean obtained points per cycle for each subject in Experiment 2.

Subject	Order	Condition	Points (yen) L/R	Delay (s) L/R	Initial-link responses L/R	Choice proportion R/(R+L)	Sessions	Cycles	Consummatory responses per cycle L/R	Obtained points per cycle L/R
S81	1	TO	0.11/0.07	32.6/0.1	5,388/905	.144	2	39	22/25	2.42/1.75
	2		0.21/0.18	130/0.1	1,553/3,639	.701	5	40	18/22	3.78/3.96
	4	No TO	0.18/0.09	80/4	159/9,663	.984	2	58	22/23	3.96/2.07
	3		0.11/0.07	32.6/0.1	1,473/6,981	.826	2	65	21/22	2.31/1.54
S82	3	TO	0.02/0.20	20/40.2	70/3,734	.982	3	49	22/19	0.44/3.80
	2		0.05/0.10	10/30	153/2,011	.929	2	40	18/19	0.90/1.90
	4	No TO	0.08/0.16	3/90	5,031/217	.041	2	56	18/21	1.44/3.36
	1		0.05/0.10	10/30	613/4,425	.878	2	48	21/23	1.05/2.30
S83	2	TO	0.10/0.05	24.4/5	2,711/2,030	.428	2	54	19/19	1.90/0.95
	1		0.13/0.10	120/0.1	1,485/2,141	.590	4	36	17/19	2.21/1.90
	3	No TO	0.30/0.18	121.5/37.8	1,259/2,561	.670	3	39	19/17	5.70/3.06
S84	1	TO	0.05/0.10	4.9/26.9	1,070/2,707	.717	2	49	21/21	1.05/2.10
	2		0.06/0.12	1/30	1,505/2,032	.574	2	48	26/27	1.56/3.24
	3	No TO	0.08/0.24	22/132	1,774/494	.218	2	28	25/26	2.00/6.24
	4		0.09/0.27	10/148.5	1,476/935	.388	2	28	24/22	2.16/5.94
S85	2	TO	0.15/0.03	28.4/6	570/129	.185	2	36	16/17	2.40/0.51
	1		0.10/0.05	40/2	475/15	.031	2	32	18/16	1.80/0.80
	4	No TO	0.11/0.05	80/6	333/526	.612	2	39	17/16	1.87/0.80
	3		0.16/0.06	67/26	313/82	.208	2	26	16/18	2.56/1.08
S86	2	TO	0.10/0.06	20.6/6	2,866/223	.072	2	50	21/19	2.10/1.14
	1		0.12/0.06	40/1	1,780/39	.021	2	36	22/21	2.64/1.26
	4	No TO	0.60/0.15	170/18	170/2,376	.933	3	44	17/17	10.20/2.55
	3		0.30/0.11	158/14	28/3,316	.992	2	45	16/20	4.80/2.20

[a] TO represents conditions with timeout periods; No TO represents conditions without timeout periods.

as the ORD view predicted preference for the larger, more delayed reinforcers. In the second condition (labeled B), the LRD view predicted preference for the smaller, less delayed reinforcer, whereas the ORD view predicted the opposite direction, that is, preference for the larger, more delayed reinforcers.

The following three conditions were arranged without timeout periods. In the third condition (labeled C), the LRD view predicted indifference, whereas the ORD view predicted preference for the smaller, less delayed reinforcers (except for S85). In the fourth condition (labeled D), the LRD view predicted preference for the larger, more delayed reinforcers, whereas the ORD view predicted preference for the smaller, less delayed reinforcers. In the fifth condition (labeled E), similar predictions were derived from two different views; that is, both views predicted preference for the smaller, less delayed reinforcers except for S82, who was exposed to the second condition (Condition B) without timeout periods.

In these five conditions, the combinations of reinforcer amounts and delays used differed across subjects and conditions. These values are given in Table 2 for each condition and each subject.

