

CONTEXT EFFECTS ON CHOICE

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Four pigeons responded on a concurrent-chains schedule in four experiments that examined whether the effectiveness of a stimulus as a conditioned reinforcer is best described by a global approach, as measured by the average interreinforcement interval, or by a local contextual approach, as measured by the onset of the stimulus preceding the conditioned reinforcer. The interreinforcement interval was manipulated by the inclusion of an intertrial interval, which increased the overall time to reinforcement but did not change the local contingencies on a given trial. A global analysis predicted choice for the richer alternative to decrease with the inclusion of an intertrial interval, whereas a local analysis predicted no change in preference. Experiment 1 examined sensitivity to intertrial intervals when each was signaled by the same houselight that operated throughout the session. In Experiment 2, the intertrial interval always was signaled by the stimulus correlated with the richer terminal link. In Experiment 3, the intertrial interval was signaled by the keylights correlated with the initial links and two novel houselights. Experiment 4 provided free food pseudo-randomly during the intertrial interval. In all experiments, subjects' preferences were consistent with a local analysis of choice in concurrent chains. These results are discussed in terms of delay-reduction theory, which traditionally has failed to distinguish global and local contexts.

Key words: conditioned reinforcement, delay-reduction theory, choice, intertrial interval, concurrent chains, key peck, pigeons

A pervasive problem in conditioning involves the role of context, including temporal context, in modulating the strength of conditioned reinforcers. Initial theories emphasized the role of global temporal variables (Gibbon & Balsam, 1981), but later research suggests an increasing role for locally mediated effects (Reilly & Schactman, 1987; W. A. Williams & Fantino, 1996).

Temporal control over the development of conditioned stimuli in classical conditioning has been most often studied using the auto-shaping paradigm (Cooper, Aronson, Balsam, & Gibbon, 1990; Kaplan & Hearst, 1982; Yin, Barnet, & Miller, 1994). This procedure is used to train key pecking in a pigeon with no history of pecking a lighted response key. An auto-shaping trial consists of the presentation of the target keylight for a fixed duration, followed immediately by food. The temporal context in which this trial occurs can be manipulated by altering the time (intertrial interval, ITI) that separates each trial. During

the ITI, the key is not typically illuminated. In general, key pecking during the trial is facilitated by increasing the duration of the ITI relative to the trial duration (Gibbon & Balsam, 1981; see Cooper, 1991, for a review). Temporal comparator models, such as scalar expectancy theory (Gibbon & Balsam, 1981), propose that the increase in key pecking with increasing ITIs is not due to the absolute temporal duration of the ITI, but rather to the relation between the ITI and trial duration. Such models suggest that the evocative effect of a stimulus is a function not only of the absolute time spent in its presence but also of the overall time between food presentations (i.e., the interreinforcement interval, IRI). Gibbon and Balsam (1981) described the acquisition of a response in terms of cycle time divided by trial duration, in which the cycle time is defined as the IRI (i.e., ITI plus trial duration). When this ratio is greater than a given value (approximately two), responding should be elicited reliably. Increasing the ITI relative to the trial duration should increase the rate of response acquisition; however, increasing the ITI while also increasing the trial duration such that the ratio is maintained should not produce an increase in speed of response acquisition. Thus, assuming that the same factors determine the conditioned reinforcing value of a stimulus,

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a complete behavioral analysis of conditioned reinforcement must take account of the *relative* temporal context in which the trial occurs.

Characterizing conditioned value (either evocative or reinforcing) of a stimulus as a function of the overall time between unconditioned stimulus presentations represents a global temporal account of conditioned value. However, additional experimental work suggests that the relevant temporal comparator term may not be the IRI. Instead, the time since the last cue or discrete environmental signal (the local context) may be more relevant in determining conditioned value. The local context has been manipulated by providing free food during the ITI (Goddard & Jenkins, 1987) or by presenting a neutral stimulus during the ITI prior to the target stimulus (an ITI "filler"; Schactman & Reilly, 1987). Both manipulations have been shown to retard response autoshaping, presumably by increasing the excitatory strength of the ITI relative to the target stimulus. Global accounts of conditioning that presuppose that the target stimulus strength is a function of the IRI cannot accurately account for the effects described above. Thus, it is necessary to reconceptualize the appropriate temporal context in which to assess conditioned value (Barnet, Grahame, & Miller, 1993).

Although the effects of global and local variables have been studied extensively in autoshaping, significantly less is known of the effects of comparable variables on choice in operant paradigms. The current investigation used a choice procedure involving concurrent-chains schedules of reinforcement (Autor, 1969) in order to assess the role of global and local temporal contexts in determining the development of conditioned reinforcement strength.

A chained schedule consists of two or more schedules, each of which is correlated with a different exteroceptive stimulus. Primary reinforcement is obtained only after the termination of the final component (the terminal link) of the chain. A concurrent chain consists of two chained schedules operating simultaneously. In research on choice, both alternatives in the initial link are signaled by stimuli of the same form. The schedules operating in the initial links are generally equal

variable-interval (VI) schedules of reinforcement. In a two-component concurrent-chains schedule, the first response after an initial-link VI schedule has timed out is reinforced with the presentation of the terminal link. The alternative not chosen is darkened at this point, and the organism responds in the chosen terminal link until primary reinforcement is obtained. After reinforcer delivery, the initial links are reinstated. This procedure is ideal in assessment of the conditioned reinforcing value of a stimulus because choice in the initial links is affected by differences arranged in the terminal-link components (see Fantino & Logan, 1979, pp. 227–234, for history and rationale). Thus, the efficacy of a terminal-link stimulus as a conditioned reinforcer can be measured by the proportion of responding in the initial link that precedes it relative to the alternative.

The present experiments were designed to determine to what extent temporal context (in this case, the IRI) and the stimuli present during the IRI influence responding on concurrent-chains schedules. With such a strong relation between ITI and trial duration in autoshaping, it is possible that such a relation exists for concurrent-chains schedules of reinforcement. The value of a terminal-link stimulus as a conditioned reinforcer often has been seen as determined by its temporal relation to the onset of the initial-link stimulus and reinforcement. From a more global perspective, the context for conditioned reinforcement can be conceptualized not in terms of trial duration (i.e., duration of the whole chain, initial and terminal links), but in terms of the relation between a stimulus and the IRI. In most previous studies, trial duration has been equivalent to the IRI because each food delivery was followed immediately by the onset of the subsequent trial. The present experiments investigated conditions in which the IRI and trial duration were not equal. The addition of an ITI between trials makes this distinction possible. If choice is modulated by more global temporal variables, the addition of an ITI preceding every trial should affect performance by increasing the IRI. If choice is determined solely by local temporal parameters, then the addition of an ITI should not affect preference measures. Within a temporal framework, only time from onset of the choice

phase should govern conditioned value and thus choice.

Choice in concurrent-chains schedules is well described by delay-reduction theory, which states that the effectiveness of a stimulus as a conditioned reinforcer is determined by the reduction in time to reinforcement correlated with the onset of that stimulus relative to the average delay to reinforcement (Fantino, 1969, 1977; Fantino, Preston, & Dunn, 1993; Squires & Fantino, 1971). The greater the improvement in terms of temporal proximity to reinforcement correlated with the onset of a stimulus, the more effective that stimulus will be as a conditioned reinforcer. In the Squires and Fantino (1971) formulation, delay-reduction theory is expressed as follows:

$$\frac{B_L}{(B_L + B_R)} = \frac{r_L(T - t_L)}{[r_L(T - t_L) + r_R(T - t_R)]}, \quad (1)$$

where B_L and B_R represent responses on the left and right alternatives, respectively; r_L and r_R represent the arranged rate of reinforcement for the left and right alternatives; t_L and t_R are the durations of each terminal-link schedule; and T is the average time to reinforcement. The present experiment investigated whether T is best viewed as sensitive to the global or local temporal context in a concurrent-chains procedure. There are at least two ways to conceptualize T : either the average time to reinforcement as measured from the onset of the initial links of a given trial (a local view) or as the average time between reinforcer presentations (a global view). In the numerous studies that have examined conditioned reinforcement with concurrent chains, these two measures of T have been equivalent because the general effects of ITI presence versus absence were not under examination.

