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CHOICE WITH UNCERTAIN OUTCOMES: CONDITIONED REINFORCEMENT EFFECTS

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Pigeons responded on concurrent chains with equal initial- and terminal-link durations. In all conditions, the terminal links of one chain ended reliably in reinforcement; the terminal links on the alternative chain ended in either food or blackout. In Experiment 1, the terminal-link stimuli were correlated with (signaled) the outcome, and the durations of the initial and terminal links were varied across conditions. Preference did not vary systematically across conditions. In Experiment 2, terminal-link durations were varied under different stimulus conditions. The initial links were variable-interval 80-s schedules. Preference for the reliable alternative was generally higher in unsignaled than in signaled conditions. Preference increased with terminal-link durations only in the unsignaled conditions. There were no consistent differences between conditions with and without a common signal for reinforcement on the two chains. In the first series of conditions in Experiment 3, a single response was required in the initial links, and the stimulus conditions during 50-s terminal links were varied. Preference for the reliable outcome approached 1.0 in unsignaled conditions and was considerably lower (below .50 for 3 of 5 subjects) in signaled conditions. In a final series of signaled conditions with relatively long terminal links, preference varied with duration of the initial links. The results extend previous findings and are discussed in terms of the delay reduction signaled by terminal-link stimuli.

Key words: conditioned reinforcement, percentage reinforcement, delay-reduction hypothesis, concurrent chains, choice, key peck, pigeons

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The strength of a stimulus as a conditioned reinforcer can be measured in terms of the frequency of responding maintained by that stimulus relative to the frequency of responding maintained by alternative stimuli. Investigations of choice behavior maintained by conditioned reinforcement have relied heavily on the concurrent-chains procedure (Autor, 1969). Typically, the initial links of two chain schedules are available concurrently, and the relative rates of responding (i.e., "preference") during the initial links are said to reflect the conditioned reinforcement by stimuli correlated with entry into the terminal links. The terminal links are mutually exclusive; entry into either one suspends the initial-link schedule on the alternative until completion of the terminal-link schedule. The properties of the terminal-link stimuli can be manipulated by varying the schedule of reinforcement during the terminal link. For example, conditioned reinforcement by the terminal-link stimuli can be described as a function of the percentages of reinforcement in the terminal links: The rate of responding maintained by one terminal-link stimulus can be compared to the responding maintained by a stimulus that ends in reinforcement less reliably.

There is some question, however, as to whether or not it is necessary to invoke the concept of conditioned reinforcement to describe the determinants of choice on concurrent-chains schedules of percentage reinforcement. For example, Mazur (1985) has suggested combination rules for delay and probability of primary reinforcement that appear to provide an adequate description of choice without reference to mediation by the terminal-link stimuli (see also Baum, 1973; Rachlin, Logue, Gibbon, & Frankel, 1986; Shull & Spear, 1987). More extreme positions include foraging models of choice with no provision for the molecular function of stimuli as reinforcers (e.g., Caraco, 1981). Other models of choice incorporate the role of the terminal-link stimulus as a conditioned reinforcer (e.g., Fantino, 1981; Vaughan, 1985), but the ap-

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plications of these models to choice on schedules of percentage reinforcement have been limited (Navarick & Fantino, 1976; Spetch & Dunn, 1987).

The experiments presented here investigate the role of stimulus-outcome contingencies during the terminal links in concurrent chains with percentage reinforcement. If the terminal-link stimulus is dispensable in the description of choice between different percentages of reinforcement, the stimulus-outcome contingencies should not influence the level of preference. Any variation in preference across manipulations in the stimulus-outcome contingency challenges the efficacy of molar models of choice. On the other hand, although models of choice that provide a role for the terminal-link stimulus as a conditioned reinforcer more readily accommodate stimulus contingency effects, most models do not include explicit provision for the stimulus-outcome contingency in percentage reinforcement procedures (e.g., Fantino, 1981; cf. Kendall, 1985).

EXPERIMENT 1

Spetch and Dunn (1987) investigated the determinants of the level of preference for the more reliable of two alternatives that provided different percentages of reinforcement in a concurrent-chains procedure. Preference for a schedule providing 100% reinforcement over one providing 33% reinforcement increased systematically with the terminal-link duration. In contrast, preference decreased systematically with increases in the initial-link duration. There is indirect evidence in the literature that these effects may depend on the stimulus conditions during the terminal links. In the procedure used by Spetch and Dunn, the reinforcement and blackout were not signaled differentially during the terminal link on the 33% alternative (i.e., the terminal-link stimulus ended in either outcome). Procedures with signaled outcomes on the unreliable alternative have generated a different pattern of results. For example, Kendall (1974) investigated choice between 100% and 50% reinforcement in a concurrent-chains procedure. Entry into the terminal link of the 50% chain was accompanied by one of two stimuli. When these stimuli were correlated with the outcomes (food or blackout), preference for the 100% alternative was sharply reduced from uncorrelated (i.e., unsignaled) conditions. Kendall provided preliminary evidence that the level of preference for the 100% alternative in signaled procedures varies directly with the duration of the initial links and inversely with the duration of the terminal links. Comparisons across the two experiments in Kendall's report show lower preference with shorter initial links, and isolated comparisons suggested that preference for the reliable alternative was reduced in conditions with longer terminal links. More recently, Kendall (1985) reported further evidence of both relations in within-subject manipulations. These patterns are the converse of those obtained in procedures without signaled outcomes on the unreliable alternative (Spetch & Dunn, 1987).

Fantino, Dunn, and Meck (1979) replicated some of the conditions investigated in Kendall's (1974) study. Their results suggest that a procedural artifact may have contributed to the reduced preference for the reliable alternative. However, their procedure did not address the effect of initial- and terminal-link schedule manipulations. The procedural problem was corrected in Kendall's (1985) replication of the reduction in preference for the reliable alternative in conditions with short initial links. Moreover, Fantino et al. reported preference for the 100% alternative in conditions with relatively long terminal links that was lower than would be expected on the basis of simple matching to the percentages of reinforcement. Fantino et al. did not replicate comparisons with fixed-ratio (FR) 1 initial links.

In related work, Mazur (1989, Experiment 3) compared reliable (100%) with unreliable (50% and 20%) reinforcement under signaled and unsignaled conditions in an adjusting-delay procedure. The delay on the unreliable alternative was constant, and the delay on the reliable alternative was adjusted to estimate an indifference point in the combination of delay and probability of reinforcement. In signaled conditions, the delay to the reliable reinforcer was shorter at the point of indifference than in conditions with unsignaled reinforcement on the unreliable alternative.

Experiment 1 explores the effect of initial- and terminal-link durations on the level of preference in a signaled percentage reinforcement procedure. The procedure replicates one of the experiments in Spetch and Dunn (1987, Experiment 2) with two modifications. First, the outcomes were signaled on the unreliable alternative in all conditions. To generalize from the results of the comparisons available in Kendall (1974, 1985), preference for the 100% alternative may be expected to decrease with decreases in the initial-link duration and increase with decreases in the terminal-link durations. Second, in the present procedure, 67%, rather than 33%, of the terminal links on the unreliable alternative ended in reinforcement. This latter change was made to reduce the likelihood of encountering a ceiling in the preference for the 100% alternative (as evident in the results of Spetch and Dunn).

METHOD

Subjects

The subjects were 5 adult White Carneau pigeons. All subjects had served previously in an experiment that used a delayed symbolic matching-to-sample procedure; none had prior experience with concurrent-chains procedures. Mixed grain obtained during and after experimental sessions maintained the pigeons at approximately 85% of their free-feeding weights. The birds were housed in individual wire-mesh cages with water and grit freely available.

Apparatus

The experimental chambers consisted of rectangular BRS/LVE animal chests that contained two horizontally aligned circular response keys, each 2.5 cm in diameter. IEE projectors mounted behind each key were used to project stimuli onto the keys. The stimuli projected onto the left key were red, blue, or green patches of light. For the right key the stimuli consisted of a set of three lines in either a vertical, horizontal, or oblique orientation superimposed on a white background. The grain feeder was centered between, and was 10 cm below, the two keys, and grain presentations were accompanied by illumination of a lamp in the feeder. The houselight was a 1.6 candle-power lamp located at the top of the response panel. An exhaust fan ventilated the chamber and provided masking noise. Experimental contingencies and data recording were controlled by a PDP-8e® computer located in an adjacent room.

Procedure

Preliminary training. Prior to exposure to the concurrent-chains procedure, all birds first received one session of training with a continuous reinforcement schedule in effect for each of the three colors on the left key and each of the three line orientations on the right key. By the end of this session all birds readily pecked each stimulus. Each bird next received between one and three sessions with concurrent variable-interval (VI) 30-s schedules, with red on the left key and oblique lines on the right key. This was followed by eight to 10 sessions with concurrent VI 60-s schedules. Averaged over the last three sessions, choice proportions for the left key were .48, .31, .57, .36, and .51 for Birds 1 to 5, respectively.

