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COMMITMENT USING PUNISHMENT

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Experimental parameters were adjusted so that pigeons' pairwise choices among three alternatives reflected the following order of preference: (a) a smaller-sooner reinforcer, (b) a larger-later reinforcer, and (c) the smaller-sooner reinforcer followed by a punishment (consisting of an extended blackout period). After this order of preference was established, the pigeons were exposed to a two-link, concurrent-chain-like choice procedure. One terminal link consisted of a choice between the smaller-sooner and the larger-later reinforcer; the other terminal link was identical to the first except that the smaller-sooner reinforcer was followed by blackout punishment. The pigeons' preference (in their initial-link choice) for the terminal link with the punished smaller-sooner alternative increased as the delay between the initial and terminal links increased. By choosing this terminal link, the pigeons are said to have "committed" themselves to obtaining the larger-later reinforcer. However, unlike prior studies of commitment (e.g., Rachlin & Green, 1972), it was still possible after making the commitment for the pigeons to choose the smaller-sooner reinforcer and undergo the punishment. The pigeons did in fact occasionally make this highly deleterious choice.

Key words: commitment, choice, self-control, punishment, concurrent chain, key peck, pigeon

Hyperbolic time discounting (Chung & Herrnstein, 1967) implies that preference between a smaller-sooner (SS) reward and a larger-later (LL) reward may reverse over time (Ainslie, 1992). Equation 1 (expressing discounted value as a hyperbolic function of delay) has been found by Mazur (1987) to describe pigeons' choices among delayed rewards of various amounts:

$$v = V/(1 + kD). \quad (1)$$

Equation 1 expresses discounted value (v) as a function of delay (D) and undiscounted value (V). The parameter k represents degree of discounting. Suppose that (with $V_{LL} > V_{SS}$; $D_{LL} > D_{SS}$; $k > 0$) $v_{SS} > v_{LL}$. Then adding a constant (ΔD) to both D_{SS} and D_{LL} must, as ΔD increases, eventually reverse the values of the alternatives ($v_{LL} > v_{SS}$).

As an illustration of such a reversal, Rachlin and Green (1972) found that food-deprived pigeons strongly preferred an immediate 2-s food reinforcer followed by a 6-s blackout (SS) to a 4-s blackout followed by a 4-s food reinforcer (LL). Because the overall rate of the preferred SS reinforcer was half that of the LL reinforcer, the pigeons effectively lost half of the possible food in exchange for 4 s less delay between choice and reinforcement. This preference was labeled *lack of self-control* or *impulsiveness.* Equation 1 predicts, however, that preference will reverse if a sufficient interval (ΔD) is added to the delays of both reinforcers. Using the commitment paradigm diagrammed in Figure 1a, Rachlin and Green (1972) increased ΔD and found a shift in preference from SS to LL as predicted by Equation 1. The pigeons strongly preferred SS to LL. However, when they chose between a delay (ΔD) followed by a choice between SS and LL (the upper branch in Figure 1a) and the same delay (ΔD) followed by a forced choice of LL (the lower branch in Figure 1a), they chose the forced-choice alternative. By initially choosing the forced-choice alternative, the pigeons were committed to LL. As ΔD increased, the pigeons more frequently committed themselves to obtaining LL.

The Rachlin–Green (1972) commitment procedure models certain everyday-life human self-control situations. A child, for example, may prefer one cookie now to two cookies tomorrow ($v_{SS} > v_{LL}$; $D_{SS} = 0$; $D_{LL} = 1$ day) but nevertheless may prefer two cookies 11 days from now to one cookie 10 days from now ($v_{LL} > v_{SS}$; ΔD = 10 days). If the child were initially offered the latter choice (two cookies in 11 days vs. one cookie in 10 days),