Each subject was exposed to four conditions in a random sequence (two conditions were with timeout periods, and the remaining two conditions were without timeout periods) except for S83, who was exposed to only three conditions. Each condition was usually presented twice. Some conditions, however, were presented from three to five times so as to equate the number of trials across conditions when longer delay values were used.

Each session was 20 min in duration, and four or five sessions were conducted per day. The experiment was conducted over 3 days. At the start of each session, the subjects were exposed to four forced cycles (trials) in which the two alternatives were presented and the available terminal link was assigned quasirandomly, with equal probability, to the right or to the left for all conditions. As in Experiment 1, these forced cycles were not included in the 20-min session or in data analysis. At the end of every session, each subject completed a questionnaire asking how he or she did during the experiment and received the money earned during that session.

Results

Table 2 shows the conditions that differed in both reinforcer amount and delay, the number of responses for both left and right alternatives, choice proportions, number of sessions and cycles, the mean number of consummatory responses per cycle, and the mean obtained reinforcer amount per cycle for each subject. Choice proportions for the larger, more delayed reinforcer varied across conditions in which reinforcer amount and delay were varied together. As in Experiment 1, the mean number of consummatory responses per cycle did not differ substantially between two alternatives, although it ranged from 16 to 27 across conditions. The measure of the difference between the programmed and obtained reinforcer ratios, averaged over all subjects and across conditions, gave a value of 1.0, indicating that the average obtained reinforcer ratio was identical to the programmed reinforcer ratio as in Experiment 1.

Figure 4 shows the obtained choice proportions for the larger, more delayed reinforcers and the predicted choice proportions from the LRD and ORD views for the first two conditions (Conditions A and B). For Condition A, the obtained choice proportions were above .5 in all cases. Further, the obtained choice proportions were above .5 in four of six cases for Condition B. Across two conditions (A and B), 10 of 12 cases were qualitatively in accord with the ORD predictions. A quantitative analysis revealed that the differences between obtained and predicted choice proportions were smaller for the ORD predictions than for the LRD predictions; mean absolute difference was .179 for the ORD predictions, whereas it was .381 for the LRD predictions. In most cases, the obtained choice proportions were greater than the ORD predictions. This finding is due to the fact that most human subjects preferred the larger, more delayed reinforcers more often than expected by the ORD predictions. Together, it seems that human preferences in a self-control choice situation were better predicted by overall reinforcement density than by local reinforcement density when timeout periods were used.

Figure 5 shows the obtained choice proportions for the larger, more delayed reinforcers and the predicted choice proportions based on the LRD and ORD views for the remaining three conditions (Conditions C, D, and E). For Condition C, the obtained choice proportions were below .5 in all but 1 subject (S85), whose choice proportion was also in accord with the ORD predictions, and were qualitatively consistent with the ORD predictions. For Condition D, the obtained choice proportions were below .5 and lower than the predicted choice proportions based on the ORD view. Although the difference between the predicted and obtained choice proportions was relatively large, the results obtained in Condition C were more consistent with the ORD than with the LRD. Further, only one case was in accord with the prediction of the LRD view for Condition E. Across three conditions (C, D, and E), 10 of 11 cases were qualitatively in accord with the ORD predictions. As in Figure 4, a quantitative analysis revealed that the difference between obtained and predicted choice proportions was smaller for the ORD predictions than for the LRD predictions; mean absolute difference was .214 for the ORD predictions, whereas it was .342 for the LRD predictions.

Figure 6 illustrates the correlation between the obtained and predicted choice proportions based on the LRD and ORD. Obtained choice proportions increased more systematically with increases in the ORD predictions than in the LRD predictions, although obtained choice proportions were more extreme than predicted from the ORD. To obtain correlation coefficients, choice proportions were transformed to response ratios (R_1/R_2), and the log-transformed response ratios underwent a linear regression (cf. Baum, 1979). This procedure yielded the correlation coefficients and the equations for the best fitting straight line, $r = 0.10$ ($y = 0.23x - 0.29$) for the LRD and $r = 0.65$ ($y = 1.91x - 0.07$) for the ORD.

