*SELF-CONTROL AND IMPULSIVENESS IN
CHILDREN AND ADULTS: EFFECTS OF
FOOD PREFERENCES*

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Experiment 1 used 6 preschool boys and Experiment 2 used 6 adult women to explore the effects of food preference on humans' choice in self-control paradigms. The boys showed a higher proportion of responses for more delayed, larger reinforcers (a measure of self-control) when those choices resulted in receipt of the most preferred food compared to when those choices resulted in the least preferred food. Further, the boys chose the less delayed, smaller reinforcers significantly more often when only those choices, as opposed to both choices, resulted in the most preferred food. Conversely, they chose the more delayed, larger reinforcers significantly more often when only those choices, as opposed to both choices, resulted in the most preferred food. Finally, the women demonstrated significantly less sensitivity to reinforcer amount relative to sensitivity to reinforcer delay (another measure of self-control) when they had a higher preference for the juice received as the less delayed, smaller reinforcer than for the juice received as the more delayed, larger reinforcer. Together, the results show that subjects' food preferences can influence self-control for food reinforcers.

Key words: self-control, impulsiveness, choice, food preferences, button press, rod push, children, adults

Self-control has been defined as the choice of a more delayed, larger amount of reinforcement over a less delayed, smaller amount of reinforcement, resulting in more total received reinforcement. Impulsiveness has been defined as the opposite. These definitions have been used by researchers working with both human and nonhuman subjects (Ainslie, 1974; Logue, 1988; Logue, King, Chavarro, & Volpe, 1990; Rachlin & Green, 1972).

Experiments have shown that a number of factors can affect the degree of self-control demonstrated by humans. For example, self-control in adult humans has been shown to be affected by manipulation of amount, delay, and rate of reinforcement (Logue et al., 1990; Logue, Forzano, & Tobin, 1992; Logue,

Peña-Correal, Rodriguez, & Kabela, 1986); the use of different methods of reinforcer delivery (King & Logue, 1990b); and current dieting status of the subject (Forzano & Logue, 1992; Logue & King, 1991). Children's self-control has been shown to vary as a function of age (Bonvino, Ackerman, & Logue, 1991¹; Mischel & Mischel, 1983; Sarafino, Russo, Barker, Consentino, & Titus, 1982; Sonuga-Barke, Lea, & Webley, 1989), gender (Funder, Block, & Block, 1983; Logue & Chavarro, 1992), and language ability (Rodriguez, Mischel, & Shoda, 1989), as well as reinforcer amount and delay (Logue & Chavarro, 1992; Schweitzer & Sulzer-Azaroff, 1988) and systematic increases in the delay to the larger reinforcer (Schweitzer & Sulzer-Azaroff, 1988).

However, each of these experiments used the same type of reinforcer for both response alternatives, despite the fact that reinforcer preference has been shown to significantly influence the choice and responding of nonhumans and humans in a variety of experiments (e.g., for nonhumans: Beninger, 1972; Beninger & Kendal, 1975; Etinger, McSweeney, & Norman, 1981; Hollard & Dav-

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¹ Bonvino, L. J., Ackerman, K., & Logue, A. W. (1991, May). *Variables related to self-control in children: Age, language ability, and sensitivity to reinforcer amount and delay*. Poster presented at the meeting of the Association for Behavior Analysis, Atlanta, GA.

ison, 1971; Miller, 1976). In addition, manipulation of reinforcer preference can significantly influence the degree of self-control typically exhibited by pigeons (King & Logue, 1990a). Further, in adult humans it has been demonstrated that self-control is positively correlated with subjective rating of desire for juice reinforcers; that is, subjects who give a higher overall rating of desire for juice demonstrate more self-control (Forzano & Logue, 1992). Finally, when given the choice between two schedules of reinforcement that are equal except that one delivers a more preferred type of food and the other a less preferred type of food, human subjects choose to respond on the schedule associated with the more preferred food (Lappalainen & Epstein, 1990).

The lack of research regarding the effects of reinforcer preference on self-control in humans is unfortunate. Laboratory research on self-control choices that involve qualitatively similar reinforcers may not be applicable to the world outside the laboratory, where animals, including humans, must often choose between qualitatively different reinforcers. Further, results from the research described above suggests that self-control should indeed vary as a function of reinforcer preference.

The purpose of the present experiments was to take a first step toward examining the effects of reinforcer preference—in particular, food preference—on humans' choice behavior in self-control paradigms. Two experiments were conducted with human subjects, one with preschool boys and one with women.

EXPERIMENT 1

The first experiment used 3-year-old boys and a standard discrete-trials self-control paradigm (see Forzano & Logue, 1992; Logue & Chavarro, 1992; Logue et al., 1986; Mazur & Logue, 1978; for other experiments using similar procedures with both human and nonhuman subjects). Previous research has shown that boys of this age tend not to show significant self-control for either stickers or preferred food items (Logue & Chavarro, 1992; Bonvino et al., 1991). Therefore the present experiment specifically examined whether or not food reinforcer preferences

could be used to increase the self-control for food demonstrated by these subjects.

