RESPONDING DURING REINFORCEMENT DELAY IN A SELF-CONTROL PARADIGM

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Eight pigeons chose between a small, immediate reinforcer and a large, increasingly delayed reinforcer. Responding during the large-reinforcer delays was examined. During large-reinforcer delays, pecks on one key produced the small, immediate reinforcer; pecks on the other key had no effect. Thus, a pigeon could reverse its initial choice of the large, delayed reinforcer, or it could maintain its original choice. Pigeons that made a relatively high number of initial large-reinforcer choices tended to maintain these choices. Those pigeons that made a relatively high number of initial large-reinforcer choices, and those pigeons that actually received a relatively high number of large reinforcers, tended to respond more frequently on the ineffective key during the delay periods. The findings suggest that some previous studies of self-control training in pigeons may have resulted in increased self-control partially due to a lack of opportunity for the pigeons to change their choices.

Key words: self-control, delay of reinforcement, amount of reinforcement, delay responding, key peck, pigeons

Self-control often has been defined in the laboratory as the choice of large, more-delayed reinforcers over small, less-delayed reinforcers (Ainslie, 1974; Mazur & Logue, 1978; Rachlin & Green, 1972). Given cer-

tain amounts and delays of reinforcement, experimentally naive nonhuman subjects will show impulsiveness, or lack of self-control, by choosing the less-delayed, small reinforcers (Ainslie, 1974; Ainslie & Herrnstein, 1981; Green, Fisher, Perlow, & Sherman, 1981; Green & Snyderman, 1980; Navarick & Fantino, 1976).

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Self-control, as defined above, has been experimentally facilitated in nonhuman subjects using several methods. For example, Ainslie (1974) and Rachlin and Green (1972) used precommitment procedures. Pigeons more frequently chose a large, more-delayed reinforcer over a small, less-delayed one when they could commit in advance to a later choice of the large reinforcer substantially before either reinforcer was to be received. Logue, Rodriguez, Peña-Correal, and Mauro (1984, Experiment 1) and Mazur and Logue (1978) increased self-control in pigeons by first giving them a choice between large or small equally delayed reinforcers, then slowly removing the delay to the small reinforcer. The pigeons continued to choose the large, delayed reinforcer more often than did a control group (Mazur & Logue, 1978) that had not been exposed to this fading procedure. Logue (1982) also trained increased self-control using a fading

procedure in which, initially, both large and small reinforcers were immediate. The delay to the large reinforcer was then slowly increased.

All of these precommitment and fading-exposure experiments have involved procedures in which a subject's choice of the large, more-delayed reinforcer could not be reversed. However, the behavior of an organism outside of the laboratory is more likely to be identified as self-control if the organism not only initially chooses the large reinforcer, but also has the opportunity to change its choice during the delay to the large reinforcer and does not do so (e.g., Ainslie, 1975). Ainslie (1974) reported an experiment that did have these procedural characteristics. Pigeons could wait for a more-preferred reinforcer or peck a key and obtain a less-preferred reinforcer. Eight of ten pigeons pecked the key during 95% of the trials.

Grosch and Neuringer (1981) used a similar procedure. They found that when pigeons were trained to peck a key located on the wall opposite that containing the choice key and food hoppers, the percentage of trials during which the pigeons obtained the large reinforcer increased. Interpretation of these findings may be somewhat constrained, however, by the fact that Grosch and Neuringer's pigeons chose between qualitatively different small and large reinforcers. Nevertheless, Grosch and Neuringer's findings are consistent with Skinner's (1953) suggestion that self-control in such situations might be facilitated "by doing something else" (pp. 239-240), and with Mischel and his colleagues' work with children (e.g., Mischel & Ebbesen, 1970; Mischel, Ebbesen, & Zeiss, 1972), which has shown that the performance of a number of different activities during the large-reinforcer delay will facilitate waiting for the large reinforcer.