Most studies that have examined the role of ITIs on choice under concurrent-chains schedules have looked at choices between certain and uncertain outcomes with discrete-trial procedures (Spetch, Belke, Barnett, Dunn, & Pierce, 1990; Spetch, Mondloch, Belke, & Dunn, 1994). Although their findings have failed to demonstrate effects of presenting an ITI preceding the choice phase on relative responding, some of Mazur's work (1991, 1993) has suggested a potential role of

ITIs on preference measures. However, his research has typically employed discrete-trial choice measures and manipulated amount or probability of reinforcement. Such results may not necessarily generalize to other paradigms such as a free-operant procedure (Mazur, 1995).

The following experiments examined conditions in which a global and a local theory of conditioned reinforcement predicted dissimilar results in a traditional concurrent-chains schedule with and without an ITI. Two conditions employed either long or short initial links, holding terminal-link duration constant. The third condition used the same short initial links as one of the prior conditions but included an ITI preceding each trial. The ITI was sufficiently long to equate the average IRI between this condition with the long initial-link condition. Thus, the ITI condition had the same global temporal context as the long initial-link condition but the same local temporal context as the short initial-link condition. If the local view of conditioned reinforcement is more accurate in describing choice, preference should be comparable between the ITI and short initial-link conditions. If this outcome occurred, delay-reduction theory as traditionally viewed would need no modification. However, if a global view is correct, preference should be similar between the ITI and long initial-link conditions. With this outcome, Equation 1 would need an additional term to incorporate the ITI.

Thus the present set of experiments had three aims: (a) to assess whether the strength of a conditioned reinforcer is accurately predicted based on the global or the local temporal context; (b) to provide conditions under which sensitivity to global temporal variables would be enhanced; and (c) to determine whether Equation 1 should assess delay-reduction value relative to the immediately preceding stimulus (local context) or to the IRI as a whole (global context).

EXPERIMENT 1

Experiment 1 examined the effects on choice of presenting a single ITI, lit by a neutral houselight, prior to the initial links of a concurrent-chains schedule. Although we were confident that the degree of preference

would be sensitive to temporal manipulations in the initial links, evidence that relative preference measures are sensitive to extratrial temporal manipulations has been mixed (Mazur, 1993; W. A. Williams & Fantino, 1996). In addition, although delay-reduction theory is a relativistic choice model, the relevant comparator term T has not been expressly clarified. Its general conception as "the average time to reinforcement" implies that choice should be a function of the IRI; yet little research has examined the appropriate temporal context by differentiating the potential effects of the IRI from the traditional calculation of T from the onset of the initial links. Inclusion of an ITI in the concurrent-chains procedure extends the IRI and allows an empirical distinction to be made between the two approaches.

METHOD

Subjects

One mixed-breed and 3 White Carneau male pigeons were maintained at 80% of their free-feeding weights. Deprived-state body weights (80%) ranged from 295 g (Subject S1) to 485 g (Subject S2). All subjects were free-fed for a period of no less than 2 weeks; stability was determined by a leveling off of body weight, with no greater than a 15-g difference (10 g for Subject S1) between the lowest and highest weights of the last week. A minimum of seven weights were averaged for assessment of ad lib body weight. The lowest two body weights were eliminated prior to this average, and the final calculation was rounded up prior to using 80% of that weight as the subjects' "running" weights. Because the reassessment of body weights closely matched the initial assessment of body weights (almost 2 years prior to this study), body weights were not reassessed for the additional studies presented below (Experiments 2 through 4). Each pigeon had prior experience with simple chained schedules. The pigeons were housed individually in a colony room, where they were provided with continuous access to grit and vitamin-enriched water.

Apparatus

Sessions were conducted in four operant chambers. Two chambers were cubes and two

were round. Each chamber contained three translucent response keys that were evenly spaced horizontally above the floor. These keys could be transilluminated various colors by a 6-W miniature bulb, located directly behind each key. Directly above each response key was a houselight that could be illuminated various colors. A solenoid-operated food hopper provided mixed grain (including milo) as the reinforcer. During reinforcement, the hopper was illuminated by a 6-W bulb and all keylights and the chamber houselights were dark. Ventilation fans provided continuous masking noise. Hopper duration was 4 s per reinforcement. Experimental events for all chambers were controlled by IBM-compatible 286 computers operating Turbo Pascal 5.0 software.

Procedure

Key pecks were reinforced according to a concurrent-chains schedule of reinforcement (Figure 1). In the presence of the two initial-link stimuli (choice phase), responses on the left and right keys were reinforced according to concurrent and independent VI schedules as generated by a Fleshler and Hoffman distribution (1962). On each key, the first response following the lapse of the interval produced the terminal-link stimulus scheduled for that key. Responding in the presence of the terminal-link stimulus (outcome phase) was reinforced by food according to a VI schedule. Once a terminal link was obtained, the other key became dark, and timing of the schedule on the dark key was interrupted until the next choice phase began. Daily sessions were terminated after a maximum of either 40 reinforcer deliveries or 4 hr, whichever came first. Each condition remained in effect for a maximum of 35 sessions, or until a stability criterion was satisfied, whichever came first. A minimum of 10 sessions had to be completed before stability was assessed by the following method: The previous nine sessions were divided into three blocks of three sessions each. The stability criterion was satisfied if the means of the choice proportions for the three blocks differed by no more than .05 and showed no increasing or decreasing trends. If preference was above .90 for one alternative for three consecutive sessions, conditions were changed given that 10 sessions had occurred. The last requirement was

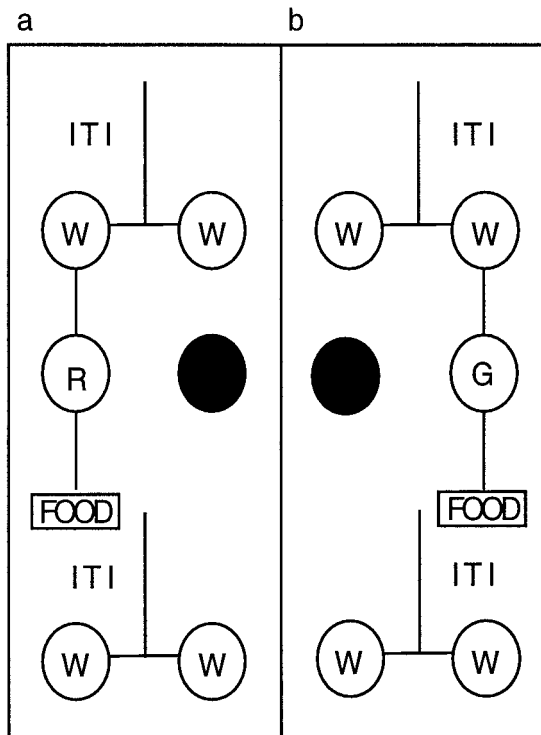


Fig. 1. The concurrent-chains procedure. (a) The sequence of events when responses on the left key are reinforced. (b) The analogous sequence of events when responses to the right alternative are reinforced. Equal VI schedules, signaled by identical white keylights, arrange access to mutually exclusive terminal links. Responses in the presence of the terminal links, correlated with distinct colored keylights, are reinforced with several seconds' access to grain. Preceding each choice phase is an ITI on a fixed-time schedule, in which all keylights are nonfunctional (stimulus presentation during the ITI varies across experiments).

instituted to prevent the development of patterns of biased performance which might have influenced responding in later conditions.

All subjects were exposed to baseline training to test for side or color biases. Each subject then was placed in three successive experimental conditions (A, B, and C), the order of which was counterbalanced across subjects. The schedule values for each condition and condition order are presented in Tables 1 and 2. The average time to reinforcement for a concurrent-chains schedule with equal VI initial links and different VI terminal links is calculated by dividing the value of the initial-link schedule in half and then adding terms equal to one half the value of the

Table 1

Variable-interval schedule values (in seconds) are presented for each component of two-link concurrent-chains procedure, along with choice predictions for the richer terminal link, as determined according to Squires and Fantino (1971).

