Self-control in the monkey *Macaca fascicularis*

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Two experiments tested two cynomolgus monkeys' self-control—choice of a longer, more delayed reinforcer over a shorter, less delayed reinforcer. In Experiment 1, subjects exhibited significant self-control in a procedure in which reinforcer amounts and delays were held constant throughout a condition. In Experiment 2, subjects exhibited significantly greater sensitivity to variation in reinforcer amount than to variation in reinforcer delay in a procedure in which the reinforcer delay associated with the self-control alternative was adjusted until each macaque was indifferent between the two alternatives. Both experiments indicated that, in laboratory paradigms in which humans show self-control and pigeons and rats show impulsiveness, macaques show self-control. These results are inconsistent with the hypothesis that species differences in self-control are a function of language ability or of specific types of prior training. The results are consistent with the hypothesis that species differences in self-control are related to the ratio of brain size to body weight (a possible indicator of general cognitive ability) or to shared phylogeny.

During the past two decades, some operant researchers investigating choice behavior have used a laboratory procedure termed the self-control paradigm. In this procedure, self-control is operationally defined as the choice of a larger, more delayed reinforcer, and impulsiveness is defined as the opposite (Ainslie, 1974, 1975; Rachlin & Green, 1972). When a subject shows self-control, that subject's choices are controlled more by the relative sizes of reinforcers (i.e., that subject tends to choose the larger reinforcers) than by the relative delays of reinforcers (i.e., that subject tends not to choose the more delayed reinforcer).

Typically, humans and pigeons have been employed as subjects in self-control experiments. Pigeons that have not received special training (e.g., a fading procedure; see Logue & Mazur, 1981; Mazur & Logue, 1978) have tended to show impulsiveness, and humans have tended to show self-control (Logue, 1988). Rats, recently tested under conditions similar to those previously used with humans and pigeons, have shown impulsiveness (Tobin, Chelonis, & Logue, 1993). Self-control investigations using each of these three species

have included both determining the proportion of self-control choices and using an adjusting delay and Baum's (1974) generalized matching law to scale the subjects' sensitivity to variation in reinforcer amount and delay.

Why humans have tended to show self-control but pigeons and rats have tended to show impulsiveness has not been determined. One explanation may be that humans can verbally cue themselves when attempting to control their behavior (Lowe, 1979; Lowe, Beasty, & Bentall, 1983). A second explanation may be that humans have had substantial previous experience with reinforcer delay, as have pigeons trained using a fading procedure. A third explanation may be the high encephalization quotient (E.Q.) of humans. E.Q. scales the relationship between brain size and body weight. In a regression of modern mammalian species' brain size on their body weight, human brain size is greater than would be predicted (i.e., humans have a higher than expected E.Q.), and rat brain size is lower than would be predicted (i.e., rats have a lower than expected E.Q.; Count, 1947; Crile & Quirling, 1940; Jerison, 1961). The E.Q. of humans is thought to be a possible indicator of their relatively greater general cognitive ability (Jerison, 1969, 1970, 1991; Martin, 1983; see Schmidt-Nielsen, 1984, for an introduction to scaling and animal size).

Lastly, the greater self-control shown by humans in the laboratory may be caused by phylogenetic constraints that are specifically relevant to human evolution but not to the evolution of rats or pigeons (Hodos & Campbell, 1969). For example, it has been suggested that a greater tendency toward self-control may be more adaptive for organism A when it lives in an environment that is relatively more stable than that in which organism B lives (Logue, 1988); there is little point in waiting for a delayed reinforcer in an unstable environment in which it is likely that the delayed

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reinforcer will never be received. Tens of millions of years of evolution have elapsed since the time of the common ancestor of humans and rats. Perhaps some later ancestors of humans evolved in niches where food sources were relatively more stable, or perhaps later ancestors of rats evolved in niches where food sources were relatively less stable than those of the common ancestor.