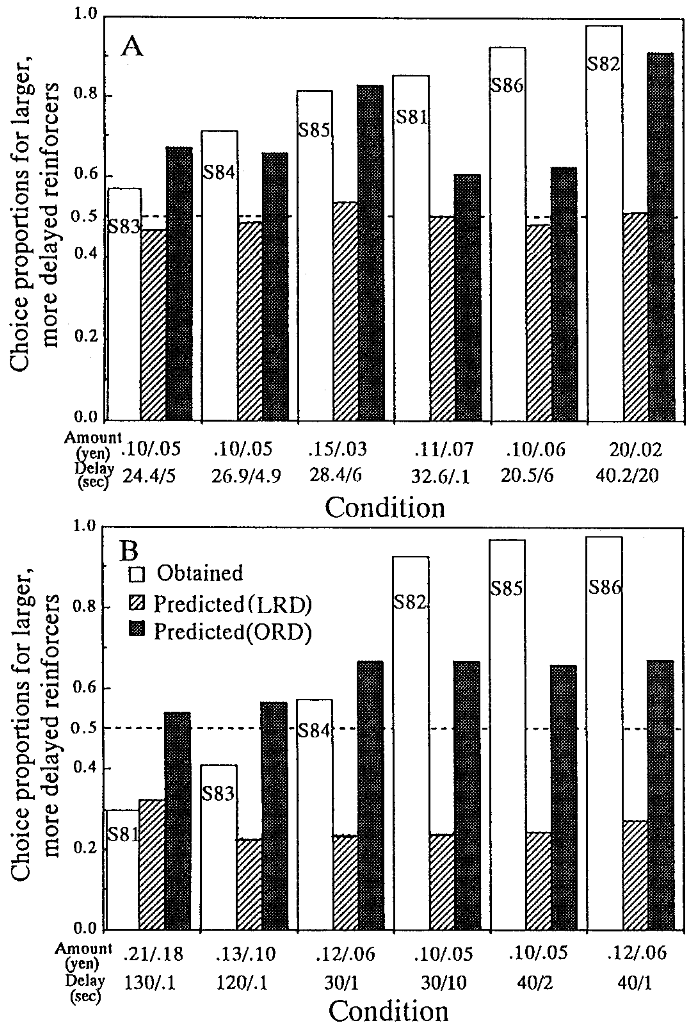

Fig. 4. The obtained and predicted choice proportions for the larger, more delayed reinforcers under Conditions A and B with timeout periods for each subject. The predictions are derived from the overall reinforcement density (ORD) and the local reinforcement density (LRD).

Thus, the difference in the correlation coefficients supported the above-mentioned differences between obtained and predicted choice proportions based on the LRD and ORD.

In a comparison of conditions with and without timeout periods, the conditions without timeout periods did not improve the difference between the ORD predictions and obtained choice proportions. This finding may be due to the fact that in most cases, the human subjects preferred the smaller, less delayed reinforcers more often when timeout periods were not included. Although the conditions without timeout periods did not improve the differences between obtained and predicted choice proportions, humans' preferences in a self-control choice situation were still better predicted by the ORD rather than by the LRD.

Discussion

The purpose of the present experiment was to examine whether human self-control choices were better predicted by the LRD or the ORD views. The present experiment arranged five conditions in which the LRD and ORD views made different predictions.