The present experiment examined responding during delay periods and its relation to self-control while exposing pigeons to a modified fading procedure (Logue, 1982; Logue et al., 1984; Mazur & Logue, 1978). During large-reinforcer delays the pigeons

were able to make pecks that had no effect and pecks that changed their choice.

METHOD

Subjects

Eight adult experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding weights.

Apparatus

A standard operant chamber for pigeons (33.5 cm long, 28.5 cm wide, and 30.5 cm high) was used. Two response keys were mounted in one wall, 12.5 cm apart. Each required a minimum force of approximately 0.17 N to operate. The left key could be transilluminated by a 7.5-W green light and the right key by a 7.5-W red light. A food hopper below the keys provided access to mixed grain. The chamber could be illuminated by two 4-W white lights, one 4-W red light, or one 4-W green light. The chamber was enclosed in a sound-attenuating wooden box. A fan provided both ventilation and partial masking of extraneous sounds. A PDP-8A computer in another room, using a SUPERSKED program, controlled the stimuli and recorded the data.

Procedure

The pigeons were first trained, using an autoshaping procedure, to peck the two keys. Each session of the subsequent experimental conditions consisted of 34 trials: 28 choice trials and 6 forced-choice trials. A typical choice trial is diagrammed in Figure 1. At the beginning of each of these trials the left key was transilluminated green (G) and the right key red (R). The chamber was illuminated by the two white lights (W). A peck on the left (green) key led to a delay period (x s) followed by the darkening of the two keys along with a 6-s period of access to grain, provided the pigeon did not peck the right key during the left-key delay period (see below). Left key pecks during the left-key delay period were ineffective. The chamber illumination was green during the left-key delay and reinforcement periods. Any

Fig. 1. Diagram of a typical trial. Each box represents one stage within a trial. The small square in the top of each box indicates the color of the overhead illumination: white (W), green (G), or red (R). The circles represent the keys, and the letters in the circles indicate the color of the keys. The rectangle in the bottom part of each box represents the food hopper. Finally, the arrows show the effect of a peck on one of the keys.

peck on the right (red) key led to a 0.11-s delay period followed by the darkening of the two keys and a 2-s reinforcement period. During the right-key delay and reinforcement periods the chamber illumination was red.

Three forced-choice trials required the pigeons to respond on the key correlated with the large reinforcer, and the other three required responding on the key correlated with the small reinforcer. On these trials, only the large-reinforcer key or the small-reinforcer key was lit and a peck on a lit key led to the same sequence of events as on the choice trials. These forced-choice trials occurred on the 5th, 15th, and 25th trials for the small-reinforcer key, and on the 10th,

20th, and 30th trials for the large-reinforcer key. These trials ensured the pigeons' exposure to the contingencies on both keys.

Pecks on all lit keys, including the left key during a left-key delay period, were followed by a feedback click. Pecks on unlit keys had no consequences and were rarely made.

The intertrial intervals (ITIs) were programmed by the method of Mazur and Logue (1978) to keep reinforcer frequency as close as possible to one reinforcer per minute. An ITI was computed and programmed following the completion of each reinforcement period, such that each trial began 1 min after the beginning of the previous trial. When this was impossible because of an occasional long response latency, the next trial began as soon as reinforcement for the previous trial had finished, and as soon as a whole number of minutes had passed since the beginning of the previous trial (e.g., 2 min, 3 min, 4 min, etc.).

The eight pigeons were first exposed to 21 conditions in which the large-reinforcer delay was progressively increased from 0.11 to 6 s. After the last condition, the pigeons were exposed to a reversal condition in which pecks on the left key were followed by 2 s of food delayed 0.11 s, and pecks on the right key were followed by 6 s of food delayed 6 s. This condition has been used to test for position and color biases (Logue & Mazur, 1981; Logue et al., 1984; Mazur & Logue, 1978), and it allowed comparison of the present results with results from those previous experiments.