Method

Subjects. The subjects were 6 boys between the ages of 41 and 46 months. Subjects 1 through 3 were recruited from the State University of New York at Stony Brook Preschool. Subjects 4 through 6 were recruited from advertisements in local newspapers and their parents were reimbursed \$25.00 for the transportation costs of their child's participation. All subjects' parents were told that the experiment involved examining children's choices between rewards of varying sizes and delays and that their children's choices would be discussed with them immediately following the end of the entire experiment. All subjects' parents were asked to ensure that their children neither ate nor drank for at least 2 hr prior to the start of each session.

Apparatus. The experiment was conducted in a small room (2.7 m by 2.9 m) down the hall from the university preschool. The room contained a small chair and a table (44 cm high by 91 cm wide by 60 cm deep) on which the experimental apparatus was placed. The apparatus was a wooden box (76 cm wide, 80 cm high, and 47 cm deep) with an open back (adapted from Schweitzer & Sulzer-Azaroff, 1988, identical to the apparatus used in Logue & Chavarro, 1992). The front panel of the apparatus (see Figure 1) had a picture of Mickey Mouse's face painted on it with a white light in the middle of Mickey's nose. Below Mickey's face there were two lights. The left light could be illuminated green, and the right light could be illuminated red. Located 10 cm below each light was a drawer (each 11 cm wide, 19 cm deep, and 6 cm high). The left drawer was green inside, and the right drawer was red inside. During periods of reinforcer access the drawer emerged from the panel. This forward movement caused the drawer to protrude 13.5 cm from the panel and thus allowed the subject to open the lid of the drawer and remove the reinforcers. At all other times the drawers remained closed, flush with the front of the apparatus. In front of each drawer, on the base of the apparatus, was a button. This button produced a feedback click when activated.

Behind the front panel of the apparatus were electromechanical switches and timers

that controlled the experimental events. The experimenter sat behind the apparatus, unobserved by the subject, and operated the apparatus and recorded the subject's responses. The subject sat in the small chair in front of the apparatus.

Procedure. Each subject was escorted into the experimental room by one or both of his parents for the first session of the experiment. Next, the subject's preferences among three food items were assessed. The subject was seated at a table across from the experimenter, who presented the food items by displaying them on the table in front of the subject. The subject was first shown, one at a time, a Cheerio®, a raisin, and an M&M®. Following the presentation of each item, he was asked to identify the food verbally. All subjects were able to identify each food item correctly. Next, each subject was given a series of choices. For the first choice, he was presented with a Cheerio and a raisin and was asked to choose which he would like to eat. Next, he was presented with the previously chosen food and an M&M and was asked to choose which he would like to eat. If he chose the M&M, his most preferred food was designated as the M&M and his least preferred food was designated as the food he did not choose when given the initial choice between a Cheerio and a raisin. If he did not choose the M&M, the alternative item was designated as his most preferred food, and he was presented with a choice between the M&M and the food item not chosen in the initial choice to determine his least preferred food. To assess the reliability of these preferences, each subject was given a final choice between the foods designated as his most and least preferred and asked which he would like to eat more. The subject was also asked if he would eat both of these foods. A subject was not allowed to participate in the experiment unless his preferences during this assessment were reliable and he was willing to eat the least as well as the most preferred food item. No subjects were excluded from the experiment based on these criteria.

The experimenter next gave the subject the following instructions:

We're going to play a game now, a fun game with Mickey Mouse and [names of most and least preferred foods]. Sit right here and I will

Fig. 1. Diagram of the apparatus for Experiment 1. The letters W, G, and R represent the white, green, and red lights, respectively. The rectangles below the green and red lights represent the two drawers, and the two solid circles at the bottom represent the two response buttons.

show you how to play. When Mickey's nose lights up like this, see Mickey's nose light up [points to nose], what you have to do is to press one of these buttons [points to left and then right buttons], whichever one you want, but not both. If you press this button [presses left button], the green light will come on. See the green light [points to light]? When the drawer comes out [pushes drawer out], you will open it up [opens it] and take out the [name of more preferred food] and eat them. Here you go, go ahead and eat them [waits for subject to eat]. If you press this button [presses right button], the red light will come on. See the red light [points to light]? When the drawer comes out [pushes drawer out], you will open it up [opens it] and take out the [name of least preferred food] and eat them. Here you go, go ahead and eat them [waits for subject to eat]. Now let's see you try. Can you press this button [points to left button and has subject press it]? Great! See how the green light came on? Now when this drawer comes out [pushes drawer out], open it up [has child open it] and what are you going to do with those [name of most preferred food]? [Waits for child to say "eat them" or to eat them.] Now let's try the other button. Can you press this button [points to right button and has subject press it]? Terrific! See how the red light came on? Now when this drawer comes

out [pushes drawer out], open it up [has child open it] and what are you going to do with those [name of least preferred food]? [Waits for child to say "eat them" or to eat them.] [If necessary, the experimenter gave the subject additional practice. When the subject could press the two buttons, open the drawers, and take out and eat the food items, totally independent of the experimenter's assistance, the experimenter then gave the subject the following instructions.] So when Mickey's nose lights up what are you going to do? [Waits for correct response or practices more.] Remember you can press any button you want. O.K., your mom (and/or dad) is going to wait right outside the door so that we can get started. [Mother (and/or father) is escorted out the door.] O.K., let's start. I'm going to sit right back here.