Experimental conditions. The following aspects of the concurrent-chains procedure were common to all phases of the experiment. During the initial links of the chains, the left key was illuminated with red and the right key with oblique lines. Access to the terminal links was made available on two equal, independent VI schedules; the particular VI values varied across phases. Upon completion of the VI schedule on either side, the initial-link stimuli terminated and a terminal-link stimulus was presented on the completed side. The VI timer on the other side was halted, and its value was retained for the next cycle. If entry to the 100% terminal link occurred (right for Birds 1, 2, and 3; left for Birds 4 and 5), the same terminal-link stimulus always occurred (green for Birds 1, 2, and 3; horizontal lines for Birds 4 and 5), and food was always presented at the end of the terminal-link schedule. Upon entry to the other terminal link, one of two terminal-link stimuli occurred. With a probability of .67, an S+ stimulus (horizontal lines for Birds 1, 2, and 3; green for Birds 4 and 5) occurred. This stimulus terminated with food delivery at the end of the terminal-link schedule. With a probability of .33, an S− stimulus (vertical lines for Birds 1, 2, and 3; blue for Birds 4 and 5) occurred, which terminated with blackout at the end of the terminal-link schedule. The terminal-link schedules were fixed-time (FT) schedules that were always of equal duration on the 100% and the 67% side, but the specific durations varied across phases. Pecks during the terminal links were recorded but had no scheduled consequence. Food delivery

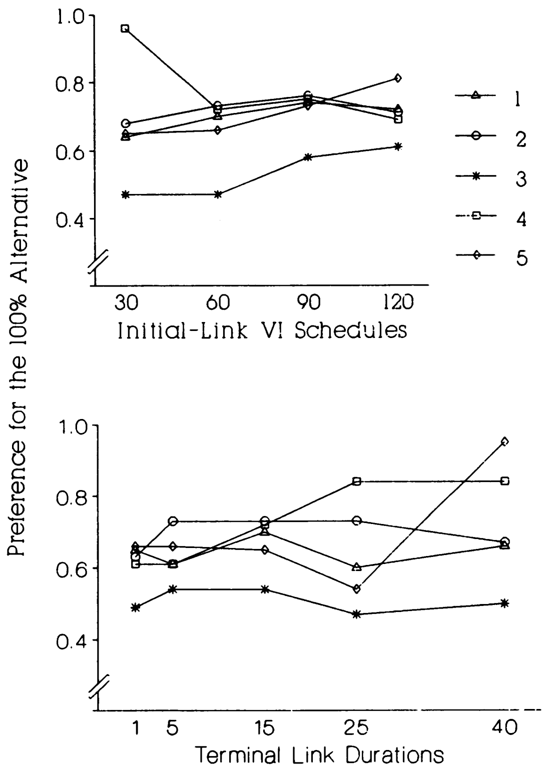

Fig. 1. Choice proportions for the 100% alternative across manipulations of the initial-link schedules (top panel) and the terminal-link durations (bottom panel) in Experiment 1.

consisted of a 4-s presentation of the illuminated grain hopper. During blackouts the houselight was turned off for 4 s. Sessions lasted for a maximum of 50 min or until 50 reinforcements occurred.

In the first series of conditions for each subject, the initial-link schedules were VI 60 s and the terminal-link durations were varied from 1 s to 40 s across conditions. A second series of conditions maintained the terminal-link duration in the last comparison of the initial series, and the initial-link schedule values were varied from VI 30 s to VI 120 s. The conditions and the number of sessions required for each subject are shown in Table 1 in the order of presentation.

Assessment of preference. The number of responses made on each initial-link stimulus was recorded, and preference for the 100% side was assessed by calculating choice proportions: the number of responses on the 100% initial-link stimulus divided by the number of responses on both initial-link stimuli. After 15 sessions (and for each session thereafter) in a condition, the choice proportions for the nine preceding sessions were divided into blocks of three sessions. Preference was considered stable when the block means (M) did not differ by more than 0.05 and showed neither an upward trend ($M1 < M2 < M3$) nor a downward trend ($M1 > M2 > M3$). All values reported are the means of the 9-day periods for which stability was achieved.

Results

Preference for the 100% chain during the manipulations of the terminal-link duration is shown in the bottom panel of Figure 1. For 4 of 5 subjects, the choice proportion was higher in the condition with 40-s terminal links than in the condition with 1-s terminal links. However, there was no consistent pattern across all conditions. Preference for the 100% chain during the manipulations of the initial-link schedule is shown in the top panel of Figure 1. For 4 of 5 subjects, the choice proportion was higher in the condition with the VI 120-s schedule than in the condition with the VI 30-s schedule. The pattern across all conditions was less consistent and appeared to be independent of the durations of the terminal links (5 to 25 s across subjects).

The response rates in the initial and terminal links are presented in Table 1. In general, absolute response rates in the initial links varied inversely with terminal-link durations. Terminal-link responding varied directly with terminal-link durations. Neither initial- nor terminal-link response rates varied systematically with initial-link schedule values. All subjects responded during the terminal link on the 100% chain. Four of 5 subjects responded consistently during the reinforced terminal link on the 67% chain and, for those subjects, response rates were considerably lower in the terminal link ending in blackout.

Discussion

The results of Experiment 1 offer no more than a suggestion that the level of preference is determined by the durations of the initial and terminal links when the outcomes are signaled on the unreliable alternative. There are several procedural distinctions to be made between Experiment 1 and Kendall's (1974, 1985) experiments. First, the percentage of reinforced terminal links on the unreliable alternative was 67% rather than 50% as in Kendall's procedures. There is little direct evidence

Table 1

Schedule values and results in each condition in the order of presentation in Experiment 1.

Schedule values (s)					Terminal link: R/min			
Initial link	Terminal link	C.P.	Rft prop on 100%	Initial link R/min	100%	S+	S−	Sessions to stability
Bird 1								
60	25	.60	.61	16.2	2.2	0.6	1.1	20
60	5	.61	.62	30.1	7.4	20.3	7.4	15
60	40	.66	.60	30.6	1.9	1.0	0.0	23
60	1	.65	.59	55.2	53.5	103.7	1.1	18
60	15	.70	.60	52.9	4.9	7.3	0.0	17
90	15	.74	.60	48.9	4.9	2.9	0.0	17
30	15	.64	.60	69.3	3.8	1.7	0.0	18
120	15	.72	.61	39.2	4.6	3.7	0.0	17
60	15	.75	.60	51.5	4.0	4.6	1.1	16
Bird 2								
60	1	.63	.59	41.9	8.6	118.2	0.0	41
60	25	.73	.59	52.3	4.1	17.0	0.0	19
06	40	.67	.61	30.1	3.0	15.5	1.1	17
60	15	.73	.61	60.8	2.4	2.5	0.2	17
60	5	.73	.60	50.4	4.6	4.1	0.2	16
120	5	.71	.60	57.0	4.1	2.9	0.5	18
30	5	.68	.60	50.1	4.2	9.2	0.0	18
90	5	.76	.61	58.4	4.9	2.6	0.2	15
Bird 3								
60	1	.49	.60	101.0	234.1	320.5	38.8	17
60	15	.54	.60	98.7	23.0	41.6	3.2	17
60	40	.50	.59	85.8	10.1	22.2	3.6	22
60	5	.54	.59	114.0	51.4	104.2	5.9	15
60	25	.47	.59	86.4	13.4	34.0	2.8	17
30	25	.47	.59	79.5	14.9	19.1	2.5	17
60	25	.58	.59	87.5	22.2	13.6	1.4	15
120	25	.61	.60	90.7	15.8	16.7	2.1	17
90	25	.58	.58	85.5	13.1	14.2	11.2	15
Bird 4								
60	1	.61	.61	52.0	16.7	0.0	0.0	15
60	40	.84	.65	30.1	1.1	0.0	0.0	19
60	5	.61	.59	50.7	3.8	0.0	0.0	15
60	25	.84	.64	37.6	1.1	0.1	0.0	16
60	15	.72	.61	53.2	2.0	1.0	0.1	16
30	15	.96	.72	54.5	1.9	1.7	0.0	15
90	15	.75	.61	54.0	2.8	1.3	0.0	15
120	15	.69	.59	55.4	2.8	0.8	0.0	17
60	15	.72	.61	60.5	2.6	0.5	0.0	15
Bird 5								
60	40	.95	.77	21.1	0.1	4.1	0.0	15
60	25	.54	.59	75.2	0.7	8.2	0.9	30
60	15	.65	.60	86.6	2.9	9.5	0.2	15
60	1	.66	.59	86.0	61.2	75.0	6.4	15
60	5	.66	.60	85.3	14.3	16.9	0.4	15
30	5	.65	.60	78.9	4.2	6.2	0.0	19
120	5	.81	.60	67.9	141.4	7.7	0.0	36
90	5	.73	.60	71.4	133.2	8.6	0.0	15

Note: C.P. is choice proportion; Rft prop on 100% is proportion of reinforcers obtained on the 100% alternative; R/min is responses per minute.

regarding the importance of this difference. Mazur (1985) reported minimal sensitivity to manipulations of percentage reinforcement in the range between 20% and 80%, but the relevance of this finding for the present procedure is tempered by other procedural differences. Second, the range of initial-link schedule values was VI 120 s to VI 30 s rather than VI

60 s to VI 20 s in the one systematic manipulation provided by Kendall (1985). Moreover, Kendall (1974, 1985) reported the lowest levels of preference for the 100% alternative in conditions with a single response requirement in the initial links. These concerns are addressed in Experiments 2 and 3 of the present study.

