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SELF-CONTROL IN ADULT HUMANS: VARIATION IN POSITIVE REINFORCER AMOUNT AND DELAY

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In five experiments, choice responding of female human adults was examined, as a function of variations in reinforcer amount and reinforcer delay. Experiment 1 used a discrete-trials procedure, and Experiments 2, 3, 4, and 5 used a concurrent variable-interval variable-interval schedule. Reinforcer amount and reinforcer delay were varied both separately and together. In contrast to results previously reported with pigeons, the subjects in the present experiments usually chose the larger reinforcers even when those reinforcers were delayed. Together, the results from all the experiments suggest that the subjects followed a maximization strategy in choosing reinforcers. Such behavior makes it easy to observe self-control and difficult to observe impulsiveness in traditional laboratory experiments that use adult human subjects.

Key words: choice, reinforcer amount, reinforcer delay, self-control, matching law, maximization, lateral rod push, adult humans

Self-control has been defined as the choice of a larger, more delayed reinforcer over a smaller, less delayed reinforcer, whereas impulsiveness is the opposite (e.g., see Ainslie, 1974, 1975; Grosch & Neuringer, 1981; Rachlin, 1974; Rachlin & Green, 1972). Pigeons presented with this type of choice often behave impulsively because, although they prefer larger reinforcers, they also prefer reinforcers with shorter delays. In fact, in order to obtain self-control in pigeons it has been found necessary to expose them to a year-long fading procedure (Logue, Rodriguez, Peña-Correal, & Mauro, 1984, Experiment 1; Mazur & Logue, 1978).

For pigeons that have not been exposed to such fading procedures, the ideal matching law (Herrnstein, 1970) has provided a good description of choices between a larger, more delayed reinforcer and a smaller, less delayed reinforcer (Ainslie & Herrnstein, 1981; Green, Fisher, Perlow, & Sherman, 1981). According to this law,

$$\frac{B_L}{B_R} = \frac{A_L D_R}{A_R D_L}, \quad (1)$$

where B_L and B_R represent the number of choices of reinforcers obtained from the left and right response alternatives, respectively, and A_L, A_R, D_L, and D_R represent the amounts (sizes) and delays of those reinforcers. Note that, assuming rate of reinforcement is equal no matter which reinforcer is chosen, whenever a smaller, less delayed reinforcer is obtained even though a larger, more delayed reinforcer is available, total received amount of reinforcement is not being maximized.

However, experimentally naive adult hu-

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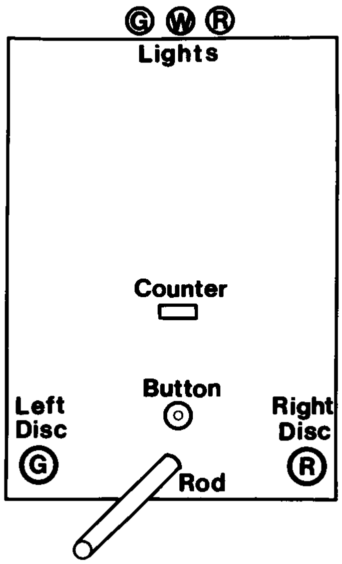

Fig. 1. Diagram of the aluminum panel used in all of the experiments. G, W, and R indicate the colors green, white, and red, respectively.

man subjects choosing between different amounts of reinforcement have shown discrepancies from matching (Bangert, Green, Snyderman, & Turow, 1985; Schmitt, 1974; Wurster & Griffiths, 1979). Further, the few laboratory experiments that have reported consistent impulsive behavior in humans have either used children (Burns & Powers, 1975) or have used negative reinforcement with adults (Navarick, 1982; Solnick, Kannenberg, Eckerman, & Waller, 1980). Both of these studies with adults used escape from loud noise as the reinforcer, and both obtained basic confirmation of the matching law when data were averaged over large groups of subjects. Millar and Navarick (1984) obtained impulsive performances in only 40% of their adult human subjects when a positive reinforcer, access to a video game, was used.

The present report describes five experiments that used a simple apparatus and several different schedules of reinforcement in examining adult humans' choices as a function of variations in positive reinforcer amount and delay. The positive reinforcer most frequently employed in operant conditioning experiments with adult human subjects, points exchangeable for money (see Buskist & Miller, 1982, for references), was used. Reinforcer amount and delay were varied both separately and together. In addition, the criterion for terminating experimental sessions was manipulated in order to determine whether this procedural change would affect the subjects' choices as reinforcer amount and reinforcer delay were varied. Both discrete-trial and concurrent variable-interval variable-interval (VI VI) schedules were used. The aim of the experiments was to begin to explore why it has been difficult to demonstrate impulsive behavior in the laboratory using positive reinforcement in adult humans.

METHOD

General aspects of the method for all of the experiments will be presented first, followed by modifications and exceptions for particular experiments.

Subjects

General. The subjects were experimentally naive adult human females ranging in age from 18 to 30 years. All were either enrolled in or employed at the State University of New York at Stony Brook. None were psychology majors and all were paid for their participation.

Experiment 1. The subjects were 4 undergraduates numbered 1, 2, 3, and 4.

Experiment 2. The subjects were 4 undergraduates numbered 5, 6, 7, and 8.

Experiment 3. The subjects were 4 undergraduates numbered 9, 10, 11, and 12.

Experiment 4. There were 3 subjects. Subjects 13 and 15 were graduate students; Subject 14 was a secretary.

Experiment 5. The subjects were 4 students numbered 16, 17, 18, and 19. Subject 18 was a graduate student; the other 3 were undergraduates.

Apparatus

The experiments were conducted in a small room, 3.1 m by 3.4 m, that could be lit by a standard 60-W bulb. One wall of the room contained a one-way mirror that allowed observation of the subjects. The room itself contained an empty table, a chair, and a desk. The experimental console was placed on the desk, which was against one wall. The console was a wooden box, 122 cm wide, 66 cm deep, and 81 cm high. The front of the console was painted black.

An aluminum panel (see Figure 1), 36 cm wide and 51 cm high, on the front of the console contained the experimental stimuli and the manipulandum, which was an aluminum rod. The rod, 1.6 cm in diameter, protruded 14 cm from the panel, 4 cm from the bottom of the panel and equidistant from the two sides. The rod could be pushed 9 cm to the left or to the right; it closed a switch if it was pushed 3 cm one way or the other with a minimum force of 18.8 N. Under some conditions, use of a manipulandum that is difficult to operate has been shown to increase the similarity of human and nonhuman behavior (Lowe, 1979). One translucent Plexiglas disc, 3.8 cm in diameter, was located on each side of the metal rod. The left disc could be transilluminated with green light and the right disc with red light. A hole, 2.5 cm in diameter, located 5 cm above the rod, gave access to a small, black button mounted 3.8 cm behind the surface of the panel. Button presses were effective only if a light inside the hole directly above the button was lit. A counter was located 11.8 cm above the hole and was continuously illuminated by a white light directly above it.

On the top front edge of the console were three 7.5-W bulbs; the left light was green, the center light was white, and the right light was red. Also on top of the console, but placed towards the wall, was a loudspeaker that emitted continuous white noise to help mask extraneous sounds.