Thus, humans differ from pigeons and rats on several characteristics that could explain the relatively greater self-control shown by humans in the laboratory. On some of these characteristics, *Macaca fascicularis* (the cynomolgus monkey) is more similar to humans than to rats and pigeons, and on some of these characteristics it is more similar to rats and pigeons. Specifically, cynomolgus monkeys, like pigeons and rats, cannot use verbal self-cuing. However, cynomolgus monkeys, like humans, have brains that are larger than what would be predicted by their body weight (although not to the same degree as humans). In addition, cynomolgus monkeys are phylogenetically more closely related to humans than to pigeons and rats, and are therefore more likely to share phylogenetic constraints with humans. For example, a common ancestor may have evolved in, and its relevant descendant species remained adapted to, niches with relatively more stable food sources. Wheatley (1980) has described the existence of constant, year-round climate and fruiting of food trees for the free-ranging cynomolgus monkeys that he studied. During some periods of human evolution, as well as in some parts of the world today, humans' food sources have been relatively abundant and constant (Logue, 1995). Therefore, in the absence of intervening historical contingencies (Lewontin, 1987; such as a postcommon ancestor of either *Macaca fascicularis* or *Homo sapiens* adapting to a less stable, more patchy environment), both descendant species may have retained a tendency toward relatively greater self-control. (For detailed explanations regarding phylogenetic constraints—that is, why phylogenetically related species tend to be [behaviorally] similar—see Harvey & Pagel, 1991). Finally, given the available evidence, it is impossible to say whether or not cynomolgus monkeys' lifetime experience with reinforcer delay is more similar to that of humans or that of rats and pigeons.

Although testing only one additional species cannot adequately address each of the possible explanations as to why humans have shown self-control and pigeons and rats have shown impulsiveness, the use of cynomolgus monkeys as subjects can help in attempts to assess the relative strength of the various explanations of species differences in self-control. If cynomolgus monkeys were to tend to show impulsiveness when tested under conditions similar to those under which rats, pigeons, and humans have been tested, this would be consistent with explanations stating that self-control requires verbal self-cuing and/or specific prior training with reinforcer delay. If cynomolgus monkeys were to tend to show self-control under these conditions, such findings would demonstrate that neither verbal self-cuing nor specific training with reinforcer delay (such as a fading procedure) is necessary for a nonhuman to demonstrate self-control. However, such findings would be

consistent with explanations stating that self-control is dependent on (1) brain size being larger than what would be predicted by body weight and/or (2) mutual human-macaque phylogenetic constraints. The present research had three goals: (1) to apply the same operant self-control procedures to cynomolgus monkeys that have previously been applied to pigeons, rats, and humans; (2) to obtain measures of self-control with two distinctly different testing procedures (one measuring proportion of self-control choices, and the other measuring relative sensitivity of behavior to variation in reinforcer amount and delay); and (3) to determine whether the measures of self-control obtained with these two procedures are consistent with each other.

EXPERIMENT 1

The measure of self-control obtained in Experiment 1 was the proportion of self-control choices out of total choices made in a discrete-trials procedure. In this procedure the inter-trial interval (ITI) was varied so that 1 min elapsed between the start of trial n and trial $n + 1$. This procedure controlled overall reinforcer frequency while measuring preference (each subject experienced the same number of trials in an equal amount of time, regardless of its choices). In this way, a subject's preference did not affect overall reinforcement frequency. This procedure has been employed in previous experiments on self-control with pigeons, adult humans, preschool children, and rats (e.g., Logue & Chavarro, 1992; Logue, Peña-Correal, Rodriguez, & Kabela, 1986; Logue, Rodriguez, Peña-Correal, & Mauro, 1984; Mazur & Logue, 1978; Tobin, Chelonis, & Logue, 1993).