On the other hand, the results are clearly inconsistent with the demonstration of strong correlations between preference and schedule parameters in a similar procedure with unsignaled outcomes on the unreliable alternative (Spetch & Dunn, 1987). Although there are other procedural differences in the two experiments, the failure to find systematic variations in preference in the present procedure is consistent with a distinction between signaled and unsignaled procedures. Indeed, in the case of Bird 4 (the only subject to replicate the patterns obtained under unsignaled procedures) there is little evidence of contact with the signal contingencies; there were low response rates during terminal links and almost none during the unreliable terminal link. On the other hand, the utility of the terminal-link response patterns is limited: There are no consistent differences between birds with increasing levels of preference (3 and 5) and birds with less consistent variation in preference (1 and 2) across the manipulations of the initial-link schedule. Moreover, terminal-link durations (25 and 5 s for Birds 3 and 5; 15 and 5 s for Birds 1 and 2) during initial-link manipulations do not differentiate between the two pairs of subjects. Thus, although these data differ from those obtained in unsignaled procedures, there is little evidence of the patterns reported by Kendall (1974, 1985). Experiments 2 and 3 offer direct comparisons of signaled and unsignaled conditions.

EXPERIMENT 2

Although the results of Experiment 1 do not support the generality of the results of Kendall's (1974) manipulations of schedule parameters, the contrast with the results of comparable procedures with unsignaled conditions (Spetch & Dunn, 1987) suggests the importance of the stimulus conditions during the terminal links. These implications are limited, however, by the comparisons across different experiments. One objective of Experiment 2 was to provide direct comparisons of the signaled and unsignaled procedures as the duration of the terminal links varied across conditions.

The second objective was to test Kendall's (1974) suggestion that a signal for a food outcome on an alternative acquires enhanced strength as a conditioned reinforcer in the context of occasional presentations of the signal for blackout on that alternative. Assuming some degree of independence between the contexts of responding on the two alternatives, the presentation of the signal for food delivery on a 50% chain would constitute a more substantial improvement over the local context than presentation of the food signal on a 100% chain. Thus, the terminal-link stimulus that signals food on the 50% chain could be expected to be the stronger (although less frequent) conditioned reinforcer. Therefore, responding during the initial links may be described as maintained by the presentation of the terminal-link stimuli, but the signal for food on the unreliable alternative may be more reinforcing per instance. According to this description, preference for the 100% alternative in signaled procedures is reduced because the strength of the stimulus correlated with food on the unreliable alternative is enhanced. One implication is that, if the same stimulus served as the conditioned reinforcer for responding on both the 100% and 50% chains, the disparity in conditioned reinforcement for the two response alternatives would be reduced.

In Experiment 2, the response alternatives were pecks on two side keys during the initial links. The outcomes contingent on either choice were signaled on a center key during the terminal links. In one series of conditions, reinforcement, when scheduled on either alternative, was signaled by a single color on the center key during the terminal links. In another series, reinforcement on the two alternatives was signaled by different colors. In both procedures, the duration of the terminal links was varied. In a third series of conditions, the outcomes were not signaled by key color during the unreliable terminal link, a replication of the Spetch and Dunn (1987) procedure.

If the signal for reinforcement on the unreliable alternative acquires enhanced strength as a conditioned reinforcer, the level of preference for the more reliable alternative should be consistently higher when reinforcement is signaled by the same rather than different colors on the two alternatives, because the discrepancy between the strength of the conditioned reinforcers for the two choice responses is eliminated, that is, both are followed by the enhanced reinforcer.

METHOD

Subjects

Three male White King pigeons, maintained at 85% of free-feeding weights, served as subjects. The duration of the food deliveries was adjusted for each subject during initial training to reduce the need for supplemental feedings. When necessary, supplemental feedings were given approximately 4 hr after the experimental sessions. Water and grit were available freely in the home cages. All subjects had prior experience on a conditional discrimination task.

Apparatus

The experimental chamber was a cube, 32 cm on a side. One side panel was a Plexiglas door; the remaining sides and ceiling were aluminum. The chambers were housed in wooden enclosures. There were three translucent response keys on the front panel, which were 2.5 cm in diameter and evenly separated at 24 cm above the grid floor. The keys could be transilluminated with various colors. A minimum force of approximately 0.16 N was required for key operation. A 50-ms blackout on all keys provided feedback for responses to lighted keys. The hopper opening was located 9 cm beneath the center key. When activated, the solenoid-operated hopper was illuminated by white light and allowed access to mixed grain. A houselight mounted in the center of the ceiling provided general chamber illumination except during operation of the hopper. Stimuli, contingencies, and data collection were controlled by electromechanical equipment.

Procedure

Training. The subjects were placed on an autoshaping procedure with an intermittent 8-s illumination of the center key followed by food delivery. All subjects responded reliably within three sessions. In the next two sessions, food delivery was arranged on concurrent-chains schedules. During the initial links the two side keys were illuminated white. Entries to the terminal links were contingent on responses on the side keys. During a terminal link the side keys were dark and the center key was illuminated with a color corresponding to the appropriate chain. The color assignments (red, green, or blue) on the center key differed across subjects. Both chains ended in reinforcement following every terminal-link entry. The initial-link schedules were initially VI 20 s and increased to VI 80 s over the course of the two sessions; the terminal links were FT 15-s schedules. During these sessions, the duration of hopper access and the number of food deliveries per session were adjusted on an individual basis to reduce the need for supplemental feeding. Prior work with schedules providing infrequent reinforcement suggested that responding is more likely to be maintained when feeding in the home cage is minimized. The durations of blackouts were adjusted to match the hopper durations for each subject. Hopper durations and the maximum number of food deliveries per session for each subject were: for G17—4 s, 90; for G20—5 s, 80; and for G42—4 s, 70. These values were not manipulated during the course of the experimental conditions.

Experimental conditions. In all conditions, the comparison was between 100% and 50% reinforcement, that is, 100% of the terminal links of one chain ended in reinforcement, whereas on the other chain 50% of the terminal links ended in reinforcement and 50% ended in blackout. The initial links were VI 80-s schedules, and terminal-link durations were varied under three stimulus conditions. In the signaled-same conditions, terminal-link stimuli on the 50% chain were correlated with the outcomes. The stimulus on the center key during the 100% terminal link was the same color that signaled reinforcement on the 50% chain. In signaled-different conditions, outcomes on the 50% chain were again signaled but the food signal was a different color than the food signal on the 100% chain. The stimulus conditions in the signaled-different procedure replicated those employed in Experiment 1 except that terminal-link stimuli were presented on the center key. In unsignaled conditions, the terminal-link stimuli on the 50% chain were not correlated with the outcomes, and the stimulus on the 100% chain was a different color than either stimulus on the 50% chain.

Each condition for a maximum of 35 ses-

Table 2

Schedule values and results in each condition in the order of presentation in Experiment 2.