The experimenter then sat on a chair in back of the apparatus. There was no further communication between the experimenter and the subject during the session unless the experimenter had to remind the subject to attend to the task (a very rare occurrence).

At the beginning of all subsequent sessions, reliability of preference between the food items and ability to operate the apparatus were reconfirmed. To reconfirm preference among the food items, each subject was shown the foods designated at the first session as his most and least preferred foods and asked which he would like to eat more. To reconfirm ability to operate the apparatus, subjects were asked two questions: "Do you remember how to play the Mickey game?" and "When Mickey's nose lights up, what are you going to do?" For each question, the experimenter waited for the correct response or demonstrated the procedure again. At the end of each session, subjects were asked, "Which button did you like to press today?" and "Why did you like to press that button?" The experimenter recorded the subjects' responses on a response sheet.

Each session consisted of 14 discrete trials. The intertrial intervals (ITIs) were adjusted such that there was always 1 min between the start of each trial, unless a subject responded extremely slowly so that 1 min had already passed when the reinforcer access period ended (in which case the next trial began immediately). Thus, unless a subject responded extremely slowly (which occurred on only 13% of the trials), this procedure ensured

that frequency of reinforcer access periods remained constant at one access period per minute regardless of a subject's choices and that session time remained constant at 14 min.

The first four trials were forced-choice trials, and the other 10 trials were free-choice trials. At the beginning of a free-choice trial, the white light in the middle of Mickey's nose was lit, signaling the availability of a choice. If the left button was pushed, a feedback click was produced, the white light was darkened, the green light above that button was lit, and a left-choice reinforcer delay began. When this delay was over, reinforcement was delivered: The left drawer slid out from the apparatus and the subject opened the lid on top of the drawer, removed the food items, and ate them. When the food had been removed from the drawer the drawer slid back in, the green light above the drawer darkened, and an ITI began. The next trial began with the reillumination of the white light in the middle of Mickey's nose. The sequence of events following a right button press was the same, except that the red light above that button was lit and the right drawer slid out from the apparatus.

For the forced-choice trials, only one response alternative was available and effective: For two of these trials the subject could only receive reinforcement by pressing the left button, and for two of these trials he could only receive reinforcement by pressing the right button. More specifically, the sequence of events for a forced-choice trial was the same as for a free-choice trial, except that only one response was functional (i.e., produced a feedback click, darkened the white light, illuminated the respective delay light above that button, began the reinforcer delay period and delivered the reinforcer). The forced-choice trials alternated between the left and right buttons, with the first forced-choice trial of each session being on the left button. In the event that a child continually pressed an ineffective button during a forced-choice trial, the experimenter instructed him to try the other button (a rare occurrence). The forced-choice trials ensured that, prior to making any free choices, the subject had been exposed to the contingencies for both left and right button presses.

Subjects were exposed to six experimental

Table 1
Conditions for Experiment 1.

Condition	Reinforcement for choosing left button			Reinforcement for choosing right button		
	Delay	Amount	Food	Delay	Amount	Food
1	15 s	2	most preferred	15 s	2	least preferred
2	15 s	2	least preferred	15 s	2	most preferred
3	0 s	1	least preferred	30 s	3	most preferred
4	30 s	3	least preferred	0 s	1	most preferred
5	30 s	3	most preferred	0 s	1	least preferred
6	0 s	1	most preferred	30 s	3	least preferred

Note. The values for amount represent the number of food item halves.

conditions, one session per condition. Table 1 shows the reinforcer delays, amounts, and types for each of the six sessions. The first two conditions were baseline sessions: Pressing either button resulted in a 15-s delay followed by two reinforcers, but pressing one button produced the subject's most preferred food and pressing the other button produced his least preferred food. Conditions 3 and 5 tested for the effects of food preference on self-control and impulsiveness when choices of the more delayed, larger reinforcer (traditionally designated as the self-control alternative) produced the subject's most preferred food and choices of the less delayed, smaller reinforcer (traditionally designated as the impulsive alternative) produced the subject's least preferred food. Conditions 4 and 6 tested for the effects of food preference on self-control and impulsiveness when choices of the less delayed, smaller reinforcer (traditionally designated as the impulsive alternative) produced the subject's most preferred food and choices of the more delayed, larger reinforcer (traditionally designated as the self-control alternative) produced his least preferred food. Note that the contingencies for the two buttons were switched for Conditions 1 and 2, 3 and 5, and 4 and 6. This was done in order to test for position and color biases.