Method

Subjects. Two experimentally naive macaques, *Macaca fascicularis* (previously known as *M. cynomolgus* or *M. irus* and commonly known as the cynomolgus monkey or long-tailed macaque), 1 male and 1 female, both born in the wild, served as subjects. The subjects were approximately 5–7 years old at the start of the experiment and had been living in their home cages approximately 3.5 years before the experiment began. They were given free access to water and monkey chow with the following exceptions: All food was removed and their home cages hosed clean approximately 6 h before each experimental session, water was removed approximately 30 min before each experimental session, and food and water were replenished approximately 30 min following each experimental session. The male and female maintained average weights of 8.7 kg and 4.3 kg, respectively, throughout the experiment.

Apparatus. Each subject was housed in a stainless steel cage that also served as the experimental chamber. Each cage measured approximately 125 cm wide, 78 cm high, and 60 cm deep. The cage could be divided into two equal sections (62 × 78 × 60 cm) by the placement of a removable sheet of stainless steel. The back and sides of the cage were formed from sheets of stainless steel; the front, top, and bottom were formed by stainless steel bars. The testing area consisted of a portion of a room partitioned by a light-proof curtain into a space 1.9 m wide, 2.8 m high, and 2.0 m deep.

During each session, a removable stimulus panel (Figure 1) was securely attached to the outside of the front of one of the cage compartments. This panel consisted of a pane of clear Plexiglas, 49.5 cm wide, 34.3 cm deep, and 1.2 cm thick, painted matte black on the side facing the subject (the front of the panel). There was a 3-cm gap between the front of the panel and the bars of the cage, and the bottom of the panel was 22 cm above the bottom of the cage. A sta-

Figure 1. The stimulus panel and houselights used in the current experiment; G, W, and R represent green, white, and red, respectively.

tionary aluminum tube, 0.5 cm in diameter, projected 5.4 cm from the front of the panel. This tube was centered left to right and was located 18.5 cm from the bottom of the panel. The tube served as a straw through which the reinforcer (cherry-flavored, sugar-sweetened Kool-Aid mixed with water by volume at 1:6.7) was presented to the subject. An aluminum rod, 0.8 cm in diameter, served as the manipulandum. This rod projected from the panel to a distance of 8 cm past the bars of the cage compartment, and was located 20.5 cm below the straw and 1.8 cm to the left of it. Pushing the rod with a force of approximately 5 N to either side activated a microswitch.

At two locations on the panel, 10.3 cm to either side of the rod, was a 3.8-cm diameter circular area that had no black paint. Each of these two circular areas (the stimulus lights) could be illuminated from behind by a Sylvania 327 1.12-W bulb enclosed by a 1.3-cm hemispherical colored translucent plastic cover (green to the left of the rod and red to the right of the rod). A similar circular area, 1.5 cm in diameter and illuminated by a white, plastic-covered Sylvania 327 1.12-W bulb, served to signal the accessibility of the reinforcer. This light was located 5.5 cm above the straw. A peristaltic pump controlled by a stepper motor delivered the reinforcer through the straw at a rate of 1 ml/3.2 sec. Three Westinghouse dbd511 7.5-W bulbs (white, green, and red) served as houselights and were suspended approximately 30 cm above the top of the cage during experimental sessions.

A PC-compatible microcomputer controlled the stimuli and recorded the responses using a program written in QuickBASIC.

Procedure. Each cage was wheeled from the subjects' home room to the testing room and back for each session. During each session, the subject was confined to one side of the cage compartment, and the only illumination present was produced by the stimulus and houselights.