Schedule (s) in initial link	Terminal links: Stimuli	Terminal links: Duration	C.P.	Responses per minute: Initial link	Responses per minute: 100% S+	Responses per minute: 50% S+	Responses per minute: 50% S−	Obt % rft: 50%	Obt % rft: Overall	Sessions to stability
G17										
VI 80	Signal-diff	15	.61	63.05	67.76	66.63	1.04	.51	.66	35
VI 80	Signal-diff	30	.59	47.84	7.97	6.62	1.09	.46	.68	35
VI 80	Signal-diff	5	.69	35.68	15.50	6.41	0.05	.47	.69	30
VI 80	Signal-same	5	.66	48.22	16.12	16.35	0.05	.46	.69	24
VI 80	Signal-same	30	.60	42.14	0.49	0.47	0.13	.51	.66	21
VI 80	Signal-same	50	.68	52.68	0.25	0.31	0.28	.50	.66	21
VI 80	Signal-diff	50	.82	41.88	0.24	0.16	0.07	.52	.62	26
VI 80	Signal-same	15	.64	54.84	2.10	1.60	0.07	.48	.68	25
VI 80	Unsignaled	15	.87	52.22	2.76	8.54	9.64	.53	.67	18
VI 80	Unsignaled	5	.86	53.81	19.87	29.58	31.87	.51	.67	19
VI 80	Unsignaled	30	.95	47.59	0.70	10.24	12.59	.49	.72	35
VI 80	Unsignaled	50	1.00	42.27	0.20	4.57	4.09	.50	.99	15
VI 80	Signal-diff	50	.91	48.27	0.49	0.38	0.06	.50	.69	18
G20										
VI 80	Signal-same	15	.64	25.70	73.99	72.09	1.24	.48	.68	32
VI 80	Signal-same	5	.81	40.36	7.59	6.46	0.00	.47	.70	28
VI 80	Signal-same	30	.42	15.15	25.76	26.60	0.17	.51	.65	18
VI 80	Signal-diff	30	.68	34.75	62.51	82.80	1.23	.53	.65	22
VI 80	Signal-diff	15	.64	34.05	35.75	38.29	0.59	.51	.66	20
VI 80	Signal-same	50	.54	29.70	98.75	99.09	1.41	.49	.67	25
VI 80	Signal-diff	50	.68	25.27	11.79	16.30	0.09	.49	.62	31
VI 80	Signal-diff	5	.87	44.76	6.09	8.89	0.00	.50	.69	28
VI 80	Unsignaled	5	.71	43.01	11.93	18.77	20.63	.49	.68	19
VI 80	Unsignaled	30	.75	34.67	27.43	35.37	40.49	.50	.67	15
VI 80	Unsignaled	50	.78	34.05	18.35	13.23	12.78	.48	.66	20
VI 80	Unsignaled	15	.77	44.53	1.08	4.69	6.15	.50	.64	21
VI 80	Signal-diff	15	.60	46.26	0.91	9.93	0.32	.49	.63	15
VI 80	Signal-diff	50	.67	38.91	10.71	26.90	0.71	.49	.66	18
G42										
VI 80	Signal-same	15	.64	44.53	5.4	5.95	0.01	.51	.67	23
VI 80	Signal-same	30	.72	28.90	1.30	1.36	0.03	.47	.69	18
VI 80	Signal-same	5	.70	39.13	6.16	13.66	0.00	.51	.68	16
VI 80	Signal-diff	5	.68	26.46	10.38	21.17	1.35	.50	.72	16
VI 80	Signal-diff	30	.62	48.11	0.45	2.94	0.21	.52	.66	19
VI 80	Signal-diff	5	.71	33.24	3.40	11.46	0.54	.49	.68	20
VI 80	Signal-diff	15	.75	20.32	1.61	4.22	0.00	.54	.69	25
VI 80	Signal-diff	50	.80	8.20	0.85	3.52	0.11	.46	.75	20
VI 80	Signal-same	50	.76	18.34	3.11	5.09	0.02	.48	.75	33
VI 80	Unsignaled	50	.93	12.15	2.71	27.94	25.43	.45	.80	16
VI 80	Unsignaled	15	.86	30.05	22.37	53.93	57.80	.54	.71	21
VI 80	Unsignaled	5	.83	21.39	31.67	59.35	61.85	.50	.69	21
VI 80	Unsignaled	30	.98	15.89	21.85	64.35	51.13	.51	.85	26
VI 80	Signal-diff	30	.66	12.13	16.99	36.94	0.00	.47	.68	31

Note: C.P. is the choice proportion; Obt % rft is the obtained percentage of reinforcement on the 50% alternative and the overall percentage of reinforcement on the concurrent-chains schedules.

sions or until the stability criteria (as described in Experiment 1) had been satisfied. In all conditions, daily sessions continued for a fixed number of food presentations, as noted above, or 180 min. The sequence of conditions for each subject and the number of sessions to stability are presented in Table 2. In all but three conditions (all for G17) stability was achieved within 35 sessions.

Results

Preference for the 100% chain in each condition is shown in Figure 2. Choice proportions were generally highest in the unsignaled

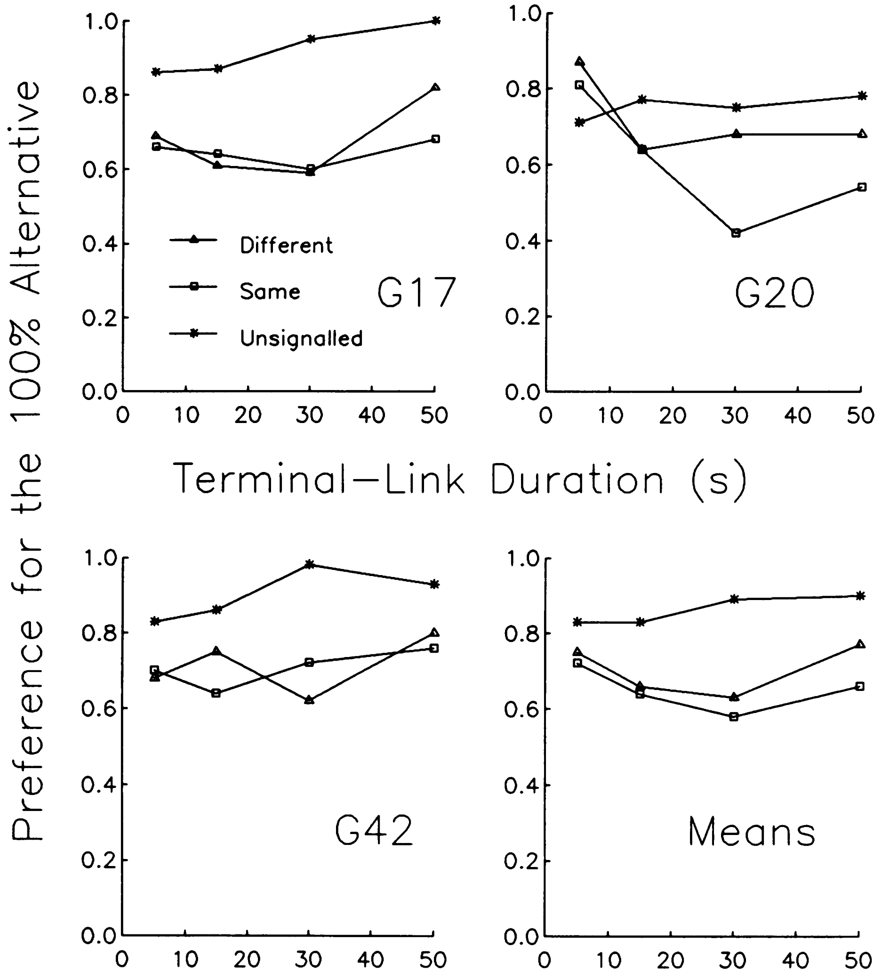

Fig. 2. Choice proportions for the 100% alternative across manipulations of the terminal-link durations under the signaled-different, signaled-same, and unsignaled conditions for each subject in Experiment 2.

conditions. Choice proportions in the signaled-same procedure were lower than in the signaled-different procedure in conditions with 50-s terminal links. There were no other consistent differences between the two signaled conditions. In general, choice proportions appeared to increase with terminal-link durations in the unsignaled conditions and did not vary systematically with terminal-link duration in the signaled procedures.

The response rates in the initial and terminal links are presented in Table 2. Response rates in the initial links did not appear to vary systematically with the signal conditions or the schedule values in the terminal links. For all subjects, there was considerable responding in the terminal links correlated with food delivery. There were few responses in the terminal link ending in blackout in the signaled conditions. In the unsignaled conditions response rates in the presence of the two colors used on the 50% chain were roughly equal.

A comparison of the response rate in the 50% terminal link and the rate in the 100% terminal link under the three stimulus conditions is provided in Figure 3. The log of the ratio of response rates is plotted for convenience. When conditions were replicated the first instance was used. As shown in Figure 3, response rates in the unsignaled conditions were considerably higher in the terminal link of the 50% chain than were response rates in the 100% terminal link. For 2 of 3 birds, the difference increased with terminal-link duration.