Subjects were exposed to one session per day, approximately 3 days per week. Occasionally (11% of the sessions), in order for a subject to complete the experiment, it was necessary to expose him to two sessions in one day. In such cases there was always at least a 3-hr interval between the two sessions. It took subjects a mean of 13.5 calendar days

($SE = 3.3$) to complete their six experimental sessions.

Results and Discussion

All subjects learned to operate the apparatus during the training session prior to the first condition. All subjects ate the reinforcers upon receipt. All subjects, with one exception, maintained their food preferences across all experimental conditions. When asked by the experimenter at the beginning of each session which reinforcer he most preferred, all but one of the subjects clearly identified the previously designated most preferred food in 100% of the sessions. Subject 1, however, switched his most preferred and least preferred foods after the first session. Subject 1's preferences remained constant for Conditions 2 through 6. Therefore, for all of the analyses, his preferences were designated as those he exhibited in Conditions 2 through 6. Five of the subjects chose M&Ms as their most preferred food, and, of these subjects, 3 chose raisins and 2 chose Cheerios as their least preferred food. Subject 2 chose raisins as his most preferred food and Cheerios as his least preferred food.

Analyses were performed for each condition using data from the free-choice trials. The dependent variable consisted of the proportions of responses that the subjects made on one of the two buttons—the left button for Conditions 1, 4, and 5 and the right button for Conditions 2, 3, and 6. Thus, these proportions represent the proportions of choices for the most preferred food when amount and delay values were equal (Conditions 1 and 2), the proportions of choices for the self-control alternative when those

Table 2
Response proportions for each condition for each subject in Experiment 1.

Subject	Condition					
	1	2	3	4	5	6
1	.9	.9	1.0	.0	.9	.5
2	.5	.5	.6	.6	.6	.2
3	1.0	.2	.4	.2	1.0	.0
4	.4	.6	.4	.5	.5	.5
5	1.0	1.0	1.0	.0	1.0	.0
6	.6	.5	.5	.1	.9	.1
<i>M (SE)</i>	.7 (.1)	.6 (.1)	.7 (.1)	.2 (.1)	.8 (.1)	.2 (.1)

choices produced the most preferred food (Conditions 3 and 5), and the proportions of choices for the self-control alternative when those choices produced the least preferred food (Conditions 4 and 6). Table 2 shows the mean proportions for each subject and each condition. Most, although not all, of the subjects (e.g., Subject 1 in Conditions 1 and 2) tended to respond similarly across the two conditions within a pair. For all of the subjects, there were no statistically significant differences between the response proportions collected in the first and second conditions, in the third and fifth conditions, or in the fourth and sixth conditions, $t(5) = 0.82, p > .05$; $t(5) = -1.49, p > .05$; and $t(5) = 0.14, p > .05$, respectively. In other words, there were no statistically significant position or color biases. Therefore, for further analyses, data from Conditions 1 and 2, 3 and 5, and 4 and 6 were combined.

During the first two sessions, when the amounts and delays for the different reinforcers were equal, there was a tendency for subjects to choose their most preferred food more often than their least preferred food (mean proportion = .68, $SE = .09$), although their choice proportions were not significantly different from indifference, that is, from .5; $t(5) = 1.96, .1 < p < .2$.

Figure 2 shows, for each subject, the mean proportion of choices of the more delayed, larger reinforcers when those choices produced the least and most preferred foods. All subjects except Subject 4 more often chose the more delayed, larger reinforcers when those choices produced the most preferred compared to the least preferred foods. Subject 4 was apparently indifferent in his choices. This figure also shows means of these

data for all subjects. As suggested by Figure 2 and confirmed with a dependent t test, the subjects chose the more delayed, larger reinforcers significantly more often in the conditions in which those choices resulted in receipt of the most preferred food (Conditions 3 and 5) than in the conditions in which those choices resulted in receipt of the least preferred food: Conditions 4 and 6; $t(5) = 3.32, p < .05$.

In addition, subjects' proportions of choices of more delayed, larger reinforcers for the conditions in which those choices resulted in receipt of the most preferred food (Conditions 3 and 5) were significantly greater than .5, $t(5) = 2.74, p < .05$. This is consistent with the fact that the subjects did not show a significant tendency to alternate from one response alternative to the other in these two conditions, $t(5) = -0.06, p > .05$, but rather tended to make subsequent responses on the same alternative. Further, subjects' choice proportions of the more delayed, larger reinforcers for the conditions in which those choices resulted in receipt of the least preferred food (Conditions 4 and 6) were significantly less than .5, $t(5) = -3.48, p < .05$. Once again, this is consistent with the fact that the subjects did not show a significant tendency to alternate from one response alternative to the other in these two conditions, $t(5) = -1.91, p > .05$, but rather tended to make subsequent responses on the same alternative. Finally, in 78% of the 36 sessions the subjects correctly identified the button that produced their most preferred food as the one that they chose more often during the session.