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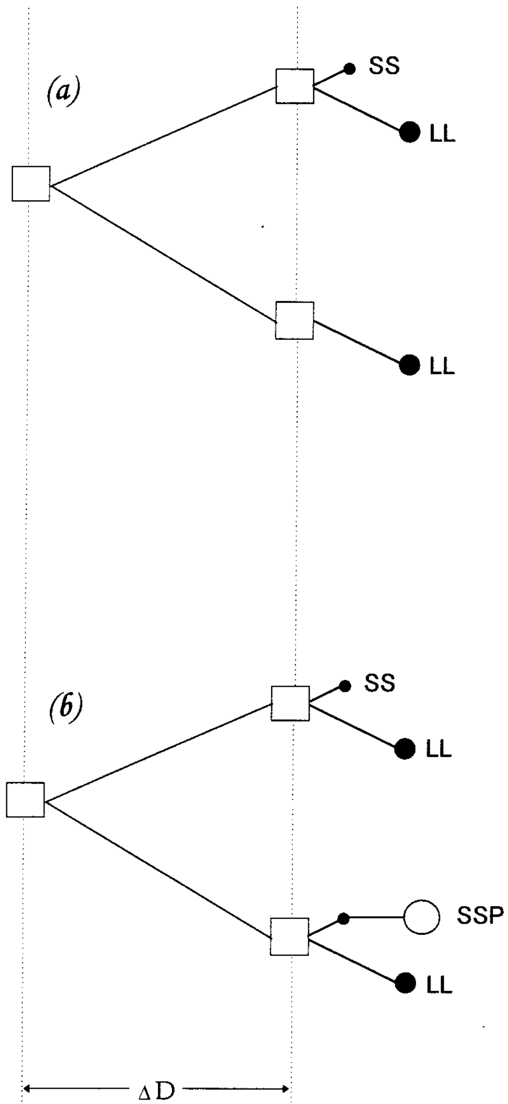

Fig. 1. (a) Schematic diagram of the commitment procedure used by Rachlin and Green (1972). The pigeon prefers the smaller-sooner (SS) reinforcer to the larger-later (LL) reinforcer. The addition of an equivalent delay (ΔD) before both reinforcers leads to a reversal in preference. The LL reinforcer, however, will be obtained only if a commitment is made that leads to the lower branch. (b) Schematic diagram of the procedure used in the present experiment. The pigeon prefers the SS reinforcer to the LL reinforcer. If the commitment is made (i.e., choose the lower branch), then the pigeon is presented with a choice between the LL reinforcer and the SS reinforcer followed by a blackout punishment (SSP).

the two rewards being fixed in time (the dates of the rewards being fixed), and then the child were offered the opportunity to reconsider the choice each day (as ΔD decreased), a day would inevitably come when the child's preference would reverse, when the smaller reward would be preferred, chosen, and obtained. However, if at the point of the initial choice the child could somehow arrange that there would be no opportunities to reconsider, the child would obtain the initially preferred two cookies.

The procedure diagrammed in Figure 1a can commit the subject irrevocably to LL. But commitment in everyday human life is rarely so rigid. Contracts, for instance, do not ordinarily prevent violation so much as impose penalties for violation. Practical self-control commitment techniques generally offer a way out. The alcoholic who takes the drug Antabuse®, for instance, is committed not to drink alcohol only in the sense that after taking the drug (the commitment response) and then drinking alcohol, an extremely painful reaction is produced; drinking is punished but not absolutely prevented by the commitment response.

The present experiment attempts to model such commitment with pigeons using punishment and the procedure diagrammed in Figure 1b. Choice between SS and LL (the upper branch) results in impulsive responding, as was the case in the Rachlin–Green (1972) experiment (Figure 1a). In Figure 1b, the lower branch differs from the upper solely by virtue of the punisher (consisting of an extended blackout period) following the SS alternative. Choice of the lower branch would be explicable only in terms of commitment to LL.

METHOD

Subjects

Five male White Carneau pigeons were maintained at 80% to 85% of free-feeding body weights via supplemental feedings of Purina® Pigeon Checkers following daily experimental sessions. Water and grit were always available in their home cages. Pigeons 2 and 3 were naive at the beginning of the experiment; Pigeons 21, 30, and 32 had previous experience pecking response keys for 45-

mg pellets. All pigeons were autoshaped to peck red, green, and yellow response keys. A 6th pigeon (31) never completed Phase 1 of the experiment and was dropped from further participation.