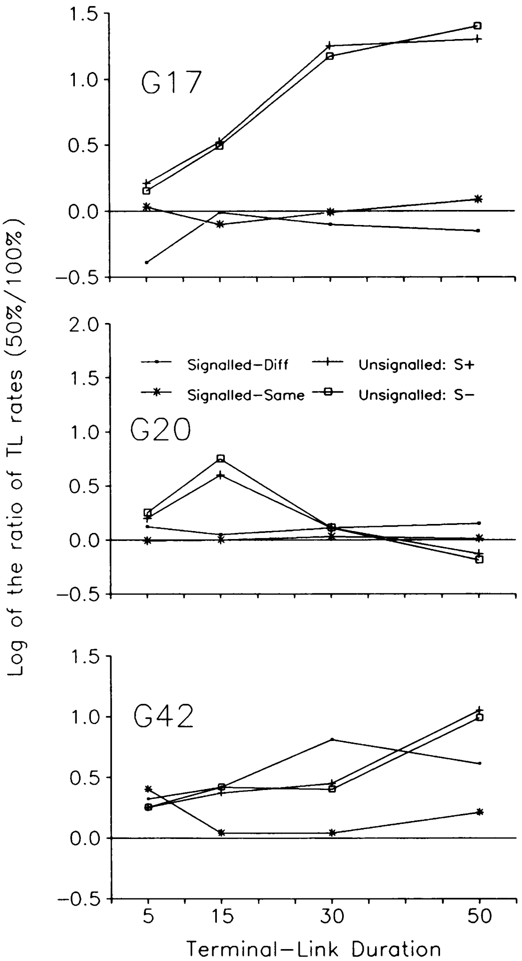

Fig. 3. The log of the ratio of responses during the unreliable (50%) terminal link over responses during the reliable (100%) terminal link across manipulations of the terminal-link durations in Experiment 2. The ratio numerators are the response rates during the terminal links ending in food on the 50% alternative in the two signaled conditions and the response rates during both terminal-link stimuli on the 50% alternative in the unsignaled conditions. Response rates during the stimulus ending in blackout in the signaled condition were uniformly very low and are not represented.

There were no consistent differences between 100% and 50% response rates in the signaled conditions.

Discussion

The results demonstrate the importance of the signal conditions in preference for reliable versus unreliable outcomes. Preference for the reliable (100%) alternative was lower in the procedures with signaled outcomes. Preference appeared to vary directly with terminal-link duration under unsignaled conditions, replicating the pattern obtained by Spetch and Dunn (1987).

The only consistent difference between comparable conditions with a common versus two distinct stimuli correlated with reinforcement on the two alternatives was that, in conditions with the longest terminal links (50 s), preference was lower in the signaled-same procedure. This latter result appears inconsistent with Kendall's (1974) suggestion that the food-correlated stimulus on the 50% alternative gains enhanced reinforcement strength in a context of uncertainty. One possibility is that the two occurrences of the terminal-link stimulus were discriminated on the basis of the preceding initial-link response (e.g., a green center key preceded by a left side-key response could be discriminated from a green center key preceded by a right side-key response; cf. Williams & Fantino, 1978). The terminal-link response rates offer a possible measure of the comparability of the two stimuli. Given that the food-correlated stimuli on the two alternatives signaled equal delays to food, a stimulus with enhanced strength as a conditioned reinforcer may be expected to control higher response rates (cf. Fantino, 1982). However, there is no consistent difference between the response rates in the presence of the two terminal links with the common stimulus in the signaled-same procedure. Even with an allowance for some limits on the generalization, the relative response rates in the signaled-same conditions would be expected to fall somewhere between the signaled-different and unsignaled rates.

In sum, these data replicate Kendall's (1974, 1985) reports of reduced preference for the reliable alternative in signaled procedures, but there is no evidence that this preference varies with terminal-link duration in conditions with VI initial-link schedules. Also, there is no support for the hypothesis that the reduced preference can be attributed to an enhancement of the food-correlated stimulus on the unreliable alternative as a conditioned reinforcer.

EXPERIMENT 3

Experiment 3 provides direct comparisons of signaled and unsignaled conditions and manipulation of the initial-link schedules under conditions similar to those employed by Kendall (1974, 1985).

METHOD

Subjects

Five male White King pigeons, maintained at 85% of free-feeding weights, served as subjects. Subjects G20, G42, and G52 served in Experiment 2 immediately prior to the start of this experiment. Subjects G52 and W91 had no prior experience in experiments. The subjects were maintained as described in Experiment 2. Subject G42 died of natural causes during the course of the experiment and was replaced by W91.

Apparatus

Each subject was assigned to one of four experimental chambers, all identical to the one used in Experiment 2. Stimuli, contingencies, and data collection were controlled by an XT-compatible computer with Turbo Pascal software.

Procedure

Training. Subject G52 and W91 were placed on an autoshaping procedure with an intermittent 8-s illumination of the center key followed by food delivery. Both subjects responded reliably within two sessions and were moved to concurrent-chains schedules with a single response requirement (FR 1). The duration of the terminal links was increased from 10 to 50 s over the next three sessions. Subjects G17, G20, and G42, continuing from Experiment 2, were moved directly to the experimental conditions.

Experimental conditions. With few exceptions (noted below), the comparison was between 100% and 50% reinforcement, as in Experiment 2. In the first series of conditions, the initial-link schedules were FR 1. The terminal-link durations were 30 s for G42 and 50 s for all others. Stimulus conditions were alternated between signaled-different and unsignaled (as described in Experiment 2) in an ABA sequence. Two birds, G17 and G20, were moved to signaled-same conditions (as described in Experiment 2) and then to pilot comparisons between 100% and either 60% or 80% reinforcement in the signaled-different procedure. In the second series of conditions, the initial-link schedule was varied from FR 1 to VI 80 with the sequence of schedule values balanced across subjects. In the last three conditions, all subjects were placed on an ABA sequence of signaled-different and signaled-same conditions with FR 1 initial-link schedules. The order of conditions for each subject is presented Table 3.

In all conditions, daily sessions continued for a fixed number of food presentations or 180 min. The hopper duration and the maximum number of food deliveries per session for G52 were 3 s and 60, respectively; for G42, they were 4 s and 70. The values for G17, G20, and G42 were as in Experiment 2. The stability criteria were those in Experiment 2. The number of sessions to stability for each subject is presented in Table 3.

RESULTS

The relative response rates in the initial ABA sequence are shown in Figure 4. Relative response rates for the 100% alternative were considerably lower in the signaled-different conditions and were below .50 for 3 of 5 subjects. Figure 5 shows the relative response rates as a function of the initial-link durations in the signaled-different procedure. For 3 of 4 birds, preference for the 100% alternative was correlated with the duration of the initial links. The exception, Bird W91, will be discussed below.

Relative response rates in signaled-same conditions are presented in Table 3. Although the differences were generally small, in all cases the preference for the 100% alternative was lower in the signaled-same conditions than in adjacent signaled-different conditions.

The results of the two pilot manipulations of percentage reinforcement on the unreliable alternative are presented in Table 3 (marked by asterisks). Preference for the 100% alternative was reduced in conditions with 80% reinforcement (Subject G17 and G20) and 67% reinforcement (G17) on the alternative chain when compared to preference obtained in conditions with 50% reinforcement on the unreliable alternative.

The response rates in the initial and terminal links are presented in Table 3. Absolute response rates in the initial links varied inversely with the initial-link schedule requirements. The latencies to the initial-link response in the FR 1 conditions were not recorded. Terminal-link response rates did not

Table 3

Schedule values and results in each condition in the order of presentation in Experiment 3.