A PDP-8/A® computer in another room controlled the stimuli and recorded responses, using a SUPERSKED® program.

Procedure

General. For each session, subjects were individually escorted into the lit experimental room. They were given no instructions except to read the following sign posted on one wall:

> Please read carefully. Do not ask for additional information about what you are about to do. Your task is to earn as many points as you can. Each point is worth 1/35 cents. For example, if you earn 3,500 points you will be paid $1.00. You may touch anything on this panel to earn points. The session will last 30 minutes and will begin when one or more lights become lit. To minimize interference with the equipment, please leave all metal objects (watches, jewelry, etc.) with the experimenter for the duration of this session. All other personal property (coats, books, writing utensils, pocketbooks, etc.) should also be left with the experimenter. These materials will be returned promptly at the session's end. The session will end when the experimenter returns.

Subjects were instructed to remove their watches and jewelry in order to ensure that no subject had access to a timing device during the experiment. Although use of timing devices in experiments with humans can yield valuable results (Lowe, 1979), conditions here were kept as similar as possible to those employed with pigeons in order to help identify the origins of any observed differences between the behavior of human and nonhuman subjects. (For previous similar instructions see Baron, Kaufman, & Stauber, 1969; Wurster & Griffiths, 1979.) Instructions concerning the contingencies were kept to a minimum because previous research has shown that, under certain conditions, with minimal instructions humans may show more sensitivity to the scheduled contingencies (e.g., see Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981).

The experimenter then left the room, closed the door, and turned off the room light. There was no further communication between the subject and the experimenter until the end of the session.

At the beginning of a session the left disc was green and the right disc was red; the white light on top of the console was lit. When a rod push toward the left produced a reinforcer, both discs and the white light were darkened, and the green light on top of the console was lit. This signaled the programmed delay period (the delay of reinforcement) to be followed by the programmed period of access to the reinforcer (the amount of reinforcement). During reinforcement, the light above the button was lit and the button was operative. Each press of the button added one point to the counter. Under some conditions, use of a consummatory response, such as the button press used here, may increase the sensitivity of human behavior to the scheduled contingencies (Matthews et al., 1977; Shimoff et al., 1981). Consummatory responses are virtually always employed in experiments with nonhuman subjects. After the reinforcement period, the white light on top of the console and the left and right discs were again lit. The sequence of events for reinforcement following a rod push toward the right was similar except that the red light on top of the console was used instead of the green light. Rod pushes were followed by a feedback click when the discs were lit; rod pushes toward darkened discs had no effect and were not recorded.

At the end of each session, each subject completed a questionnaire asking how she thought the button became available and what she thought she did during the experiment. Subjects also received money based upon the points they had earned. At the end of the entire experiment, they received an additional sum per hour of session time.

Occasionally, in order for a subject to complete the experiment, it was necessary to expose that subject to two sessions in one day. In such cases there was always at least a 4-hr interval between the two sessions. On a few other occasions, it was necessary for as many as 16 days to elapse between two of a subject's sessions. However, in at least 63% of the cases in each experiment, sessions were on the same or consecutive days.

Experiment 1. The subjects were paid $2.00 per session at the end of the experiment. There were two changes from what was described above in the General Procedure section regarding the written instructions posted on the wall of the experimental room. One change concerned how much the points were worth; 600 points were necessary to earn $1.00. The other change concerned the criterion for ending a session; subjects were instructed that the session would end after a maximum of 90 min.

Reinforcers were scheduled according to a discrete-trials paradigm similar to one used previously with pigeons (see Logue & Mazur, 1981; Logue & Peña-Correal, 1984; Logue et al., 1984, Experiment 1; Mazur & Logue, 1978). Each session consisted of 24 trials—20 choice trials and 4 no-choice trials. When the discs were lit, one push on the rod to either side led to delay and reinforcement periods. During the no-choice trials, only one disc was lit and subjects were required to push the rod to one side or the other. Pushes toward the unlit disc had no consequences. No-choice trials requiring a rod push to the left occurred on Trials 1 and 3; no-choice trials requiring a rod push to the right occurred on Trials 2 and 4. The no-choice trials ensured the subjects' exposure to the contingencies on both sides.

During intertrial intervals, the white light on top of the console was lit. Intertrial intervals were programmed by a timer that emitted a pulse every 3 min beginning with the start of the first trial. A new trial was initiated by the next emitted pulse following completion of a reinforcement period. Therefore, intertrial intervals varied such that there was one trial every 3 min regardless of the subject's choices, so long as the total of a subject's latency to respond (delay time) and reinforcement time in a given trial was no longer than 3 min.

Table 1 shows the conditions and the order in which they were conducted. For the initial training condition, both the delay period following a rod push toward the left (green) disc and the delay period following a rod push toward the right (red) disc were set at 0.5 s. In the subsequent five conditions, reinforcer amounts and delays were varied together. Reinforcer amounts were varied between 8 and 12 s, and reinforcer delays were set at either 0.5 or 120 s. Subjects 1 and 2 were exposed to these five conditions in one sequence, and Subjects 3 and 4 in the reverse order.

Each subject was exposed to each condition for one session. A pilot experiment with several sessions per condition had shown that, perhaps due to the no-choice trials at the beginning of each session, subjects' behavior in the choice trials appeared stable upon the first session of exposure to a condition.

Experiments 2–5. Concurrent, independent, VI 30-s VI 30-s schedules were used. Rod pushes toward the left (green) disc were reinforced according to one VI schedule, while rod pushes toward the right (red) disc were reinforced according to the other VI schedule. The VI schedules were constructed according to the progression suggested by Fleshler and Hoffman (1962).

A 3-s changeover delay (COD) was in effect; 3 s had to elapse after a changeover response from pushing the rod toward the left to pushing it toward the right or vice versa, or after the first response following reinforcement, before a subsequent rod push could produce a reinforcer. The COD was used to decrease the probability of reinforcement of sequences of responses involving rod pushes to both sides (Catania & Cutts, 1963; de Villiers, 1977).

The programming of the VI schedules was

identical to that used by Logue et al. (1984, Experiment 2) with pigeons, and was similar to the linear VI schedules used by Vaughan (1982), which generate response rates similar to the usual VI schedules (see discussion by Prelec, 1983). Both VI schedules ran continuously during a session. Each time an interval in one of the VI schedules was completed, the schedule continued but a counter indicating reinforcers available from that VI schedule was incremented. Each time a reinforcer was received, the appropriate counter was decremented. A rod push toward a lit disc was followed by delay and reinforcer periods if the counter for the VI schedule for that side had a value of at least one and if the COD had been satisfied. This type of concurrent VI VI programming tends to keep overall reinforcer frequency for the two alternatives more similar than does traditional concurrent VI VI programming, although reinforcer frequency will be somewhat affected by reinforcer preference (see Logue et al., 1984, Experiment 2).

A subject was exposed to the first condition for at least four sessions, and to each subsequent condition for at least two sessions. Before a condition could be terminated, a subject's data also had to satisfy a stability criterion. The conditions used, the order in which they were conducted, and the number of sessions that each condition was in effect are shown for each subject in Table 1.