Conditions were changed for each pigeon after a minimum of 10 sessions and after the subject's performance had satisfied a stability criterion. This criterion specified at least five consecutive sessions in which the number of large-reinforcer choices for that pigeon on each of those sessions was, at the most, four more than or, at the least, four less than the mean number of large reinforcer choices in the preceding five sessions for that pigeon. With this as the criterion, pigeons were exposed to conditions for between 10 and 51 sessions, as indicated in Table 1, with a median of 11 sessions, over

all of the pigeons and conditions. The greater numbers of sessions tended to occur for conditions in which the large-reinforcer delay was set at 2.5 or 3 s, conditions in which the pigeons' large-reinforcer choices were near neither the maximum nor the minimum possible.

RESULTS

All analyses are based on means of the last five sessions from the choice trials of each condition for each pigeon.

Fading Exposure

For each of the eight pigeons, Figure 2 shows the number of initial and final large-

reinforcer choices as a function of the different conditions. Initial large-reinforcer choices are defined as the number of times a pigeon chose the large reinforcer by pecking the large-reinforcer key (filled circles). Final large-reinforcer choices are defined as the number of times that a pigeon actually received the large reinforcer—that is, the number of times in which an initial large-reinforcer choice was made without a peck on the small-reinforcer key during the subsequent large-reinforcer delay. The plus signs in Figure 2 indicate the number of final large-reinforcer choices. The number of trials that a pigeon chose the large reinforcer, but then pecked the small-reinforcer key during the subsequent large-reinforcer

Fig. 2. The mean number of large-reinforcer choices in each condition for each experimental subject. 6-R refers to the reversal condition. The filled circles represent the initial large-reinforcer choices and the plus signs represent the final large-reinforcer choices.

delay, is defined as the number of changes of choice. The difference between the initial and the final large-reinforcer choices equals the number of changes of choice.

All pigeons chose the large reinforcer almost exclusively when the delays to the large reinforcer were 2.5 s or less. For five of the pigeons (Pigeons 17, 18, 19, 55, and 59) the large-reinforcer choices abruptly decreased when the delays to the large reinforcer were increased to between 2.75 and 4 s. The other three pigeons (Pigeons 16, 26, and 58) showed a more gradual decrease in the number of large-reinforcer choices. Pigeons 16 and 58 continued to choose the large reinforcer for more than half of the trials during all of the training conditions.

Figure 2 also shows that three pigeons (17, 18, and 55) never chose the small reinforcer during the large-reinforcer delay: Pigeon 55 never changed its choices, and Pigeons 17 and 18 changed their choices only in the reversal condition. Pigeons 16, 19, 26, 58, and 59 began to change their choices when the number of initial (and therefore final) large-reinforcer choices began to decrease.

Figure 3 presents the data from Figure 2 in an alternative manner: the mean waiting time for a reinforcer on each trial for each of the experimental pigeons. These values were calculated by first summing three products:

final large-reinforcer choices multiplied by the programmed delay for a large reinforcer, final small-reinforcer choices multiplied by the programmed delay for a small reinforcer, and the number of changes of choice multiplied by the mean latency to the changes of choice. This sum was then divided by the total number of choice trials (28). The solid lines in the figure indicate the maximum possible waiting time, the waiting time if a pigeon had received only large reinforcers. Similar to what was shown in Figure 2 with the number of large-reinforcer choices, for all eight pigeons, with delays to the large reinforcer of 2.5 s or less, the waiting times were close to the maximum. For all of the subjects except Pigeons 16 and 58, there was a gradual decrease in the waiting times as the delay to the large reinforcer was increased. For Pigeons 16 and 58 the waiting times in each training condition were longer than half of the maximum waiting time.

Table 1 shows the mean number of responses made in a session on the left (green), ineffective key during the large-reinforcer delays, as well as the mean total large-reinforcer delay time for a session. The data are shown separately for each pigeon and each condition. These data were used to calculate frequency of pecking during the large-reinforcer delays. Figure 4 presents Pearson product-moment correlation coefficients between large-reinforcer choices and the frequency of pecking on the ineffective key during the large-reinforcer delays. Correlations using initial large-reinforcer choices are shown by the filled circles; those using final large-reinforcer choices are shown by the plus signs. These correlations were calculated separately for each condition, each correlation being based on the data from the eight pigeons. Thus, these correlations measure the relationship between the pigeons' self-control choices and their frequency of doing something else (something other than pecking the immediate-reinforcer key) while waiting for the large reinforcer.