Condition	Terminal links				
	ITI	Initial links	Rich	Lean	Predictions
Baseline		180	60	60	.50
A		120	30	90	.81
B		600	30	90	.57
C	240	120	30	90	

left terminal link plus one half the value of the right terminal link. Thus, the average time to reinforcement in Condition A is $120/2 + 90/2 + 30/2 = 120$ s. The average time spent in the initial links is 60 s, not 120 s, because both schedules are operating simultaneously and independently. Therefore, each chained schedule arranges one access to its terminal link every 120 s; collectively, this is two accesses every 120 s, or one every 60 s (on average). The average time to reinforcement for Condition B is $600/2 + 90/2 + 30/2 = 360$ s. For Condition C, if the ITI is not important in determining choice (a local view), the effective average time to reinforcement is calculated from the onset of the initial links and is identical to Condition A. The ITI does increase the IRI, however, and according to a global view of choice and conditioned reinforcement, should affect choice. If this view is correct, then the effective average time to reinforcement is $240 + 120/2 + 90/2 + 30/2 = 360$ s, identical to the IRI in Condition B.

During the choice phase, the left and right keys were illuminated white. One terminal link was signaled by a green keylight; the other was signaled by a red keylight (the termi-

Table 2

The order of conditions for all subjects across all four experiments.

Subject	Condition			
1	Baseline	A	B	C
2	Baseline	B	C	A
3	Baseline	A	C	B
4	Baseline	C	B	A

Table 3

Average response rates (responses per minute) in each component of the concurrent-chains schedule in Experiment 1.

Subject	Condition	Initial links	Terminal links	
			Rich	Lean
1	Baseline	44 (31)	55 (20)	71 (32)
	A	38 (12)	59 (13)	58 (12)
	B	53 (4)	82 (5)	77 (4)
	C	65 (7)	86 (8)	73 (6)
2	Baseline	55 (19)	49 (7)	40 (5)
	A	63 (3)	80 (5)	40 (2)
	B	47 (7)	97 (8)	49 (5)
	C	63 (6)	102 (10)	47 (3)
3	Baseline	72 (18)	67 (5)	59 (12)
	A	84 (5)	89 (3)	59 (7)
	B	88 (3)	144 (13)	86 (5)
	C	117 (3)	129 (4)	81 (14)
4	Baseline	63 (16)	85 (8)	89 (14)
	A	92 (11)	89 (6)	77 (6)
	B	90 (24)	100 (12)	83 (10)
	C	109 (29)	111 (14)	74 (8)

Note. Values in parentheses represent standard deviations. All values for Subject 3 in Condition C and Subject 4 in Condition A represent data averaged over the last three sessions; remaining values for all subjects were averaged over the last nine sessions.

nal link that corresponded to each stimulus was counterbalanced across subjects). During the ITI in Condition C, all stimuli were darkened except for a single white houselight above the center key, which was illuminated throughout the session. In Condition C, the first trial began with the ITI; each subsequent ITI immediately followed the reinforcer presentation.

RESULTS AND DISCUSSION

Individual means and standard deviations of response rates in each component of the procedure for each condition are presented in Table 3; individual-subject choice proportions and time-allocation measures are illustrated in Figure 2. (Time spent in an initial-link schedule per visit was measured from the first response to that schedule until the first response to the other schedule.) The means were taken from the final nine sessions of each condition, except when the final three sessions (after a minimum of 10 sessions) were above .90 preference. Under these circumstances, mean preference was obtained from these final three sessions only.

The average time to reinforcement was the

same for Conditions B and C. According to a global analysis, subjects should have responded similarly in these conditions because behavior should be mediated by the IRI. In Conditions A and C, the IRI differed, but the trial duration (time from the onset of the initial links to reinforcement) was held constant. A local analysis predicted that choice proportions should be more similar in Conditions A and C than between Conditions B and C. Figure 2 shows the individual choice proportions and time allocations for each condition. Despite intersubject variability, an analysis of variance (ANOVA) showed a main effect of condition, $F(3, 9) = 15.49$; $p < .01$, on choice proportion and a main effect of condition, $F(3, 9) = 18.4$; $p < .001$, on time allocation. The difference in choice proportions for Conditions A and C failed to meet the criterion for statistical significance, $F(1, 3) = 0.14$; $p = .74$. Thus, the two conditions did not statistically differ. By itself, this comparison is not informative because it is possible that Condition B was not different from either A or C. The relevant test is whether the mean of Conditions A and C is statistically different from Condition B. An ANOVA showed that there was a statistically significant difference in this comparison, $F(1, 3) = 44.0$; $p < .01$, meaning that, in addition to being equivalent, choice in Conditions A and C was different from that in B. These findings suggest that the addition of an ITI preceding each trial did not generally affect choice on the concurrent-chains schedule in this experiment. On an individual-subject level, only Subject S1 appeared to demonstrate a possible devaluation of the richer terminal link in Condition C, resulting in a mean choice proportion intermediate between that of Conditions A and B. All other subjects demonstrated a strong preference for the VI 30-s alternative in Condition C (most notably Subject S3), consistent with a local analysis of choice.

It is possible that the inclusion of an ITI preceding the choice phase did affect behavior: Because choice is a relative measure, it may be insensitive to changes in absolute responding. There was an overall significant increase in response rate in the richer VI 30-s terminal link, $F(1, 3) = 44.5$; $p < .01$, between Condition A and Condition C; however, there were no increases found in response