The cynomolgus monkeys were first shaped to push the rod according to the method of successive approximations. The actual experiment used a discrete-trials procedure in which each session consisted of 34 trials, of which 28 were free-choice trials and 6 were forced-choice trials. Figure 2 diagrams the procedure followed for each free-choice trial. At the start of each free-choice trial, the white houselight and both stimulus lights were lit. If a left rod push successfully activated the left microswitch (an effective push), the white houselight and both stimulus lights were extinguished and the green houselight was lit. When the delay period (D_1) associated with a left lever choice had timed out, the reinforcer access signal light was lit and the pump delivered reinforcement for the duration of the left reinforcer access period (A_1), regardless of whether or not the subject's mouth was over the straw (although observations indicated that it almost always was). When the access period ended, the pump stopped, the green houselight and the reinforcer access signal light were extinguished, and the white houselight was lit for the ITI. The next free-

choice trial began with the reillumination of both stimulus lights. If an effective right push was made instead of a left push, an analogous sequence of events was followed except that the red houselight was used instead of the green houselight for the right reinforcer delay and access periods (D_2 and A_2).

Frequency of reinforcement was controlled by adjusting the ITIs so that a total of 1 min elapsed from the beginning of one trial to the beginning of the next trial. If on any one trial a subject's response latency was so long that the trial could not be completed within 1 min, the next trial would begin immediately following the end of the reinforcer access period.

During a forced-choice trial only one stimulus light was lit, and only an effective push toward that light was operative. There were three forced-choice trials in which only a left push was effective, and three forced-choice trials in which only a right push was effective. A forced-choice trial occurred every fifth trial throughout the session (alternating left and right) to ensure that the subjects were exposed to the contingencies for both choice alternatives during each session.

Both subjects first received a training condition in which all of the reinforcer delay and access periods were of the same duration. Following the training condition, both subjects received a second condition in which a larger, more delayed reinforcer (self-control choice) followed effective left pushes, and a smaller, less delayed reinforcer (impulsive choice) followed effective right pushes. In order to control for position and color biases, the last (third) condition reversed the second condition's contingencies for left and right rod pushes (see Table 1 for the durations of the reinforcer delay and access periods in each condition).

A subject remained in a condition until its behavior met three specific stability criteria: (1) The condition had to have been in effect for at least 10 sessions, (2) none of the proportions of self-control choices made by the subject in the last five consecutive sessions could have been a maximum or a minimum for that subject in that condition, and (3) the number of self-control choices made during the last 5 days of a condition could not have monotonically increased

Figure 2. Diagram of the general procedure for one free-choice trial. The small square at the top of each rectangle represents the houselights. The circles represent the stimulus lights. Access to reinforcement is represented by the small rectangles. G, W, and R represent green, white, and red, respectively.

Table 1
Durations of the Reinforcer Access and Delay Periods
(in Seconds) for Each Condition and the Number of Sessions
Each Subject Was Exposed to Each Condition in Experiment 1

Condition	Reinforcer				No. of Sessions	
	Amount		Delay			
	Left	Right	Left	Right	Female	Male
1	6.0	6.0	6.0	6.0	11	16
2	6.0	2.0	6.0	0.1	12	16
3	2.0	6.0	0.1	6.0	10	11

or decreased for more than four consecutive sessions. Table 1 shows the number of sessions to which each subject was exposed for each condition. Sessions were conducted 6 or 7 days per week.

Results and Discussion

All analyses were performed using the mean data from the last 5 (stable) days of the two conditions that tested for self-control (see Table 2). Statistical significance was set at $p \leq .05$.

There was no significant difference between the proportions of self-control choices obtained in the two conditions that tested for self-control [$t(1) = 1.5$; see Figure 3]. In other words, the subjects did not show an overall position/color bias. Therefore the data from these two conditions were combined in order to obtain each subject's mean proportion of self-control choices. The mean proportion of self-control choices produced by the male was .975, and by the female it was .985, producing an overall mean proportion of self-control choices of .980 ($SE = 0.005$). Even with only 2 subjects, the overall mean self-control proportion for the cynomolgus monkeys is significantly different from indifference [i.e., from .5; $t(1) = 67.6$]. The overall mean self-control proportion is not significantly different from complete self-control [i.e., from 1.0; $t(1) = 2.9$]. All of these results are consistent with the conclusion that, given the conditions in the present experiment, the cynomolgus monkeys showed self-control.