Apparatus

A standard Coulbourn Instruments modular test cage, approximately 25 cm wide, 28 cm long, and 30 cm high, was enclosed in a sound- and light-attenuating chamber equipped with a ventilating fan. There was a houselight located at the top of the center of the front panel with its light deflected upward. The front panel also contained three response keys, each 2.5 cm in diameter with its center located 6.5 cm from the ceiling. The middle key was 8.5 cm from the left and right keys. The keys could be illuminated from behind by colored lights.

Effective key pecks required a force of approximately 0.2 N and produced a feedback click by operating a relay. Food reinforcement was access to mixed grains delivered from a hopper located below the middle key and 2.54 cm from the grid floor. During reinforcement, the hopper was illuminated with white light, and the houselight and keylights were extinguished. A computer located in an adjoining room arranged experimental events and recorded data using the MED Associates MED-PC® programming notation.

Procedure

There were two phases to the experiment. In Phase 1, we determined the blackout-duration and food-amount values to be associated with the red, green, and yellow keys that would be used in Phase 2. The outcome associated with the red key was an SS food reward. The outcome associated with the green key was an LL food reward. The outcome associated with the yellow key was the SS food reward followed by a long postreinforcement blackout (SSP). Phase 2 was the experiment proper in which a concurrent-chain-like procedure was used. The delay from the initial link to the terminal link (ΔD) was varied. The left terminal link (henceforth called the unpunished terminal link) offered a choice between the SS and LL outcomes, whereas the right terminal link (henceforth called the punished terminal link) offered a choice between the LL and SSP outcomes (Figure 1b). Sessions were conducted daily.

Phase 1. Each daily session consisted of 48 trials. On a trial, either the SS and LL keys were both illuminated or the LL and SSP keys were both illuminated. On the first eight trials, the pigeon was forced to experience the outcome associated with each of the keys. Specifically, the SS and LL keys were illuminated on four trials. On two of these trials, three responses to the SS key (fixed-ratio [FR] 3 schedule) would produce its outcome, and on the other two trials, three responses to the LL key would produce its outcome. Similarly, the LL and SSP keys were illuminated on four trials. On two of these trials, three responses to the LL key would produce its outcome, and on the other two trials, three responses to the SSP key would produce its outcome. Which pair of keys was presented on a given trial, and which of the colors was effective on that particular trial, were determined quasi-randomly. These eight trials were followed by 40 trials, 20 of which presented the SS and LL keys and the other 20 of which presented the LL and SSP keys. The pigeon was free to choose between the pair of colors presented on these trials. Outcomes were delivered according to independent FR 3 schedules.

The initial value for the SS outcome was 1 s of blackout followed by 2 s of food; for LL, it was 4 s of blackout followed by 6 s of food; for SSP, it was 1 s of blackout followed by 2 s of food followed by 30 s of blackout. The blackout and food durations were manipulated in this phase until the pigeon showed a consistent and strong preference for SS over LL and also showed a consistent and strong preference for LL over SSP. The criteria for a consistent and strong preference required that the food and blackout values were in effect for a minimum of 10 days and that the pigeon chose SS over LL and chose LL over SSP on more than 80% of the trials during the last 5 days. For Pigeons 21, 30, and 32, this phase took under 60 sessions; for Pigeons 2 and 3, it took over 100 sessions to determine the food and blackout values. Pigeon 31 never attained criteria and was dropped from the experiment. The final values for each of the three outcomes (SS, LL, and SSP) for each pigeon are given in Table 1.

Phase 2. A concurrent-chain-like procedure

Table 1

Food and blackout durations used in the terminal links for each pigeon.

Pigeon	Terminal-link response key SS (red)	LL (green)	SSP (yellow)
2	1-s blackout then 2-s food	4-s blackout then 7-s food	1-s blackout, then 2-s food, then 60-s blackout
3	1-s blackout then 2.5-s food	6-s blackout then 8-s food	1-s blackout, then 2.5-s food, then 240-s blackout
21	1-s blackout then 1.4-s food	4-s blackout then 6-s food	1-s blackout, then 1.4-s food, then 60-s blackout
30	1-s blackout then 2-s food	8-s blackout then 6-s food	1-s blackout, then 2-s food, then 90-s blackout
32	1-s blackout then 2-s food	4-s blackout then 6-s food	1-s blackout, then 2-s food, then 75-s blackout

