

*CONTIGUITY AND CONDITIONED REINFORCEMENT IN
PROBABILISTIC CHOICE*MARGARET A. MCDEVITT, MARCIA L. SPETCH,
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In a baseline condition, pigeons chose between an alternative that always provided food following a 30-s delay (100% reinforcement) and an alternative that provided food half of the time and blackout half of the time following 30-s delays (50% reinforcement). The different outcomes were signaled by different-colored keylights. On average, each alternative was chosen approximately equally often, replicating the finding of suboptimal choice in probabilistic reinforcement procedures. The efficacy of the delay stimuli (keylights) as conditioned reinforcers was assessed in other conditions by interposing a 5-s gap (keylights darkened) between the choice response and one or more of the delay stimuli. The strength of conditioned reinforcement was measured by the decrease in choice of an alternative when the alternative contained a gap. Preference for the 50% alternative decreased in conditions in which the gap preceded either all delay stimuli, both delay stimuli for the 50% alternative, or the food stimulus for the 50% alternative, but preference was not consistently affected in conditions in which the gap preceded only the 100% delay stimulus or the blackout stimulus for the 50% alternative. These results support the notion that conditioned reinforcement underlies the finding of suboptimal preference in probabilistic reinforcement procedures, and that the signal for food on the 50% reinforcement alternative functions as a stronger conditioned reinforcer than the signal for food on the 100% reinforcement alternative. In addition, the results fail to provide evidence that the signal for blackout functions as a conditioned punisher.

Key words: conditioned reinforcement, probabilistic reinforcement, delay-reduction theory, hyperbolic decay model, choice, key peck, pigeons

Conditioned reinforcement has long been central to descriptions of operant contingencies in everyday life (e.g., Skinner, 1953), but the nature of the conditioned reinforcer per se has received little direct attention. When invoked, conditioned reinforcement is most often employed as a convenient way to represent the effects of delayed primary reinforcement (cf. Williams, 1994). Probabilistic reinforcement procedures provide one of the few phenomena that force a separation of the effects of conditioned and primary reinforcement.

In a typical procedure with delayed probabilistic reinforcement (e.g., Dunn & Spetch, 1990; Spetch, Belke, Barnet, Dunn, & Pierce, 1990), pigeons are given a choice between a 100% reinforcement alternative and a 50% reinforcement alternative. A sin-

gle response to the 100% choice stimulus produces a terminal-link stimulus that, after a delay, always leads to food. A single response to the 50% choice stimulus produces one of two terminal-link stimuli that, after a delay, leads to food on half of the trials and blackout on half of the trials. When the terminal-link stimuli on the 50% alternative do not signal the outcomes (i.e., each occurs equally often on food and blackout trials), pigeons show extreme preference for the 100% alternative, as expected. However, when the terminal-link stimuli on the 50% alternative signal the outcomes (i.e., one stimulus always leads to food and the other stimulus always leads to blackout), pigeons show a suboptimal shift (in the sense of reduced rate of reinforcement) in preference away from the 100% alternative (Dunn & Spetch, 1990; Spetch et al., 1990; Spetch, Mondloch, Belke, & Dunn, 1994). When the equal terminal-link delays are relatively long (e.g., 30 s or longer), this shift in preference is maximized, usually resulting in approximate indifference between the two alternatives on average (Spetch et al., 1990).

This research was supported by NSERC Grant OGP0038861 held by Marcia L. Spetch. We thank D. Kelly and S. Reid for their assistance with the research.

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It is important to note that the rate of primary reinforcement is exactly the same in both signaled and unsignaled conditions. The 100% reinforcement alternative always provides food twice as frequently as the 50% reinforcement alternative. It is only the contingency between the 50% terminal-link stimuli and the outcomes that has been altered. Thus, the signaling contingency decreases pigeons' apparent sensitivity to differences between the alternatives in the rate of primary reinforcement. Choice appears to be determined more by the conditioned reinforcement on the two alternatives, and the two more successful models of probabilistic reinforcement focus on conditioned reinforcement in their explanations of this suboptimal preference.