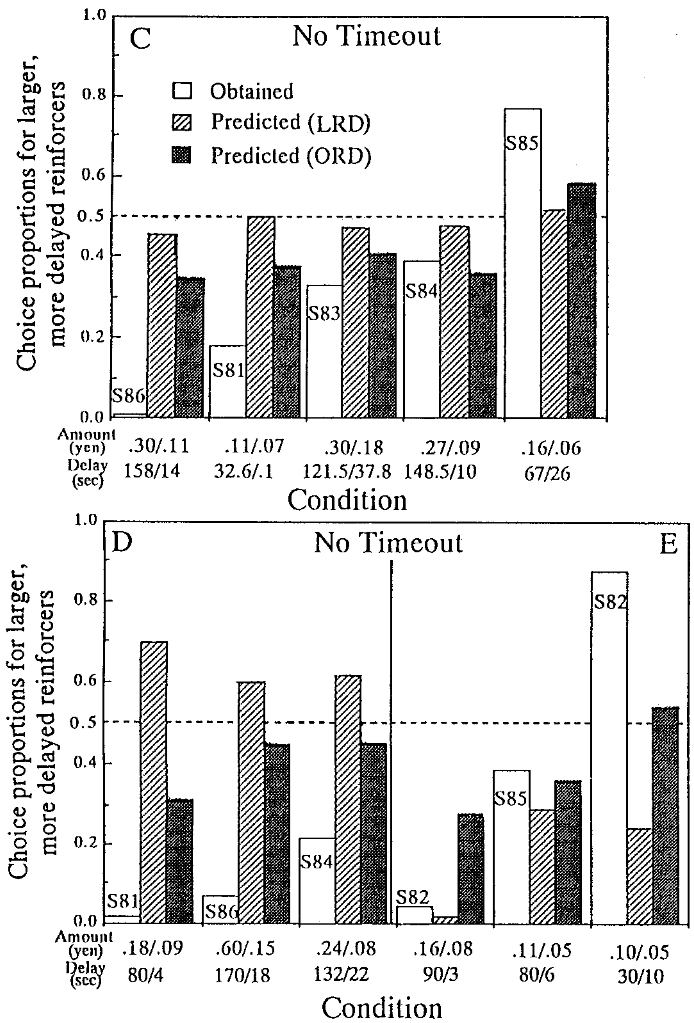

Fig. 5. The obtained and predicted choice proportions for the larger, more delayed reinforcers under Conditions C, D, and E without timeout periods for each subject. The predictions are derived from the overall reinforcement density (ORD) and the local reinforcement density (LRD).

Choice proportions for the larger, more delayed reinforcers varied across conditions and were qualitatively consistent with the ORD rather than the LRD predictions in 20 of 23 cases across five conditions. Therefore, the present results support previous findings that human self-control choices are better described by the ORD (e.g., Flora & Pavlik, 1992; Logue et al., 1990). The present results extended the generality of Logue et al.'s (1990) results to a situation in which the predictions derived from both the LRD and ORD views were examined systematically in several conditions.

One explanation for why the parameters of Equation 1 failed to predict choice proportions in the self-control choice situation is that the sensitivity parameters were obtained in situations in which only one dimension (i.e., reinforcer amount or delay) was varied, whereas choice proportions were obtained in situations in which reinforcer amount and delay were varied together. That is, different factors (i.e., the LRD and ORD) may play a role in determining choices for different situations in which only one or two dimensions of reinforcers are varied, as in Experiments 1 and 2. If this is the case, parameters must be obtained in situations in which both reinforcer amount and delay are varied together to