was used in Phase 2. There were eight forced-choice trials followed by 40 free-choice trials. At the beginning of a choice trial (i.e., during the initial link of the chain) both the left and right keys were transilluminated with white light. Entry to the terminal links was on independent FR 3 schedules. Three initial-link key pecks on the left key led to a delay period, during which both response keys were darkened but the houselight remained on, followed by the onset of the left key illuminated red and the middle key illuminated green. Three pecks at the red or green key produced different combinations of food reinforcement and blackout. As in Phase 1, pecks on the red key led to an SS reward (i.e., 1-s blackout followed by a small amount of food), and pecks on the green key led to an LL reward (i.e., a longer blackout followed by a larger amount of food). After the blackout-food period, the initial-link keys (left and right) were reilluminated with white light and a new trial began.

Three initial-link key pecks on the right key led to the same delay period (during which both response keys were darkened but the houselight remained on), followed by the onset of the right key illuminated yellow and the middle key illuminated green. Three pecks at the yellow or green key produced different combinations of food reinforcement and blackout. As in Phase 1, pecks on the yellow key led to the SS reward, except that the food was now followed by a relatively long blackout period during which all lights in the chamber were extinguished. Pecks on the green key led to the LL reward (i.e., a blackout followed by the larger amount of food). After the food-blackout period, the initial-link keys (left and right) were reilluminated with white light and a new trial began.

The eight forced-choice trials were identical to the free-choice trials except that the FR 3 schedule during the initial link was effective on only one key. There were four trials in which the three pecks were required on the left initial-link key and four in which they were required on the right initial-link key, determined in a quasi-random fashion. These forced-choice trials ensured daily familiarity with the delay values and with the outcomes from both terminal links.

The delay from the initial link to the onset of the terminal link (ΔD) was varied across conditions for each pigeon. During the delay, the response keys were darkened, but the houselight remained illuminated; this distinguished the prereinforcement delay period (ΔD) from the postreinforcement blackout. Each delay was in effect for a minimum of 14 sessions and until choice responses in the initial link appeared stable by visual inspection, or for a maximum of 50 sessions. The average number of sessions per condition was 21. (The delays studied and the order in which the pigeons experienced those delays are given in Table 3 below.)

RESULTS

Phase 1

As noted in the Procedure, food and blackout durations were varied for each pigeon until it consistently and strongly preferred SS to LL and LL to SSP during pairwise presentations. Table 2 presents for each pigeon the mean percentage of choices of SS when presented with the SS-LL choice and the mean percentage of choices of LL when presented with the LL-SSP choice. These data are derived from the last five sessions of Phase 1.

Phase 2

On those occasions when the pigeons selected the unpunished terminal link (the up-

Table 2

Results from Phase 1: Mean percentage of choices of smaller-sooner (SS) reward over larger-later (LL) reward, and of LL reward over SS reward followed by punishment (SSP). SS was signaled by a red key, LL by a green key, and SSP by a yellow key.

Pigeon	SS (red) vs. LL (green)	LL (green) vs. SSP (yellow)
2	80	100
3	96	82
21	98	99
30	100	100
32	99	99

Table 3

Results from Phase 2, terminal link: Mean percentage of choices of smaller-sooner (SS) reward over larger-later (LL) reward during the unpunished terminal link, and of LL reward over SS reward followed by punishment (SSP) during the punished terminal link. The order in which the delays (ΔD, in seconds) were studied is given for each pigeon in parentheses. Replications are in brackets.

Pigeon	Delay	SS vs. LL (unpunished link)	LL vs. SSP (punished link)
2	5 (4)	100	86.7
	15 (1)	100	65.5
	30 (2)	100	76.7
	45 (3)	100	55.1
3	2 (4)	100	85.5
	15 (1)	100	81.5
	30 (2)	100	19.7
	45 (3)	100	99.0
21	0.5 (2)	100	88.2
	2 (1)	100	94.9
	[2] (6)	[100]	[100]
	10 (3)	77	46.2
	30 (4)	86.5	49.7
	60 (5)	66.7	34.5
30	0.5 (5)	100	100
	1 (6)	100	100
	2 (4)	100	95.4
	5 (3)	100	86.8
	10 (2)	100	80.8
	15 (1)	—[a]	74.5
	[15] (7)	[100]	[50.8]
32	0.5 (3)	100	92.3
	2 (1)	100	95.1
	10 (2)	100	98
	20 (4)	100	98.6