Mazur (1991, 1993, 1995) has proposed that the value of an alternative is a function of the conditioned reinforcing strength of stimuli on the alternative. The strength of a stimulus as a conditioned reinforcer is said to depend on the delay to primary reinforcement in its presence. Thus, the conditioned reinforcer is the intermediary between the choice response and the primary reinforcement and, in most choice procedures, the effects of conditioned and primary reinforcement are indistinguishable. However, it is critical to note that Mazur proposes that the value of an alternative is determined by the strength of the conditioned reinforcer, not the rate of conditioned reinforcement on an alternative. This is a critical distinction in probabilistic reinforcement procedures. Consider the contingencies of a signaled probabilistic reinforcement alternative. As the probability of the food outcome is decreased to 50% on an alternative, the strength of the signal for the food outcome is not altered (i.e., the terminal-link stimulus still signals the same delay to food each time it occurs). Thus, the expectation from Mazur's account is that the choice response for that alternative will be maintained despite the lowered rate of primary reinforcement. This expectation is consistent with the finding of suboptimal choice of the 50% alternative when the outcomes are signaled. In contrast, responding on the 50% alternative is reduced if the outcomes are not differentially signaled during the delay. Here the choice response leads to a stimulus that has weakened strength as a

conditioned reinforcer because it sometimes ends in blackout, so the value of the alternative should be reduced.

Mazur's (1991, 1993, 1995) explanation relies on a traditional description of the strength of the conditioned reinforcer as determined by the parameters of primary reinforcement in its presence. Fantino (1977) proposed an alternative description, that the strength of a stimulus as a reinforcer is a function of the extent to which the stimulus signals an improvement over the existing context. The greater the signaled reduction in the delay to primary reinforcement, the greater the strength of the stimulus as conditioned reinforcer. This orientation provides another explanation for suboptimal choice in probabilistic delay procedures (Dunn & Spetch, 1990; Spetch & Dunn, 1987). If 100% of the choice responses on an alternative are followed by delayed reinforcement, the stimulus that occurs during the delay provides no improvement over the existing context (i.e., when the choice response is a single key peck, the response itself predicts the delay to primary reinforcement). Therefore, the terminal-link stimulus on a 100% alternative may not function as a conditioned reinforcer because it is a redundant cue. However, if only 50% of the choice responses are followed by delayed reinforcement, the stimulus that signals primary reinforcement does provide an improvement over the existing context. When a choice response occurs for the 50% alternative, both food and blackout outcomes are equally likely. The onset of the signal for food, then, is correlated with a reduction in the waiting time to food, relative to the choice component. Thus, the signal for food on the 50% alternative is expected to be a stronger conditioned reinforcer than is the signal for food on the 100% alternative. According to this description, this difference in the value of stimuli that are presented immediately after the choice response reduces the effects of the differences in the rate of the delayed primary reinforcement on the two alternatives.

Although the two models differ with respect to how the delay stimuli acquire reinforcing properties, and these differences lead to conflicting predictions of the details of the suboptimal choice phenomenon, both models point to reinforcement by the delay stim-

ulus as the critical factor in probabilistic reinforcement procedures. The present experiment assesses the efficacy of the delay stimuli as conditioned reinforcers by systematically manipulating the contiguity between the choice response and each delay stimulus, using a method similar to that employed by Belke and Spetch (1994, Experiment 2). In a variation of the signaled percentage-reinforcement procedure, Belke and Spetch separated choice responses from terminal-link stimuli by interposing a 5-s gap between the initial and terminal links. The keylights were dark and inoperative during the gap. It was assumed that the presence of the gap would reduce the effectiveness of the terminal-link stimuli as conditioned reinforcers for the responses that produce them. Belke and Spetch found that the gap produced a strong shift in preference toward the 100% alternative, indicating that immediate presentation of the terminal-link stimuli, contingent on the initial-link response, is important in maintaining suboptimal preference.

In all conditions of the present experiment, one of two concurrently available responses led to food after a 30-s delay (100% reinforcement) and the other response led to either food or blackout after an equal delay (50% reinforcement). Thus, the ratio of primary reinforcement on the 100% alternative to primary reinforcement on the 50% alternative was constant at 2:1 in all conditions, and the rate of reinforcement is maximized by exclusive choice of the 100% alternative. The conditions differed only in the sequence of stimuli during the delays.

In the baseline condition, the delay stimulus on the 100% alternative was presented immediately following the choice response and terminated in the presentation of food. The delay stimuli on the 50% alternative were also presented immediately after the choice response. One 50% stimulus terminated in food and the other terminated in blackout (i.e., the outcomes were signaled by the delay stimuli). This procedure has been the mainstay of the investigations of delayed probabilistic reinforcement and reliably produces suboptimal choice of the 50% alternative (i.e., on average, pigeons fail to show a consistent preference for the 100% alternative) (Dunn & Spetch, 1990; Spetch et al., 1990, 1994).