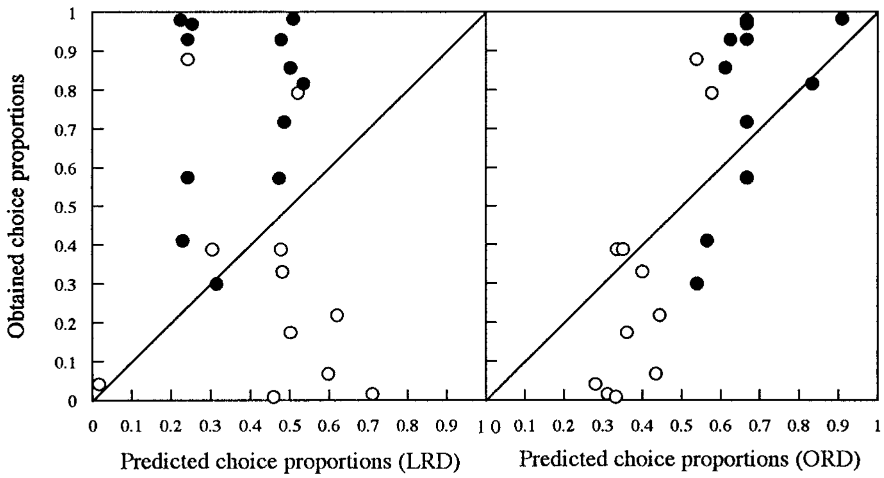

Fig. 6. The obtained choice proportions plotted against those predicted by the local reinforcement density (LRD) and overall reinforcement density (ORD) for all subjects. Filled circles are data from conditions with timeout periods, and unfilled circles are data from conditions without timeout periods. The straight lines show the locus of perfect matching between the obtained and predicted choice proportions.

predict self-control choices. However, the validity of this explanation remains to be examined.

The present experiment assessed predictions of the LRD and ORD views in conditions with and without timeout periods. In conditions with timeout periods, a timeout followed the shorter delay so as to equate total time between reinforcements for the two alternatives. Therefore, the difference in reinforcement density depended only on reinforcer amounts arranged for the two alternatives in terms of the ORD view. In conditions without timeout periods, however, the difference in reinforcement density depended on total time and reinforcer amounts for the two alternatives. Thus, this procedure (no timeout) was thought to favor the ORD predictions if human subjects were sensitive to the difference in total time between the two alternatives. As shown in Figures 4 and 5, the pattern of the obtained choice proportions across conditions with and without timeout periods revealed that most of the human subjects preferred the larger (and more delayed) reinforcers more often in conditions with timeout periods (Conditions A and B), whereas they preferred the smaller (and less delayed) reinforcers more often in conditions without timeout periods (Conditions C, D, and E). This pattern suggests that the performance of human subjects can be sensitive to the presence and absence of a timeout period. This finding is inconsistent with the results obtained with pigeons by Logue, Smith, and Rachlin (1985). In that study, the effects of pre- and postreinforcer delays in a discrete-trials self-control choice situation were studied. They observed that the performance of pigeons was less sensitive to postreinforcer delay than to prereinforcer delay. This inconsistency may reflect the difference in sensitivity to timeout periods (i.e., postreinforcer delay) between pigeons and humans, although the investigators did not examine the conditions in which postreinforcer delay was excluded for a smaller, less delayed reinforcer, as in the present experiment.

GENERAL DISCUSSION

The present study investigated the sensitivity of human behavior to variations in reinforcer amount and delay by varying the ratio of two reinforcers for each reinforcer dimension (i.e., amount and delay). The study found that the choice ratios for most of the human subjects were more sensitive to reinforcer amount than to reinforcer delay. That is, in most cases sensitivity values for reinforcer amount (S_d) based on Equation 1 were greater than sensitivity values for reinforcer delay (S_d). Thus, the present results confirm and extend the previous findings of Logue et al. (1986, 1990) to the situation in which each sensitivity value for reinforcer amount and delay was determined based on data obtained from four conditions (including a baseline condition).

Sensitivity values based on Equation 1 have been used as a quantitative measure of human as well as nonhuman animal preferences (Chavarro & Logue, 1988; Ito, 1985; Logue et al., 1986, 1990; Omino & Ito, 1993). The absolute values of S_a and S_d have been shown to vary depending on the difference in the type of reinforcement schedules (e.g., Chavarro & Logue, 1988), the difference in the terminal-link duration of a concurrent-chains schedule (e.g., Ito, 1985), and the difference in the terminal-link stimulus conditions, that is, the conditioned reinforcing effects (e.g., Omino & Ito, 1993). The relative values of sensitivity to reinforcer amount and delay (S_a/S_d) have also been shown to covary with the degree of pigeons' self-control exhibited (e.g., Logue, Rodriguez, Peña-Correal, & Mauro, 1984). The more pigeons show self-control, the larger S_a is relative to S_d. This measure can also be used in describing rats' points of indifference between two alternatives differing in both reinforcer amount and delay (e.g., Ito & Oyama, 1996). Together, it seems that the absolute and relative sensitivity values are affected by the procedures used and are useful as a post hoc description of self-control and impulsiveness in a self-control choice situation (Green & Snyderman, 1980; Ito & Asaki, 1982; Logue et al., 1984, 1986, 1990). Although a few studies with human subjects have attempted to relate the relative measure of sensitivity (S_a/S_d) to the degree of self-control (e.g., Logue, Forzano, & Tobin, 1992), it appears that the results of Experiment 2 question this attempt because humans' self-control choices are better predicted by the ORD than by the LRD under some conditions.

