JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1978, 30, 11-17 NUMBER 1 (JULY)

CHOICE IN A "SELF-CONTROL" PARADIGM: EFFECTS OF A FADING PROCEDURE

JAMES E. MAZUR[1] AND A. W. LOGUE

HARVARD UNIVERSITY

Pigeons chose between an immediate 2-second reinforcer (access to grain) and a 6-second reinforcer delayed 6 seconds. The four pigeons in the control group were exposed to this condition initially. The four experimental subjects first received a condition where both reinforcers were delayed 6 seconds. The small reinforcer delay was then gradually reduced to zero over more than 11,000 trials. Control subjects almost never chose the large delayed reinforcer. Experimental subjects chose the large delayed reinforcer significantly more often. Two experimental subjects showed preference for the large reinforcer even when the consequences for pecking the two keys were switched. The results indicate that fading procedures can lead to increased "self-control" in pigeons in a choice between a large delayed reinforcer and a small immediate reinforcer.

Key words: delay of reinforcement, amount of reinforcement, self-control, fading, key pecking, pigeons

---

Two factors known to affect an organism's behavior are the amount or duration of reinforcement (Keller and Gollub, 1977; Neuringer, 1967) and the delay between a response and reinforcement (Ainslie, 1975; Chung, 1965). Baum and Rachlin (1969) attempted to integrate the results of studies on amount and delay of reinforcement. They suggested that the *value* of a reinforcer, or its ability to sustain instrumental responding, is proportional to the amount of reinforcement and inversely proportional to the delay of reinforcement:

$$V_i = c_i \cdot a_i \cdot (1/d_i), \qquad (1)$$

where V_i is the value of reinforcer i, a_i is the amount (*e.g.*, the size of a food pellet or the duration of access to grain), and d_i is the delay between response and reinforcer. The constant c_i subsumes all other factors that determine a reinforcer's value, such as the rate of reinforcement and the subject's motivational level. In a simple binary choice situation where these other factors are equal for both alternatives, Equation 1 predicts that a subject will choose alternative 1 whenever $a_1/d_1 > a_2/d_2$ and alternative 2 whenever $a_1/d_1 < a_2/d_2$.

Experiments by Chung (1965) and Chung and Herrnstein (1967) found support for the inverse relationship between delay and reinforcer value described in Equation 1. This equation provides at least a good first approximation to the results of these two studies as well as those on amount or duration of reinforcement (see de Villiers, 1977, for a review).

Despite these results, there is evidence that any formulation that specifies a single, unchanging relationship between delay and reinforcer effectiveness is inadequate. An experiment by Fantino (1966) gave pigeons a choice between a small immediate reinforcer and a larger delayed reinforcer. The study showed increasing preference for the large delayed reinforcer by pigeons during six months of daily sessions. Interpretation of these results is complicated, however, by the fact that a timeout followed each choice of the small immediate reinforcer—in effect, small reinforcer choices were punished by timeouts. Ferster's (1953) work is probably the most similar to the research presented in this paper. Ferster showed that if delays of 60 or 120 sec were introduced between response and reinforcement under a

[1]This research was supported by Grant MH-15494 from the National Institute of Mental Health to Harvard University. A. W. Logue is a National Science Foundation Graduate Fellow. We would like to thank Ginie Upham for training the animals in a large part of this experiment. Reprints may be obtained from James E. Mazur, Department of Psychology, Yale University, New Haven, Connecticut 06520.

variable-interval (VI) schedule, pigeons' response rates declined. However, if the delay were short at first and increased gradually, three of four pigeons showed no reduction in response rate. Ferster argued that a particular delay in reinforcement does not uniquely determine a subject's behavior but that "the effect of a delay on the frequency of a response depends critically on the way in which the bird is introduced to the particular delay" (1953, p. 223).