The present study employed a gap manipulation, but one that differed in several ways from that in the Belke-Spetch (1994) study. First, the presence of the gap in the Belke-Spetch study increased the duration of the terminal link by 5 s. In the present study, the presence of a gap did not alter the duration of the terminal links. This modification maintained a constant delay to primary reinforcement from the choice response, regardless of whether a gap was presented or not. In addition, Belke and Spetch investigated preference in only one condition, in which the gap followed every choice response. The present investigation included conditions in which the gap preceded only one, only two, or all terminal-link stimuli. These additional conditions provided the opportunity for investigating the role of individual terminal-link stimuli in maintaining choice behavior, as well as providing greater differentiation between competing models of choice.

A primary question in the present experiment concerns whether the two alternatives are approximately equivalent in conditioned reinforcement strength, as suggested by Mazur (1991), or whether the 50% alternative provides greater conditioned reinforcement, as suggested by Dunn and Spetch (1990). The relative conditioned reinforcement strength of the two alternatives was assessed by comparing preference in the baseline (no gaps) condition with preference in conditions in which a gap was presented only following choice of the 100% alternative and when a gap was interposed only between choice of the 50% alternative and presentation of the signal for food. If the two alternatives are nearly equivalent in conditioned reinforcement strength, as Mazur's account implies, preference should shift away from the alternative with the gap, and this shift in preference should be approximately equal (but opposite in direction) when the gap is placed prior to the 100% signal for food and when the gap is placed prior to the 50% signal for food. If the signal for food on the 50% alternative is a stronger conditioned reinforcer than the signal for food on the 100% alternative, as Dunn and Spetch predict, there should be a greater shift in preference when the gap is placed prior to the signal for food on the 50% alternative than when it is placed

prior to the signal for food on the 100% alternative.

A second and related question specifically concerns the value of the delay stimulus on the 100% alternative. Mazur's (1991) model implies that the signal for food on the 100% alternative functions as a conditioned reinforcer. Dunn and Spetch (1990), on the other hand, have proposed that this stimulus may fail to acquire conditioned reinforcement properties because it signals no further reduction in the waiting time to food than is already signaled by the 100% choice response. The value of the 100% delay stimulus was measured by the degree to which preference was altered when a gap was presented only following choice of the 100% alternative, relative to the baseline condition. If the signal for food on the 100% alternative functions as a conditioned reinforcer, as Mazur predicts, imposing a gap prior to this stimulus should shift preference toward the 50% alternative. However, if the signal for food on the 100% alternative does not function as a conditioned reinforcer, as Dunn and Spetch predict, imposing a gap prior to this stimulus should not alter preference.

A third question addressed in the present experiment concerns the value of the signal for blackout on the 50% alternative. In Mazur's (1991) model, the signal for blackout has no role, that is, it neither enhances nor detracts from the value of the 50% alternative. An assumption underlying the delay-reduction formulation is that the presence of the signal for blackout is necessary for the enhancement of the value of the signal for food on the 50% alternative, but this account does not clearly specify what the value of the blackout signal itself should be. One possibility that is consistent with Mazur's position is that the blackout signal has no value. Another possibility is that it functions as a conditioned punisher because it signals an increase in the waiting time to food, relative to the 50% choice response. Imposing a gap between choice of the 50% alternative and presentation of the signal for blackout should have no effect on preference if the signal for blackout has no value, whereas it should increase preference for the 50% alternative if the signal for blackout has negative value.

METHOD

Subjects

The subjects were 4 adult Silver King pigeons with extensive experimental histories. They were maintained at approximately 85% of their free-feeding weights by mixed grain obtained during experimental sessions and supplemental feedings of pigeon chow in home cages when necessary. The birds were housed in large individual cages under a 12:12 hr light/dark cycle. Water and grit were freely available in the home cages.

Apparatus

The birds were tested in standard operant conditioning chambers that contained three horizontally aligned pecking keys (2.5 cm in diameter) mounted 23 cm above the floor. The center key was never used in these experiments. Projectors mounted behind the keys were used to illuminate the side keys with colored fields of red, white, yellow, and green. The houselight was mounted above the center key and was shielded to direct the light toward the ceiling. A BRS/LVE grain feeder was mounted below the center key, and a lamp within the feeder illuminated food presentations. A fan provided ventilation and background masking noise. Presentation of stimulus events and recording of responses were accomplished with a microcomputer located in an adjacent room.

Procedure

Prior to exposure to the experimental conditions, each bird was given two or three preliminary training sessions to establish reliable pecking on both side keys when the keys were illuminated with red light (the color subsequently used as the initial-link stimuli). Each bird was then exposed to six experimental conditions in varying orders, as described below.