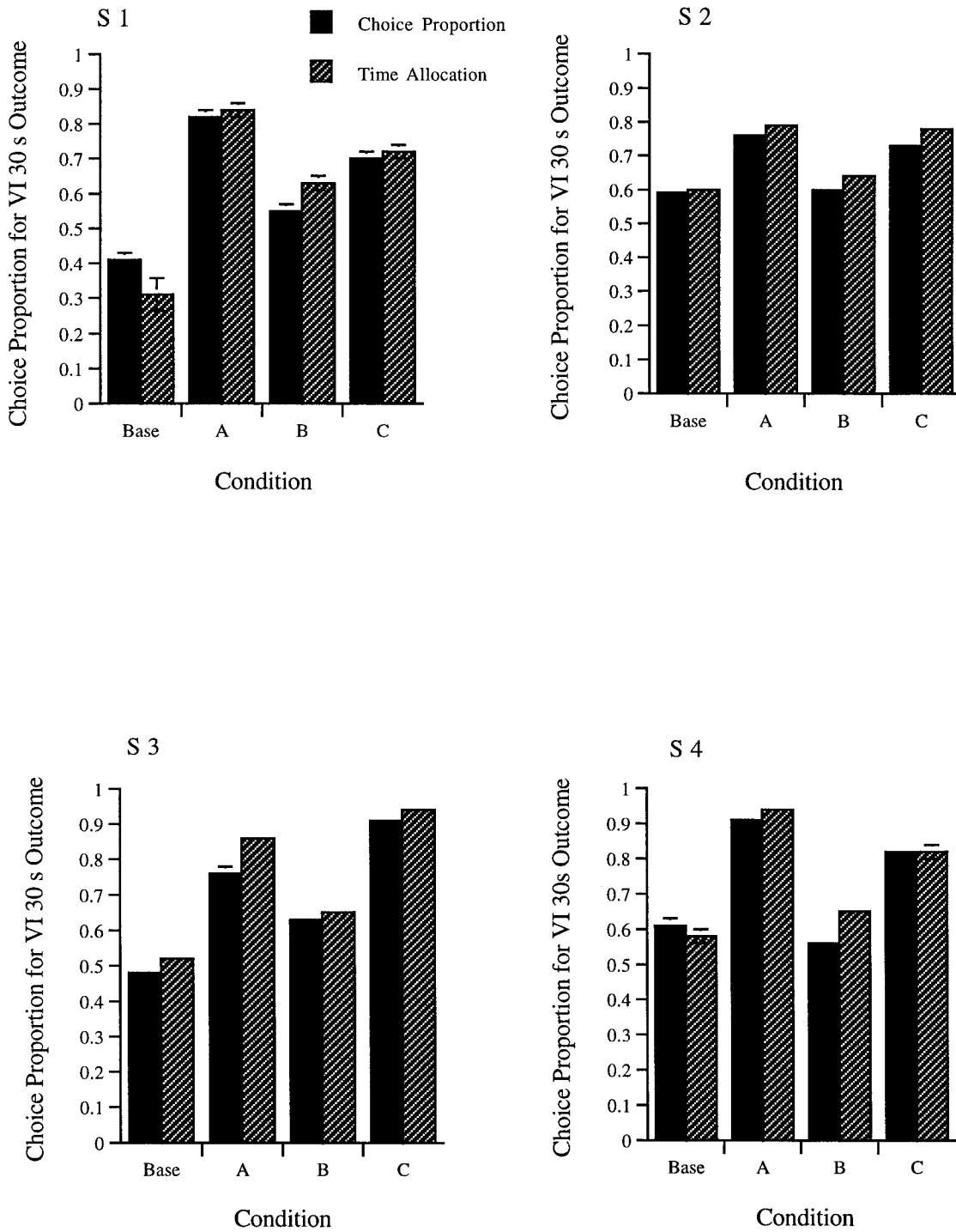


Fig. 2. Choice proportion (dark bars) and time allocation (hatched bars) for the richer VI 30-s alternative in the terminal link of a concurrent-chains schedule, for Experiment 1 (ITI signaled by white houselight). Condition A utilized short (VI 120 s) initial links, Condition B presented long (VI 600 s) initial links, and Condition C utilized short (VI 120 s) initial links preceded by a 4-min ITI. A local analysis predicts that choice should be equivalent in Conditions A and C, whereas a global analysis assumes that choice in Condition C should approximate that in Condition B. The error bars represent standard errors of the means of each data point.

rate in the initial links, $F(1, 3) = 7.09$; $p = .076$, nor in the leaner VI 90-s terminal link, $F(1, 3) = 3.77$; $p = .15$. This result indicates that the subjects' behavior was sensitive to the addition of the ITI, but that such effects were isolated to increases in rate of responding to the VI 30-s schedule. Also recall that relative measures, such as choice proportion or time allocation, did not change. These findings are consistent with similar findings of differential effects on absolute versus relative measures (LaFiette & Fantino, 1989).

The behavior of the subjects was reliably sensitive to temporal manipulations in the initial links, however. Choice proportions and time allocation were dramatically reduced in Condition B, in which initial-link values were increased to concurrent VI 600-s schedules, replicating Fantino's (1969) findings. Thus, the absence of systematic effects on choice of ITI manipulation (presence or absence) does not indicate insensitivity to temporal variables. Instead, position of the temporal manipulation seems critical to predicting subsequent effects on choice measures.

Choice in a concurrent-chains schedule reflects the relative value of terminal-link stimuli as conditioned reinforcers. Thus, the results of Experiment 1 suggest that the context that determines conditioned reinforcer value is better conceptualized in terms of the reduction in time to reinforcement compared to the onset of a trial (the onset of the choice phase) than in terms of the total time between reinforcer presentations. In other words, these results imply that delay-reduction theory, in the context of choice, can be properly stated in terms of the relative reduction in time a stimulus signals to reinforcement, as calculated from the onset of the preceding stimulus (here, the initial-link stimuli), rather than relative to the overall time to reinforcement (time between reinforcer presentations).

The results of Experiment 1 are consistent with the findings of Mazur (1989). He varied the ITI and examined choice between a probabilistic reinforcer and a certain reinforcer in a discrete-trial adjusting-delay procedure. He found no effect of ITI duration on preference. As in the current experiment, the ITIs in Mazur's experiment were signaled by a stimulus that was not differentially correlated with either choice alternative. Subsequent re-

search by Mazur (1991) suggests that if the stimuli presented during the ITI are the same as stimuli correlated with the richer of two concurrently available schedules, the ITI's effectiveness in controlling choice will increase. Mazur argued that a houselight correlated with the probabilistic alternative became a conditioned reinforcer due to its occasional pairing with food. By signaling the ITI with this same houselight, conditioned reinforcing strength should decrease, because the effective stimulus duration increased while the number of primary reinforcer presentations stayed the same. The next experiment attempted to extend this reasoning to a concurrent-chains procedure. By signaling the ITI with a stimulus identical to one of the terminal links, the conditioned reinforcing value of that stimulus might decrease, because the time spent in the presence of that stimulus has increased significantly. Thus, the preference ratios obtained would be more consistent with a global interpretation of the determinants of conditioned reinforcement.

EXPERIMENT 2

The results of Experiment 1 were best described by a local view of conditioned reinforcement. Experiment 2 examined the effects of signaling the ITI with a stimulus configuration directly associated with reinforcement: the terminal-link keylight and houselight correlated with the richer VI 30-s schedule of reinforcement. The ITI condition of Experiment 2 was identical to Condition C of Experiment 1, except that the ITI was signaled by the richer terminal-link keylight, which was presumed to function as a relatively strong conditioned reinforcer and which provided subjects the opportunity to respond during the ITI to a lit keylight (although reinstatement of the initial links was not contingent upon any response requirement). If Mazur's (1993) results with probabilistic reinforcement are applicable in the case of concurrent chains, then one might expect that signaling the ITI with a stimulus correlated with the preferred alternative would decrease preference for that stimulus. Increasing the time spent in the presence of that stimulus, whether it precedes or follows reinforcement, should devalue the reinforcing effectiveness of that stimulus because its

Table 4

Average response rates (responses per minute) in each component of the concurrent-chains schedule in Experiment 2.

Subject	Condition	Initial links	Terminal links		ITI stimulus
			Rich	Lean	
1	Baseline	88 (3)	93 (5)	103 (5)	5
	A	55 (6)	75 (4)	69 (3)	
	B	56 (10)	82 (7)	83 (3)	
	C	80 (8)	96 (7)	95 (5)	
2	Baseline	54 (6)	47 (6)	50 (5)	1
	A	69 (4)	59 (5)	52 (5)	
	B	59 (2)	46 (4)	46 (5)	
	C	65 (5)	45 (3)	55 (13)	
3	Baseline	108 (6)	95 (7)	93 (11)	18
	A	72 (4)	81 (5)	77 (11)	
	B	82 (7)	81 (8)	70 (12)	
	C	91 (7)	122 (21)	95 (11)	
4	Baseline	102 (16)	81 (8)	73 (6)	12
	A	90 (3)	130 (3)	87 (2)	
	B	75 (9)	129 (8)	113 (7)	
	C	91 (7)	87 (17)	88 (27)	

Note. Values in parentheses represent standard deviations. Values for Subject 4 in Conditions A and C represent data averaged over last three sessions; all remaining values were averaged over the last nine sessions.

absolute duration would increase relative to that of the less preferred alternative; thus, subjects spend a greater amount of time in the presence of the former stimulus in the absence of reinforcement, degrading cue salience (B. A. Williams & Ploog, 1992). The onset of the formerly less preferred stimulus now signals a greater relative reduction in time to primary reinforcement and should be more highly valued. Also, providing an explicit opportunity for subjects to respond during the ITI may increase the salience of this time interval and thus increase its influence on choice. Because pigeons are unlikely to respond to darkened keylights (as in Experiment 1), presenting a lit key during the ITI should evoke responses from subjects with a strong history of responding to that stimulus.

METHOD

Subjects and Apparatus

The subjects and apparatus were the same as in Experiment 1.

Procedure

The schedules and schedule values were identical to those of Experiment 1. The terminal links, in addition to being signaled by red or green keylights, as in Experiment 1, were also signaled, respectively, by red or

green houselights located above the terminal-link keylight that was currently illuminated. The initial-link houselight, which was white, was illuminated above the center (nonfunctional) keylight. The keylight and houselight that were illuminated during the VI 30-s terminal link also were illuminated during the ITI. Thus, the ITI was always paired with the same stimulus configuration located in the same position during the ITI as during the terminal link. Color and position of the VI 30-s terminal link were counterbalanced across subjects. All other schedule and stimulus conditions were identical to Experiment 1.

RESULTS AND DISCUSSION

Individual response-rate data and responses during the intertrial interval for each condition are shown in Table 4. Choice proportions and time-allocation measures are graphically represented in Figure 3.