Further analyses were conducted comparing subjects' choices in the present experi-

Fig. 2. Experiment 1's proportions of choices of the more delayed, larger reinforcers when those choices resulted in the least preferred food and when those choices resulted in the most preferred food, shown separately for each subject; Experiment 1's mean proportions, over all subjects; and mean proportions found by Bonvino et al. (1991), in which both choices resulted in the preferred food. The dashed line represents indifference.

ment with choices in another experiment (Bonvino et al., 1991) in which five 3-year-old boys were exposed to procedures identical to those used in the present experiment, with the exception that they received preferred food for choices of both the more delayed, larger reinforcer and the less delayed, smaller reinforcer (see far right bar, Figure 2). Subjects chose the less delayed, smaller reinforcers significantly more often when only those choices (present experiment), as opposed to both choices (Bonvino et al., 1991), produced the preferred food, $t(10) = 2.35$, $p < .05$. Conversely, subjects chose the more delayed, larger reinforcers significantly more often when only those choices (present experiment), as opposed to both choices (Bonvino et al., 1991), produced the preferred food, $t(10) = 2.58$, $p < .05$.

EXPERIMENT 2

Previous research has suggested that adult women's self-control should vary as a function of reinforcer preference. Therefore, the present experiment specifically examined the effects of food preference on adult women's choice behavior. The use of women in Experiment 2 permitted several procedural differences from Experiment 1, including a larger number of sessions and longer sessions. Because of these procedural differences, a more sophisticated quantitative analysis of choice was permitted. The experimental procedure was identical to that used by Forzano and Logue (1994), and involved a discrete-trials procedure similar to that used in Experiment 1, except that the delay to the larger reinforcer adjusted in accordance with a subject's choices (see Mazur, 1987).

In this experiment, choices were made between a larger reinforcer with an adjusting delay and a smaller reinforcer with a fixed delay. The delay to the larger reinforcer adjusted according to the subject's past choices until she was indifferent between the two alternatives. With this procedure, at indifference, $B_1/B_2 = 1.0$ in the generalized matching law for self-control (Logue et al., 1986):

$$\frac{B_1}{B_2} = k \left(\frac{A_1}{A_2} \right)^{s_A} \left(\frac{D_2}{D_1} \right)^{s_D}, \quad (1)$$

in which B_1 and B_2 represent choices made for the two response alternatives, A_1 and A_2 are the reinforcer amounts for those two alternatives, D_2 and D_1 are the delays, the constant k is response bias, and s_A and s_D describe a subject's sensitivity to variation in the size of reinforcement and sensitivity to variation in delay of reinforcement, respectively. Therefore, assuming $B_1 = B_2$ and no response bias (i.e., $k = 1.0$, a reasonable assumption based on previous research using similar procedures with similar reinforcer amounts: Logue et al., 1986, 1990), and using a logarithmic transformation of Equation 1, it is possible to calculate s_A/s_D :

$$\frac{s_A}{s_D} = \frac{\log \left(\frac{D_1}{D_2} \right)}{\log \left(\frac{A_1}{A_2} \right)}. \quad (2)$$

Using the adjusting-delay procedure and Equation 2, it is possible to calculate s_A/s_D from the results of a single condition. The greater the value of s_A/s_D , the more the subject's behavior is affected by reinforcer amount relative to reinforcer delay. In other words, the greater the value of s_A/s_D , the more the subject will tend to choose the larger amount over the less delayed reinforcers in a self-control paradigm; therefore, the subject will tend to show self-control (Logue et al., 1986).

Thus, employing the discrete-trials adjusting procedure and scaling subjects' choices using the generalized matching law, it is possible to obtain a quantitative measure of sensitivity to variation in reinforcer amount relative to sensitivity to variation in reinforcer delay, a quantitative measure of self-control

(see Alsop & Elliffe, 1988; Forzano & Logue, 1994; Logue, Tobin, et al., 1992; McCarthy, 1991; for similar approaches). Employing s_A/s_D as a measure of self-control may make it possible to compare self-control across experiments that have not used identical reinforcer parameters. In the present experiment, subjects chose between more and less preferred foods in order to investigate whether s_A/s_D would vary as a function of food preference.

Method

Subjects. The subjects were 6 experimentally naive nondieting adult women ranging in age from 18 to 24 years. All were either enrolled or employed at the State University of New York at Stony Brook. None were psychology majors. All were paid \$5.00 per session and received juice in return for their participation. Each subject was asked to neither eat nor drink for at least 4 hr prior to the start of each session.

Apparatus. The experiment was conducted in a small, windowless room (3.7 m by 1.9 m) that could be lit by a fluorescent light. In the middle of the room were a chair and a desk. The experimental apparatus was placed on the desk. It was a wooden box, open in the back, 81 cm high, 122 cm wide, and 66 cm deep. The front of the apparatus was painted black. On the top front edge of the apparatus were three 7.5-W light bulbs. The left light could be illuminated green, the center light white, and the right light red. On the top back edge of the apparatus was a speaker that emitted continuous white noise. The white noise helped to mask extraneous sounds.