Ferster's experiment involved what has since become known as a "fading" procedure, employing gradual changes along some stimulus dimension. Later studies demonstrated that fading procedures could lead to behavior patterns that were rarely observed otherwise. For example, fading procedures resulted in "errorless" discrimination learning in pigeons (Terrace, 1963) and in human subjects (Moore and Goldiamond, 1964; Sidman and Stoddard, 1967) and facilitated monkeys' learning of serial position sequences (Mackay and Brown, 1971). To our knowledge, however, no study besides Ferster's has examined the effects of fading along the dimension of reinforcer delay.

The present experiment examined the effects of gradual change in reinforcer delay in a two-choice situation that could be called a "self-control" paradigm—one involving a choice between a small immediate reward and a large delayed reward. In such a procedure, the choice of the large delayed reward over the earlier smaller one has been called *self-control* (Rachlin, 1970, 1974), *impulse control* (Ainslie, 1974), or *delay of gratification* (Mischel and Gilligan, 1964). This experiment gave pigeons a choice between 6 sec of access to grain (hereafter called the "large reinforcer") and 2 sec of access to grain (the "small reinforcer"). The large reinforcer was delivered 6 sec after a choice response was made. For the experimental group, the delay between a response and the small reinforcer was initially also 6 sec, but this delay was gradually reduced and eventually eliminated during the course of the experiment. The final choice for these pigeons was between an immediate small reward and a large delayed reward. A control group also received this choice but without any training with other delay intervals. The experiment thus sought to determine whether training experience would lead to more large reinforcer choices in the experimental group.

METHOD

Subjects

Eight adult White Carneaux pigeons were maintained at 80% of their free-feeding weights. All had experience with a variety of experimental procedures. However, none of the birds had previously participated in experiments employing varying delays or durations of reinforcement.

Apparatus

The experimental chamber was 33.5 cm long, 28.5 cm wide, and 30.5 cm high. Two response keys were mounted in one wall, 12.5 cm apart, and each required a force of 0.17 N to operate. A food hopper below the keys provided access to mixed grain. The chamber could be illuminated by two 6-W white lights, one 6-W red light, or one 6-W green light. The chamber was enclosed in a sound-attenuating box. The box contained a speaker that produced continuous white noise to help mask extraneous sounds, and an air blower for ventilation. A PDP-8 computer in another room, using a SKED program, controlled the stimuli and recorded responses.

Procedure

Because all subjects had learned to peck a key for grain in earlier experiments, the only training they received was designed to ensure that they initially sampled both keys.

Each session consisted of 34 trials—31 choice trials and three no-choice trials. At the beginning of each choice trial, the left key was transilluminated by a 6-W green light, the right key by a 6-W red light. The chamber was illuminated with white light. A left-key peck turned both keys dark and led to a 6-sec delay period, followed by a 6-sec reinforcement period of access to grain. A right-key peck turned both keys dark and led to a delay period followed by a 2-sec reinforcement period. The delay period following a response to the right key was varied between conditions. During the left-key delay and reinforcement periods, the chamber illumination was green; during the right-key delay and reinforcement periods it was red. The no-choice trials required the subjects to respond on the key associated with the 2-sec reinforcer. On these trials, only the right key was lit, and a peck on this key led to the same sequence of events as on a choice trial. Left pecks had no consequence on no-choice trials. The no-choice trials occurred on Trials 10, 20, and 30. After the first session, two subjects that made no left-key responses received one or two sessions with the right key covered. Both of these pigeons responded on both keys on subsequent trials.

The intertrial intervals varied so that each trial occurred 1 min after the beginning of the previous trial as long as the subjects' response latencies were less than 48 sec. For latencies longer than 48 sec, intertrial intervals were multiples of 1 min (*e.g.*, 4 min if the response latency was between 2 min 48 sec and 3 min 48 sec). Because latencies were almost always shorter than 48 sec, sessions usually lasted exactly 34 min, and the overall reinforcement rate was one reinforcement per minute regardless of the distribution of left and right choices.

For both experimental and control subjects, each right-key delay duration was maintained for at least 10 sessions. In addition, a condition was terminated only when each subject in that condition satisfied a strict criterion of stability. This criterion specified at least five consecutive sessions in which the number of large reinforcer choices was neither higher nor lower than the number of large reinforcer choices in all previous sessions within that condition.