Correlations above the dashed line in Figure 4 differed significantly from chance ($df = 6$, $p < .05$). No correlations were sig-

Fig. 3. Mean time waiting for reinforcement for each experimental subject during each condition. The times were calculated for both reinforcers combined. The solid line represents the maximum possible waiting time in each condition.

Table 1
Number of sessions, mean responses during the large-reinforcer delays per session, and total large-reinforcer delay time per session for each pigeon in each condition.

Condition	Number of Sessions	Delay Responses	Delay Time (s)	Number of Sessions	Delay Responses	Delay Time (s)
Pigeon 26				Pigeon 16		
0.11	16	0.0(0.0)	3.1(0.0)	11	0.0(0.0)	3.1(0.0)
0.25	14	0.2(0.2)	5.9(0.2)	10	1.0(0.6)	7.0(0.0)
0.50	16	13.6(1.0)	12.6(0.3)	11	15.6(2.6)	13.7(0.1)
0.75	11	17.6(0.7)	17.8(0.6)	10	30.0(2.9)	21.0(0.0)
1.00	26	19.4(3.5)	24.6(0.8)	10	11.3(1.9)	27.8(0.2)
1.50	10	35.2(4.9)	39.5(0.5)	10	28.6(4.9)	41.7(0.3)
2.00	11	27.4(6.9)	47.7(1.2)	10	62.0(12.7)	55.2(0.4)
2.50	33	24.8(5.9)	58.1(1.9)	10	114.0(19.1)	69.4(0.5)
3.00	51	8.8(1.2)	69.9(2.2)	13	202.0(1.8)	74.6(1.2)
3.25	10	6.4(1.5)	67.3(2.0)	10	163.8(10.3)	78.4(2.4)
3.50	13	8.2(2.5)	83.5(3.3)	10	199.4(3.6)	88.8(1.0)
3.75	15	14.8(5.4)	70.1(3.8)	10	224.6(5.1)	97.7(2.5)
4.00	10	12.4(3.3)	71.5(3.8)	11	187.8(6.4)	95.7(4.0)
4.25	20	14.4(5.5)	30.5(5.5)	10	145.4(2.6)	93.5(2.5)
4.50	12	11.3(2.5)	61.4(4.7)	15	135.6(3.6)	80.5(3.5)
4.75	12	7.0(1.5)	48.7(5.9)	14	116.4(9.2)	87.5(3.6)
5.00	22	1.5(0.8)	37.5(5.7)	10	110.8(6.2)	111.6(3.8)
5.25	11	1.6(0.6)	13.6(3.1)	10	77.6(10.9)	130.6(3.4)
5.50	11	6.2(2.6)	31.8(5.5)	10	88.4(7.9)	135.7(2.5)
5.75	11	2.0(1.4)	13.1(4.3)	10	74.4(13.7)	148.0(3.6)
6.00	10	0.0(0.0)	5.3(0.9)	11	49.3(7.0)	157.7(2.4)
Pigeon 55				Pigeon 19		
0.11	22	1.0(0.6)	3.1(0.0)	10	0.4(0.2)	3.1(0.0)
0.25	13	0.6(0.4)	7.0(0.0)	11	0.0(0.0)	6.9(0.1)
0.50	17	0.6(0.5)	14.0(0.0)	10	7.0(0.7)	13.6(0.3)
0.75	11	0.4(0.2)	21.0(0.0)	10	19.3(4.2)	16.3(4.1)
1.00	25	0.0(0.0)	28.0(0.0)	10	8.4(1.2)	28.0(0.0)
1.50	10	0.0(0.0)	42.0(0.0)	11	35.3(3.1)	42.0(0.0)
2.00	11	1.0(0.7)	53.0(1.2)	10	19.8(4.1)	55.5(0.4)
2.50	33	0.8(0.4)	65.7(0.8)	10	22.6(4.6)	70.0(0.0)
3.00	50	0.0(0.0)	42.4(4.1)	12	0.8(0.2)	76.8(3.3)
3.25	18	0.0(0.0)	25.1(4.1)	10	7.4(1.8)	65.1(2.3)
3.50	11	0.0(0.0)	50.5(3.6)	10	1.0(0.5)	26.5(2.5)
3.75	14	0.0(0.0)	40.2(3.5)	11	0.4(0.2)	13.3(2.1)
4.00	12	0.0(0.0)	42.0(5.3)	10	0.2(0.2)	11.3(0.8)
4.25	10	0.0(0.0)	20.5(4.3)	17	0.6(0.5)	14.4(1.3)
4.50	10	0.0(0.0)	18.5(3.3)	15	1.4(0.0)	26.4(2.5)
4.75	10	0.0(0.0)	17.0(1.6)	17	0.6(0.4)	14.4(1.3)
5.00	12	0.0(0.0)	15.8(4.1)	12	0.2(0.2)	34.0(6.0)
5.25	12	0.2(0.2)	18.5(5.2)	10	0.6(0.2)	54.6(5.6)
5.50	10	0.0(0.0)	14.9(4.7)	13	0.2(0.2)	35.4(5.7)
5.75	10	0.0(0.0)	12.1(3.0)	10	0.2(0.2)	22.6(5.7)
6.00	10	0.0(0.0)	14.9(2.9)	10	0.0(0.0)	11.3(3.6)
Pigeon 58				Pigeon 17		
0.11	22	0.6(0.4)	3.1(0.0)	12	0.2(0.2)	3.1(0.0)
0.25	12	1.4(0.4)	6.5(0.1)	10	0.3(0.2)	6.4(0.1)
0.50	17	0.6(0.4)	12.9(0.2)	10	1.0(0.9)	12.9(0.2)
0.75	11	0.4(0.4)	18.2(0.4)	10	0.0(0.0)	18.6(0.4)
1.00	26	10.8(1.3)	25.8(0.5)	11	0.4(0.4)	25.7(0.7)
1.50	10	21.6(1.3)	39.8(0.5)	16	0.4(0.4)	34.5(1.5)