The basic procedure used for all conditions was a concurrent-chains procedure with 100% reinforcement for one alternative and 50% reinforcement for the other. The houselight was illuminated at all times except during brief blackout periods. During the initial link of the chain, both side keys were illuminated with red light until a single response was made on either key. Completion of this fixed-ratio (FR) 1 requirement resulted in

termination of both initial-link stimuli. In some experimental conditions, this was followed by a 5-s gap, during which all keys were darkened, and then a terminal-link stimulus (i.e., delay stimulus) on the chosen key was presented. In other experimental conditions, a terminal-link stimulus on the chosen key was presented immediately following completion of the initial link. In either case, the terminal-link stimulus ended, independently of responding, 30 s after completion of the initial link. If the 100% alternative was chosen (left key for Birds A103 and 67; right key for Birds 14 and 45), the terminal-link stimulus was always the same color (yellow for Birds A103 and 67; white for Birds 14 and 45), and completion of the terminal link always ended with a 3-s food presentation. If the 50% alternative was chosen, the terminal link sometimes ended with a 3-s food presentation ($p = .5$) and otherwise ended with a 3-s blackout (house light off). The color of the terminal-link stimulus on the 50% side varied depending on whether a food or blackout outcome would follow. The terminal-link stimulus that signaled a food outcome (S+) was white for Birds A103 and 67 and yellow for Birds 14 and 45. The terminal-link stimulus that signaled a blackout outcome (S-) was green for all birds. The initial link was reinstated immediately after the food or blackout outcome. Sessions lasted for 61 cycles or a maximum of 1 hr, and were usually conducted 6 days per week.

The six experimental conditions differed only in whether a gap preceded the onset of one or more of the terminal-link stimuli, as depicted in Figure 1. In the none condition, none of the terminal-link stimuli were preceded by a gap, and in the all condition, all terminal-link stimuli on both sides were preceded by gaps. In the 100% condition, the gap preceded onset of the 100% terminal-link stimulus. In the 50% both condition, the gap preceded onset of both the S+ terminal-link stimulus and the S- terminal-link stimulus on the 50% side. Finally, in the 50% S+ condition, the gap preceded only the S+ stimulus on the 50% side, and in the 50% S- condition, the gap preceded only the S- stimulus on the 50% side. Preference was assessed twice in the none condition. The order of exposure to the conditions and the num-

ber of sessions to stability are shown in Table 1 for each bird.

To ensure that birds experienced the contingencies in effect on both alternatives in each condition, two sessions with a forced-choice procedure were given at the beginning of each condition. Forced-choice trials were identical to choice trials, with the exception that only the 100% key was available during half of the initial links (i.e., the 50% key remained dark and ineffective), and only the 50% alternative was available during the remaining initial links (half of which were food trials and half of which were blackout trials). In addition, all regular sessions began with eight forced-choice warm-up trials. Four of these trials provided access only to the 100% key, and four provided access only to the 50% key (two were S+ trials and two were S- trials). The order of forced-choice trials was randomly determined, and they were excluded from all data collection.

Each bird was exposed to each condition for a minimum of 15 regular sessions and until the bird's choice proportions (number of initial-link responses on the 100% side divided by the total number of initial-link responses) were judged to be stable. Stability was assessed on the 15th session and each session thereafter by dividing the preceding nine sessions into blocks of three sessions. Preference was considered to be stable if the mean choice proportions of these three blocks did not differ by more than .05 and showed neither an upward ($M1 < M2 < M3$) nor a downward ($M1 > M2 > M3$) trend. All data reported are the means of the nine sessions that satisfied these stability criteria. Because preference was assessed twice in the none condition, the average of the two assessments is used for comparison of preference between conditions.

RESULTS

The choice proportions for the 50% alternative in the none, all, 100%, and 50% both conditions are shown for each bird in Figure 2. The average across subjects indicated indifference between the 100% and 50% alternatives in the none condition in which there were no gaps ($M = .55$), although there was considerable variability across subjects. For all 4 birds, choice of the 50% alternative was