Experiment 2. This experiment also varied reinforcer amount and delay together. For half of the conditions, the written instructions posted on the wall of the experimental room contained the sentence, "The session will last 30 minutes and will begin when one or more lights become lit." For the other half of the conditions, "The session will last 90 opportunities to earn points" was substituted for "The session will last 30 minutes." These changes in the instructions reflected actual changes in the procedure.

The stability criterion that was used specified that rod pushes toward the left divided by rod pushes toward the right, for the last half-session of the prior session and for both halves of the most recent session, all had to be within one half of a base 10 logarithmic unit of each other. For example, rod-push ratios of 1.0, 1.5, and 3.1 (logarithms 0.00, 0.18, and 0.49, respectively) would be considered stable, whereas ratios of 1.0, 1.5 and 3.2 (logarithms 0.00, 0.18, and 0.51, respectively) would not. Subjects 5 and 6 were exposed first to the sessions that ended after 30 min, and Subjects 7 and 8 were exposed first to the sessions that ended after 90 reinforcers (90 periods of access to the button).

Experiment 3. Reinforcer amount and delay were varied separately. The same stability criterion was used as in Experiment 2.

Experiment 4. In the first five conditions, reinforcer size and delay were varied separately, whereas in the last two conditions they were varied together. Reinforcer values for the last two conditions were chosen for each subject based on a prediction of impulsiveness using a generalized version of Equation 1 (see Equation 2 below) and the data from the first five conditions. The stability criterion was the same as in Experiments 2 and 3.

Experiment 5. In the final experiment, reinforcer amount and delay were varied together. The stability criterion specified that a condition not be terminated for a given subject unless the values of left/right rod pushes in the last two half-sessions were neither higher nor lower than the values of left/right rod pushes in all of the previous half-sessions of that condition.

RESULTS

Analyses were performed using the stable data from each experiment: These were the 20 free-choice trials of each condition in Experiment 1 except the training condition, the last three half-sessions of each condition in Experiments 2, 3, and 4, and the last two half-sessions of each condition in Experiment 5.

All subjects learned to operate the equipment efficiently during the first session. In Experiment 1 (the discrete-trials procedure) the 4 subjects' latencies to push the rod were generally short, so that the mean experiment time was close to 72 min, corresponding to 3 min per trial ($M = 74.3$ min, $SE = 2.0$, $N = 4$).

The subjects did not appear to suspect why they were asked to remove their watches and jewelry, yet in the postsession questionnaires they reported attempting to time the reinforcer delays and amounts. In the conditions in which only reinforcer amount was varied, the subjects reported that they preferred the larger

Table 1

Order of the conditions, number of sessions, rod pushes, and reinforcers in each experiment.

Experiment	Subject	Condition (in seconds) A_L	A_R	D_L	D_R	No. of sessions	Responses per min[c] Left	Right
1[a]	1	10	10	0.5	0.5	1	15	5
		12	8	120	0.5	1	18	2
		8	12	0.5	0.5	1	3	17
		10	10	0.5	0.5	1	17	3
		12	8	0.5	0.5	1	19	1
		8	12	0.5	120	1	4	16
	2	10	10	0.5	0.5	1	18	2
		12	8	120	0.5	1	1	19
		8	12	0.5	0.5	1	0	20
		10	10	0.5	0.5	1	16	4
		12	8	0.5	0.5	1	18	2
		8	12	0.5	120	1	1	19
	3	10	10	0.5	0.5	1	13	4
		12	8	120	0.5	1	14	6
		8	12	0.5	0.5	1	1	19
		10	10	0.5	0.5	1	16	4
		12	8	0.5	0.5	1	19	1
		8	12	0.5	120	1	19	1
	4	10	10	0.5	0.5	1	10	10
		12	8	120	0.5	1	20	0
		8	12	0.5	0.5	1	3	17
		10	10	0.5	0.5	1	13	7
		12	8	0.5	0.5	1	17	3
		8	12	0.5	120	1	11	9
2: Sessions[b] ended after 30 min	5	7	7	7	7	4	38.6 (3.9)	83.5 (7.3)
		11	3	11	0.1	3	103.2 (8.5)	41.8 (9.2)
		3	11	0.1	11	2	43.4 (1.7)	112.9 (3.6)
	6	7	7	7	7	4	27.0 (.8)	10.0 (3.0)
		11	3	11	0.1	3	29.5 (1.9)	0.0 (.2)
		3	11	0.1	11	3	0.2 (.2)	19.1 (4.5)
	7	7	7	7	7	3	54.5 (17.0)	108.7 (1.6)
		11	3	11	0.1	5	167.1 (8.4)	0.0 (0)
		3	11	0.1	11	3	0.0 (0)	164.1 (5.6)
	8	7	7	7	7	2	59.0 (8.3)	109.7 (11.7)
		11	3	11	0.1	2	131.1 (6.9)	42.5 (1.1)
		3	11	0.1	11	2	49.2 (2.1)	149.3 (3.7)
2: Sessions[b] ended after 90 reinforcers	5	7	7	7	7	2	39.8 (6.8)	47.0 (12.0)
		11	3	11	0.1	3	110.8 (4.6)	7.3 (2.0)
		3	11	0.1	11	2	8.0 (2.6)	61.2 (13.6)
	6	7	7	7	7	3	0.2 (.07)	15.1 (1.4)
		11	3	11	0.1	3	46.9 (7.8)	0.09 (.08)
		3	11	0.1	11	2	0.0 (0)	47.3 (8.1)
	7	7	7	7	7	5	47.0 (14.0)	54.5 (2.0)
		11	3	11	0.1	2	104.6 (13.5)	0.0 (0)
		3	11	0.1	11	3	0.0 (0)	119.2 (14.4)
	8	7	7	7	7	4	16.9 (4.7)	21.4 (4.0)
		11	3	11	0.1	2	58.8 (9.6)	0.9 (.2)
		3	11	0.1	11	5	0.0 (0)	58.7 (15.9)
3	9	6	6	6	6	4	55.0 (4.3)	22.9 (3.0)
		10	2	6	6	2	67.5 (3.8)	16.4 (2.9)
		6	6	10	2	2	18.5 (2.2)	79.5 (2.2)
		1	11	6	6	2	4.6 (.4)	101.0 (2.3)
		6	6	1	11	2	110.1 (5.9)	14.8 (.3)
		2	10	6	6	2	23.0 (2.8)	91.4 (2.5)
		6	6	2	10	2	93.1 (3.1)	21.0 (3.4)