[a] The unpunished terminal link was never chosen by Pigeon 30 in this delay condition.

per branch in Figure 1b) and were therefore presented with the SS and LL keys, 4 of the pigeons chose SS exclusively during the final five sessions of each delay. Only Pigeon 21 chose SS on fewer than 100% of its opportunities to do so, and this was only at the three longest delays (see Table 3).

When the pigeons selected the punished terminal link (the lower branch in Figure 1b) and were therefore presented with the LL and SSP keys, preference was below 100% for LL over SSP (see Table 3). At some of the long delays, in fact, 2 pigeons (3 and 21) decreased choice of LL relative to SSP to below 50%. Specifically, Pigeon 3 chose LL over SSP on only 19.7% of the trials when the delay was 30 s (although it chose LL on over 80% of the trials at delays of 2 s, 15 s, and 45 s). Although Pigeon 21 chose LL on over 88% of the trials when the delay was 0.5 s and 2 s, it chose LL on fewer than 50% of the trials at delays of 10, 30, and 60 s. For the other 3 pigeons, at all delays LL was chosen over SSP on more than 50% of the trials. More specifically, Pigeon 2 averaged 71% choice of LL, Pigeon 30 averaged 84%, and Pigeon 32 averaged 96% (see Table 3).

With regard to behavior during the initial link, the pigeons generally increased choice of the punished terminal link (i.e., made more commitment responses) as ΔD increased. Figure 2 shows, for each pigeon, the mean percentage of initial-link commitment responses (i.e., percentage of responses to the key leading to the punished terminal link) during the free-choice trials from the final five sessions at each value of ΔD. Pigeon 2 was the only major exception to the increase in commitment responses with delay. That pigeon showed a very high preference for the punished terminal link at its lowest delay value (5 s), perhaps because this delay followed three conditions in which delay and commitment responses had been increasing.

Table 4 presents mean absolute initial-link response rates from the final five sessions of each delay condition. As delay increased, response rate generally decreased on the initial-link key leading to the unpunished terminal link and increased on the initial-link key leading to the punished terminal link. The largest deviation from this pattern are the data from Pigeon 21, for which rate decreased on both keys. Figure 3 shows time spent in the initial link as a function of delay for each pigeon. As delay increased and the time to rewards therefore increased, the pigeons generally