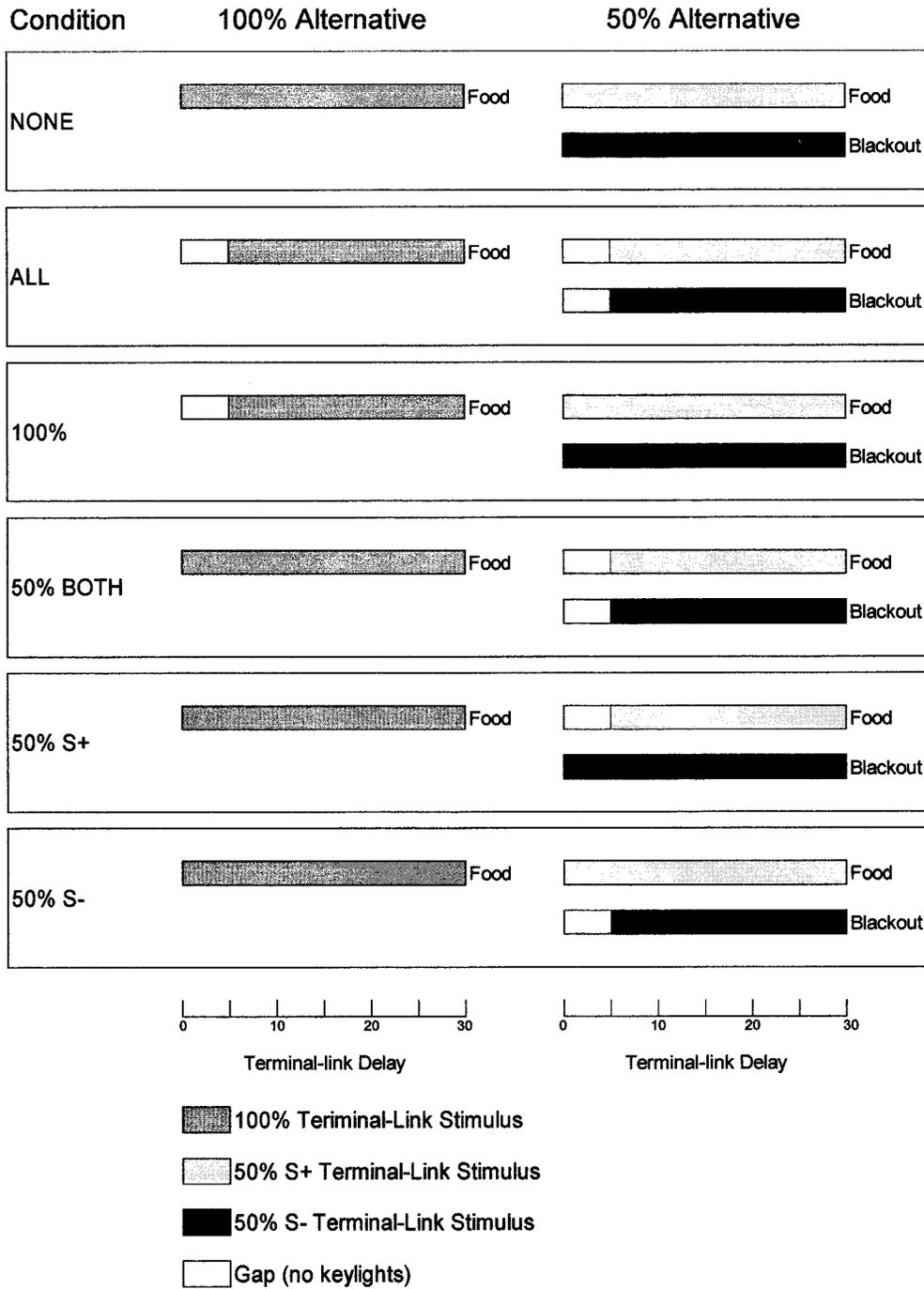


Fig. 1. The sequences of terminal-link stimuli are shown for the 100% alternative and 50% alternative in each condition.

Table 1
Order of exposure to each condition (O) and the number of sessions to stability (S) for each subject.

Condition	A103		14		67		45	
	O	S	O	S	O	S	O	S
None	3	15	3	19	3	21	3	27
None (replication)	7	25	7	33	7	22	7	28
All	4	35	5	26	5	30	6	60
100%	2	16	2	41	1	30	1	25
50% both	1	23	1	15	2	20	2	19
50% S+	6	43	6	24	4	15	4	15
50% S-	5	21	4	19	6	21	5	15

higher in the none, 100%, and 50% S- conditions than in any of the three conditions in which a gap preceded onset of the 50% S+ stimulus (the all, 50% both, and 50% S+ conditions). Figure 3 shows the degree to which the mean choice proportions in the five conditions that included a gap deviated from the baseline preference obtained in the none condition. Relative to the none condition,

preference for the 50% alternative was lower for all subjects in the all condition ($M = .24$), the 50% both condition ($M = .10$), and the 50% S+ condition ($M = .20$). Preference levels in the 100% condition and the 50% S- condition did not systematically differ from the baseline preference in the none condition.