On the front of the box was an aluminum panel, 51 cm high and 35.5 cm wide (see Figure 3). The panel contained the experimental stimuli and the manipulandum (an aluminum rod). The rod (1.2 cm in diameter) protruded 13.5 cm from the panel and was mounted 26 cm from the bottom of the apparatus, 86 cm from the floor. The rod could be pushed to the left or the right and required a minimum force of 10 N to operate in either direction. On each side of the rod was a translucent Plexiglas disk (3.5 cm in diameter). The left disk could be transilluminated green and the right disk red. A knob (1.8 cm in diameter and 1.5 cm long), located 5 cm above the rod, allowed access to the reinforcer (points). Knob turns of 90° in ei-

ther direction were effective only if a small white light 4.5 cm above the knob was lit. A counter, which displayed increments of 1 point for each turn of the knob, was located 14.7 cm above each Plexiglas disk. The counter above the left disk displayed increments of 1 point for each turn of the knob following a leftward rod push. The counter above the right disk displayed point increments following a rightward rod push.

An IBM XT® computer located in a separate room controlled the stimuli and recorded responses using a CONMAN program (Lucas, 1988).

Procedure. At the beginning of each session, each subject completed a questionnaire that requested information about what she had had to eat and drink that day (to ensure proper food and water deprivation). The subject was then instructed to rate her preference for each of nine different juices (apple, cranapple, cranberry, cranraspberry, grape, grapefruit, orange, pineapple, prune; these were the juices chosen most frequently by subjects in Forzano & Logue, 1992). On the preference rating sheet next to each juice's name was a horizontal line 4.5 in. long. The subject was instructed to rate how much she liked each juice by placing a vertical mark through the line, thus marking off a line length for each juice. A short line indicated that she liked the juice "not at all," and a long line indicating that she liked the juice "extremely." By measuring each juice's line length, the experimenter was then able to assign a ranking of preference for each juice for each subject. This method helped to prevent subjects from indicating the same ranking merely from memory of previous sessions.

The experimenter designated each subject's median rated juice as her more preferred juice and the next lowest ranked juice as her less preferred juice (with the constraint that the less preferred juice had to be rated below the more preferred juice on all sessions; otherwise a new less preferred juice was designated). Each subject's median rated juice, rather than a more highly rated juice, was used as her more preferred juice because pilot research conducted using the most highly rated juice as the more preferred juice had resulted in exclusive responding for that juice, so that a point of indifference, as required in order to obtain the value of s_A/s_D ,

Fig. 3. Diagram of the apparatus for Experiment 2. The letters W, G, and R represent the white, green, and red lights, respectively.

could never be reached. Next, a small sign was posted above each counter indicating for which juice the points on that counter would be exchangeable. Each subject was then escorted into the experimental room.

In order to simulate as much as possible the conditions to which nonhuman subjects are exposed, and because previous research has shown that (under certain conditions) with minimal instructions humans may show more sensitivity to the scheduled contingencies (Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981), subjects were asked to remove all timing devices and were given no instructions except to read the following instructions posted on the wall of the experimental room:

Please read carefully. Do not ask for additional information concerning what you are about to do. The task is to earn points. Each point is worth 0.024 ounces of juice. For example if you earn 100 points, you will earn 2¼ oz of juice. You may touch anything on this panel to earn points. The session will begin when one or more lights become lit, and it will end when all the lights are off. To minimize interference with the equipment, please leave all metal objects (watches, jewelry, etc.) with the experimenter for the duration of the session. All other personal property (coats, books, writing utensils, pocketbooks, etc.) should be left with the experimenter. These materials will be returned promptly at the session's end.

After subjects read this sign the light was turned off, the door was closed, and the experimenter left the room. There was no further contact between the subject and the experimenter until the end of the session.

Each session consisted of 20 trials scheduled using a discrete-trials adjusting procedure. These trials were divided into five blocks of four trials each. The first two trials of each block were forced-choice trials (only one response alternative, a left or a right rod push, was effective in producing a reinforcer). The forced-choice trials randomly consisted of either first a left forced-choice trial and then a right forced-choice trial, or vice versa. The remaining two trials of a block were free-choice trials (both response alternatives were effective). The forced-choice trials ensured exposure to the contingencies for both a left and a right rod push before the subject had to choose between those two response alternatives.

At the beginning of a free-choice trial (e.g., one with the adjusting delay programmed for the right alternative), the two disks were transilluminated green and red, and the white houselight was also lit. If the rod was then pushed to the left, both disks and the white houselight were darkened, the green light on top of the apparatus was lit, and a fixed, nonadjusting, 1-s delay began. This was followed by a programmed period during which the subject could earn points. After the point-access period was over, an ITI began with only the white houselight lit. As in Experiment 1, and consistent with other experiments using human adults and food as the reinforcers (i.e., Forzano & Logue, 1992; Logue & King, 1991), the ITI varied such that

the frequency of point-access periods was kept constant at 1 point-access period per 3 min. If, due to a long response latency or an unusually long adjusting delay, the trial extended over 3 min, the next trial began immediately. The next trial began with the illumination of the two disks. The sequence of events for a right rod push was the same, except that the red overhead light was lit and the delay period could adjust (see below). The sequence of events for forced-choice trials was the same, except that only one disk was illuminated and only a response in that direction was effective.