Table 1 *(Continued)*

Reinforcers per min[c]		Left[c] / (Left + Right)	
Left	Right	Responses	Reinforcers
15	5	.75	.75
18	2	.90	.90
3	17	.15	.15
17	3	.85	.85
19	1	.95	.95
4	16	.20	.20
18	2	.90	.90
1	19	.05	.05
0	20	.00	.00
16	4	.80	.80
18	2	.90	.90
1	19	.05	.05
13	4	.77	.77
14	6	.70	1.00
1	19	.05	.05
16	4	.80	.80
19	1	.95	.95
19	1	.95	.95
10	10	.50	.50
20	0	1.00	1.00
3	17	.15	.15
13	7	.65	.65
17	3	.85	.85
11	9	.55	.55
4.0 (.01)	7.4 (.5)	.32 (.02)	.35 (.02)
8.3 (.4)	3.7 (.9)	.71 (.06)	.70 (.06)
3.1 (.4)	7.5 (.3)	.28 (.01)	.29 (.01)
5.6 (.8)	2.3 (.8)	.75 (.05)	.73 (.04)
6.9 (.6)	0.0 (0.0)	.99 (.01)	1.00 (0)
0.07 (.05)	5.9 (1.2)	.01 (.01)	.01 (.01)
3.5 (1.1)	8.1 (1.9)	.34 (.10)	.33 (.13)
7.3 (.2)	0.3 (.006)	1.00 (0)	1.00 (0)
0.0 (0)	7.0 (.2)	.00 (0)	.00 (0)
4.9 (.4)	7.2 (1.1)	.35 (.05)	.42 (.06)
8.0 (.9)	3.2 (.1)	.75 (.01)	.71 (.02)
3.5 (.4)	7.9 (.1)	.25 (.01)	.31 (.02)
4.4 (.9)	4.5 (1.2)	.47 (.04)	.50 (.05)
7.3 (.2)	0.9 (.3)	.94 (.01)	.90 (.03)
0.7 (.1)	4.5 (1.0)	.11 (.01)	.14 (.01)
0.03 (.02)	3.6 (.1)	.01 (.004)	.01 (.01)
4.9 (.5)	0.05 (.04)	1.0 (.001)	.99 (.01)
0.0 (0)	6.0 (.6)	.00 (0)	.00 (0)
3.7 (1.4)	4.8 (.2)	.43 (.06)	.39 (.10)
6.2 (.8)	0.1 (.02)	1.00 (0)	1.00 (0)
0.0 (0)	6.5 (.6)	.00 (0)	.00 (0)
3.6 (.9)	4.0 (.7)	.43 (.04)	.47 (.02)
6.0 (.7)	0.1 (.02)	.99 (.001)	.98 (0)
0.0 (0)	5.1 (.7)	.00 (0)	.00 (0)
5.0 (.4)	3.4 (.4)	.71 (.02)	.60 (.01)
4.8 (.2)	2.0 (.2)	.81 (.03)	.71 (.03)
2.1 (.09)	4.1 (.2)	.19 (.02)	.33 (.02)
0.4 (.04)	4.7 (.09)	.04 (.004)	.08 (.01)
3.4 (.03)	1.3 (.1)	.88 (.01)	.73 (.02)
1.9 (.2)	5.1 (.3)	.20 (.02)	.27 (.01)
3.9 (.1)	1.7 (.1)	.82 (.02)	.70 (.01)

(continued next page)

reinforcer because of the greater time to earn points. In the conditions in which only reinforcer delay was varied, the subjects reported that they preferred the shorter delays because of greater numbers of opportunities to earn points. When reinforcer amount and delay were varied together, subjects reported various strategies, but all were attempts to maximize the total number of points earned. In Experiment 1, the subjects were able to report that trials began every 3 min regardless of the reinforcer they chose.

Table 1 shows, for Experiment 1, numbers of rod pushes and reinforcers, and, for Experiments 2 through 5, mean rod pushes and reinforcers per minute using a time base of total session time minus reinforcer-access time and reinforcer-delay time. The proportions of rod pushes made to the left and the proportion of reinforcers received for rod pushes to the left are also shown. Preference data calculated for Experiments 2 through 5 using time spent rod pushing were similar to those using rod pushes. Therefore, the time data are not reported here.

Figure 2 depicts, for each condition involving a choice between a larger, more delayed reinforcer and a smaller, less delayed reinforcer, the proportion of total rod pushes that the subjects made toward the side that produced the smaller reinforcer. Figure 2 demonstrates that, with the exception of Experiment 1, the subjects' behavior was fairly consistent when the contingencies were reversed for pushing the rod to the left or to the right. Figure 2 also shows the predictions of the ideal matching law (Equation 1). Despite some intersubject variability, particularly in Experiment 1, Table 1 and Figure 2 show that every subject in every condition (46 of 46 cases) chose a lower proportion of smaller, less delayed reinforcers than is predicted by the ideal matching law, and than is usually chosen by pigeons. In fact, in 35 of 46 cases, individual subjects actually chose more of the larger, more delayed than the smaller, less delayed reinforcers, even though the ideal matching law predicts the opposite. Note that, as shown in Table 1, when reinforcer delay but not reinforcer amount was varied (e.g., in Experiment 3), the subjects consistently preferred the less delayed reinforcer.

The lowest proportions of smaller reinforcers chosen occurred in the Experiment 2 con-

Table 1 (*Continued*)