The choice proportions and obtained pro-

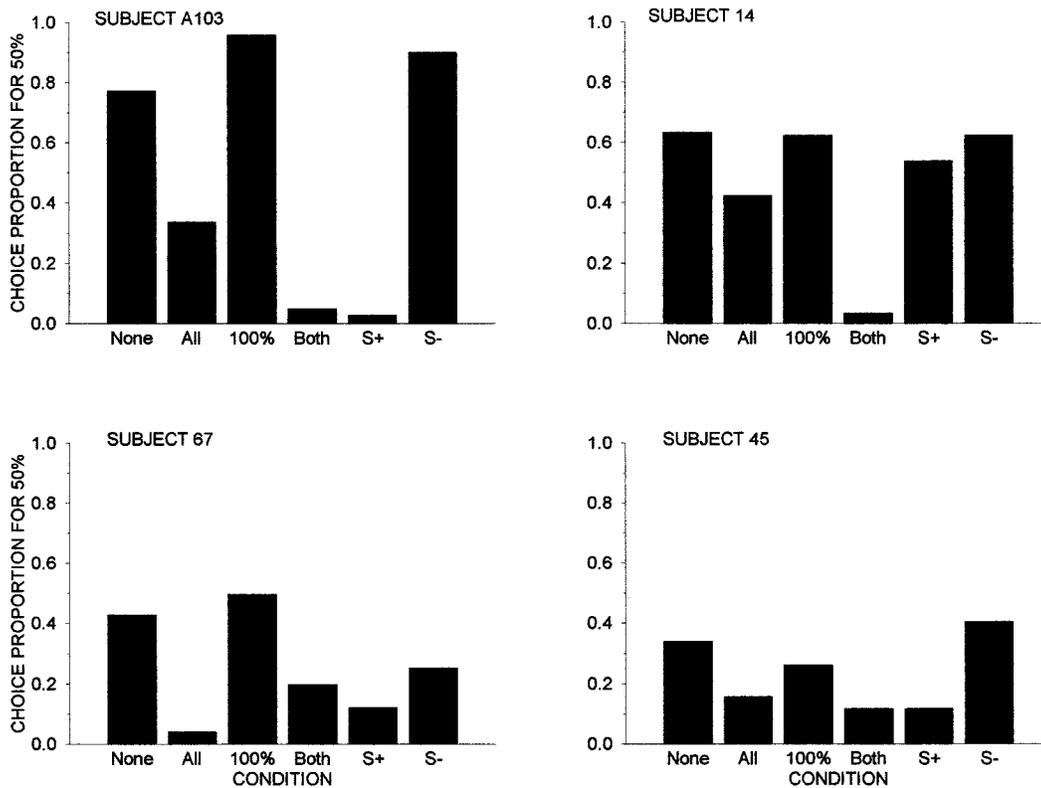


Fig. 2. Choice proportions for the 50% alternative for each bird in all conditions (averaged over both assessments of preference in the none condition).

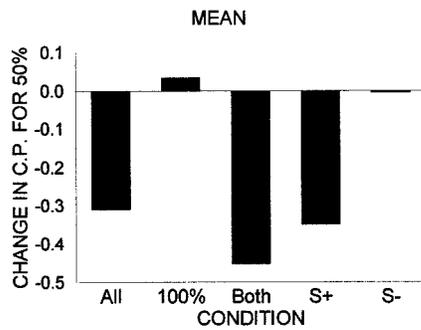


Fig. 3. Choice proportions for the 50% alternative in conditions in which a 5-s gap preceded one or more delay stimuli, shown as deviations from the mean choice proportions obtained in the none condition (no gaps).

portions of reinforcement on the 50% alternative in each condition are presented in Table 2. Response rates during the delay stimuli in all conditions are presented in Table 3. Rates during the 50% S+ tended to be higher in the 100% and 50% both conditions and lower in the 50% S+ condition. Response rates during the S+ on the 50% alternative were higher than rates during the delay on the 100% alternative for all birds in all conditions except the 50% S+ condition. Response rates during the delay on the 100% alternative did not vary systematically across conditions. Response rates during the S-

were generally the lowest except in the two conditions in which both outcomes on the 50% alternative were preceded by a gap (all and 50% both).

DISCUSSION

The none condition of the present experiment replicates the basic finding of suboptimal preference (Dunn & Spetch, 1990; Kendall, 1974; Spetch *et al.*, 1990). In this condition, subjects were given a choice between a 100% reinforcement alternative and a signaled 50% reinforcement alternative. The mean choice proportion in this condition (.55) suggests that despite substantial inequality between the alternatives in the rate of primary reinforcement, the values of the two alternatives were approximately equal on average. The considerable variability in preference levels of individual subjects is also consistent with previous findings, and may, as Belke and Spetch (1994) postulated, reflect differences in the relative sensitivity of subjects to the factors that determine choice behavior.

The two explanations of suboptimal choice behavior both rely on conditioned reinforcement as a central feature. Mazur's (1991) hyperbolic decay model states that choice is

Table 2

Choice proportions (CP) for the 50% alternative (with standard error values in parentheses) and obtained proportions of reinforcement on the 50% alternative (%) for each subject.