Table 1—continued

Condition	Number of Sessions	Delay Responses	Delay Time (s)	Number of Sessions	Delay Responses	Delay Time (s)
Pigeon 58				Pigeon 17		
2.00	10	38.6(1.3)	46.9(1.2)	10	2.0(0.4)	41.8(1.4)
2.50	31	94.0(11.1)	61.9(1.6)	13	0.0(0.0)	50.3(2.3)
3.00	49	114.6(7.6)	60.6(3.4)	20	0.0(0.0)	11.0(1.2)
3.25	10	140.2(4.6)	75.3(2.5)	11	0.0(0.0)	13.1(2.4)
3.50	10	110.0(4.9)	79.7(3.9)	10	0.0(0.0)	6.5(1.7)
3.75	13	119.8(15.5)	77.7(4.1)	10	0.0(0.0)	4.4(1.2)
4.00	10	74.8(9.0)	65.5(2.2)	10	0.2(0.2)	11.6(3.7)
4.25	10	55.4(5.0)	67.8(4.5)	27	0.0(0.0)	8.1(3.6)
4.50	11	43.6(1.2)	68.9(1.8)	10	0.0(0.0)	9.2(3.8)
4.75	13	141.3(5.9)	91.2(10.0)	13	0.0(0.0)	90.1(9.5)
5.00	10	128.8(15.4)	85.0(2.7)	11	0.0(0.0)	20.2(2.7)
5.25	10	187.2(23.7)	95.0(6.1)	11	0.0(0.0)	23.6(5.5)
5.50	12	147.6(14.4)	99.4(0.4)	14	0.3(0.2)	7.1(3.5)
5.75	10	167.2(20.3)	109.9(4.5)	10	0.0(0.0)	6.5(1.2)
6.00	10	134.2(3.6)	79.6(2.2)	10	0.0(0.0)	3.7(0.5)
Pigeon 59				Pigeon 18		
0.11	22	0.2(0.2)	3.1(0.0)	13	0.2(0.2)	3.1(0.0)
0.25	14	0.6(0.4)	6.8(0.1)	10	0.0(0.0)	6.7(0.1)
0.50	17	22.4(1.3)	13.8(0.1)	10	18.6(11.2)	13.4(0.1)
0.75	11	18.6(2.3)	20.7(0.1)	10	0.5(0.3)	20.7(0.2)
1.00	25	75.8(1.8)	28.0(0.0)	10	3.8(1.0)	28.0(0.0)
1.50	10	95.4(3.5)	42.0(0.0)	12	0.2(0.2)	35.0(1.4)
2.00	10	146.8(5.0)	56.0(0.0)	10	0.5(0.4)	54.6(1.2)
2.50	31	83.6(8.3)	69.0(0.5)	10	0.4(0.4)	64.7(1.8)
3.00	49	151.6(21.0)	81.7(1.5)	14	0.0(0.0)	43.5(1.8)
3.25	10	183.4(6.5)	86.0(1.7)	10	0.8(0.5)	39.5(2.9)
3.50	10	152.2(21.5)	81.7(1.5)	11	1.2(0.3)	32.9(2.4)
3.75	10	112.2(37.3)	92.6(3.9)	13	0.8(0.4)	45.9(3.2)
4.00	11	16.6(3.2)	55.7(4.6)	22	0.8(0.3)	31.9(3.9)
4.25	10	18.8(2.5)	39.5(3.8)	17	1.8(0.6)	79.2(7.2)
4.50	10	10.2(1.5)	43.5(4.2)	10	0.2(0.2)	41.7(3.8)
4.75	11	26.2(5.8)	29.7(3.4)	10	0.0(0.0)	36.5(5.6)
5.00	10	8.0(1.5)	23.8(2.2)	13	0.3(0.2)	33.6(5.6)
5.25	11	11.0(3.7)	13.5(2.1)	11	3.6(1.7)	138.2(3.0)
5.50	10	11.6(1.7)	21.6(3.5)	18	4.0(2.5)	40.8(5.1)
5.75	10	8.5(0.6)	18.6(2.1)	10	0.4(0.2)	18.9(1.9)
6.00	10	6.0(0.2)	12.0(1.2)	17	4.8(1.6)	23.1(2.7)

Note. The numbers in parentheses indicate the standard errors of the means.