If conditioned reinforcer value is sensitive to the global temporal context, or IRI, then choice in Condition C should match that in B, given that the average IRI was equal for the two conditions. If, however, a local contextual analysis is appropriate, and choice in concurrent chains is insensitive to ITIs, then choice in Condition C should match that in Condition A. Analysis of variance on aggre-

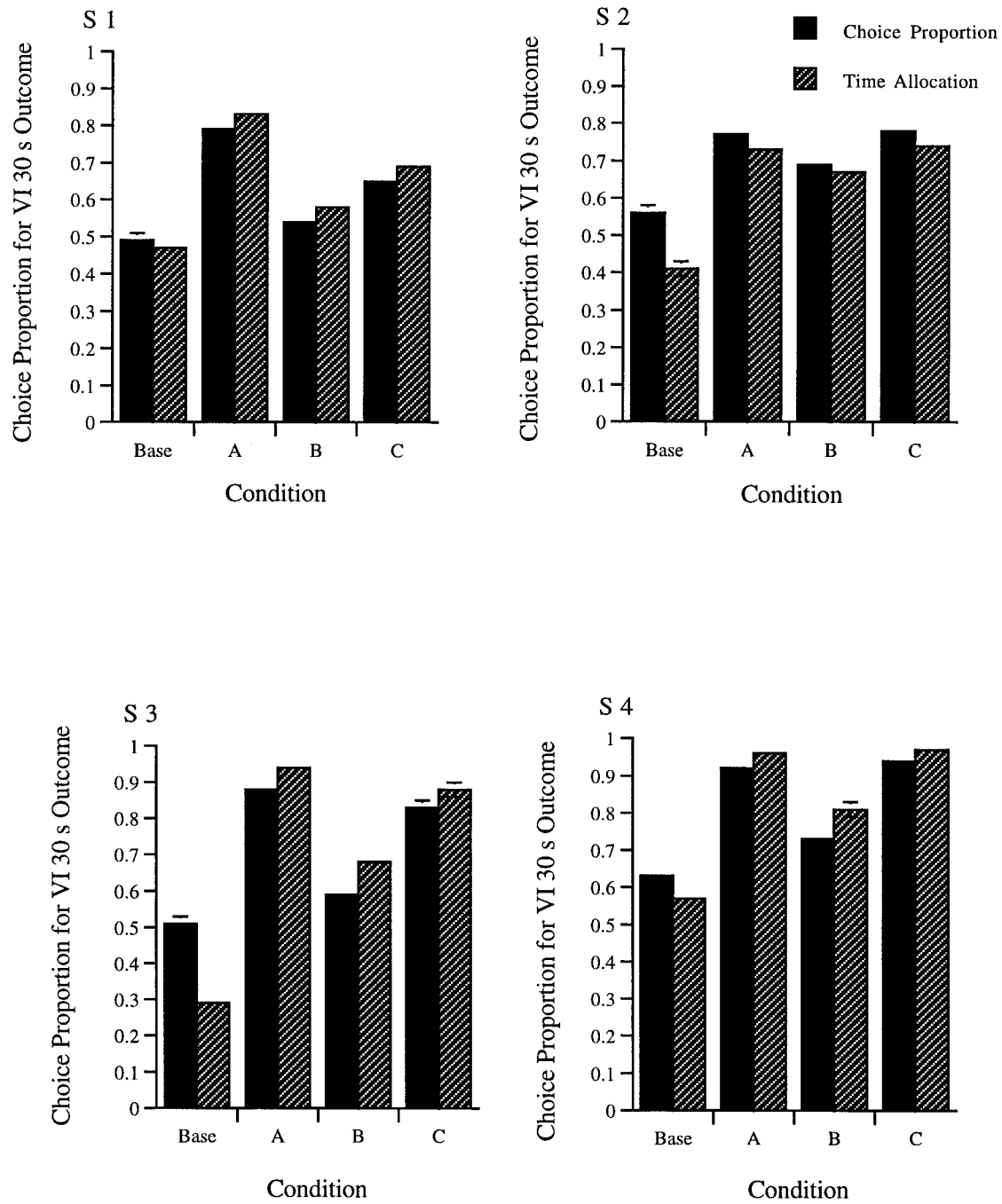


Fig. 3. Choice proportion (dark bars) and time allocation (hatched bars) for the richer VI 30-s alternative for Experiment 2, in which the ITI was signaled by the richer terminal-link keylight and houselight. The error bars represent standard errors of the means of each data point.

grate data demonstrates a main effect of condition, $F(3, 9) = 28.07$; $p = .0001$, for choice proportion and a main effect of condition, $F(3, 9) = 23.34$; $p = .0001$, for time allocation. Analyses indicated that choice in Condition C, whether measured by responses or time allocation, was equivalent with that in Condition A and different from Condition B, consistent with a local analysis of conditioned reinforcement. Absolute measures of responding did not show a significant effect of ITI manipulation for the richer terminal link, $F(1, 3) = .003$; $p = .96$, for the longer terminal link, $F(1, 3) = 3.56$; $p = .16$, or for response rates in the initial links, $F(1, 3) = 2.29$; $p = .23$. Thus, the subjects' behavior appeared to be insensitive to the addition of the ITI in Condition C on both relative and absolute measures, unlike in Experiment 1 in which absolute rates proved to be partially sensitive to the ITI manipulation.

It should be noted, as seen in Table 4, that 2 of the 4 subjects did respond consistently to the keylight when presented during the ITI, whereas for the other 2 subjects, responding was nearly extinguished by the end of the condition. Yet all subjects demonstrated a pattern of choice that was most consistent with a local contextual view of conditioned reinforcement. Thus, responding during the ITI did not increase the likelihood that the ITI would have an impact on choice and push preference closer to indifference, as might be predicted by a global analysis. Indeed, those subjects who responded most robustly showed the highest preferences for the VI 30-s schedule in Condition C, indicating the lowest sensitivity to the temporal effects of the ITI on relative response rates. Further, it cannot be argued that the subjects were attending to unrelated events during the ITI (such as preening) because 2 of the subjects showed a reasonably robust level of responding to the keylight during the ITI.

Although many studies have indicated that time spent in the presence of stimuli not associated with food should have relatively little or no effect on conditioned reinforcer value (Dunn, 1990; Mazur, 1991; B. A. Williams & Dunn, 1991), work by Mazur (1993; Mazur & Romano, 1992) has shown some effects of ITIs or interlink intervals (ILIs: intervals between multiple linked response components) when signaled by stimuli correlated with food

delivery. Results from the second experiment, consistent with findings from the first, are not supportive of this hypothesis: If extending the stimuli correlated with the smaller, more valued terminal link into the ITI increases the effective duration of this alternative in the concurrent-chains procedure, then its value should have declined and approached the value of the longer terminal-link alternative, resulting in a decline in preference for the smaller terminal link and approximating preference found in the condition with the same IRI. This was clearly not the case.

EXPERIMENT 3

Experiment 2 examined whether extending the stimulus configuration of the preferred outcome into the ITI would shift preference for a richer alternative toward indifference. In addition, such a signal provided an opportunity for subjects to respond during the ITI, which could have increased the salience of the ITI sufficiently to affect choice. Consistent with earlier findings in Experiment 1, pairing the ITI with a reinforcer-relevant stimulus did not change or affect preference and, thus, conditioned reinforcer value. Perhaps the ITI would affect choice (and therefore provide support for a more global contextual view) if the ITI contained stimuli correlated with the choice phase rather than those correlated with the outcome phase. Specifically, by extending stimuli paired with the initial links into the ITI, preference might shift toward indifference if the ITI were sufficiently long. This also provided an opportunity for subjects to respond during the ITI, as in Experiment 2.

METHOD

Subjects and Apparatus

The subjects and apparatus were the same as in Experiment 1.

Procedure

The schedules and schedule values were identical to those of Experiments 1 and 2. The initial- and terminal-link stimuli were identical to those in Experiment 2. In Condition C, ITI presentation was signaled by the two white side keylights present during the initial links, as well as by two novel orange

Table 5

Average response rates (responses per minute) in each component of the concurrent-chains schedule in Experiment 3.