The fixed delay was kept constant at 1 s for each condition. The adjusting delay was constant within each block but could change after the two free-choice trials of a block, depending on a subject's responses on those free-choice trials. If the adjusting-delay alternative was chosen on both free-choice trials, the delay for this alternative was increased by 15 s for the next block of trials. Conversely, if the fixed-delay alternative was chosen on both free-choice trials, the adjusting delay was decreased by 15 s down to a minimum of 1 s. If each alternative was chosen once in a given block's two free-choice trials, no change was made in the adjusting delay for the subsequent block. For the first block of the first session of each condition, the value of the adjusting delay was preset (see Table 3). For the first block of all subsequent sessions of a condition, the value of the adjusting delay was determined by the subject's responses in the final block of the preceding session, as if that preceding session were simply continuing. This adjusting discrete-trials procedure was employed in order to establish each subject's indifference point, thus permitting the use of Equation 2 to calculate s_A/s_D for each subject.

Each subject was exposed to three conditions. The first condition was a baseline condition in which the points earned on both counters could be exchanged for more preferred juice at the end of the session (0.024 ounces of juice for each point earned). For the nonbaseline conditions (Conditions 2 and 3), the fixed delay preceded a relatively smaller amount of access time for earning points later exchangeable for more preferred juice, and the adjusting delay preceded a relatively larger amount of access time for earning points later exchangeable for less preferred

Table 3
Conditions for Experiment 2.

Condition	Reinforcement for left rod push			Reinforcement for right rod push		
	Delay	Amount	Food	Delay	Amount	Food
1	80A	6	more preferred	1	3	more preferred
2	80A	6	less preferred	1	3	more preferred
3	1	3	more preferred	80A	6	less preferred

Note. The reinforcer parameters (delay and amount periods) are listed in seconds. "A" indicates the initial value of the adjusting delay.

juice. For one of these experimental conditions the adjusting delay was programmed for the left alternative, and for the other condition the adjusting delay was programmed for the right alternative, thus controlling for position and color biases. In addition, to control for order effects, 3 subjects were exposed to Conditions 2 and 3 in the order indicated in Table 3 (Subjects 1, 2, and 4), and 3 subjects were exposed to those conditions in the opposite order (Subjects 3, 5, and 6).

All conditions lasted for a minimum of two sessions (10 blocks). A condition was terminated for a particular subject when, at the end of a session, at least one of the following stability criteria was met (for similar criteria see Forzano & Logue, 1994; Mazur, 1988): (a) The adjusting delay had to show a nonmonotonic trend during that condition with at least two blocks of equal adjusted delay after the first indication of nonmonotonicity, or (b) the adjusting delay had to remain at the same value for three blocks, or (c) the adjusting delay had to show a nonmonotonic trend during that condition with at least three blocks after the first indication of nonmonotonicity, the last three blocks of that condition had to have adjusted delays that were neither longer nor shorter than any previous adjusted delays for that subject in that condition, and the last three blocks of that condition had to have adjusted delays that did not monotonically increase or decrease.

Subjects were exposed to one session per day, approximately 5 days per week. Occasionally, in order for a subject to complete the experiment, it was necessary to expose that subject to two sessions in 1 day. In such cases there was always at least a 4-hr interval between the two sessions. This happened for only 10% of the sessions. On a few other oc-

casions, it was necessary for several days to elapse between two sessions. However, 71% of the sessions were conducted with no more than one intervening day.

At the end of each session, the amount of each of the two juices earned was calculated and given to each subject in two separate disposable cups. In addition, at the end of each session, each subject was paid \$1.25 (one quarter of the \$5.00 per session payment). At the end of the last session, each subject was paid a lump sum total of the remaining payments (\$3.75) for each session.

Results and Discussion

All subjects learned to operate the apparatus within the first few minutes of the first session, and their behavior in each condition stabilized quickly. Analyses were performed for each condition using the means of the stable free-choice trials data (the data defined as stable according to the stability criteria). Table 4 displays the data for each subject in Conditions 1, 2, and 3.

Although not all subjects' adjusted delays were similar for Conditions 2 and 3, for all subjects there were no statistically significant differences in the data obtained from these conditions, thus indicating no statistically significant color or position biases. Therefore the data from these conditions were combined. In addition, there were no significant differences as a function of the order of the conditions to which the subjects were exposed. Therefore the data were collapsed across order. Further, as indicated with dependent *t* tests, there were no significant differences between Condition 1 and Conditions 2 and 3 in terms of mean number of stable trials and mean number of sessions, $t(5) = 0.48, p > .05$; $t(5) = -1.95, p > .05$;

Table 4
Results for Conditions 1, 2, and 3 for each subject in Experiment 2.