Experiment	Subject	Condition (in seconds) A_L	A_R	D_L	D_R	No. of sessions	Responses per min[c] Left	Right
		11	1	6	6	2	82.5 (2.2)	12.7 (.3)
		6	6	11	1	2	15.1 (2.4)	89.7 (4.0)
	10	6	6	6	6	4	152.4 (6.1)	106.1 (2.5)
		10	2	6	6	2	138.6 (7.1)	106.0 (15.7)
		6	6	10	2	2	112.0 (4.9)	146.5 (3.9)
		1	11	6	6	2	81.9 (4.9)	155.6 (5.6)
		6	6	1	11	2	180.3 (7.6)	97.2 (3.5)
		2	10	6	6	2	114.9 (18.3)	148.3 (11.3)
		6	6	2	10	2	195.5 (1.7)	89.6 (2.3)
		11	1	6	6	2	202.6 (9.2)	92.3 (.6)
		6	6	11	1	2	82.0 (11.8)	153.7 (13.2)
	11	6	6	6	6	4	73.8 (4.4)	74.2 (3.3)
		10	2	6	6	3	118.6 (1.4)	58.6 (6.1)
		6	6	10	2	2	72.7 (2.8)	126.1 (1.9)
		1	11	6	6	2	77.4 (6.2)	132.9 (1.6)
		6	6	1	11	2	139.9 (4.3)	82.7 (2.2)
		2	10	6	6	2	83.5 (2.7)	137.2 (2.5)
		6	6	2	10	2	136.2 (1.9)	91.8 (1.1)
		11	1	6	6	2	150.4 (2.7)	77.7 (2.8)
		6	6	11	1	2	94.9 (4.3)	135.7 (5.2)
	12	6	6	6	6	4	33.1 (6.2)	36.5 (10.7)
		10	2	6	6	2	84.8 (3.4)	46.7 (2.1)
		6	6	10	2	2	62.9 (4.3)	81.8 (3.6)
		1	11	6	6	2	59.0 (5.7)	95.7 (7.6)
		6	6	1	11	2	97.0 (6.5)	45.3 (1.9)
		2	10	6	6	2	55.2 (2.6)	91.7 (5.3)
		6	6	2	10	2	109.9 (3.1)	53.5 (1.8)
		11	1	6	6	2	164.1 (3.4)	64.3 (10.1)
		6	6	11	1	2	57.6 (2.0)	179.1 (5.8)
4	13	6	6	6	6	6	68.6 (.8)	58.5 (7.7)
		10	2	6	6	2	124.6 (5.5)	31.1 (.6)
		6	6	10	2	2	35.0 (5.5)	90.4 (6.1)
		2	10	6	6	2	50.0 (1.1)	87.3 (2.1)
		6	6	2	10	2	108.2 (7.2)	39.2 (.5)
		10	2	6.4	0.1	2	85.5 (4.0)	53.8 (5.6)
		2	10	0.1	6.4	2	52.7 (3.3)	79.6 (3.8)
	14	6	6	6	6	8	168.1 (7.6)	30.0 (3.4)
		10	2	6	6	2	114.8 (13.9)	24.1 (5.8)
		6	6	10	2	5	10.3 (4.7)	186.1 (21.0)
		2	10	6	6	2	25.2 (3.6)	206.1 (4.8)
		6	6	2	10	2	215.4 (11.2)	26.5 (2.2)
		10	2	2	0.1	2	132.5 (6.9)	91.7 (3.8)
		2	10	0.1	2	2	90.0 (5.3)	133.9 (3.3)
	15	6	6	6	6	4	113.9 (3.5)	149.0 (4.2)
		10	2	6	6	2	194.2 (2.5)	73.4 (6.4)
		6	6	10	2	2	105.0 (6.6)	169.3 (5.1)
		2	10	6	6	2	69.8 (9.9)	171.3 (11.8)
		6	6	2	10	2	170.1 (14.8)	80.3 (16.1)
		10	5	12.5	0.1	2	88.7 (2.9)	177.1 (15.2)
		5	10	0.1	12.5	2	149.8 (9.8)	106.2 (4.1)
5	16	6	6	6	6	5	50.9 (4.8)	40.0 (2.9)
		10	2	7	0.1	2	56.1 (3.0)	20.4 (2.2)
		10	5	13	0.1	2	50.5 (.03)	60.1 (.6)
		2	10	0.1	7	3	63.6 (1.5)	72.8 (1.0)
		5	10	0.1	13	2	77.3 (8.2)	59.9 (11.2)

Table 1 (*Continued*)

Reinforcers per min[c]		Left[c] / (Left + Right)	
Left	Right	Responses	Reinforcers
5.3 (.03)	1.8 (.2)	.87 (.01)	.75 (.02)
1.7 (.1)	3.9 (.4)	.14 (.02)	.31 (.01)
7.2 (.1)	6.2 (.1)	.59 (.02)	.54 (.004)
7.1 (.5)	6.2 (.9)	.54 (.04)	.54 (.02)
6.4 (.2)	7.3 (.6)	.43 (.02)	.47 (.01)
4.9 (.2)	7.2 (.7)	.35 (.02)	.41 (.01)
6.6 (.4)	5.3 (.3)	.65 (.01)	.55 (.003)
6.3 (1.1)	6.8 (.5)	.43 (.06)	.47 (.04)
6.4 (.09)	5.2 (.2)	.69 (.01)	.55 (.01)
6.9 (.4)	4.9 (.6)	.69 (.01)	.59 (.02)
4.8 (.6)	6.0 (.5)	.35 (.02)	.44 (.02)
6.2 (.4)	6.7 (.4)	.50 (.02)	.48 (.01)
6.7 (.2)	4.8 (.3)	.67 (.02)	.58 (.01)
5.3 (.2)	6.1 (.2)	.37 (.01)	.47 (.01)
4.8 (.4)	6.9 (.5)	.37 (.02)	.41 (.01)
6.5 (.6)	5.4 (.2)	.63 (.01)	.54 (.02)
5.6 (.1)	6.8 (.2)	.38 (.01)	.45 (.01)
6.7 (.4)	5.7 (.2)	.60 (.002)	.54 (.01)
7.1 (.4)	5.2 (.2)	.66 (.01)	.58 (.01)
5.9 (.5)	6.6 (.6)	.41 (.01)	.47 (.03)
5.4 (.6)	5.9 (.9)	.50 (.03)	.48 (.02)
7.2 (.5)	5.0 (.1)	.65 (.01)	.59 (.01)
6.7 (.4)	7.3 (.4)	.43 (.03)	.48 (.006)
5.6 (.5)	6.9 (.5)	.38 (.01)	.45 (.01)
5.7 (.7)	4.2 (.3)	.68 (.02)	.57 (.01)
9.9 (.4)	6.8 (.2)	.38 (.02)	.42 (.02)
5.8 (.5)	4.6 (.5)	.67 (.01)	.56 (.01)
6.4 (.4)	3.4 (.6)	.72 (.03)	.67 (.03)
3.6 (.4)	5.1 (.5)	.24 (.01)	.41 (.004)
5.8 (.6)	5.1 (.2)	.55 (.03)	.52 (.03)
6.2 (.4)	3.1 (.2)	.80 (.01)	.67 (.01)
3.0 (.4)	4.8 (.3)	.27 (.02)	.38 (.02)
4.4 (.1)	6.3 (.3)	.36 (.004)	.41 (.004)
5.4 (.2)	3.7 (.1)	.73 (.01)	.59 (.001)
5.2 (.2)	4.7 (.4)	.62 (.04)	.53 (.02)
5.0 (.3)	5.4 (.3)	.40 (.01)	.49 (.02)
4.7 (.3)	2.5 (.3)	.85 (.02)	.66 (.02)
5.1 (.7)	1.7 (.4)	.83 (.02)	.76 (.02)
0.5 (.2)	2.9 (.1)	.05 (.02)	.14 (.05)
1.4 (.2)	5.0 (.2)	.11 (.01)	.22 (.02)
3.6 (.04)	1.3 (.08)	.90 (.003)	.75 (.01)
3.6 (.2)	3.5 (.1)	.59 (.02)	.51 (.01)
3.7 (.01)	3.6 (.05)	.40 (.01)	.50 (.01)
6.6 (.5)	7.4 (.7)	.43 (.01)	.47 (.01)
5.8 (.2)	3.9 (.3)	.73 (.02)	.60 (.01)
5.6 (.1)	6.5 (.3)	.38 (.02)	.46 (.01)
3.7 (.4)	5.9 (.2)	.29 (.04)	.38 (.02)
5.9 (.4)	5.0 (1.1)	.68 (.06)	.55 (.03)
5.1 (.5)	6.8 (.6)	.34 (.03)	.43 (.01)
7.6 (.8)	6.0 (.5)	.58 (.02)	.56 (.01)
5.8 (.2)	5.3 (.5)	.56 (.01)	.52 (.02)
5.0 (.01)	3.9 (.2)	.74 (.01)	.57 (.01)
5.0 (.1)	6.6 (.2)	.46 (.003)	.43 (.001)
5.3 (.3)	5.3 (.004)	.47 (.01)	.50 (.01)
6.0 (.3)	4.6 (.2)	.57 (.02)	.57 (.01)

(*continued next page*)

ditions in which sessions terminated after 90 reinforcers. In the 90-reinforcer conditions, the 4 subjects received a mean of 98.7% of the programmed larger reinforcers ($SE = 0.1$, $N = 4$) but only 4.2% of the programmed smaller reinforcers ($SE = 3.1$, $N = 4$). In the 30-min conditions, these subjects received essentially the same percentage of programmed larger reinforcers as in the 90-reinforcer conditions ($M = 96.5$, $SE = 0.6$, $N = 4$) but a larger percentage of the programmed smaller reinforcers ($M = 21.7$, $SE = 10.7$, $N = 4$).