Subject	Condition	Initial links	Terminal links		Response rate to ITI stimuli	
			Rich	Lean	Rich	Lean
1	Baseline	60 (8)	68 (6)	85 (4)		
	A	65 (15)	65 (6)	60 (10)		
	B	56 (9)	84 (7)	77 (12)		
	C	79 (8)	100 (5)	94 (11)	10	6
2	Baseline	67 (6)	34 (6)	47 (5)		
	A	66 (5)	48 (3)	41 (5)		
	B	58 (3)	60 (5)	50 (4)		
	C	76 (6)	66 (5)	58 (6)	4	4
3	Baseline	78 (5)	75 (13)	70 (8)		
	A	74 (9)	108 (16)	55 (7)		
	B	81 (9)	143 (28)	84 (14)		
	C	94 (12)	144 (23)	77 (7)	1	6
4	Baseline	72 (6)	75 (4)	78 (8)		
	A	85 (11)	89 (6)	70 (6)		
	B	79 (8)	105 (7)	82 (5)		
	C	98 (9)	84 (6)	77 (4)	4	9

Note. Values in parentheses represent standard deviations. Under the heading "Response rate to ITI," "Rich" and "Lean" refer to responses to stimuli located on sides on which the richer and leaner terminal links would be presented.

houseslights located directly above the left and right keylights. Thus, the change in house-light illumination, from two orange side houseslights to a single white houseslight located centrally, was the only explicit signal of the transition from ITI to choice phase. The side keylights during the ITI were illuminated but not operational (responding had no effect on the schedules or availability of reinforcement), although responses were recorded throughout the 4-min ITI. All other schedule and stimulus conditions were identical to Experiment 1.

RESULTS AND DISCUSSION

Individual means and standard deviations for response rates are presented in Table 5, in addition to responses to the white side keylights during the ITI. Although the overall choice proportions (in Figure 4) were lower than predicted by delay-reduction theory, this can be accounted for by the below-indifference baselines, suggesting a possible side bias present in all subjects. However, when obtained differences between the baseline and experimental conditions are compared to the predicted changes from baseline, obtained results better match the predictions made by Squires and Fantino (1971). Baseline choice proportions should approximate .50. Squires

and Fantino's model predicts an increase in choice proportion to .81 in Condition A, representing a .31 change from baseline; the obtained difference from baseline was .27. Squires and Fantino's model also predicts an increase in choice proportion to .57 in Condition B, representing a .07 change from baseline; the obtained difference from baseline was .10. The obtained difference between baseline and Condition C was .22, more closely approximating changes evident in Condition A.

Given the stimulus manipulation during the ITI and the fact that all subjects responded at least marginally to the side keys while the ITI was instated, it is unclear how thoroughly subjects discriminated between the ITI phase and the choice phase despite signaling the ITI phase with novel orange houseslights. Choice proportion could be conceptualized in two ways: incorporating relative responding during the ITI (assuming that subjects did not discriminate between the two phases clearly) and as typically measured by relative responding during the scheduled choice phase alone. An ANOVA did not reveal a statistically significant difference between these two measures of choice proportion, $F(1, 3) = 1.94$; $p = .26$, and all accompanying statistics used the traditional

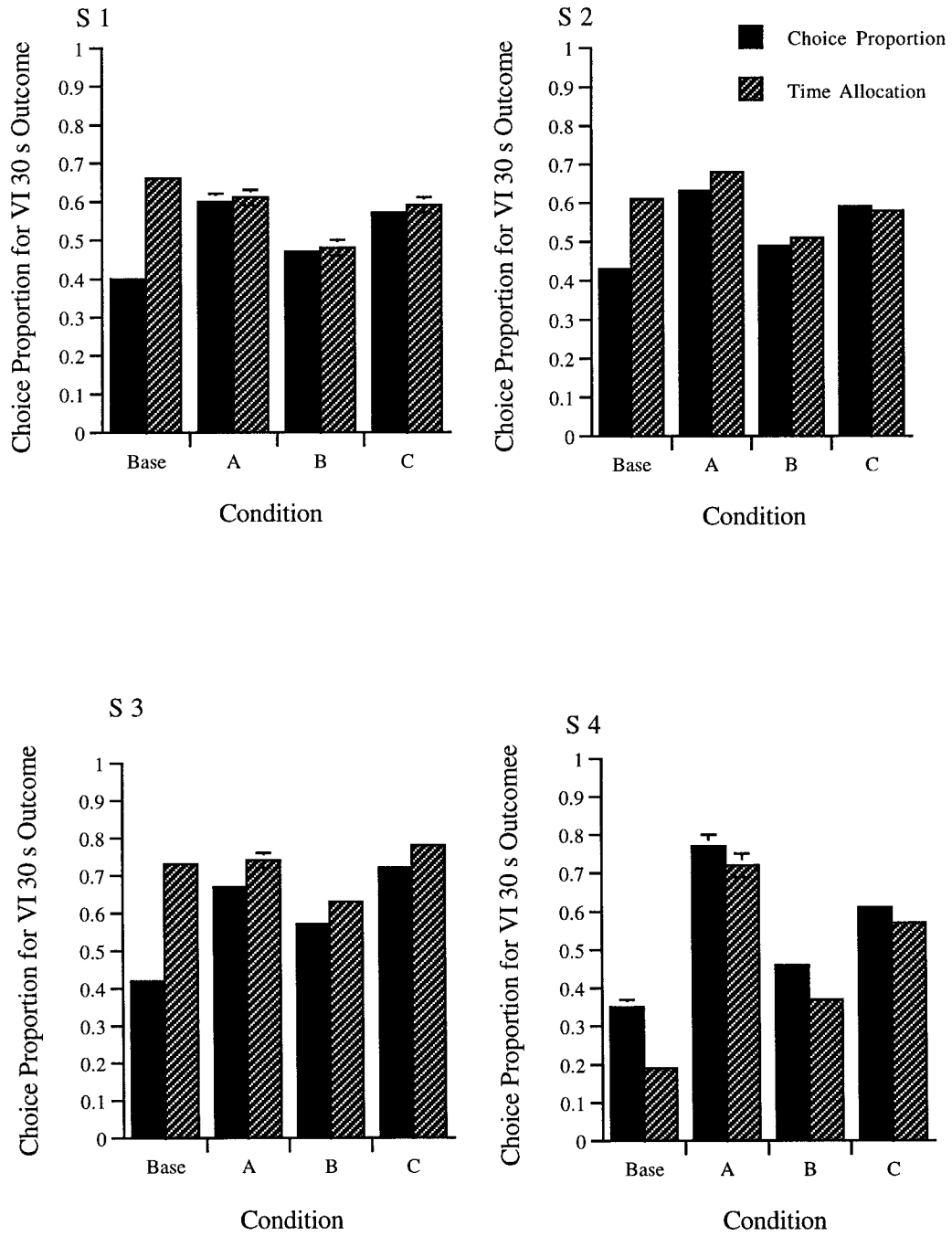


Fig. 4. Choice proportion (dark bars) and time allocation (hatched bars) for the richer VI 30-s alternative for Experiment 3, in which the ITI was signaled by white side keys and novel orange houselights. The error bars represent standard errors of the means of each data point.

measure in testing for differences between conditions. There was a main effect of condition, $F(3, 9) = 13.75$; $p = .001$, for choice proportion and for time allocation, $F(3, 9) = 8.49$; $p < .05$. Post hoc analyses indicate that preference in the ITI condition (C) was equivalent to Condition A, $F(1, 3) = .018$; $p = .90$, and was statistically lower than the control condition, B, $F(1, 3) = 32.4$; $p = .01$, suggesting that the ITI did not have an effect on choice proportions (consistent with a local analysis of choice). Most measures of absolute responding did show an effect of ITI manipulation: Response rates in the initial links were much higher following an ITI presentation (Condition C) than in Condition A, $F(1, 3) = 13.1$; $p < .01$; response rates for the leaner VI 90-s terminal link increased between Conditions A and C, $F(1, 3) = 12.1$; $p < .05$; and although response rates for the richer VI 30-s schedule did increase across conditions (lowest in Condition A and highest in Condition C), they were not statistically different, $F(1, 3) = 4.74$; $p = .12$. The subjects' behavior thus appeared to be insensitive to ITI manipulation when one examines choice or time allocation and some measures of terminal-link response rates, but not when one examines response rates in the initial links.