The present study also investigated the predictability of human self-control choice from the LRD and ORD views by arranging five conditions, and demonstrated that human self-control and impulsiveness were better predicted, in a qualitative sense, by the ORD than by the LRD. In most cases across the five conditions used, self-control and impulsive choices varied as a function of the combinations of reinforcer amount and delay, consistent with the ORD predictions. This finding is in accord with the finding obtained in Experiment 1 of Logue et al. (1990), in which a no-timeout procedure was used with two independent VI schedules in the initial links of a concurrent-chains schedule. In this respect, the results of both studies are similar despite different values of reinforcer amount and delay, different procedures for manipulating reinforcer amounts (points obtained by a consummatory response vs. duration of reinforcer access periods), different operanda (screen touch vs. rod push), and different monetary values (yen vs. dollar) as reinforcers. Therefore, the results appear to be fairly general. Further, the present study supports the previous finding that human self-control and impulsiveness are predicted reasonably well by the ORD, although the fit to the data was well predicted only in a qualitative sense.

These results indicate that human self-control and impulsiveness might usefully be reconsidered within the framework of the ORD view (e.g., Rachlin, 1989); in the molar conception of self-control, self-control can be defined based on the total time and reinforcer amount integrated over a whole session. From that perspective, human choices of a smaller, less delayed reinforcer would not be defined as impulsiveness but as self-control in the molar view if choices of a smaller, less delayed reinforcer produced a higher reinforcement density than did choices of a larger, more delayed reinforcer.

In a concurrent-chains schedule, which has usually been studied with nonhuman subjects, the data obtained in this procedure have been well predicted by Fantino's delay-reduction model (i.e., a model without free parameters), which derives predictions in advance of an experiment (cf. Fantino & Davison, 1983). Does the delay-reduction model handle the present data with human subjects better than the ORD? To address this question, an analysis of the present data was carried out in terms of the delay-reduction model, which states that choice for an alternative depends on the reduction in overall time to the reinforcer correlated with choice for the alternative. A parameter for reinforcer amount was not included in the delay-reduction model, however. By assuming that rate and amount of reinforcement are functionally equivalent, it has been suggested that reinforcer amount could be transformed to a delay value (cf. Ito & Asaki, 1982; Navarick & Fantino, 1976). Based on this transforming procedure, predicted choice proportions were calculated for each condition and each subject. Mean absolute differences between obtained and predicted choice proportions across all 6 subjects were .397 for conditions with timeout periods (Conditions A and B) and .167 for conditions without timeout periods (Conditions C, D, and E). Together, these results reveal that the delay-reduction model did not handle the present data better than the ORD, although a slightly better fit to the data in conditions without timeout periods was obtained. Other models of choice with free parameters, such as Killeen's incentive model (1982) and Grace's contextual choice model (1995), share the nature of a post hoc description and are, therefore, limited to predict choices in advance of an experiment. As in the present approach, the parameters of these models must be estimated in a different situation to predict choices. However, the application of these models to the present data is beyond the scope of the present study and remains to be examined in future research.