Initial-link schedule	Terminal links: Stimuli	Terminal links: Duration	C.P.	Responses per minute: Initial link	Responses per minute: 100% S+	Responses per minute: 50% S+	Responses per minute: 50% S−	Obt % rft: 50%	Obt % rft: Overall	Sessions to stability
G17										
FR 1	Signal-diff	50	.14	—	1.36	0.85	0.06	.51	.24	25
FR 1	Unsignaled	50	.94	—	0.44	0.66	1.16	.49	.97	18
FR 1	Signal-diff	50	.20	—	0.82	0.26	0.08	.50	.34	25
FR 1	Signal-same	50	.09	—	0.58	0.23	0.00	.52	.16	20
FR 1	Signal-diff	50	.11	—	1.25	0.47	0.01	.50	.19	20
FR 1*	Signal-diff	50	.07	—	1.50	0.83	0.00	.61	.10	30
FR 1**	Signal-diff	50	.06	—	2.17	0.84	0.09	.80	.07	27
FR 1	Signal-diff	50	.14	—	0.94	1.19	0.00	.53	.22	30
VI 30 s	Signal-diff	50	.68	33.68	0.41	0.60	0.05	.49	.70	21
FR 1	Signal-diff	50	.15	—	0.40	1.26	0.02	.48	.25	31
VI 10 s	Signal-diff	50	.19	36.50	0.33	0.95	0.00	.48	.61	34
VI 80 s	Signal-diff	50	.76	60.80	1.01	1.46	0.03	.46	.69	18
FR 1	Signal-diff	50	.31	—	1.25	1.60	0.04	.49	.49	20
FR 1	Signal-same	50	.20	—	3.12	3.29	0.01	.48	.34	30
FR 1	Signal-diff	50	.34	—	0.48	0.55	0.00	.49	.50	25
G20										
FR 1	Signal-diff	50	.72	—	5.18	34.85	0.04	.48	.84	35
FR 1	Unsignaled	50	.93	—	7.10	8.59	0.00	.50	.96	35
FR 1	Signal-diff	50	.54	—	5.39	9.27	0.00	.52	.69	35
FR 1	Signal-same	50	.25	—	12.59	13.49	0.03	.52	.41	35
FR 1**	Signal-diff	50	.05	—	22.06	15.90	0.01	.80	.06	32
FR 1	Signal-diff	50	.40	—	8.47	1.98	0.01	.49	.59	35
VI 30 s	Signal-diff	50	.95	9.98	1.50	3.63	0.00	.44	.95	23
VI 10 s	Signal-diff	50	.86	12.53	0.78	0.39	0.02	.55	.94	35
VI 80 s	Signal-diff	50	.87	9.20	1.42	2.34	0.00	.48	.93	30
FR 1	Signal-diff	50	.62	—	2.96	0.51	0.00	.51	.70	21
FR 1	Signal-same	50	.58	—	1.51	1.44	0.00	.50	.68	35
FR 1	Signal-diff	50	.06	—	1.97	1.26	0.01	.50	.68	35
G42										
FR 1	Signal-diff	30	.24	—	24.13	34.04	0.00	.53	.39	35
FR 1	Unsignalled	30	.93	—	12.39	15.37	0.42	.51	.96	23
FR1	Signal-diff	30	.47	—	6.92	15.77	0.00	.51	.61	18
G52										
FR 1	Signal-diff	50	.14	—	37.62	33.92	0.25	.48	.25	18
FR 1	Unsignaled	50	.83	—	51.22	50.32	50.83	.58	.90	35
FR 1	Signal-diff	50	.17	—	47.28	44.07	0.03	.50	.26	35
VI 80 s	Signal-diff	50	.88	13.46	12.58	29.61	0.00	.52	.82	18
VI 30 s	Signal-diff	50	.74	10.24	22.28	33.02	0.00	.47	.84	35
VI 10 s	Signal-diff	50	.46	15.61	23.93	30.01	0.02	.48	.70	35
FR 1	Signal-diff	50	.35	—	37.43	37.21	0.03	.47	.52	33
FR 1	Signal-same	50	.31	—	32.56	31.31	0.00	.48	.46	27
FR 1	Signal-diff	50	.34	—	25.36	26.96	0.00	.50	.51	28
W91										
FR 1	Signal-diff	50	.72	—	—	—	—	.52	.80	35
FR 1	Unsignaled	50	.90	—	0.04	0.00	0.06	.46	.95	16
FR 1	Signal-diff	50	.87	—	0.01	0.00	0.00	.49	.94	35
VI 30 s	Signal-diff	50	.85	17.78	0.00	0.00	0.00	.49	.89	29
VI 80 s	Signal-diff	50	.75	21.16	0.00	0.03	0.00	.49	.75	35
VI 10 s	Signal-diff	50	.86	26.76	0.00	0.00	0.00	.47	.86	28
FR 1	Signal-diff	50	.65	—	0.00	0.00	0.00	.49	.73	35
FR 1	Signal-same	50	.46	—	0.00	0.00	0.00	.48	.65	35
FR 1	Signal-diff	50	.49	—	0.00	0.00	0.00	.45	.66	35

Note: C.P. is the choice proportion; Obt % rft is the obtained percentage of reinforcement on the 50% alternative and the overall percentage of reinforcement on the concurrent-chains schedules; a single asterisk marks the condition

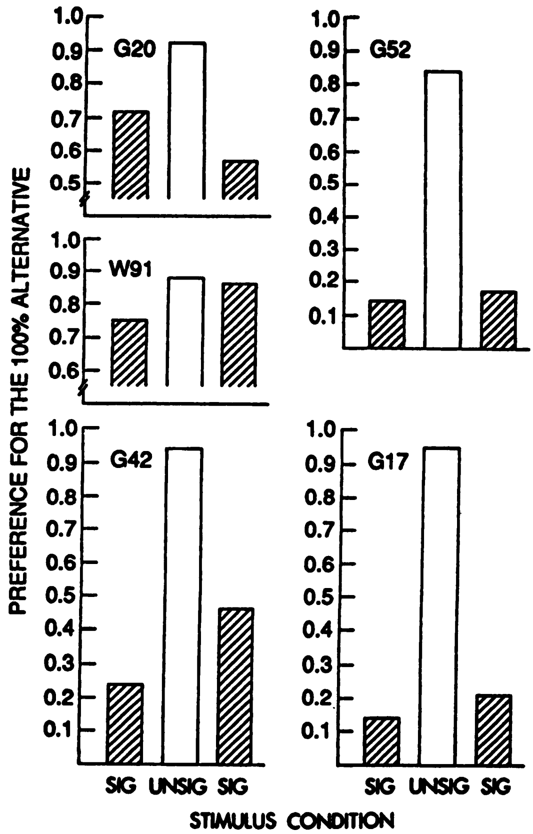

Fig. 4. Choice proportions for the 100% alternative in signaled and unsignaled conditions with an FR 1 initial-link schedule and 50-s terminal links in Experiment 3.

vary systematically with either the initial-link schedules or the stimulus contingencies.

Discussion

The results demonstrate that the level of preference for the more reliable alternative depends in part on the stimulus conditions during the terminal links and in part on the schedule values in the initial links. Relative response rates differed substantially between the signaled and unsignaled conditions. Although the procedure did not include side or stimulus reversals, the contrast between the levels of preference under signaled and unsignaled conditions with FR 1 initial links appears independent of extraneous bias variables: The position and stimulus variables were identical in this comparison, yet preference differed markedly between the two procedures.

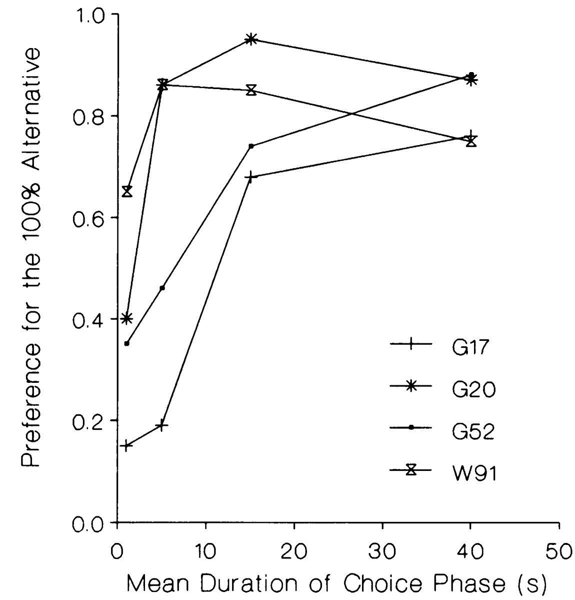

Fig. 5. Choice proportions for the 100% alternative across manipulations of the initial-link duration in Experiment 3.

Preference for the 100% alternative varied directly with initial-link duration under signaled conditions with relatively long terminal links (Figure 5). The pattern of data for W91 provides the one exception to this description; indeed, the trend for W91 across the conditions with VI schedules shows the opposite relationship and is characteristic of performance in unsignaled conditions. The terminal-link data for W91 suggest a possible explanation. There were few or no responses to the center key during the terminal links, and there is no evidence of a discrimination or even contact with the stimulus conditions. Thus, for that subject the outcomes may have been unsignaled in all conditions (see also Subjects II-2 and II-3 in Experiment 2 of Kendall's, 1974, report).

The extension of Kendall's (1974) enhancement hypothesis (as described in Experiment 2) predicts an increase in preference for the 100% alternative when the same stimulus signals reinforcement on the two alternatives. Again, the data do not support this hypothesis: Preference for the 100% alternative was lower in signaled-same conditions than in signaled-different conditions.

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with 60% reinforcement programmed on the unreliable alternative for G17; a double asterisk marks conditions with 80% reinforcement for G17 and G20.

GENERAL DISCUSSION

In general, preference for the 100% alternative was lower in the signaled conditions than in unsignaled conditions. This finding is consistent with the results of procedures that have demonstrated preference for signaled over unsignaled reinforcement in concurrent chains (e.g., Bower, McLean, & Meacham, 1966; Fantino & Moore, 1980; Green, 1980; Green & Rachlin, 1977; Moore, 1985; Prokasy, 1956) and in observing procedures (e.g., Dinsmoor, 1983; Kendall, 1973; McMillian, 1974; Wyckoff, 1952). In Experiments 2 and 3, preference for an unreliable alternative with either signaled or unsignaled outcomes was measured against a standard comparison, an alternative that reliably ended in food delivery. Given the preference for the signaled alternative in the direct comparisons cited above, it is not surprising that the levels of preference for the standard 100% alternative were reduced in the signaled conditions presented here. The comparisons across procedures do not appear to lead directly to an adequate description of the controlling variables. Preference for signaled over unsignaled percentage reinforcement has been interpreted as evidence of the strength of the food-correlated stimulus on the unreliable alternative as a conditioned reinforcer either because of the reduction in the overall delay to primary reinforcement (Fantino, 1977; Fantino & Moore, 1980; Hursh & Fantino, 1974) or because of the discriminative function of the stimulus (from a wide variety of perspectives: Bower et al., 1966; Green & Rachlin, 1977; Hendry, 1969; Kendall, 1975; Wilton, 1972; Wyckoff, 1959; cf. Perone & Baron, 1980). Neither interpretation addresses the trend observed in the manipulation of the initial links in Experiment 3; that is, preference for the reliable alternative decreased with decreases in the initial-link requirement (Figure 5). As traditionally employed, delay reduction has been based on the interreinforcement interval (Fantino, 1981; see Spetch & Dunn, 1987, for application to percentage reinforcement). In these terms, the relative delay reduction correlated with the signal for food on the unreliable chain remains constant with decreases in the initial-link requirement. And, from the alternative perspective, uncertainty could be described as either constant or decreasing with decreasing initial-link duration, thereby reducing the discriminative function of the signal.