In order to examine the subjects' sensitivity to variations in reinforcer amount and delay over all conditions, a modification of the ideal matching law was used—that is, the generalized matching law (Baum, 1974):

$$\frac{B_L}{B_R} = \left(\frac{A_L}{A_R}\right)^{s_A}\left(\frac{D_R}{D_L}\right)^{s_D}. \tag{2}$$

This equation differs from the ideal matching law (Equation 1) in that it includes two additional parameters, s_A and s_D, which represent sensitivity to variations in reinforcer amount and delay, respectively (see Davison, 1982; Logue et al., 1984). Actual determination of the values of s_A and s_D is performed using the base-10 logarithmic form of Equation 2:

$$\log(B_L/B_R) = s_A\log(A_L/A_R) + s_D\log(D_R/D_L). \tag{3}$$

Multiple linear regression is then employed when reinforcer amounts and delays are both varied, so as to obtain the coefficient s_A for the independent variable relative reinforcer amount and the coefficient s_D for the independent variable relative reinforcer delay; and regular linear regression is employed when either $A_L = A_R$ (which reduces Equation 3 to $\log[B_L/B_R] = s_D\log[D_R/D_L]$) or $D_R = D_L$ (which reduces Equation 3 to $\log[B_L/B_R] = s_A\log[A_L/A_R]$).

Table 2 shows the results of analyses using Equation 3 and the programmed amounts and delays. The regression analyses for Experiment 4 were performed using data from only the first five conditions. The method of least squares was used for all analyses. An adjusted value of r^2 is given in each case. The formula used here attempts to compensate for the sometimes artificially high values of r^2 generated by small samples (Pedhazur, 1982, pp. 147–149). When, occasionally, no responses

Table 1 (*Continued*)

Experiment	Subject	Condition (in seconds) A_L	A_R	D_L	D_R	No. of sessions	Responses per min[c] Left	Right
	17	6	6	6	6	4	41.0 (9.7)	45.3 (2.2)
		10	2	7	0.1	4	99.3 (9.8)	1.5 (.08)
		10	5	13	0.1	2	88.4 (10.2)	40.2 (28.5)
		2	10	0.1	7	2	2.8 (.7)	59.4 (3.7)
		5	10	0.1	13	4	.1 (.08)	95.6 (22.9)
	18	6	6	6	6	5	124.6 (8.0)	65.3 (3.5)
		10	2	7	0.1	5	115.0 (1.2)	45.8 (1.2)
		10	5	13	0.1	2	59.7 (9.1)	117.1 (23.3)
		2	10	0.1	7	4	82.8 (12.9)	90.0 (6.1)
		5	10	0.1	13	2	146.9 (28.9)	85.0 (14.6)
	19	6	6	6	6	4	73.1 (5.6)	68.2 (5.4)
		10	2	7	0.1	2	87.8 (10.7)	93.1 (9.8)
		10	5	13	0.1	3	114.3 (9.6)	46.9 (7.4)
		2	10	0.1	7	3	87.2 (9.7)	85.9 (6.2)
		5	10	0.1	13	3	89.3 (39.0)	90.6 (40.1)

Note. Experiment 1 used a discrete-trials procedure. Experiments 2–5 used a concurrent VI VI procedure.

[a] The first condition was a training condition. Subjects 3 and 4 were exposed to the second through sixth conditions in the reverse of the order indicated.

[b] Subjects 5 and 6 were exposed first to the sessions that ended after 30 min; Subjects 7 and 8 were exposed first to the sessions that ended after 90 reinforcers.

[c] Means are shown with standard errors in parentheses. $N = 5$ in each case, except Experiment 1 where $N = 1$. For Experiment 1, numbers of rod pushes and reinforcers are shown instead of rates.

were made to one side, the standard transformation of $\log(X' = X + 1)$ was used in performing the regressions (see Snedecor & Cochran, 1967, p. 329).

Table 2 shows that in general Equation 3 fit the data well; 86% of the 28 values of adjusted r^2 for Experiments 1 and 3 through 5 were .60 or above. The value of −.017 obtained for Subject 2 in Experiment 1 would have been .49 if a nonadjusted value of r^2 had been used. Analyses for Experiments 3 through 5 using obtained amounts (number of button presses) and obtained delays (programmed delay plus the latency to first push the button in a given reinforcer period) resulted in poorer fits. The original analyses yielded values of r^2 that ranged between .46 and .98 with a mean of .81 (SE = .037, N = 18). The analyses with obtained amounts and delays yielded values of r^2 that ranged between −.28 and .85 with a mean of .37 (SE = .089, N = 18). Other models of choice also have found good fits with programmed as compared to obtained delays of reinforcement (e.g., Fantino & Davison, 1983).

Although each regression analysis was based on a small number of points, together, the results from all of the analyses are fairly consistent. The values of s_A and s_D listed in Table 2 for Experiments 1 and 2, in which 2 subjects were exposed to the conditions in one order and 2 in another order, show that order of exposure does not appear to have affected the outcomes. The values of s_A/s_D in Table 2 indicate subjects' sensitivity to variations in reinforcer amount relative to variations in reinforcer delay. For Experiments 3 and 4, in which reinforcer amount and reinforcer delay were varied separately, the mean values of s_A/s_D were both equal to 1.1. However, when reinforcer amount and delay were varied together in Experiments 1 and 5, the obtained values of s_A/s_D were all much larger than 1.0, with the largest values being obtained in Experiment 1. There was no overlap in the range of the values of s_A/s_D obtained in Experiments 3 and 4 compared with those obtained in Experiments 1 and 5.