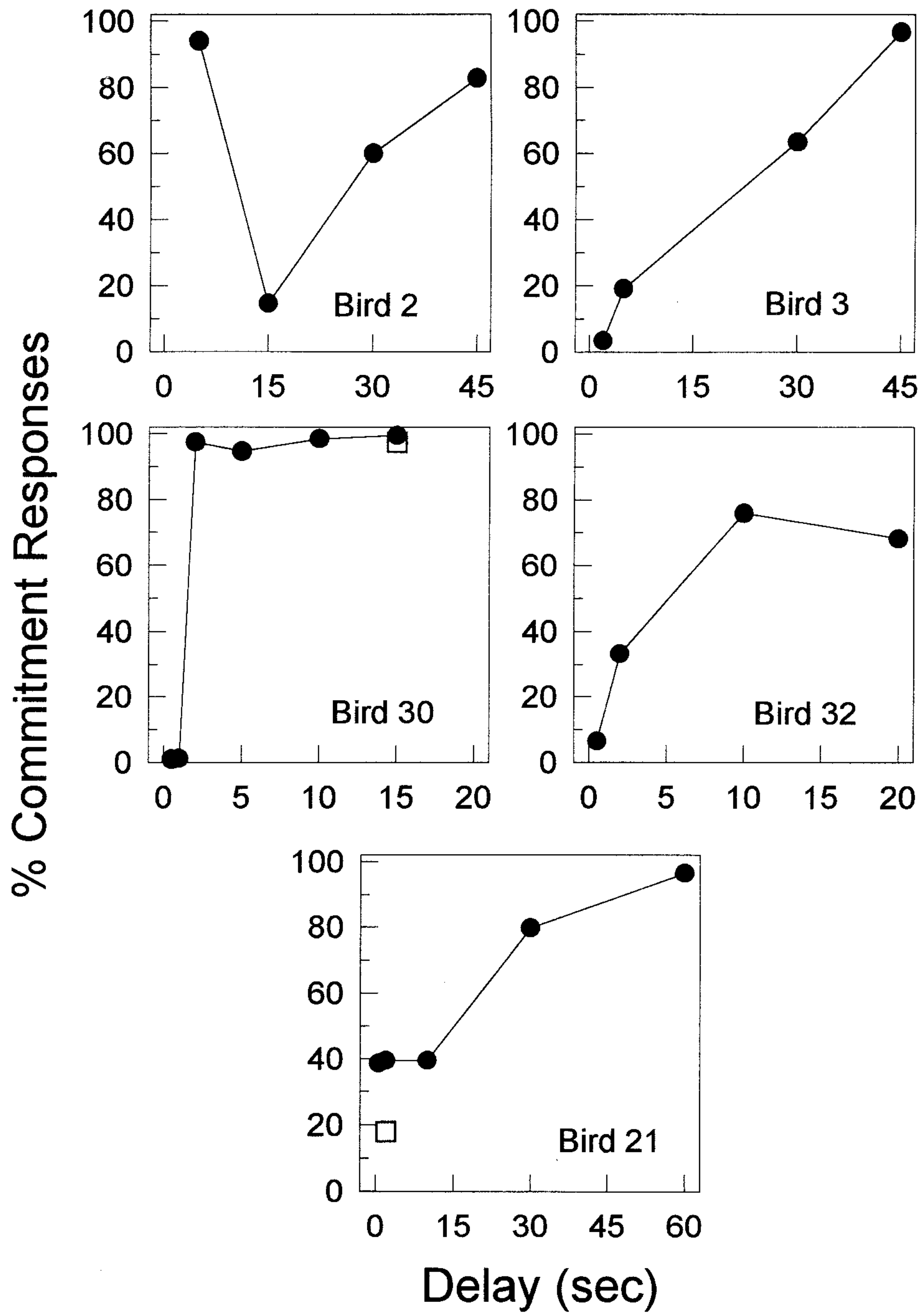

Fig. 2. Mean percentage of initial-link commitment responses (percentage of responses on the key leading to the punished terminal link) for each pigeon as a function of the delay (ΔD). Open squares represent replications. Note the different abscissa scales.

Table 4

Absolute initial-link response rates (responses per minute). Data are the mean of the final five sessions of each delay for each pigeon. Replications are in brackets.

Pigeon	Delay (in seconds)	Initial-link response rates Left	Right
2	5	12.4	194.3
	15	16.8	2.9
	30	26.5	39.6
	45	7.1	34.3
3	2	337.1	12.2
	15	49.1	11.7
	30	10.3	18.0
	45	1.2	36.1
21	0.5	210.8	132.6
	2	193.5	126.3
	[2]	[274.9]	[60.3]
	10	126.4	82.6
	30	5.2	20.6
	60	1.1	28.3
30	0.5	518.8	5.2
	1	456.9	6.2
	2	8.6	340.2
	5	14.9	267.0
	10	2.4	162.3
	15	0.5	97.7
	[15]	[2.6]	[95.1]
32	0.5	325.2	22.6
	2	190.8	95.6
	10	33.9	106.3
	20	20.0	42.6

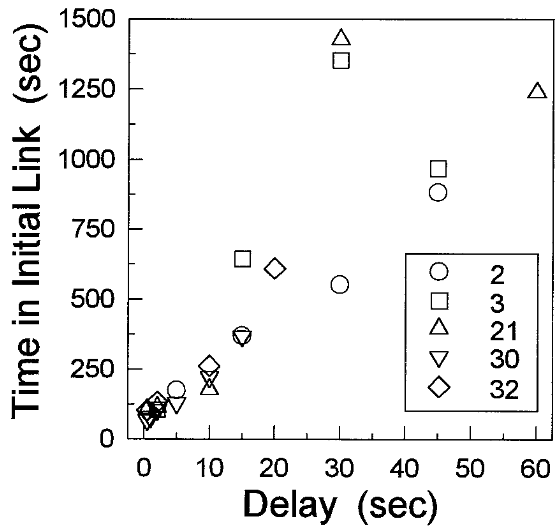

Fig. 3. Time spent in the initial link as a function of the delay (ΔD) between the initial link and the terminal links. Data are the means of the final five sessions at each delay for each pigeon.

took longer to complete the initial-link FR schedule.