nificant for any of the conditions between 0.11- and 3-s large-reinforcer delay. The correlations using initial large-reinforcer choices were significant for all of the conditions between 3.25 and 4.5 s, and for three of the conditions between 4.75 and 6 s. The correlations using final large-reinforcer choices were significant for the conditions between 3.25 and 4 s, and for the 4.5- and the 5-s conditions. The sizes of any correlations calculated from the 0 to 2.5-s and the

5.25- to 6-s conditions, compared with the correlations calculated for the 3- to 5-s conditions, were necessarily restricted. This restriction occurred because of the low frequency of responses on the ineffective key until the large reinforcer was delayed about 3 s, and because of ceiling and floor effects, respectively, in the number of large-reinforcer choices when the large reinforcer was delayed 0 to 3 and 5 to 6 s.

Pearson product-moment correlation co-

Fig. 4. Correlations between large-reinforcer choices and the frequency of pecking during the large-reinforcer delays. The results are shown separately for each condition. Each point is based on data from all eight subjects. Correlations using initial large-reinforcer choices are shown by filled circles; those using final large-reinforcer choices are shown by plus signs ($df=6$ in each case). Correlations above the horizontal dashed line are statistically significant ($p < .05$).

efficients were also calculated between the number of initial large-reinforcer choices and the probability of changing an initial large-reinforcer choice. Only data from the five pigeons that showed changes of choice were used (Pigeons 16, 19, 26, 58, and 59). The correlations were calculated separately for each condition in which at least one of these five pigeons showed changes of choice—that is, the 3-s and all subsequent large-reinforcer delay conditions in the fading procedure. Probability of changing an initial large-reinforcer choice was calculated as the number of changes of choice divided by the number of initial large-reinforcer choices. Table 2 shows these correlations, which were all negative but significantly different from chance ($df=3$, $p < .05$) for only the 3.50-s and 3.75-s conditions.