As mentioned in the discussion of Experiment 2, the pattern of the differences between obtained and predicted values reveals that the performance of the human subjects was more sensitive to overall reinforcement density than was expected from the ORD view. Therefore, this overweighting of overall reinforcement density must be incorporated in models of human self-control choices. Based on the present results, the generalized matching law applied to the self-control choice situation may be transformed to the following function:

$$\frac{R_1}{R_2} = k\left(\frac{ORD_1}{ORD_2}\right)^{S_{\mathrm{ord}}}, \qquad (3)$$

where ORD is the overall reinforcement density, R is the number of responses to that alternative, and k and S_{ord} are empirical constants. The parameter S_{ord} represents the sensitivity to overall reinforcement density. To obtain values of sensitivity to overall reinforcement density, Equation 3 was applied to the present data. As in the case of Equation 1, a linear regression was applied to the log-transformed data obtained from four conditions with and without timeout periods for each subject (except for S83, who was exposed to three conditions). For all subjects, the slopes of the functions were more than 1.0 and ranged from 1.0 to 7.91, showing substantial individual differences in sensitivity to overall reinforcement density. The percentages of data variance accounted for ranged from 25% to 98%; in particular, those values were more than 92% in 3 of 6 subjects, and in the remaining 3 subjects these values were 72%, 58%, and 25%. The median value of the slopes of the functions across all 6 subjects was 1.8, indicating that the sensitivity to overall reinforcement density was greater than expected when predicted values were calculated from the ORD view. Together, the present analysis suggests that the differences between obtained and predicted values from the ORD are interpretable as high sensitivity to overall reinforcement density in human subjects.

In conclusion, the present study demonstrated that human self-control choices were, in a qualitative sense, well predicted by the overall reinforcement density, and also that most human subjects preferred the larger reinforcers more often in conditions with timeout periods, whereas they preferred the less delayed reinforcers more often in conditions without timeout periods. These patterns of human choice in the present self-control choice situation were consistent with Equation 3, indicating a high degree of sensitivity to overall reinforcement density. These findings remain to be incorporated in the modeling of human self-control choices within the framework of the ORD view. It should be stressed, however, that the present results were obtained under conditions in which the reinforcers were points that were exchanged for money after the end of the session. There are reasons to suspect that the results might have been more consistent with predictions based on LRD if the scheduled reinforcers had been significant in their own right (e.g., consumable) rather than being derived through a delayed exchange (Hyten, Madden, & Field, 1994; Jackson & Hackenberg, 1996).

REFERENCES

Baum, W. H. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior, 22,* 231–242.

Baum, W. H. (1979). Matching, undermatching, and overmatching in studies of choice. *Journal of the Experimental Analysis of Behavior, 32,* 269–281.

Belke, T. W., Pierce, W. D., & Powell, R. A. (1989). Determinants of choice for pigeons and humans on concurrent-chains schedules of reinforcement. *Journal of the Experimental Analysis of Behavior, 52,* 97–109.

Chavarro, A., & Logue, A. W. (1988). Sensitivity to amount and delay of reinforcement: Effects of different types of concurrent variable-interval schedules. *The Psychological Record, 38,* 421–435.

de Villiers, P. (1977). Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 233–287). Englewood Cliffs, NJ: Prentice Hall.

Fantino, E., & Davison, M. (1983). Choice: Some quantitative relations. *Journal of the Experimental Analysis of Behavior, 40,* 1–13.

Fleshler, M., & Hoffman, H. S. (1962). A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior, 5,* 529–530.

Flora, S. R., & Pavlik, W. B. (1992). Human self-control and the density of reinforcement. *Journal of the Experimental Analysis of Behavior, 57,* 201–208.

Forzano, L. B., & Logue, A. W. (1994). Self-control in adult humans: Comparison of qualitatively different reinforcers. *Learning and Motivation, 25,* 65–82.

Grace, R. C. (1995). Independence of reinforcement delay and magnitude in concurrent chains. *Journal of the Experimental Analysis of Behavior, 63,* 255–276.

Green, L., & Snyderman, M. (1980). Choice between rewards differing in amount and delay: Toward a choice model of self control. *Journal of the Experimental Analysis of Behavior, 34,* 135–147.

Hyten, C., Madden, G. J., & Field, D. P. (1994). Exchange delays and impulsive choice in adult humans. *Journal of the Experimental Analysis of Behavior, 62,* 225–233.