Experimental group. Four pigeons (Subjects 46, 291, 492, and 127) served in the experimental group. The small reinforcer delay for this group was initially 6 sec, but it was progressively shortened during the course of the experiment, as indicated in Table 1. Because only the duration of the right-key delay varied between conditions, this parameter will be used to refer to a particular condition (*e.g.*, the third condition will be called the "5-sec condition"). The final condition, called "0-sec-left" in Table 1, was like the 0-sec condition except that the delay and reinforcement durations (but not the colors) for the two keys were reversed. Table 1 also shows the number of sessions for each condition.

Control group. Conditions for the controls (Birds 9, 53, 83, and 133) were identical to those for the experimentals, except that the controls began with the 0-sec condition (24 sessions) for the right (small reinforcer) key and then received a 5.5-sec condition (28 sessions). The 5.5-sec delay was selected simply because it was representative of the long right-key delays that produced nearly exclusive preference for the large reinforcer in the experimental group.

Table 1

Order of Conditions for the Experimental Group

Condition (right delay, sec)	*Number of Sessions*
6.0	21
5.5	13
5.0	12
4.5	18
4.25	15
3.75	10
3.25	15
2.75	16
2.5	14
2.25	24
2.0	19
1.75	38
1.5	19
1.25	33
1.0	35
0.75	22
0.5	18
0.0	15
0.0-left[a]	25

[a]The 0-sec-left condition was like the 0-sec condition except that the delay and reinforcer durations for the two keys were reversed.

At the end of the 5.5-sec condition, Subject 9, which consistently responded on the right key during this condition, received a session with the right key dark and inoperative. This session was followed by 13 more sessions of the 5.5-sec condition, when the five-day criterion was again satisfied for this subject.

RESULTS

For both groups, all analyses were based on the last five days of each condition. For each subject in the experimental group, Figure 1 shows the number of large reinforcer choices as a function of the delay interval for the small reinforcer. As can be seen, all subjects showed nearly exclusive preference for the large reinforcer with delays of 3.25 sec or longer. The individual animals varied in the extent to which they continued to select the large reinforcer with decreasing small reinforcer delays, but small reinforcer choices increased for all subjects.

These results can be compared with the performance of the control animals that did not receive the extensive training experience by the experimental group, although both

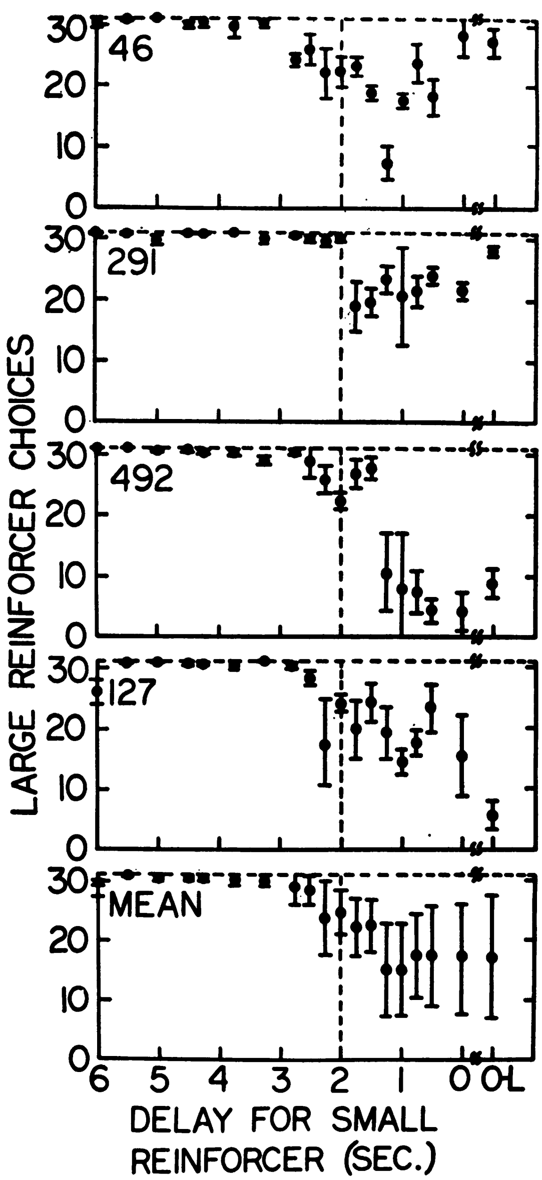

Fig. 1. The mean number of large reinforcer choices in the last five days of each condition for each experimental subject and the group as a whole. "0-L" refers to the 0-sec-left condition. The vertical lines depict one standard deviation on each side of the mean.