The sometimes extreme reductions in preference obtained with FR 1 initial links offer the most demanding challenge to existing models of choice. The delay-reduction hypothesis has provided a successful model of conditioned reinforcement in a variety of choice paradigms. The cornerstone of the model is that "the greater the improvement, in terms of temporal proximity to reinforcement, correlated with the onset of the stimulus, the more effective it will be as a conditioned reinforcer" (Fantino, 1977, p. 330). The definition of delay reduction may be critical to the analysis of the present results. On both alternatives, onset of the terminal-link stimulus signals food delivery after a delay of 50 s. The two terminal-link stimuli signal equal reductions in the overall delay to reinforcement (the interreinforcement interval). However, the two stimuli signal unequal reductions in delay as signaled by other elements of the context. Consider the FR 1 signaled-different condition with 50-s terminal links. A response in the initial link of the 100% chain signals food delivery in 50 s. The onset of the terminal-link stimulus does not signal a reduction in that delay. However, a response in the initial link of the 50% chain is followed by either a timeout of 50 s or food delivery in 50 s. In this case, the onset of the terminal-link stimulus correlated with food delivery signals a delay reduction and can be expected to reinforce the initial-link response.

Within this framework, the consequences of responding in the initial links of the two chains can be described as delayed primary reinforcement on the 100% chain and, on the 50% chain, less probable, delayed primary reinforcement with immediate conditioned reinforcement. Thus, this procedure may be described as similar to the self-control paradigm; the results presented here parallel the findings that choice between a larger, delayed reinforcer and a smaller, immediate reinforcer is influenced disproportionately by the immediate reinforcer (e.g., Green, Fisher, Perlow, & Sherman, 1981; Rachlin & Green, 1972).

This analysis extends to other aspects of the present procedures. The terminal-link stimulus on the 100% alternative is a redundant signal only with FR 1 initial-link schedules. The effect of longer initial links is to increase the average delay to reinforcement correlated with initial-link responding on both the 100% and 50% chains. Consequently, the terminal-link stimulus on the 100% chain signals a delay reduction and thereby functions as a conditioned reinforcer. Under these conditions, initial-link responses to both alternatives are followed occasionally by delayed primary reinforcement as well as immediate conditioned reinforcement. Moreover, as the initial-link durations increase, the delay reductions signaled by the two terminal-link stimuli correlated with food approach equality regardless of the terminal-link durations, and the relative strength of the initial-link responses becomes dependent on the relative frequency of the terminal-link stimuli. Note that the role of the terminal-link duration in signaled procedures in the present study differs from that in other applications of the delay-reduction hypothesis (Fantino, 1981). Here the terminal-link duration acts on preference only as the delay to primary reinforcement (in the balance with immediate conditioned reinforcement); terminal-link duration does not influence the *relative* delay reduction signaled by the onset of the terminal-link stimuli.

In general, the results of the three experiments reported here appear consistent with this description. In Experiment 3, the level of preference for the 100% alternative rose sharply as the initial-link schedule increased from FR 1 to VI 30 s (Figure 5). Within the context described above, the delay signaled by a response on the VI 30-s schedule is reduced by the onset of food-correlated stimuli on either alternative. Given the relatively slight differences in preference between the VI 30 s and VI 80 s conditions in Experiment 3, it may be that the initial-link schedules of VI 30 s or more in Experiments 1 and 2 are sufficient to ensure that responses on both alternatives are reinforced by immediate conditioned reinforcement. Manipulations of the equal terminal-link durations under these conditions are not expected to alter the level of preference. Finally, the distinction between the signaled-same and signaled-different conditions in Experiments 2 and 3 is not critical to this analysis. However, there is no ready explanation for the reduced preference for the 100% alternative obtained in signaled-same conditions. Unlike Kendall's (1974) enhancement hypothesis, the argument here is that the function, rather than the value per se, of the terminal-link stimulus is influenced by the signaled reduction in the delay correlated with other elements of the context. The function of the terminal-link stimulus on the unreliable alternative will differ from the function on the reliable alternative even if the stimuli are identical.

There is other support for this description. If terminal links were manipulated in conditions with FR 1 initial links, the contrast between the delayed food and the immediacy of conditioned reinforcement on the 50% chain would be expected to increase with increased terminal-link durations, and preference for the 100% chain would be expected to decrease accordingly. These conditions were not explored in the present procedure, but the results of the relevant manipulations described by Kendall (1974, 1985) and a more extensive investigation reported by Spetch, Belke, Barnet, Dunn, and Pierce (1990) are consistent with this implication. Similar results have been demonstrated within the autoshaping paradigm. Aucella (1984) compared responding to two compound stimuli: one ending in more probable, delayed reinforcement, the other in less probable, immediate reinforcement. With short delays, the high- and low-probability compounds elicited comparable response rates; with longer delays, the low-probability compound exerted greater control.

The results of a recent series of serial autoshaping studies (Collins & Pearce, 1985; Kaye & Pearce, 1984; Pearce, Kaye, & Collins, 1985; Rashotte, Marshall, & O'Connell, 1981) parallel the pattern of results presented here. A procedure reported by Pearce et al. (Experiment 3, 1985) is closely analogous to the signaled conditions in the present study. During initial training, a stimulus (B) was presented occasionally and followed reliably by food delivery. In subsequent sessions, there were three trial types: Stimulus A followed by B and then food (AB+); Stimulus A not followed by food (A−); and Stimulus C followed by B followed by food (CB+). All stimulus durations were 10 s. Each session consisted of the quasi-random presentation of 10 AB+, 10 A−, and 20 CB+ trials separated by a 90-s intertrial interval. Thus, A was followed by delayed food with a probability of .50; C was followed by delayed food with a probability of 1.0. Pearce et al. reported substantially more responding in the presence of A than in the presence of C. Kaye and Pearce (1984) were able to discriminate between magazine-oriented and signal-oriented responses in a similar procedure with rats. Magazine-oriented responses were more frequent during the reliable signal (similar to C). Signal-oriented responding was more frequent during the partially reinforced signal (similar to A).

In the terms of delay reduction, presentations of A signaled some reduction in delay but, because A was sometimes not followed by food, the presentation of B signaled a substantial, additional improvement. In contrast, the onset of the B stimulus signaled a much smaller improvement over the onset of C; food always followed C onset by 20 s. In operant terminology, attention to the A stimulus is reinforced by presentation of the B stimulus because B signals a substantial delay reduction. Presentation of B provides minimal reinforcement of attending to C; food is already well predicted. In the Pearce et al. procedure with pigeons, both attention, the putative operant, and elicited responding would be expected to occur on the keylight, and the responses on A may sum to exceed the responding on C. Whatever the efficacy of this analysis, the parallels between the results of the serial conditioning procedures and the operant procedures employed here compel the search for common mechanisms.

The results of the present work have at least three other implications for general models of choice. First, the task for molar analyses of percentage reinforcement on concurrent chains seems clear. The relative response rates in the initial links were determined in a large part by the stimulus conditions during the terminal links. These results define the need to explain the role of those stimuli. Mazur (1989, Equation 3) has superimposed a provision for stimulus conditions on a model (Mazur, 1984) that incorporates percentages of reinforcement in the distribution of response–reinforcer delays. The revised model predicts reduced preference for the reliable alternative under signaled conditions. However, although it may be possible to include a provision for initial-link schedules as well, the model does not offer a specific role for the stimuli other than that they allow the animal to treat explicit delays as different from other components of the response–reinforcer interval. Second, the present results provided no evidence that the presentation of a stimulus correlated with a period of extinction (a timeout) punishes the contingent choice response. On average, levels of preference for the 100% alternative in the signaled conditions did not exceed matching to the relative frequency of reinforcement regardless of the timeout contingency. In the unsignaled conditions in which there were no signaled response-contingent timeouts, preference exceeded matching in conditions with short initial links or long terminal links as required by the delay-reduction hypothesis. These results are consistent with those of Dunn, Williams, and Royalty (1987): When response-contingent periods of extinction were signaled by a terminal-link stimulus, preference for that terminal link decreased. However, preference was near indifference when the periods of extinction were signaled by another stimulus not presented in the terminal links. Furthermore, in the latter conditions the level of preference was similar whether the periods of extinction were response contingent or response independent (cf. Dunn, 1990). Third, if our analogy to the self-control procedures has merit, the literature suggests that the reduced preference found in the signaled conditions might be expected to be obtained with pigeons, but perhaps not with adult humans (Logue, Peña-Correal, Rodriguez, & Kabela, 1986; cf. Navarick, 1982; Ragotzy, Blakely, & Poling, 1988).