Across all free-choice trials of the stable sessions of Conditions 2 and 3 (the two conditions that tested for self-control), and across both subjects, the mean latency to respond was 7.0 sec ($SE = 1.0$; median of 2 sec; $N = 560$). There was no significant difference between the mean self-control and impulsive response latencies [$M(SE)$ for self-control responses = 6.8(4.4); $M(SE)$ for impulsive responses = 11.6(0.5), $t(1) = 1.0$; see Table 2]. Both subjects made few ineffective responses during the reinforcer delay periods and the ITIs. Specifically, across all trials of the stable sessions of Conditions 2 and 3 (the two conditions that tested for self-control), and across both subjects, the mean number of ineffective responses per trial during the reinforcer delay period was 0.3 ($SE = 0.1$), and the mean number of ineffective responses per trial during the ITI was 1.7 ($SE = 1.2$; see Table 2). These analyses of the mean latency to respond and ineffective response data show that the subjects responded fairly quickly and rarely responded when their responses would not result in reinforcement. In other words, their responses seemed to be under the control of the procedural contingencies.

EXPERIMENT 2

An overall measure of self-control was obtained in Experiment 1. In Experiment 2, the relative contributions of reinforcer delay and reinforcer amount to the subject's choice behavior were determined by using a modified discrete-trials procedure and the generalized matching law. This approach has been used with adult humans and with rats (Forzano & Logue, 1994; Tobin et al., 1993). In this modified discrete-trials procedure, the subject chooses between a smaller, immediate reinforcer and a larger reinforcer the delay of which is adjusted. The delay associated with the larger reinforcer is adjusted until the subject chooses that reinforcer amount and delay combination as frequently as it chooses the smaller, immediate reinforcer—that is, until the subject is indifferent between the two alternatives (Mazur, 1987).

Table 2
Mean Proportions of Self-Control Choices, Mean Free-Choice Response Latencies,
and Mean Ineffective Responses in Each Condition of Experiment 1

Condition	Subject	Free-Choice Response Latencies									Ineffective Responses per Trial			
		Self-Control		Response Latencies							During Delays		During ITIs	
				Self-Control	Impulsiveness									
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>n</i>	<i>M</i>	<i>SE</i>	<i>n</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
2	Female	.99	.01	11.7	2.6	5	2.0	0.0	1	0.01	0.01	0.0	0.0	
	Male	.98	.01	3.7	1.5	5	6.3	6.3	2	0.01	0.01	1.2	0.2	
	<i>M</i>	.99	.005	7.7	4.0	2	4.1	2.1	2	0.01	0.0	0.6	0.6	
3	Female	.98	.01	10.8	2.4	5	20.3	9.1	3	0.6	0.03	1.0	0.2	
	Male	.97	.01	1.2	0.2	5	18.0	17.3	4	0.3	0.04	4.3	0.6	
	<i>M</i>	.98	.005	6.0	4.8	2	19.7	1.2	2	0.5	0.2	2.7	1.7	
<i>M</i>	Female	.99	.005	11.2	0.4	2	11.2	9.2	2	0.3	0.3	0.5	0.5	
	Male	.98	.005	2.5	1.3	2	12.1	5.9	2	0.2	0.1	2.8	1.6	
	<i>M</i>	.98	.005	6.8	4.4	2	11.6	0.5	2	0.3	0.1	1.7	1.2	

Note—ITI, intertrial interval. The *ns* for the individual subjects' mean latencies for impulsive responses in the two separate conditions are not equal to 5 (representing the 5 stable days of each condition) because each monkey made no impulsive responses on some of these days.

Figure 3. Mean proportions of self-control choices in Experiment 1. (The horizontal dashed line indicates indifference. Data are shown separately for each subject and for each condition. Condition and subject means are also shown. The standard errors of the means are too small to be seen.)