groups were trained until stable performance was achieved. Table 2 shows the large reinforcer choices of experimental and control subjects in the 5.5-sec and 0-sec delay conditions. The 0-sec-left condition of the experimental group is also included. All animals except Subject 9 averaged less than one small reinforcer choice in the 5.5-sec condition. After a session with the right key dark and inoperative, Subject 9 switched to near-exclusive preference for the large reinforcer. The performance of the control subjects in the 0-sec condition was markedly different from that of the experimental subjects in both the 0-sec and 0-sec-left conditions. All control subjects averaged less than three large reinforcer choices in the last five days of this condition, and two made no large reinforcer choices in the last five days. All experimental subjects averaged more large reinforcer choices than all control subjects. As t-tests showed, the results of the 0-sec control condition were significantly different from those of both the 0-sec experimental condition ($t = 3.22$, $df = 6$, $p < 0.02$) and the 0-sec-left experimental condition ($t = 2.80$, $df = 6$, $p < 0.05$).

In the 0-sec-left condition for experimental subjects, the large reinforcer followed a peck on the red right key instead of the green left key. The largest change in the number of large reinforcer choices occurred for Subject 127; those choices dropped from 15.4 to 5.6. However, a t-test showed that this difference was not significant at the 0.05 level ($t = 2.26$, $df = 4$, $p < 0.1$). The only bird showing a significant change between the 0-sec and 0-sec-left conditions was Subject 291. This animal made significantly more large reinforcer choices in the 0-sec-left condition, even though it chose

Table 2

Large Reinforcer Choices in Three Conditions

	5.5 sec		*0.0 sec*		*0.0 sec left*	
	M	*SD*	*M*	*SD*	*M*	*SD*
EXPERIMENTALS						
46	30.8	0.4	28.2	3.2	26.2	2.4
291	30.8	0.4	21.6	1.4	28.0	0.9
492	31.0	0.0	4.2	3.1	8.8	2.5
127	31.0	0.0	15.4	6.7	5.6	2.4
CONTROLS						
9	0.0	0.0	0.0	0.0		
9[a]	30.4	0.8				
53	31.0	0.0	0.0	0.0		
83	30.6	0.5	2.8	1.9		
133	31.0	0.0	0.4	0.5		

Note. The means (M) and standard deviations (SD) are based on the last five days of each condition.

[a]After the 5.5-sec condition, Subject 9 received one session with the right key dark and inoperative. This session was followed by further sessions with the 5.5-sec delay until the stability criterion was again met. This row shows the results of this condition.

the large reinforcer on 70% of the trials in the 0-sec condition ($t = 12.55$, $df = 4$, $p < 0.002$).

Figure 2 shows the median response latencies of each experimental subject for the large and small reinforcers on choice trials. The latency of each response incremented a counter in one of 40, 0.1-sec bins. Response latencies larger than 4 sec were recorded in the 4-sec bin. (Before the 1.75-sec condition, small reinforcer latencies on choice trials were not separated from latencies on no-choice trials, so these results are not shown). No systematic pattern emerges from Figure 2. As the small reinforcer delay was shortened to less than 2 sec, the latencies of large reinforcer choices decreased for Subject 127, increased for Subjects 291 and 492, and remained about the same for Subject 46. For two subjects, small reinforcer latencies tended to be shorter than large reinforcer latencies, but they were longer for the other two subjects.