Table 2 also shows that, consistent with the results shown in Table 1 and Figure 2 and described above, every subject's behavior was more sensitive to changes in the amount of the reinforcers in the 90-reinforcer than in the 30-min conditions. When relative reinforcer

Table 1 (*Continued*)

Reinforcers per min[c]		Left[c] / (Left + Right)	
Left	Right	Responses	Reinforcers
3.9 (.3)	5.3 (.05)	.46 (.05)	.42 (.02)
4.1 (.01)	0.2 (.002)	.99 (.002)	.97 (.004)
8.1 (.7)	2.0 (1.4)	.78 (.16)	.85 (.11)
0.2 (.02)	2.8 (.1)	.04 (.01)	.06 (.002)
0.0 (0)	7.7 (.7)	.002 (.001)	.00 (0)
6.1 (.09)	5.3 (.5)	.66 (.003)	.54 (.03)
5.0 (.05)	4.7 (.3)	.72 (.01)	.51 (.02)
3.6 (.1)	5.5 (.2)	.34 (.01)	.40 (.02)
5.2 (.09)	5.2 (.03)	.47 (.02)	.50 (.003)
6.5 (.5)	5.0 (.3)	.63 (.01)	.57 (.01)
5.6 (.1)	5.5 (.3)	.52 (.001)	.50 (.01)
5.0 (.09)	4.8 (.4)	.48 (.004)	.51 (.02)
8.5 (.3)	3.6 (.5)	.71 (.02)	.71 (.02)
5.2 (.4)	5.3 (.07)	.50 (.001)	.50 (.02)
6.0 (3.1)	6.8 (.3)	.45 (.13)	.41 (.15)

amount was increased and relative reinforcer delay decreased, these subjects' relative preferences increased less in the 30-min than in the 90-reinforcer conditions. The reverse was also true. The mean slope in the 30-min conditions was 2.5, whereas in the 90-reinforcer conditions the corresponding value was 3.9. Note, however, that due to intersubject variability, this difference is not statistically significant [$t(3) = -2.14$, $.1 < p < .2$].

DISCUSSION

The procedures used in the experiments reported here were typically successful in obtaining stable, consistent behavior from adult human subjects in relatively short periods of time. Perhaps because minimal instructions were used (see Matthews et al., 1977; Shimoff et al., 1981), the subjects' behavior was sensitive to changes in the contingencies and, in Experiments 2 through 5, usually stabilized within two or three sessions following a change in contingencies. Experiments 1 and 2 showed that the sequence in which the conditions were presented did not affect the data. In addition, the values obtained for s_A and s_D using Equation 3 were similar across experiments that used similar procedures.

Together, the experiments consistently showed that relative reinforcer amount controlled the subjects' behavior more than did relative reinforcer delay; the subjects frequently chose the larger, more delayed reinforcers over the smaller, less delayed reinforcers. This pattern of responding resulted in these subjects obtaining more total reinforcement (money) than they would have obtained had they followed the ideal matching law (Equation 1), which does adequately describe experimentally naive pigeons' choices in similar situations.

The generalized matching law analyses, used to help assess sensitivity of the subjects' behavior to reinforcer amount and reinforcer delay over all conditions, confirmed and extended these conclusions. The behavior was sensitive to variations in delay of reinforcement relative to variations in amount of reinforcement only to the extent that the variations in reinforcer delay affected the total amount of reinforcement that could be received. For example, in Experiment 1—in which one reinforcer was received every 3 min no matter which reinforcer the subject chose, so that maximal reinforcement was received by always choosing the largest reinforcer and ignoring reinforcer delay—the lowest value of s_A/s_D for any subject was 10.0; variations in reinforcer delay made very little difference in the subjects' behavior relative to variations in reinforcer amount. In Experiment 2—in which conditions ended after 90 reinforcers—the total amount of reinforcement received could again be maximized by choosing only the larger reinforcers, and in this part of the experiment, behavior was relatively more sensitive to reinforcer amount than in the conditions that ended after 30 min. In general, the subjects' behavior was relatively more sensitive to reinforcer amount when both amount and delay were varied together (Experiments 1 and 5) than when they were varied separately (Experiments 3 and 4). As a result, more reinforcement was received than would have been received had the subjects been more sensitive to reinforcer amount when amount and delay were varied separately. In the experiments in which reinforcer amount and reinforcer delay were varied separately, total reinforcement as well as rate of reinforcement

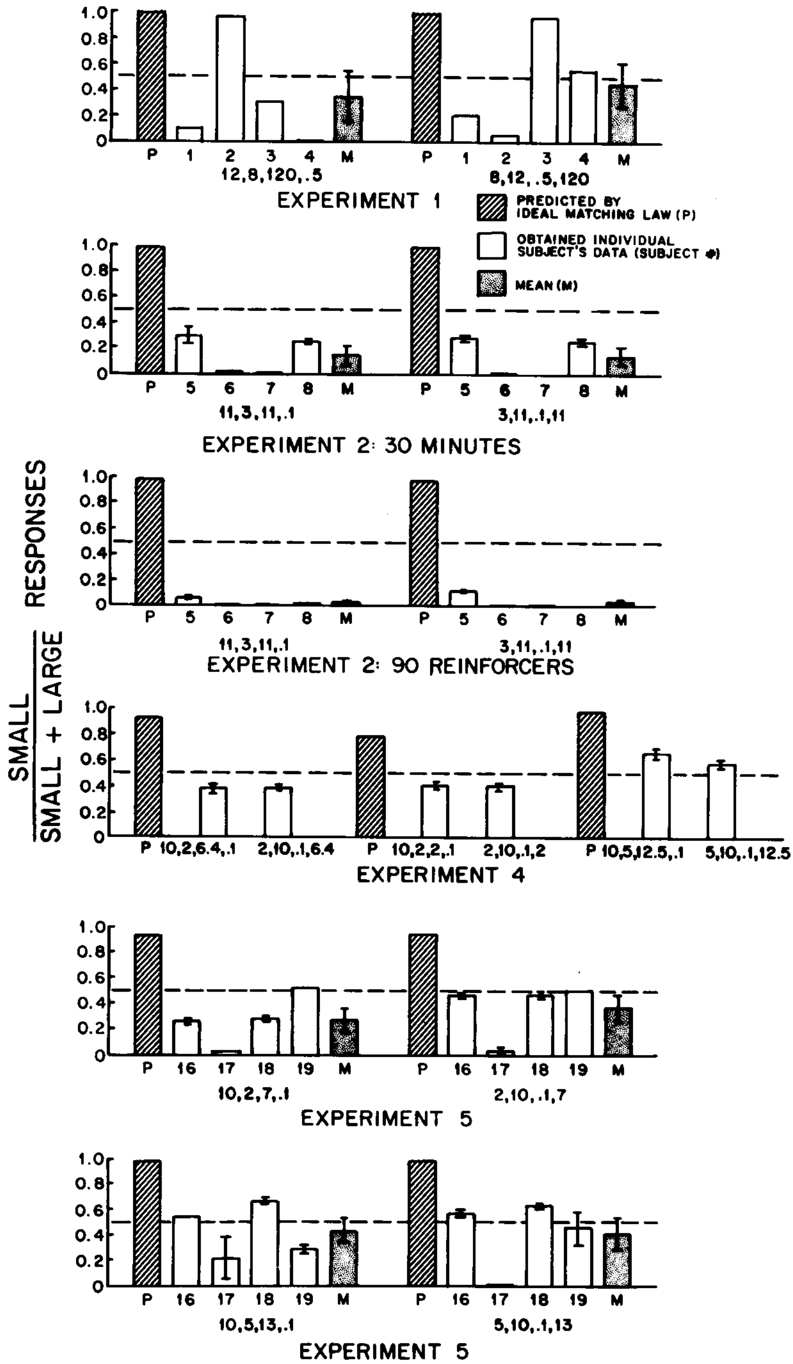

Fig. 2. The proportion of responses made to the side correlated with the smaller reinforcer for each of the conditions in which the choice was between a larger, more delayed reinforcer and a smaller, less delayed reinforcer. (Note that this omits conditions with differing delays but identical amounts and with differing amounts but identical delays, which are all shown in Table 1.) The cross-hatched bars (P) show the predictions of the ideal matching law, the open bars represent the individual subjects' obtained mean proportions, and the stippled bars (M) show the mean proportions over all of the subjects in a given condition. The vertical lines depict one standard error on each side of the mean. The dashed lines indicate the loci corresponding to equal preference for rod pushes to either side, a proportion of .50.

could be maximized by choices of the less delayed reinforcers during the conditions in which reinforcer delays were varied. But when both reinforcer amount and reinforcer delay were varied together, there was an advantage to choosing the smaller, less delayed reinforcer only when a larger reinforcer was unavailable.