Bird	None		None (replication)		All		100%		50% both	
	CP	%	CP	%	CP	%	CP	%	CP	%
A103	.77 (.02)	.56	.77 (.03)	.49	.34 (.06)	.50	.96 (.01)	.50	.05 (.02)	.46
14	.56 (.01)	.48	.71 (.03)	.50	.42 (.02)	.50	.62 (.02)	.49	.03 (.01)	.53
67	.34 (.03)	.59	.52 (.02)	.43	.04 (.01)	.54	.50 (.03)	.51	.20 (.02)	.44
45	.40 (.03)	.42	.28 (.02)	.48	.16 (.01)	.47	.26 (.02)	.46	.12 (.02)	.46
<i>M</i>	.52	.51	.57	.48	.24	.50	.58	.49	.10	.47

Table 3

Terminal-link response rates (pecks per second) in each condition.

Bird	None			None (replication)			All			100%			50% both		
	S+	S-	100	S+	S-	100	S+	S-	100	S+	S-	100	S+	S-	100
A103	1.97	0.01	0.25	2.81	0.05	0.03	0.08	0.45	0.01	3.34	0.42	1.81	10.02	2.45	0.09
14	6.86	0.00	0.59	14.09	0.00	1.98	6.90	0.47	0.93	7.31	0.02	0.92	33.87	0.00	2.13
67	4.84	0.54	1.74	2.89	0.15	0.33	4.36	7.25	0.45	9.34	2.14	1.38	5.94	2.55	2.11
45	7.28	0.15	1.24	2.63	0.14	1.03	4.27	1.44	0.74	9.79	0.25	1.41	1.57	0.33	1.49
<i>M</i>	5.24	0.18	0.96	5.61	0.09	0.84	3.90	2.40	0.53	7.44	0.71	1.38	12.85	1.33	1.45

solely a function of conditioned value, and that conditioned value is inversely related to the delay associated with the conditioned reinforcer for each alternative. The signaled delay to blackout on the 50% alternative is not considered a conditioned reinforcer, so it is ignored in the calculation of conditioned value. Thus, both alternatives provide conditioned reinforcement and are considered to have approximately equivalent conditioned value.

The delay-reduction account proposes that choice is influenced by both primary reinforcement and conditioned reinforcement. Although primary reinforcement favors choice of the 100% alternative, conditioned reinforcement is said to favor the 50% alternative. The conditioned reinforcer on the 50% alternative (the delay stimulus correlated with food) is assumed to be enhanced by the possibility of signaled blackout. At the point at which a 50% choice response is made, both the signal for food and the signal for blackout are equiprobable. Therefore, presentation of the signal for food constitutes a reduction in the overall waiting time to food, increasing its potency as a conditioned reinforcer.

The present investigation tested some of the fundamental differences between these

competing explanations of suboptimal choice. A decrement in choice responding as a function of the gap indicates the value of the delay stimulus as a conditioned reinforcer (i.e., it can be inferred from a consistent shift in preference away from the alternative with a gap that the delay stimulus preceded by the gap provided conditioned reinforcement). Thus, the primary focus is placed on the differences in preference levels across conditions, rather than the absolute levels of preference. Varying the placement of the gap allowed comparison of relative conditioned reinforcement strength within and between alternatives.

The primary question addressed concerns the overall conditioned reinforcement strength of each alternative. According to Mazur's (1991) model, both alternatives provide approximately equal conditioned reinforcement. Dunn and Spetch (1990), however, suggest that the 50% alternative provides greater conditioned reinforcement than the 100% alternative. A comparison of the none condition and the all condition provides some information on this question. There were no gaps in the none condition, whereas all delay stimuli were preceded by gaps in the all condition. Any difference between the two alternatives in overall conditioned reinforcement strength should be reflected by the difference in choice proportions between these conditions. Consistent with the results of Belke and Spetch (1994), all 4 birds showed greater preference for the 50% alternative in the none condition, suggesting that conditioned reinforcement was greater on the 50% alternative. This disproportionate impact on the 50% alternative is consistent with the special status accorded the S+ on the 50% alternative in the delay-reduction account.