DISCUSSION

For this experiment, Equation 1 predicts exclusive preference for the large reinforcer with all delays longer than 2 sec, and exclusive preference for the small reinforcer with all delays shorter than 2 sec. Figure 1 shows that the predictions were approximately confirmed for small reinforcer delays longer than 3 sec. When the small reinforcer delay decreased to about 2 sec, all four experimental subjects began to choose the small reinforcer more often than at longer delays. The experimental subjects varied in their performance, but no subject showed the exclusive preference for the

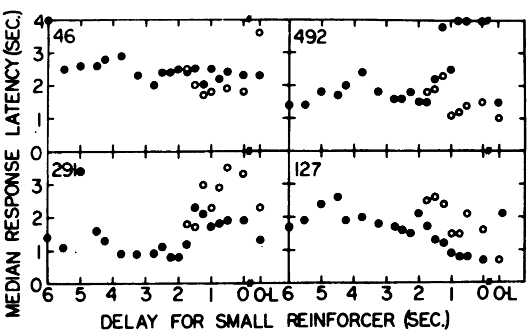

Fig. 2. Median response latencies for large reinforcer choices (closed circles) and small reinforcer choices (open circles) *versus* the delay interval for a small reinforcer. "0-L" refers to the 0-sec-left condition. Results are shown individually for each subject.

small reinforcer, as predicted by Equation 1. In averaging across the seven conditions with delays shorter than 2 sec, three subjects actually exhibited more large reinforcer choices than small reinforcer choices.

The results indicate that a simple inverse relationship between delay and reinforcer value (as described in Equation 1) cannot be correct. This experiment, as well as Ferster's (1953) research, shows that the effects of delayed reinforcement depend on a subject's experience. Individual differences in choice behavior within the self-control paradigm may be caused by systematic experimental manipulations (*e.g.,* the difference between experimentals and controls) or by other factors (*e.g.,* the differences among experimental subjects). No equation that fails to allow for individual differences can describe the effects of reinforcer delay on choice behavior.

Ferster's (1953) experiments showed that a gradual increase in delay between response and reinforcement had less of a detriment on response rate than a sudden one. The present results also suggest that the manner of introducing reinforcer delays is an important determinant of a subject's behavior in a choice situation. For the experimental group, the delays for large and small reinforcers were initially equal, but the delay for a small reinforcer was gradually decreased. Only after 342 sessions did the subjects choose between a 6-sec reinforcer delayed 6 sec *versus* an immediate 2-sec reinforcer. By this time, the experimental subjects had received over 10,000 trials in which they chose between 6 sec of access to grain and 2 sec of access to grain. Some aspect of their extensive experience led to more large reinforcer choices in these subjects than in a control group that began with the 0-sec condition. The effect of this differential experience was especially noticeable for two of the experimental animals, which chose the large delayed reward on over two-thirds of the trials in the 0-sec condition. No control subject chose the large reward on as many as 10% of the trials.

The design of this experiment eliminates several possible explanations of the increased large reinforcer choices made by the experimental subjects. Because subjects were forced to choose the small reinforcer on at least three trials each session, it cannot be argued that their nearly exclusive preference for the large reinforcer on choice trials in some conditions prevented them from learning about the decreasing delay associated with the small reinforcer. In addition, it cannot be argued that the very gradual decrease in the delay interval was not discriminated by the subjects. With delays of about 2 sec or less, all subjects chose the small reinforcer more often than with the longer delays—they simply failed to choose the small reinforcer on *every* trial.

The 0-sec-left condition was directed at two other potential explanations of behavior of the experimental subjects. If this condition were not included, it could be argued that the results were based on a position habit or a key-color habit that developed as a result of the thousands of training trials on which pigeons chose the left green key. However, when the large delayed reward was switched to the right red key, the two experimental subjects showing the most large reinforcer choices in the 0-sec condition continued to choose the large reinforcer on over two-thirds of the trials. Thus, at least for these subjects, the choice of the large delayed reward was not simply a by-product of the preference for a particular key position or key color.