Although the generalized matching law appeared to fit the data well with fairly high values of r^2, it does not predict the above changes in the exponents that occur with changes in the procedure. The subjects' behavior instead seemed consistent with a strategy that tended to maximize the total number of points received over the whole session. The subjects behaved as if events over entire sessions were integrated, with their behavior being affected by postreinforcer delays (the delays between the end of a reinforcer and the next opportunity to choose), as well as by the prereinforcer delays (the delays between a choice and the receipt of a reinforcer; D_L and D_R in the matching law, Equations 1–3). In addition, in accordance with their instructions, the subjects stated that they attempted to determine which pattern of responding would yield the largest total number of points over the entire session by trying to time the events during the experiment.

Therefore, a maximization strategy, resulting in self-control, approximately describes the subjects' behavior. These results are consistent with those of Mawhinney (1982), who found that, with concurrent variable-interval fixed-ratio schedules, an adult human subject tended to maximize total amount of received reinforcement instead of matching.

In contrast, pigeons' choices appear to be little affected by postreinforcer delays (Lea, 1979; Logue, Smith, & Rachlin, 1985; McDiarmid & Rilling, 1965; Shull, Spear, & Bryson, 1981). Consequently, the behavior of pigeons is well described by the matching law; they frequently choose the smaller, less delayed reinforcer in a self-control paradigm, even in experiments in which frequency of reinforcement is controlled and in which these choices result in less total reinforcement being received (e.g., see Logue & Peña-Correal, 1984).

Previous research (Bentall & Lowe, 1982; Bentall, Lowe, & Beasty, 1985; Harzem, Lowe, & Bagshaw, 1978; Lowe, 1979, 1983) suggests that differences between human and nonhuman subjects' performance on various schedules of reinforcement are due, at least in part, to human subjects' producing their own verbally based cues. Likewise, subjects in the present experiment reported that they deter-

Table 2

Results of regression analyses for all experiments.

Subject	s_A	s_D	s_A/s_D	r^2
		Experiment 1		
1	5.8	0.1	57.8	.87
2	6.4	0.5	13.5	−.017
3	7.3	0.7	10.0	.68
4	4.3	0.06	69.6	.59
M	5.9	0.3	37.7	.53
(*SE*)	(0.6)	(0.1)	(13.2)	(.17)
		Experiment 2		
5	0.8	1.9	0.4	.64/.98
6	3.3	4.5	0.7	.97/.67
7	5.0	5.1	1.0	.99/.99
8	0.9	4.0	0.2	.80/.99
M	2.5	3.9	0.6	.85/.91
(*SE*)	(0.9)	(0.6)	(0.2)	(.071)/(.069)
		Experiment 3		
9	1.0	0.8	1.2	.88/.93
10	0.3	0.3	0.9	.86/.88
11	0.3	0.2	1.3	.94/.89
12	0.3	0.4	0.9	.95/.89
M	0.5	0.4	1.1	.91/.90
(*SE*)	(0.2)	(0.1)	(0.1)	(.020)/(.0099)
		Experiment 4		
13	0.6	0.6	1.0	.96/.98
14	1.2	1.8	0.7	.46/.60
15	0.6	0.4	1.5	.94/.74
M	0.8	0.9	1.1	.79/.77
(*SE*)	(0.2)	(0.3)	(0.2)	(.13)/(.092)
		Experiment 5		
16	0.8	0.2	4.9	.68
17	2.5	0.07	36.8	.85
18	1.0	0.3	3.8	.52
19	−0.5	−0.2	2.7	.68
M	0.9	0.07	12.1	.68
(*SE*)	(0.5)	(0.09)	(7.1)	(.059)

Note. For Experiment 2, the two exponents given for each subject and the mean indicate the subjects' sensitivity to reinforcer amount when sessions ended after 30 min and 90 reinforcers, not s_A and s_D. The two values for r^2 correspond to these regressions. Two values of r^2 are shown for each subject and the mean of Experiments 3 and 4, in which linear regressions were performed separately for variations in reinforcer amount and reinforcer delay. The values before the slashes are for the conditions in which amounts were varied. The values after the slashes are for the conditions in which delays were varied. For Experiment 4, the regressions were performed using only the data from the first five conditions.

mined which strategy maximized reinforcement by counting the passage of time.

An alternative explanation of these differences between human and pigeon behavior is based on the fact that subjects in the present experiments worked for points that could later be exchanged for money. The money could not be spent until a session was over, so there was no advantage to obtaining points before the end of a session. All of the previous experiments with pigeons described above, however, used food-deprived pigeons and food as the reinforcer. In such situations, depending on the degree of food deprivation, there might be some advantage to obtaining food quickly, even if that meant obtaining less total reinforcement. Perhaps if adult human subjects were similarly deprived (e.g., see Buskist & Miller, 1981), impulsiveness would be more easily obtained with adult humans and positive reinforcement. This conclusion is in agreement with the fact that the only experiments that have consistently found impulsiveness in adult humans have used a negative reinforcer of immediate value: escape from loud white noise (see Navarick, 1982; Solnick et al., 1980).

Finally, perhaps other types of adult human subjects, such as institutionalized criminals, might show less self-control than the subjects used here. A lack of self-control has been described as contributing to psychopathology and criminality (Wilson & Herrnstein, 1985).

In conclusion, with points exchangeable for money, the usual reinforcer for adult human subjects in operant conditioning experiments, these subjects frequently demonstrated self-control, and not impulsiveness. This behavior seemed to result because adult humans, unlike pigeons, are sensitive to events as integrated over whole sessions and tend to maximize total reinforcement over whole sessions. Therefore, the only way to generate impulsive behavior in these adult human subjects in this type of situation is to arrange the contingencies such that choosing the smaller, less delayed reinforcer yields more total reinforcement over the entire session. However, note that the traditional definition of self-control given at the beginning of this paper does not specify over what time period a single reinforcer is defined. If the entire session in the above hypothetical experiment were used as the time unit instead of an individual trial, choices of the smaller, less delayed reinforcer would no longer be defined as impulsiveness, but as self-control, because those choices would now actually be choices of the larger reinforcer.

These apparent differences between human and pigeon behavior, and the factors responsible for these differences, need to be examined in greater detail if pigeons are to continue being used to examine models of human impulsiveness and self-control.

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