DISCUSSION

Preference for the SS reinforcer over the LL reinforcer made it impossible for 4 of the 5 subjects (and unlikely for the 5th subject, Pigeon 21) to obtain LL by choosing the unpunished terminal link. The only avenue by which LL could be obtained was through choice of the punished terminal link. The pigeons chose the punished terminal link more frequently as the overall delay to both reinforcers (ΔD) increased, as predicted by Equation 1. To this extent the present experiment replicated the results of Rachlin and Green (1972).

The only difference between the two terminal links in this experiment was the presence of punishment in the generally preferred terminal link. Why did the pigeons choose one terminal link that differed from the other only by virtue of the fact that it contained the possibility of punishment? The value of the punished alternative was that, at the point of initial-link choice, punishment prevented the pigeons from later choosing the SS reinforcer and enabled them to obtain the LL reinforcer, which, at the initial point of choice, they preferred. In other words, by choosing the punishment alternative the pigeons committed themselves to obtaining the larger reinforcer.

The commitment observed in this experiment differed from that observed by Rachlin and Green (1972) in that it could be broken, at the cost of punishment (in this case, a drastic reduction of overall reinforcement rate imposed by a blackout ranging from 60 s to 240 s). The pigeons frequently availed themselves of this way out, especially at the longer delays. Perhaps the most interesting result of this experiment is that the commitment *was* broken. The pigeons frequently chose the commitment alternative and then defected from commitment by choosing the punished SS reward anyway (when they could have obtained this reward without punishment). Pigeon 21 (the same pigeon that occasionally chose LL over SS in the unpunished terminal link) chose SSP over LL more frequently than not at delays of 10 s to 60 s (see Table 3). For the other pigeons, the present procedure was a fairly effective way to obtain the larger reinforcer (although not as effective as the complete commitment used in the Rachlin & Green, 1972, experiment).

The fact that all pigeons occasionally chose commitment during the initial link and then, during the terminal link, chose SSP over LL is reminiscent of human self-control phenomena. Alcoholics occasionally take Antabuse® and then drink alcohol anyway, accepting the inevitable punishment (Davison & Neale, 1994). In other human affairs, contracts (ranging from health club memberships to marriage) are often made in an effort at self-control by commitment and then broken with more or less painful consequences. Given pigeons' very strong preference for the SS reinforcer when it was immediately available, it is perhaps surprising that they did not defect more often. But commitment followed by defection would be an unstable behavioral pattern because commitment could be maintained only by the LL reinforcer.

The present procedure is like the soft commitment procedure of Siegel and Rachlin (1995), in that both allow defections. In the Siegel and Rachlin experiment, pecks on one colored key produced SS, and pecks on the other colored key produced LL. When only a single peck to either key was required to earn the outcome, the pigeons strongly preferred SS. However, when the outcome was contingent on the completion of 31 pecks (the first 30 pecks distributed in any way on the two keys), the pigeons frequently began pecking the LL key, kept pecking that key for 31 pecks, and obtained LL. That is, once having started to peck the LL key, the pigeons did not defect.

However, the present procedure, unlike the Siegel and Rachlin (1995) procedure, explicitly punished defection. In the Siegel–Rachlin experiment, the penalty for defection from commitment was only the cost of disrupting a rigid behavioral pattern. The explicit punishment imposed in the present experiment was generally more effective in initiating commitment (60% to 97% at delays greater than 15 s) than was an FR pattern in the Siegel–Rachlin experiment (45% to 75% initiations of commitment). However, in that experiment, once the FR pattern (leading to an LL reinforcer) was begun, pigeons virtually never defected. Perhaps the reason for the rigidity of the FR pattern was that the cost of pattern disruption must by definition have been immediate (and the SS reinforcer was obtained only after the ratio was completed), whereas in the present experiment punishment was delayed from the point of defection (and the SS reinforcer was immediate).