In experiments involving choices between large delayed rewards and small immediate rewards, Rachlin and Green (1972) and Ainslie (1974) found increased self-control if pigeons had the opportunity to make an early and irreversible commitment to the large delayed reward; early in each trial, the subject could perform a response that eliminated the possibility of choosing the small immediate reinforcer later in the trial. The significance of the present experiment is that it demonstrates that some pigeons can be trained to choose the large reinforcer on a majority of trials even without precommitment devices like those available in the Rachlin and Green (1972) and Ainslie (1974) experiments.

This experiment did not identify exactly which aspects of the training procedure produced the difference between experimental and control subjects. Two possible factors include the gradual change in the small reinforcer delay and the large number of trials for the experimental subjects. The present experiment was not designed to test these possibilities, but merely to determine whether one type of training experience could alter behavior in a self-control paradigm. A related issue is the question of how general the increased self-control of the experimental subjects would be. Would experimental subjects exhibit more self-control with other combinations of delays and reinforcer durations, or with different instrumental responses, different procedures, or different reinforcers? All these questions could be answered by further research.

Individual differences in self-control seem to be the rule for both humans and nonhumans. In Ainslie's (1974) experiment, only three of 10 pigeons came under apparent control of the precommitment procedure. In the present experiment, only two of four experimental subjects made a majority of large reinforcer choices under all conditions, although all showed more self-control than control subjects. Empirical research (*e.g.*, Mischel, 1966), as well as everyday experience, suggests that there are substantial individual differences among humans in their ability to delay gratification in such varied areas as weight control, saving money, and getting work done on time. Further research with nonhuman subjects might lead to the discovery of methods for improving self-control in humans. A more complete understanding of the phenomenon of impulse control could have many important implications for human behavior, both theoretical and practical.

REFERENCES

Ainslie, G. Impulse control in pigeons. *Journal of the Experimental Analysis of Behavior*, 1974, **21**, 485-489.

Ainslie, G. Specious reward: a behavioral theory of impulsiveness and impulse control. *Psychological Bulletin*, 1975, **82**, 463-496.

Baum, W. M. and Rachlin, H. Choice as time allocation. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 861-874.

Chung, S. H. Effects of delayed reinforcement in a concurrent situation. *Journal of the Experimental Analysis of Behavior*, 1965, **8**, 438-444.

Chung, S. H. and Herrnstein, R. J. Choice and delay of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 67-74.

de Villiers, P. A. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig and J. E. R. Staddon, *Handbook of operant behavior*. Englewood Cliffs: Prentice-Hall, 1977. Pp. 233-287.

Fantino, E. Immediate reward followed by extinction *vs.* later reward without extinction. *Psychonomic Science*, 1966, **6**, 233-234.

Ferster, C. B. Sustained behavior under delayed reinforcement. *Journal of Experimental Psychology*, 1953, **45**, 218-224.

Keller, J. V. and Gollub, L. R. Duration and rate of reinforcement as determinants of concurrent responding. *Journal of the Experimental Analysis of Behavior*, 1977, **28**, 145-153.

Mackay, H. A. and Brown, S. M. Teaching serial position sequences to monkeys with a delayed matching-to-sample procedure. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 335-345.

Mischel, W. Theory and research on the antecedents of self-imposed delay of reward. *Progress in Experimental Personality Research*, 1966, **3**, 85-132.

Mischel, W. and Gilligan, C. Delay of gratification, motivation for the prohibited gratification, and response to temptation. *Journal of Abnormal and Social Psychology*, 1964, **69**, 411-417.

Moore, R. and Goldiamond, I. Errorless establishment of visual discrimination using fading procedures. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 269-272.

Neuringer, A. J. Effects of reinforcement magnitude on choice and rate of responding. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 417-424.

Rachlin, H. *Introduction to modern behaviorism*. San Francisco: W. H. Freeman, 1970.

Rachlin, H. Self-control. *Behaviorism*, 1974, **2**, 94-107.

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

Sidman, M. and Stoddard, L. The effectiveness of fading in programming a simultaneous form discrimination for retarded children. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 3-15.

Terrace, H. S. Discrimination learning with and without "errors". *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 1-27.

Received 22 July 1977.
(Final acceptance 16 January 1978.)