These results are consistent with our previous findings that time spent in the ITI did not affect relative choice proportions, regardless of how the interval was signaled. Response rates during the interval, although low, might have been expected to facilitate an effect of ITI manipulation; yet, no subject showed a decline in choice that would indicate such an effect, even when responding during the ITI was incorporated into our estimation of choice proportion.

EXPERIMENT 4

The prior three experiments tested whether including an ITI before each choice phase of a concurrent chain would shift preference in a manner consistent with a global analysis of conditioned value (which assumes that the IRI is the relevant comparator context for conditioned stimuli). In Experiment 1, the ITI was correlated with a neutral houselight; in Experiment 2, each ITI was correlated with the richer terminal-link stimulus configura-

tion; and in Experiment 3, the ITI was correlated with the initial-link keylights and novel houselights. Across all three experiments, the ITI manipulations had no systematic effect on choice: Subjects' preferences matched their relative response proportions in the preceding control condition that had the same schedule values but no ITI preceding choice. However, some research in classical conditioning has suggested that providing free food during the ITI of an autoshaping procedure interferes with the acquisition of responding to the keylight (Durlach, 1984), although results have been mixed (Cooper, 1991; Durlach, 1983; Jenkins, Barnes, & Barrera, 1981; see also Mazur, 1994, for effects of ITI reinforcers on self-control). Perhaps providing unsignaled free food pseudorandomly during the ITI would increase choice sensitivity to global temporal variables.

METHOD

Subjects and Apparatus

The subjects and apparatus were the same as in Experiments 1 through 3.

Procedure

The schedules and schedule values were identical to those of Experiments 1 through 3. The initial- and terminal-link stimuli were the same as in Experiments 2 and 3. In Condition C, the ITI was signaled by a single white houselight over the central darkened keylight, as in Experiment 1. However, a single food presentation (4-s access to grain) was presented randomly at one of three temporal positions: at 60 s, 120 s, or 180 s, corresponding to one quarter, one half, or three quarters through the 240-s ITI. Food presentations were unsignaled, and the ITI ended after completion of the remaining time interval. All subjects were observed informally to eat during the ITI food presentations. All other schedule and stimulus conditions were identical to those in Experiment 1.

RESULTS AND DISCUSSION

The addition of unsignaled free food during the ITI should have increased the excitatory strength of contextual stimuli during the ITI and resulted in a subsequent decline in preference for the richer terminal link by decreasing the relative conditioned difference between the two outcomes. Again, av-

eraged choice was not affected by the duration of the ITI (Figure 5). There was a main effect of condition for choice, $F(3, 9) = 7.45$; $p < .01$, and time allocation, $F(3, 9) = 8.07$; $p < .01$; Conditions A and C did not differ, $F(1, 3) = 0.16$; $p = .72$, whereas Condition B differed from both A and C, $F(1, 3) = 12.1$; $p < .05$, indicating that the ITI was not incorporated into subjects' estimates of relative conditioned value. Examination of individual-subject performance reveals the strongest differentiation between choice in Condition B and Condition C, especially for Subject S1, whose prior choice measures in Condition C were typically intermediate between Conditions A and B.

Unlike Experiments 1 and 3, there were no systematic effects of our manipulations on response rates in either the initial links or the two terminal-link alternatives (Table 6). Some subjects (S3 and S4) seemed to show an increase in response rates to the richer terminal-link schedule during the ITI condition, and others showed a decline or no effect. Subject S1 was the only subject to show a dramatic decline in absolute response rates in the initial links preceded by the ITI (a drop from 82 responses per minute in Condition A to 16 responses per minute in Condition C), which may be a residual satiating effect of the free food during the ITI. It is important to remember that Subject S1 had the lowest 80% body weight at 295 g. This decline may also be accounted for by the fact that the initial links were the only components that were not immediately associated with food. Thus, they signaled a greater delay to reinforcement, resulting in the observed decrement in responding.

These results are consistent with our previous findings that time spent in the ITI does not affect relative choice proportions, despite our attempts to increase the salience of the interval preceding the choice phase by including unsignaled free food in the ITI. Although a decline in choice proportion was noted in Condition B, in which the initial links were increased from VI 120-s to VI 600-s schedules, choice in the critical condition, C, best approximated choice in Condition A, indicating that the lengthy ITI had little impact on relative choice measures. It is possible that a single reinforcer presentation during the 4-min ITI was insufficient to increase the

excitatory strength of the ITI such that it would disrupt responding. Indeed, Mazur (1994) found that using a richer ITI reinforcement schedule had a greater impact on choice in a self-control procedure than did a leaner schedule. If this is a correct assumption for the present experiment, Experiment 4 would simply reduce to a replication of Experiment 1.

GENERAL DISCUSSION

Although ITIs may be important variables in modulating animal learning in other areas of conditioning, such as autoshaping (Gibbon, Baldock, Locurto, Gold, & Terrace, 1977; Gibbon & Balsam, 1981), the present experiments did not reveal evidence to suggest that these contextual variables were relevant in establishing conditioned reinforcer value in a concurrent chain. The results of all four experiments support a local contextual analysis of choice on concurrent-chains schedules of reinforcement. Adding an ITI, whether signaled by stimuli uncorrelated with reinforcement or by stimuli correlated with obtaining reinforcement, did not affect relative responding in the initial links of the concurrent chains. In Experiment 1, subjects were provided a choice between a VI 30-s or a VI 90-s schedule in the terminal link of a two-link free-operant concurrent-chains schedule of reinforcement. Condition A used moderate VI 120-s schedules in the initial links, and Condition B used VI 600-s schedules in the initial links. The critical condition, C, used the same 120-s initial links as in Condition A, but each choice phase was preceded by a 240-s ITI. Thus, Conditions B and C had the same mean IRI (6 min), and Conditions A and C had the same locally measured time to reinforcement (assuming that the ITI was not weighted into subjects' estimates of average time to reinforcement in assessment of conditioned value). We might have argued that if choice proportions in Condition C matched those in B, the ITI is incorporated into organisms' estimates of the relevant comparator term when assessing terminal-link cue value. If, however, choice in Condition C matched that in A, it would have indicated that choice in concurrent chains is not mediated by the IRI and that the value of stimuli in the terminal links is best conceptualized