Ito, M. (1985). Choice and amount of reinforcement in rats. *Learning and Motivation, 16,* 95–108.

Ito, M., & Asaki, K. (1982). Choice behavior of rats in a concurrent-chains schedule: Amount and delay of reinforcement. *Journal of the Experimental Analysis of Behavior, 37,* 383–392.

Ito, M., Nakamura, K., & Kuwata, S. (1997). Humans' choice between different reinforcer amounts and delays: Effects of choice procedures and monetary deduction. *Learning and Motivation, 28,* 102–117.

Ito, M., & Oyama, M. (1996). Relative sensitivity to reinforcer amount and delay in a self-control choice situation. *Journal of the Experimental Analysis of Behavior, 66,* 219–229.

Jackson, K., & Hackenberg, T. D. (1996). Token reinforcement, choice, and self-control in pigeons. *Journal of the Experimental Analysis of Behavior, 66,* 29–49.

Killeen, P. R. (1982). Incentive theory: II. Models for choice. *Journal of the Experimental Analysis of Behavior, 38,* 217–232.

King, G. R., & Logue, A. W. (1987). Choice in a self-control paradigm with human subjects: Effects of changeover delay duration. *Learning and Motivation, 18,* 421–438.

King, G. R., & Logue, A. W. (1990). Humans' sensitivity to variation in reinforcer amount: Effects of the method of reinforcer delivery. *Journal of the Experimental Analysis of Behavior, 53,* 33–45.

Logue, A. W. (1988). Research on self-control: An integrating framework. *Behavioral and Brain Sciences, 11,* 665–709.

Logue, A. W., Forzano, L. B., & Tobin, H. (1992). Independence of reinforcer amount and delay: The generalized matching law and self-control in humans. *Learning and Motivation, 23,* 326–342.

Logue, A. W., King, G. R., Chavarro, A., & Volpe, J. S. (1990). Matching and maximizing in a self-control paradigm using human subjects. *Learning and Motivation, 21,* 340–368.

Logue, A. W., Peña-Correal, T. E., Rodriguez, M. L., & Kabela, E. (1986). Self-control in adult humans: Variation in positive reinforcer amount and delay. *Journal of the Experimental Analysis of Behavior, 46,* 159–173.

Logue, A. W., Rodriguez, M. L., Peña-Correal, T. E., & Mauro, B. C. (1984). Choice in a self-control paradigm: Quantification of experience-based differences. *Journal of the Experimental Analysis of Behavior, 41,* 53–67.

Logue, A. W., Smith, M., & Rachlin, H. (1985). Sensitivity of pigeons to prereinforcer and postreinforcer delay. *Animal Learning & Behavior, 13,* 181–186.

Matthews, B. A., Shimoff, E., Catania, A. C., & Sagvolden, T. (1977). Uninstructed human responding: Sensitivity to ratio and interval contingencies. *Journal of the Experimental Analysis of Behavior, 27,* 453–467.

Mazur, J. E. (1988). Estimation of indifference points with an adjusting-delay procedure. *Journal of the Experimental Analysis of Behavior, 49,* 37–47.

Millar, A., & Navarick, D. J. (1984). Self-control and choice in humans: Effects of video game playing as a positive reinforcer. *Learning and Motivation, 15,* 203–218.

Navarick, D. J. (1982). Negative reinforcement and choice in humans. *Learning and Motivation, 13,* 361–377.

Navarick, D. J., & Fantino, E. (1976). Self-control and general models of choice. *Journal of Experimental Psychology: Animal Behavior Processes, 2,* 75–87.

Omino, T., & Ito, M. (1993). Choice and delay of reinforcement: Effects of terminal-link stimulus and response conditions. *Journal of the Experimental Analysis of Behavior, 59,* 361–371.

Rachlin, H. (1989). *Judgment, decision, and choice: A cognitive/behavioral synthesis.* New York: Freeman.

Rachlin, H., & Green, L. (1972). Commitment, choice and self-control. *Journal of the Experimental Analysis of Behavior, 17,* 15–22.

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