Reversal Condition

In the reversal condition the large reinforcer followed a choice of the red, right key instead of the green, left key. Figure 2 shows that, compared to the previous condition, all but Pigeon 16 showed increased numbers of initial large-reinforcer choices. This indicates some response bias for the right key during the reversal and the previous condi-

Table 2

Correlations between the number of initial large-reinforcer choices and the probability of changing choices given an initial large-reinforcer choice.

Condition	Correlation
3.00	-.77
3.25	-.49
3.50	-.95**
3.75	-.99**
4.00	-.86
4.25	-.65
4.50	-.55
4.75	-.47
5.00	-.49
5.25	-.75
5.50	-.57
5.75	-.62
6.00	-.57

Note. Each correlation is based on data from the five subjects that exhibited any changes of choice. Correlations are shown for all conditions in which at least one of these pigeons showed changes of choice ($df=3$ in each case).

** $P < .01$

tion, and possibly during other conditions. This response bias could have affected the correlational results described above. However, note that it was not until a large-reinforcer delay of about 4 s that most of the pigeons showed a preference for the right side, and that most of the pigeons made at least a few initial large-reinforcer choices in all conditions, even though in all conditions except the last this required pecking the left key. Similar to the previous condition, four pigeons in the reversal condition, Pigeons 16, 17, 18, and 59, made essentially no final large-reinforcer choices. Pigeons 19, 26, 55, and 58 made a substantial number of these choices.

The mean of the last two conditions (i.e., of the 6-s and the reversal conditions) measures self-control with position bias canceled out (see Logue et al., 1984). Figure 5 shows these means for both initial and final large-reinforcer choices. Results are shown for each pigeon. Initial large-reinforcer choices were greater than final large-reinforcer choices in each case except for Pigeon 55, but the size of this difference varied among pigeons.

Table 3 compares the percentages of the

Fig. 5. The mean number of initial (blank bars) and final (shaded bars) large-reinforcer choices during the 6-s condition and the reversal condition for each subject. The vertical lines indicate one standard error above and below the mean.

initial and final large-reinforcer choices over the last two conditions in the present experiment with the percentages of large-reinforcer choices in comparable conditions in the experiments of Mazur and Logue (1978) and Logue et al. (1984). These latter experiments used procedures similar to the one used here except that both keys were unlit and ineffective during the reinforcer delays. When the initial large-reinforcer choices in the present experiment were compared with

the large-reinforcer choices in the other experiments, the pigeons in the present experiment did not differ significantly from the subjects exposed to fading procedures in the previous experiments. The behavior of the present subjects did, however, differ significantly from that of a control group not exposed to fading (Mazur & Logue, 1978). In contrast, the final large-reinforcer choices in the present experiment differed significantly from the experimental group of Mazur and Logue (1978) and from the initial large-reinforcer choices in the present experiment (see Logue & Mazur, 1981; Logue et al., 1984, and Mazur & Logue, 1978, for previous similar uses of *t* tests).

DISCUSSION

The present experiment used a fading procedure that involved progressive exposure to longer delays, with opportunity for changes of choice and for alternative responses during the delays. If initial large-reinforcer choices are examined, the pigeons

Table 3

Comparisons of the mean percentage of large-reinforcer choices in the present and previous experiments.