Use of this modified discrete-trials procedure permits quantification of the subject's relative sensitivity to variation in reinforcer amount and delay in the following way. In the generalized matching law (Baum, 1974; Logue et al., 1984),

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

B_1 and B_2 represent the number of choices of Alternatives 1 and 2, respectively; A_1 , A_2 , D_1 , and D_2 represent the values of the amounts and delays associated with the two alternatives; the constant k represents response bias (for Alternative 1 if $k > 1.0$, and for Alternative 2 if $k < 1.0$); and the exponents s_A and s_D represent sensitivity to changes in the relative values of reinforcer amount and delay, respectively. At indifference, $B_1 = B_2$, and therefore $B_1/B_2 = 1.0$. If we assume that there is no overall response bias (i.e., $k = 1.0$, a reasonable assumption given the results from Experiment 1), the base-ten logarithm of Equation 1 can be transformed into:

$$s_A/s_D = (\log D_1/\log D_2)/(\log A_1/\log A_2). \quad (2)$$

Substituting the data obtained from the adjusting procedure described above, Equation 2 can be used to obtain s_A/s_D , which measures the relative contributions of reinforcer amount and delay to a subject's preference between the two alternatives in a self-control paradigm. A value of s_A/s_D equal to 1.0 indicates equal control over behavior by reinforcer amount and delay. A value of $s_A/s_D > 1.0$ indicates greater control over behavior by reinforcer amount, and a value of $s_A/s_D < 1.0$ indicates greater control over behavior by reinforcer delay. Relatively greater values of s_A/s_D are thus associated with more self-control and vice versa. Note that the generalized matching law is being used here simply as a scaling method, independently of its validity as a general model of choice (Alsop & Elliffe, 1988; Logue, Forzano, & Tobin, 1992; McCarthy, 1991).

Method

Subjects and Apparatus. The same subjects and apparatus were used as in Experiment 1, except that the experiment was conducted in a room 5.8 m wide, 2.7 m high, and 2.4 m deep.

Procedure. Although the within-trial sequence of events remained the same as in Experiment 1, the sequence of trials within a session was changed and the delay associated with the larger reinforcer was systematically adjusted in accordance with the subject's previous choices. More specifically, each session comprised 40 trials arranged in 10 blocks of 4 trials each. Each block began with a forced-choice trial (randomly selected left or right). This was followed by a second forced-choice trial of the opposite alternative. This pair of forced-choice trials was followed by a pair of free-choice trials. Both subjects first received a training condition in which the access periods of both the left and the right alternatives were all of the same duration (see Table 3). In Session 1 of this condition, the initial value for both reinforcer delays was 6 sec. The delay associated with the right alternative was then adjusted as follows. If both free choices in a block were for the right alternative, the delay to the right alternative in the next block was increased by 0.5 sec. If both free choices in a block were for the left alternative, the delay to the right alternative in the next block was decreased by 0.5 sec. If one of each type of free choice was made during a block, no change was made in the delay to the right alternative in the next block.

Conditions 2 and 3 were the experimental conditions. In Condition 2, a right rod push was associated with the reinforcer delay that could adjust and with the larger reinforcer amount, and a left rod push was associated with the short, fixed reinforcer delay and the smaller reinforcer amount. These contingencies were reversed for Condition 3 (see Table 3). The reinforcer delay to the larger reinforcer amount was adjusted by the same method as that described for Condition 1.

Except for the first session of Condition 1, the initial value of the adjusting delay for each session, within conditions and across conditions, was determined by the subject's choices in the last block of the previous session. In order to keep each trial to a 60-sec duration, while allowing 6 sec for the reinforcer amount associated with the adjusting delay and allowing time for the subject to respond, the adjusting delay was limited to a maximum duration of 46 sec.