It is not entirely clear, however, why SSP tended to be chosen more as delay increased. One possible reason is that as delay increased, the value of both alternatives decreased so much that the pigeons became relatively indifferent between them. A vivid indication of the common devaluation due to increases of delay (ΔD) was the sharp and consistent increase in time to complete the initial-link FR 3 by all pigeons as a function of the delay imposed immediately afterwards (Figure 3). But ΔD occurred *before* either terminal link and therefore should have had no effect on those choices. It might be thought that increases in ΔD could act, not directly on the value of the reinforcer currently being chosen, but on the value of subsequent reinforcers. But as ΔD increases, the influence of subsequent reinforcers on current choice should become less, not more.

A more likely cause of the increase in choice of SSP over LL at long delays might be a devaluation of the punishment itself. Several lines of evidence (e.g., Fantino & Davison, 1983; Gibbon, 1977) point to a relative rather than absolute effect of reinforcement strength. As delay increased, the punishment used in this experiment (long-duration blackout) might have become less and less aversive relative to the overall situation. As ΔD increased, the constant-duration blackout punisher may have decreased reinforcer strength proportionally less and less. In other words, although delay *prior* to a reinforcer discounts reinforcer strength as Equation 1 predicts, blackout punishment *subsequent* to a reinforcer may discount the reinforcer only proportionally to its reduction of overall reinforcement rate.

To see how this entirely speculative supposition would affect the calculated values of the alternatives in the present experiment, let us assume that a reinforcer (V) is discounted by blackout punishment according to the following:

$$v_p = V/(1 + k'BO/D^*), \qquad (2)$$

where v_p is discounted value, k' is a constant, D^* ($= BO + \Delta D$) is the expected delay to the subsequent reinforcer, and BO is the segment of that delay imposed by choice of that alternative (i.e., the punishment). In Equation 2, if $BO = 0$, then $v_p = V$. Combining Equations 1 and 2,

$$v = V/(1 + kD)(1 + k'BO/D^*). \quad (3)$$

Recall that D is the delay prior to the next reinforcer, whereas D^* is the delay subsequent to the next reinforcer. Simplifying further, suppose that V is the amount of reinforcement (hopper duration), and that in the present experiment all delays subsequent to a reinforcer other than BO and ΔD are negligible. Then, if $k = 1$ and $k' = 2$ (chosen arbitrarily), SS = 2-s immediate food, LL = 4-s food delayed by 4 s, and SSP = 2-s immediate food followed by 30-s blackout: $v_{SS}(\Delta D = 0; BO = 0) = 2$; $v_{LL}(\Delta D = 0; BO = 0) = 0.8$; $v_{SSP}(\Delta D = 0; BO = 30 \text{ s}) = 0.67$. This is the order of values established in Phase 1. As ΔD increases, v_{SSP} at the beginning of the initial link sinks sharply. For example, with $\Delta D = 10$ s, $v_{SSP}(\Delta D = 10 \text{ s}; BO = 30 \text{ s}) = 0.073$. However, in the terminal link this value rises again. In the terminal link, the additional delay, ΔD, does not enter into the calculation of D in Equation 1 (because the initial link has passed), but it does enter into the calculation of D^* in Equation 2 (because it still lies between reinforcers). Now $v_{SSP} = 0.8$, which is equal to v_{LL} in the terminal link. Consequently, although pigeons may prefer LL to SS to SSP in the initial link when there is a significant ΔD and thus choose the commitment option, they may be indifferent between LL and SSP after the initial link ends, as they occasionally were in this experiment. As ΔD increases (BO remaining constant), the discount due to punishment would be further reduced and, in the terminal link, SSP would actually be preferred to LL, even while LL would still be preferred in the initial link, as we found. According to this speculation, had the punisher been some discrete event like electric shock that did not in itself reduce overall reinforcement rate, the effect of ΔD on choice between SSP and LL would not have been observed. This implication has yet to be tested.

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