Experiments for Comparison	Comparison with Present Experiment	
	Initial Choices	Final Choices
Fading		
Mazur & Logue (1978) (<i>M</i> = 55.6, <i>SE</i> = 16.6, <i>N</i> = 4)	<i>t</i> (10) = -1.30	<i>t</i> (10) = -2.30*
Logue et al. (1984) (<i>M</i> = 33.9, <i>SE</i> = 5.9, <i>N</i> = 7)	<i>t</i> (13) = .59	<i>t</i> (13) = -1.35
Present Experiment		
Initial Choices (<i>M</i> = 38.4, <i>SE</i> = 5.1, <i>N</i> = 8)	—	<i>t</i> (8) = 3.14*
Final Choices (<i>M</i> = 21.8, <i>SE</i> = 6.6, <i>N</i> = 8)	<i>t</i> (8) = 3.14*	—
No Fading		
Mazur & Logue (1978) (<i>M</i> = 2.6, <i>SE</i> = 2.2, <i>N</i> = 4)	<i>t</i> (10) = 4.83**	<i>t</i> (10) = 1.98

Note. Paired *t* tests were used to compare the initial with the final choices in the present experiment; all other comparisons used unpaired *t* tests.

p* < .05 *p* < .01

demonstrated a relatively high level of self-control over the last two conditions. However, if final large-reinforcer choices are examined, the number of large-reinforcer choices decreases to less than 10% of all choices for three of the eight pigeons (Pigeons 17, 18, and 59, see Figure 5). The differences between the initial and the final large-reinforcer choices are consistent with the Ainslie (1974), Green et al. (1981), and Rachlin and Green (1972) findings that pigeons show more self-control when given an earlier, as compared with a later, opportunity to choose the large, more-delayed reinforcer. At least some pigeons that chose the large reinforcer when it was delayed for 6 s later switched to the small reinforcer when they had the opportunity to do so. The pigeons in the last two conditions (6-s and reversal) of Logue et al's (1984) and Mazur and Logue's (1978) experiments might have shown somewhat less self-control had they been given the opportunity to change their choices (see Table 3).

The negative correlations between the initial large-reinforcer choices and the probabilities of changing an initial large-reinforcer choice (Table 2) show that both the tendency to make an initial choice of a large reinforcer and the tendency to change that choice can be used as measures of self-control. However, these correlations were calculated only for pigeons that made at least some changes of choice; they do not apply to other pigeons.

The high positive correlations between large-reinforcer choices and rates of response on the ineffective key during the large-reinforcer delays (see Table 1 and Figure 4) are consistent with Grosch and Neuringer's (1981) finding that activity during the waiting period can facilitate waiting. The correlational nature of the present analyses does not allow determination of the direction of causation—whether responses during the reinforcement delay produced better self-control or vice-versa. However, it should be noted that, unlike Grosch and Neuringer's experiment with pigeons, responses on the ineffective key during the large-reinforcer

delays occurred here even though they were independent of any consequences. Mischel and Ebbesen (1970), working with children, observed that some subjects who are better at self-control perform alternative responses during the large-reinforcer delay periods, even though there are no explicit consequences contingent upon doing so.

It is not clear to what extent stimulus generalization of a tendency to peck one of the initial choice keys, and/or consequences at the end of the delay period, and/or auto-shaped activity during the delay period, may have adventitiously affected delay-interval responding and the correlations obtained here. Future research might investigate these factors by varying the present procedure. For example, a stimulus-generalization explanation of the pecks on the ineffective key during the large-reinforcer delays could be explored by illuminating a third key of a different color during the large-reinforcer delays, instead of illuminating the key that delivers the large reinforcer.

The procedure used here also produced large intersubject differences in pigeons' self-control (see Figures 2 and 3). Large intersubject differences are a general finding in laboratory experiments on self-control (e.g., Ainslie, 1974; Grosch & Neuringer, 1981; Logue & Mazur, 1981; Logue et al., 1984). Unidentified variables are contributing to the control of behavior in these situations and many variables remain to be investigated.

In summary, the present experiment shows that some pigeons can be trained to show self-control even when they can change their choice at any point during the large-reinforcer delays. Such an opportunity does, however, decrease the number of large reinforcers that are actually received. Self-control may be enhanced by also giving the pigeons the opportunity to make an alternative response during the large-reinforcer delays.

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