Stability criteria used to terminate a condition were the same as those used in Experiment 1, except that stability was assessed by using a subject's mean adjusted delay for each session. As in Experiment 1, sessions were conducted 5 or 6 days per week.

Results and Discussion

As in Experiment 1, all analyses were performed using the mean data from the last 5 (stable) days of Conditions 2 and 3 (the two conditions that tested for self-control), and statistical significance was set at $p \leq .05$.

Table 4 shows, for each subject, the mean adjusted delays as well as the mean values of s_A/s_D (calculated using Equation 2). As in Experiment 1, there were no significant

Table 3
Durations of the Reinforcer Access and Delay Periods
(in Seconds) for Each Condition and the Number of Sessions
Each Subject Was Exposed to Each Condition in Experiment 2

Condition	Reinforcer				No. of Sessions	
	Amount		Delay			
	Left	Right	Left	Right	Female	Male
1	6.0	6.0	6.0	A	26	21
2	2.0	6.0	0.1	A	19	15
3	6.0	2.0	A	0.1	10	21

Note—A, adjusted delay (set at 6 sec for the first block of Condition 1).

differences between the values of the mean adjusted delays for Conditions 2 and 3, indicating no overall position or color bias (see Figure 4). Therefore, the data were combined across these two conditions. The mean s_A/s_D for the female was 5.6 ($SE = 0.0$), and the mean s_A/s_D for the male was 5.2 ($SE = 0.3$), producing an overall mean s_A/s_D of 5.4 ($SE = 0.2$). Again, even with only 2 subjects, this value is significantly different from equal sensitivity to changes in reinforcer amount and delay. That is, this mean is significantly different from 1.0 [$t(1) = 15.6$], indicating that the subjects were more sensitive to changes in reinforcer amount than to changes in reinforcer delay. The overall mean s_A/s_D of 5.4 is not significantly different from the value that s_A/s_D would have had if each subject had exclusively chosen the adjusted delay alternative. That is, the overall mean value of s_A/s_D is not significantly different from 5.6 [$t(1) = 0.7$], indicating that the obtained value of s_A/s_D may have been limited by a ceiling effect imposed by the 46-sec upper value of the adjusting alternative.

Across all free-choice trials of the stable sessions of Conditions 2 and 3 (the two conditions that tested for the value of s_A/s_D), and across both subjects, the mean response latency was 10.3 sec ($SE = 1.6$; median of 6 sec; $N = 400$). There was no significant difference between the mean adjusting-delay and fixed-delay free-choice response latencies [$M(SE)$ for adjusting-delay responses = 10.8(3.5), $M(SE)$ for fixed-delay responses = 6.5(0.2), $t(1) = 1.2$; see Table 4]. Both subjects made few ineffective responses during the reinforcer delay periods and the ITIs. Specifically, across all trials of the stable sessions of Conditions 2 and 3 (the two conditions that tested for self-control), and across both subjects, the mean number of ineffective responses per trial during the reinforcer delay period was 0.4 ($SE = 0.2$), and the mean number of ineffective responses per trial during the ITI was 0.1 ($SE = 0.04$; see Table 4). As in Experiment 1, the mean latency to respond and ineffective response data indicated that the subjects responded fairly quickly and rarely responded when their responses would not result in reinforcement. In other words, in both

experiments, the subjects' responses seemed to be under the control of the procedural contingencies.

GENERAL DISCUSSION

Although there were only 2 subjects, both cynomolgus monkeys demonstrated a high degree of self-control in both experiments. In fact, in both experiments the subjects' number of self-control choices was not significantly different from the maximum number possible. The choice behavior demonstrated by these macaques is different from that obtained in comparable situations with rats or pigeons, which have consistently shown impulsiveness. The choice behavior of these macaques is more similar to that obtained with humans, many of whom tend to show self-control for food reinforcement (Forzano & Logue, 1994).