REFERENCES

Aucella, A. (1984). Delay versus probability of reinforcement in discrimination learning. *Journal of Experimental Psychology: Animal Behavior Processes*, **10**, 453–460.

Autor, S. M. (1969). The strength of conditioned reinforcers as a function of frequency and probability of reinforcement. In D. P. Hendry (Ed.), *Conditioned reinforcement* (pp. 127–162). Homewood, IL: Dorsey Press.

Baum, W. M. (1973). The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior*, **20**, 137–153.

Bower, G., McLean, J., & Meacham, J. (1966). Value of knowing when reinforcement is due. *Journal of Comparative and Physiological Psychology*, **62**, 184–192.

Caraco, T. (1981). Energy budgets, risk and foraging preferences in dark-eyed juncos (*Junco hyemalis*). *Behavioural Ecology and Sociobiology*, **8**, 213–217.

Collins, L., & Pearce, J. M. (1985). Predictive accuracy and the effects of partial reinforcement on serial autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*, **11**, 548–564.

Dinsmoor, J. A. (1983). Observing and conditioned reinforcement. *Behavioral and Brain Sciences*, **6**, 693–728. (Includes commentary).

Dunn, R. (1990). Timeout from concurrent schedules. *Journal of the Experimental Analysis of Behavior,* **53,** 163–174.

Dunn, R., Williams, B., & Royalty, P. (1987). Devaluation of stimuli contingent on choice: Evidence for conditioned reinforcement. *Journal of the Experimental Analysis of Behavior,* **48,** 117–131.

Fantino, E. (1977). Conditioned reinforcement: Choice and information. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 313–339). Englewood Cliffs, NJ: Prentice-Hall.

Fantino, E. (1981). Contiguity, response strength, and the delay-reduction hypothesis. In P. Harzem & M. D. Zeiler (Eds.), *Advances in analysis of behaviour: Vol. 2. Predictability, correlation, and contiguity* (pp. 169–201). Chichester, England: Wiley.

Fantino, E. (1982). Effect of initial-link length on responding in terminal link. *Behaviour Analysis Letters,* **2,** 65–70.

Fantino, E., Dunn, R., & Meck, W. (1979). Percentage reinforcement and choice. *Journal of the Experimental Analysis of Behavior,* **32,** 335–340.

Fantino, E., & Moore, J. (1980). Uncertainty reduction, conditioned reinforcement, and observing. *Journal of the Experimental Analysis of Behavior,* **33,** 3–13.

Green, L. (1980). Preference as a function of the correlation between stimuli and reinforcement outcomes. *Learning and Motivation,* **11,** 238–255.

Green, L., Fisher, E. B., Jr., Perlow, S., & Sherman, L. (1981). Preference reversal and self control: Choice as a function of reward amount and delay. *Behaviour Analysis Letters,* **1,** 43–51.

Green, L., & Rachlin, H. (1977). Pigeons' preferences for stimulus information: Effects of amount of information. *Journal of the Experimental Analysis of Behavior,* **27,** 255-263.

Hendry, D. P. (1969). Reinforcing value of information: Fixed-ratio schedules. In D. P. Hendry (Ed.), *Conditioned reinforcement* (pp. 300-341). Homewood, IL: Dorsey Press.

Hursh, S. R., & Fantino, E. (1974). An appraisal of preference for multiple *versus* mixed schedules. *Journal of the Experimental Analysis of Behavior,* **22,** 31–38.

Kaye, H., & Pearce, J. M. (1984). The strength of the orienting response during Pavlovian conditioning. *Journal of Experimental Psychology: Animal Behavior Processes,* **10,** 90–109.

Kendall, S. B. (1973). Effects of two procedures for varying information transmission on observing responses. *Journal of the Experimental Analysis of Behavior,* **20,** 73–83.

Kendall, S. B. (1974). Preference for intermittent reinforcement. *Journal of the Experimental Analysis of Behavior,* **21,** 463–473.

Kendall, S. B. (1975). Enhancement of conditioned reinforcement by uncertainty. *Journal of the Experimental Analysis of Behavior,* **24,** 311–314.

Kendall, S. B. (1985). A further study of choice and percentage reinforcement. *Behavioural Processes,* **10,** 399–413.

Logue, A. W., Peña-Correal, T. E., Rodriguez, M. L., & Kabela, E. (1986). Self-control in adult humans: Variation in positive reinforcer amount and delay. *Journal of the Experimental Analysis of Behavior,* **46,** 159–173.

Mazur, J. E. (1984). Tests of an equivalence rule for fixed and variable reinforcer delays. *Journal of Experimental Psychology: Animal Behavior Processes,* **10,** 426–436.

Mazur, J. E. (1985). Probability and delay of reinforcement as factors in discrete-trial choice. *Journal of the Experimental Analysis of Behavior,* **43,** 341–351.

Mazur, J. E. (1989). Theories of probabilistic reinforcement. *Journal of the Experimental Analysis of Behavior,* **51,** 87–99.

McMillian, J. C. (1974). Average uncertainty as a determinant of observing behavior. *Journal of the Experimental Analysis of Behavior,* **22,** 401–408.

Moore, J. (1985). Choice and the conditioned reinforcing strength of informative stimuli. *Psychological Record,* **35,** 89–100.

Navarick, D. J. (1982). Negative reinforcement and choice in humans. *Learning and Motivation,* **13,** 361–377.

Navarick, D. J., & Fantino, E. (1976). Self-control and general models of choice. *Journal of Experimental Psychology: Animal Behavior Processes,* **2,** 75–87.

Pearce, J. M., Kaye, H., & Collins, L. (1985). A comparison of the effects of partial reinforcement schedules using a within-subject serial autoshaping procedure. *Quarterly Journal of Experimental Psychology,* **37B,** 379–396.

Perone, M., & Baron, A. (1980). Reinforcement of human observing behavior by a stimulus correlated with extinction or increased effort. *Journal of the Experimental Analysis of Behavior,* **34,** 239-261.

Prokasy, W. F., Jr. (1956). The acquisition of observing responses in the absence of differential external reinforcement. *Journal of Comparative and Physiological Psychology,* **49,** 131–134.

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

Rachlin, H., Logue, A. W., Gibbon, J., & Frankel, M. (1986). Cognition and behavior in studies of choice. *Psychological Review,* **93,** 33–45.

Ragotzy, S. P., Blakely, E., & Poling, A. (1988). Self-control in mentally retarded adolescents: Choice as a function of amount and delay of reinforcement. *Journal of the Experimental Analysis of Behavior,* **49,** 191–199.

Rashotte, M. E., Marshall, B. S., & O'Connell, J. M. (1981). Signaling functions of the second-order CS: Partial reinforcement during second-order conditioning of the pigeon's keypeck. *Animal Learning & Behavior,* **9,** 253-260.

Shull, R. L., & Spear, D. J. (1987). Detention time after reinforcement: Effects due to delay of reinforcement? In M. L. Commons, J. E. Mazur, J. A. Nevin, & H. Rachlin (Eds.), *Quantitative analyses of behavior: Vol. 5. The effect of delay and of intervening events on reinforcement value* (pp. 187–204). Hillsdale, NJ: Erlbaum.

Spetch, M. L., Belke, T. W., Barnet, R. C., Dunn, R., & Pierce, W. D. (1990). Suboptimal choice in a percentage-reinforcement procedure: Effects of signal condition and terminal-link length. *Journal of the Experimental Analysis of Behavior,* **53,** 219–234.

Spetch, M. L., & Dunn, R. (1987). Choice between reliable and unreliable outcomes: Mixed percentage-reinforcement in concurrent chains. *Journal of the Experimental Analysis of Behavior,* **47,** 57–72.

Vaughan, W., Jr. (1985). Choice: A local analysis. *Journal of the Experimental Analysis of Behavior,* **43,** 383–405.

Williams, B. A., & Fantino, E. (1978). Effects on choice of reinforcement delay and conditioned reinforcement. *Journal of the Experimental Analysis of Behavior,* **29,** 77–86.

Wilton, R. N. (1972). The role of information in the emission of observing responses and partial reinforcement acquisition phenomena. *Learning and Motivation,* **3,** 479–499.

Wyckoff, L. B., Jr. (1952). The role of observing responses in discrimination learning: Part I. *Psychological Review,* **59,** 431–442.

Wyckoff, L. B., Jr. (1959). Toward a quantitative theory of secondary reinforcement. *Psychological Review,* **66,** 68–78.

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