Condition	Subject	Number of stable trials	Number of sessions	Mean adjusted delay (s)	s_A/s_D
1	1	4	4	237.5	7.9
	2	4	5	158.5	7.3
	3	4	5	158.5	7.3
	4	16	2	66.7	6.1
	5	8	2	95.0	6.6
	6	8	3	143.0	7.1
	$M (SE)$	7.3 (1.9)	3.5 (0.6)	143.2 (24.2)	7.1 (0.3)
2	1	8	2	155.0	7.3
	2	6	2	1.0	0.0
	3	4	2	162.5	7.3
	4	16	2	55.0	5.8
	5	4	2	1.0	0.0
	6	4	2	1.0	0.0
	$M (SE)$	7.0 (1.9)	2.0 (0.0)	62.6 (31.6)	3.4 (1.5)
3	1	6	2	5.0	2.3
	2	4	3	3.0	1.6
	3	4	3	230.0	7.8
	4	8	2	95.0	6.6
	5	4	3	1.0	0.0
	6	6	2	6.0	2.6
	$M (SE)$	5.3 (0.7)	2.5 (0.2)	56.7 (37.7)	3.5 (1.2)

$t(5) = 0.98, p > .05$; $t(5) = 2.37, p > .05$, respectively.

The critical variable in this experiment was obtained by using the mean adjusted delays to calculate each subject's value of sensitivity to variation in reinforcer amount divided by sensitivity to variation in reinforcer delay (s_A/s_D ; see Table 4 and Equation 2). (In the present experiment, the reinforcers consisted of periods of access time for earning points that could later be exchanged for juice.) There were two such calculations for each subject—one measure of self-control for when both responses resulted in receipt of the subject's more preferred juice (Condition 1), and one for when impulsive responses resulted in receipt of the subject's more preferred juice and self-control responses resulted in receipt of the subject's less preferred juice (Conditions 2 and 3).

Figure 4 shows the values of s_A/s_D for both Condition 1 and the mean values of s_A/s_D over Conditions 2 and 3 separately for each subject. Although there is variation in the results for individual subjects, some general conclusions can be drawn. This figure demonstrates that 4 of the 6 subjects were more sensitive to reinforcer amount relative to reinforcer delay in Condition 1 than in the

combined Conditions 2 and 3. The behavior of Subjects 3 and 4 appears not to change across these conditions. This figure also shows the mean values over all subjects. As indicated in Figure 4 and confirmed with a dependent t test, on average subjects demonstrated significantly more sensitivity to amount relative to sensitivity to delay in Condition 1 than in the combined Conditions 2 and 3, $t(5) = 2.75, p < .05$. Further, in Condition 1, s_A/s_D was significantly greater than 1.0, $t(5) = 23.1, p < .05$; in other words, the subjects' behavior was more controlled by reinforcer amount than by reinforcer delay, consistent with self-control. However, in the combined Conditions 2 and 3, s_A/s_D was not significantly different from 1.0, $t(5) = 1.89, p > .05$; in other words, subjects were approximately equally sensitive to variation in amount and delay of reinforcement. Note that, in performing the calculations for s_A/s_D , k (response bias) was assumed to be equal to 1.0, a value consistent with results from similar previous research (Logue et al., 1986, 1990). An alternative might have been to estimate k based on the results from Condition 1, the condition in which the more preferred juice was available for both responses. However, preference during the baseline condi-

Fig. 4. Values of s_A/s_D for Experiment 2 when both choices resulted in receipt of the subject's more preferred food (Condition 1) and when only choices of the less delayed, smaller reinforcer resulted in receipt of the subject's more preferred food (mean s_A/s_D over Conditions 2 and 3). Individual-subject data, as well as means over all subjects, are shown. The dashed line represents indifference.

tion represented the effects on responding of s_A and s_D , as well as of k , with no way to separate these effects.

GENERAL DISCUSSION

Although there were some individual differences, in general, the results from both experiments indicate that humans' food preferences can influence self-control for food reinforcers. First, for all subjects in Experiment 1, the proportion of responses for more delayed, larger reinforcers (a measure of self-control) was significantly greater when those responses resulted in receipt of the most preferred food compared to when those choices produced the least preferred food. Second, for all subjects in Experiment 1, the subjects

chose the less delayed, smaller reinforcers significantly more often when only those choices, as opposed to both choices (Bonvino et al., 1991), resulted in receipt of the preferred food. Conversely, subjects chose the more delayed, larger reinforcers significantly more often when only those choices, as opposed to both choices (Bonvino et al., 1991), produced the preferred food. Third, in Experiment 2 the subjects demonstrated significantly less sensitivity to reinforcer amount relative to sensitivity to reinforcer delay (a measure of self-control) when they had a higher preference for the juice received as the less delayed, smaller reinforcer than for the juice received as the more delayed, larger reinforcer. Together, these results add to the literature demonstrating that choice between

reinforcers is affected by reinforcer quality as well as by reinforcer frequency, amount, and delay (e.g., Forzano & Logue, 1994; King & Logue, 1990a; Logue et al., 1986, 1990; Logue, Forzano, & Tobin, 1992).

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