The present results are useful in evaluating explanations of the fact that rats and pigeons tend to show less self-control than do humans when these species are tested using similar laboratory paradigms. First, the present results contradict explanations that verbal self-cuing is necessary for self-control. Macaques do not have spoken language abilities, but the 2 subjects in these experiments showed self-control. Second, these results suggest that special training, such as a fading procedure, is not necessary for all non-human species to show self-control. However, the degree, if any, of prior informal experience with delay necessary for self-control is not addressed by the current experiments.

Third, the present results are consistent with explanations stating that a species' greater self-control (and, possibly, its greater general cognitive ability) may be related to that species' brain size being greater than what would be predicted by its body weight (the E.Q. ratio). Both humans and macaques tend to have greater than predicted brain sizes, and both species have tended to demonstrate self-control. Fourth, although inferences about traits inherited from a common ancestor cannot be drawn from only two species, the present results are consistent with hypotheses stating that a tendency toward self-control or impul-

Table 4
Mean Adjusted Delay (in Seconds), s_A/s_D , Mean Free-Choice Response Latencies,
and Mean Ineffective Responses in Each Condition of Experiment 2

Condition	Subject	Adjusted Delay		s_A/s_D		Free-Choice Response Latencies						Ineffective Responses per Trial			
						Adjusted		Fixed				During Delays		During ITIs	
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>n</i>	<i>M</i>	<i>SE</i>	<i>n</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
2	Female	46.0	0.0	5.6	0.0	18.4	8.2	5	6.8	0.2	2	0.1	0.02	0.02	0.01
	Male	22.6	1.0	4.9	0.04	5.9	1.9	5	8.1	1.8	5	0.1	0.01	0.2	0.04
	<i>M</i>	34.3	11.7	5.3	0.4	12.1	6.3	2	7.5	0.6	2	0.1	0.1	0.1	0.1
3	Female	46.0	0.02	5.6	0.0	10.2	1.2	5	5.9	1.1	3	0.2	0.05	0.01	0.01
	Male	40.5	0.5	5.5	0.01	8.7	0.8	5	5.3	0.5	5	0.9	0.02	0.01	0.01
	<i>M</i>	43.3	2.8	5.6	0.1	9.5	0.3	2	5.6	0.3	2	0.6	0.4	0.01	0.0
<i>M</i>	Female	46.0	0.0	5.6	0.0	14.3	4.1	2	6.4	0.5	2	0.2	0.1	0.02	0.01
	Male	31.6	9.0	5.2	0.3	7.3	1.4	2	6.7	1.4	2	0.5	0.4	0.1	0.1
	<i>M</i>	38.8	7.2	5.4	0.2	10.8	3.5	2	6.5	0.2	2	0.4	0.2	0.1	0.04

Note—ITI, intertrial interval. The *ns* for the female subject's mean latencies for fixed-delay responses in the two separate conditions are not equal to 5 (representing the 5 stable days of each condition) because the female monkey made no impulsive responses on some of these days.

Figure 4. Means and standard errors for s_A/s_D in Experiment 2. (The horizontal dashed line indicates equal sensitivity to changes in reinforcer amount and delay, i.e., $s_A/s_D = 1.0$. Data are shown separately for each subject and for each condition. Condition and subject means are also shown. The standard errors of the means are too small to be seen.)

siveness may be subject to phylogenetic constraints and result from homologous behavioral mechanisms. Humans and macaques share more of their evolutionary history than do humans and rats or pigeons. An evolutionarily parsimonious prediction following from this explanation would be that the other descendants of the *Macaca fascicularis/Homo sapiens* common ancestor, such as other Old World monkeys and apes, would also tend to show self-control.

The current experiments have applied the same operant self-control procedures to cynomolgus monkeys that have been previously applied to pigeons, humans, and rats. Two different procedures, both controlling reinforcer frequency, provided two mutually consistent measures of choice behavior. Together, the results suggest that, like humans, but unlike rats or pigeons, macaques tend to show self-control.

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