However, although the decrease in preference for the 50% alternative in the all condition is consistent with the delay-reduction account, it cannot be considered to be inconsistent with the hyperbolic decay model. According to Mazur's (1991) model, the all condition should weaken conditioned reinforcement more for the 50% alternative than for the 100% alternative, because the 5-s gap prior to the presentation of the signal for blackout must be included in the calculation of value for the 50% alternative (in the none condition, the entire delay to blackout is ex-

Table 2
(Extended)

50% S+		50% S-	
CP	%	CP	%
.03 (.01)	.47	.90 (.02)	.49
.54 (.02)	.45	.62 (.02)	.53
.12 (.03)	.49	.25 (.03)	.46
.12 (.01)	.42	.41 (.02)	.46
.20	.46	.55	.48

Table 3
(Extended)

50% S+			50% S-		
S+	S-	100	S+	S-	100
0.00	0.00	0.02	2.76	0.19	0.30
3.18	0.00	0.99	4.58	0.02	1.22
0.00	0.00	0.98	4.64	0.24	1.31
1.91	0.35	1.28	5.69	0.10	1.24
1.27	0.09	0.82	4.42	0.14	1.02

cluded from the calculation of value). Thus, the hyperbolic decay model predicts some increase in preference for the 100% alternative in the all condition. A more informative comparison involves the 100% and 50% S+ conditions. In these conditions, gaps were presented only prior to the signals for food, and therefore should have equivalent, but opposite, effects on preference according to Mazur's model. Relative to the none condition, 3 of 4 birds showed substantially greater change in preference in the 50% S+ condition than in the 100% condition. This comparison provides further support for the delay-reduction notion that the signal for food on the 50% alternative provides more conditioned reinforcement than does the signal for food on the 100% alternative, and is inconsistent with the assumption, associated with Mazur's hyperbolic decay model, that conditioned reinforcement is approximately equivalent on the two alternatives.

Although the foregoing analysis demonstrates that there is more conditioned reinforcement on the 50% alternative than on the 100% alternative, it does not identify whether the 100% alternative provides any conditioned reinforcement. The delay-reduction account has proposed that the 100% delay stimulus may fail to acquire conditioned reinforcement properties because it signals no further reduction in the waiting time to food than is already signaled by the 100% choice peck. If this is true, one would expect that preference would be approximately equivalent in the none condition and the 100% condition. Two birds showed greater preference for the 50% alternative in the 100% condition, 1 showed less preference, and 1 showed no change in preference. Another test of the reinforcing effectiveness of the 100% signal for food involves a comparison of the all condition and the 50% both condition. Preference for the 50% alternative should be higher in the all condition if imposing the gap following choice of the 100% alternative decreases the value of that alternative. This pattern was observed for 3 of the 4 birds. Overall, these results, although failing to clearly establish the 100% delay stimulus as a conditioned reinforcer, suggest that further investigation of this issue is warranted.

A third question relates to the function of

the signal for blackout. Mazur's (1991) model provides no role for it, simply ignoring it in the calculation of value for the 50% alternative. The delay-reduction account maintains that the signal for blackout functions to enhance the value of the signal for food, but does not clearly specify what the value of the blackout signal itself should be. One possibility is that the signal for blackout functions as a conditioned punisher, because it signals an increase in the waiting time to food relative to the preceding choice phase. This expectation is consistent with Fantino's delay-reduction theory, from which the Dunn and Spetch (1990) account is drawn (Case & Fantino, 1981; Fantino, 1983). Two comparisons in the present experiment relate to this issue. First, if the signal for blackout functions as a conditioned punisher, preference for the 50% alternative should be lower in the 50% S+ condition than in the 50% both condition, because imposing a gap prior to the signal for blackout in the latter condition should enhance the value of that alternative. Only 2 birds showed this pattern, and overall, preference was higher in the 50% S+ condition than in the 50% both condition. A second comparison relating to the role of the signal for blackout is the none condition versus the 50% S- condition. Preference for the 50% alternative should be higher in the latter condition if the signal for blackout functions as a conditioned punisher. However, the mean choice proportions did not systematically differ between the two conditions. Overall, these comparisons fail to provide evidence that the signal for blackout has a negative impact on choice responding.

In summary, both Mazur's (1991) hyperbolic decay model and Dunn and Spetch's (1990) delay-reduction framework explain suboptimal choice by relying on conditioned reinforcement as the central explanatory feature. However, the two accounts differ in their conceptualization of what determines conditioned reinforcement value. The present investigation explored one method of assessing the strength of conditioned reinforcement in a probabilistic reinforcement procedure. The results support the delay-reduction notion that suboptimal choice is influenced by conditioned reinforcement factors that favor the 50% alternative and provide a challenge for the hyperbolic decay

model. The results fail to provide evidence that the signal for blackout functions as a conditioned punisher, and this finding is inconsistent with Fantino's (1983) delay-reduction theory. In addition, the results fail to provide evidence that the 100% signal for food acts as a conditioned reinforcer. However, these negative results should be interpreted with caution, because the intersubject variability common in these procedures may obscure small effects.

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Received November 8, 1996
Final acceptance June 18, 1997