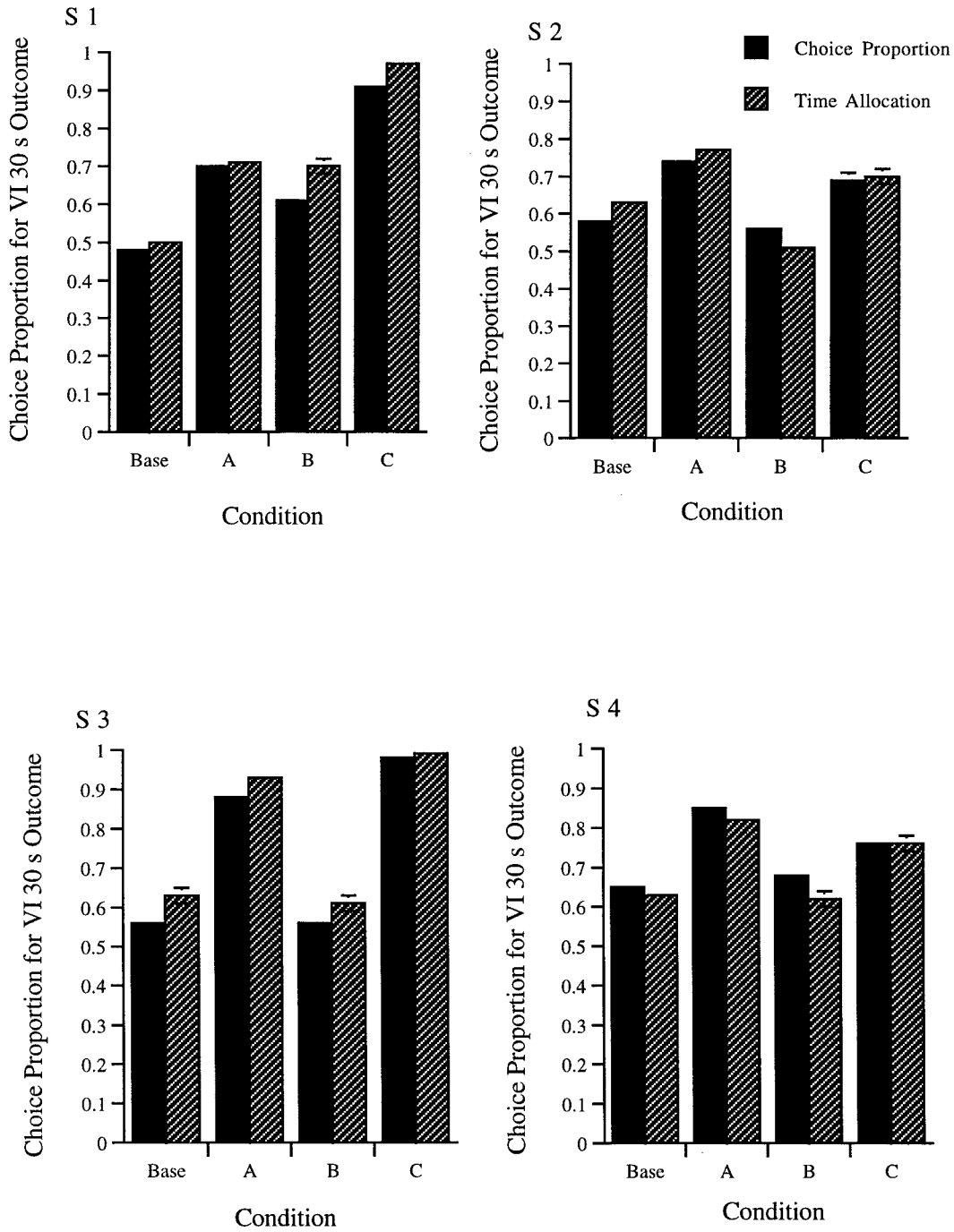


Fig. 5. Choice proportion (dark bars) and time allocation (hatched bars) for the richer VI 30-s alternative for Experiment 4, in which a single noncontingent reinforcer was pseudorandomly delivered during each ITI presentation. The error bars represent standard errors of the means of each data point.

Table 6

Average response rates (responses per minute) in each component of the concurrent-chains schedule, along with the mean temporal position of the reinforcer presentation (in seconds) during the ITI, are presented for Experiment 4.

Subject	Condition	Initial links	Terminal links		ITI position
			Rich	Lean	
1	Baseline	83 (5)	84 (8)	73 (9)	121
	A	82 (5)	68 (5)	60 (5)	
	B	38 (12)	79 (9)	70 (6)	
	C	16 (5)	54 (3)	37 (19)	
2	Baseline	58 (2)	40 (4)	34 (2)	113
	A	61 (4)	46 (2)	34 (4)	
	B	59 (3)	48 (3)	47 (5)	
	C	77 (5)	22 (7)	41 (14)	
3	Baseline	104 (8)	77 (3)	117 (9)	125
	A	70 (7)	72 (2)	75 (10)	
	B	95 (14)	98 (8)	124 (9)	
	C	79 (3)	135 (2)	111 (10)	
4	Baseline	77 (6)	81 (8)	74 (4)	123
	A	93 (9)	72 (7)	70 (7)	
	B	79 (4)	65 (2)	76 (4)	
	C	86 (7)	105 (4)	72 (4)	

Note. Values in parentheses represent standard deviations. Values for Subject 1 in Condition C and Subject 3 in Condition C represent data averaged over the last three sessions; all remaining values were averaged over the last nine sessions.

relative to the onset of the preceding stimuli (the initial links). Current findings corroborate this view that ITIs do not affect choice responding or time allocation. These general findings should not be surprising given that much research has demonstrated that time spent in the presence of contextually irrelevant stimuli, such as the neutral white house-light employed during the ITI in Experiment 1, tends not to affect temporal discrimination and measures of conditioned reinforcement value (Dunn, 1990; Mazur, 1993).

This outcome led to Experiments 2 and 3, which were identical to the previous experiment except that the ITI was signaled either by the richer terminal-link keylight and houselight or by stimuli correlated with the initial links. Signaling the ITI with these stimulus configurations should have increased the salience of the ITI, which could have resulted in a subsequent decline in preference. Instead, as in Experiment 1, choice was unaffected by incorporation of the ITI prior to each choice phase, even when responding occurred during the ITI on the keylights. These findings suggest that increasing the salience or relevance (as defined by the relation to obtaining reinforcement) of stimuli presented during the ITI does not increase the prob-

ability that this temporal unit will alter relative response rates in a concurrent-chains paradigm.

Experiment 4 provided unsignaled reinforcement pseudorandomly during the ITI. Such a manipulation could have increased the excitatory strength or salience of the ITI and thus increased the likelihood that time spent in the ITI would decrease choice for the richer terminal-link alternative. Findings were consistent with those from the prior three experiments: The ITI did not systematically affect choice proportion, the determinant of which was best described by comparing time in the terminal links relative to time from the onset of the initial links.

These results do not reflect simple null findings: Inclusion of the ITI did occasionally affect response rates in the terminal links and initial links of the concurrent chains, suggesting sensitivity of absolute measures to this manipulation. Moreover, choice responding was sensitive to initial-link duration (as required by delay-reduction theory) in all four experiments: Choice proportion decreased systematically and significantly in Condition B, in which initial-link values were increased to VI 600-s schedules. An additional and somewhat curious finding was a correlation

between changes in the absolute initial-link response rates and the direction of change in the choice proportions between Conditions A and C (conditions characterized by shorter initial links with and without an ITI). Although choice proportion did not significantly differ between Conditions A and C, for approximately half the cases possible, changes in response rates in the initial links produced contrary shifts in preference. If response rates increased (from A to C), preference was more likely to decrease (seven cases) than increase (three cases) or remain constant (only one case). If response rates decreased, preference was equally likely to show an increasing trend, from Conditions A to C, as it was to show a decreasing shift. In the remaining cases, there were no strong correlations between changes in rate of responding during the initial links and changes in preference. This result suggests that absolute and relative responding in the initial links may not be wholly independent, so that changes in preference as a function of ITI may be mediated by changes in absolute responding, a possibility that requires further examination.

Taken together, these results indicate that, across a range of stimulus manipulations, the effectiveness of a terminal-link stimulus as a conditioned reinforcer in a concurrent-chains schedule of reinforcement is best described relative to the onset of the choice phase, not to the IRI, and more specifically, that delay-reduction theory does not require modification to account for potential effects of ITIs (for a similar view, see Bateson & Kacelnik, 1995). Although this set of experiments was designed to emphasize implications for the delay-reduction model, other theories of choice are equally affected. Although most models do not incorporate a term for the ITI, two researchers have made clear attempts at addressing the implications that global temporal effects (sensitivity to an ITI) would have on their respective theories. Mazur (1995) has concluded, based on a wealth of research that the current authors have merely touched upon, that his hyperbolic decay model affords no role for context (ITI), a finding similar to our own concerning delay-reduction theory. However, the hyperbolic decay model was developed using a discrete-trials procedure with a single re-

sponse requirement in the choice phase (Mazur, 1987), and its generality to other procedures (including those similar to the ones used in the current set of experiments) has recently been cautioned by Mazur (1995).

Of more interesting note are the potential implications for Grace's (1994) contextual choice model, a descriptive model that has proven to be highly successful at accounting for choice. In its simplified form, this model states that the relative value of an outcome is a function of its relative immediacy. However, this value is moderated by the effect of the context in which the outcome is presented: The reinforcing effectiveness of a terminal link in concurrent chains is determined by its relative value, modified by the ratio of the mean duration of the terminal links to the mean duration in the initial links (thus, value and its functional expression are separate, according to the contextual choice model). Although no explicit term for ITI is included in the model, Grace (1994) has stated that postreinforcer delays or blackouts are associated with the terminal links, and their value should be included in estimates of mean duration of the terminal links. This would increase the effect of context on choice, and should result in an increase in sensitivity to terminal-link delays, producing an increase in preference for the richer terminal-link schedule. However, our own data do not confirm this assumption. Preference for the richer terminal link did not show systematic increases when an ITI followed the terminal-link schedules. In only 3 out of 16 possible cases did choice converge on predictions by the contextual choice model if the ITI duration is incorporated into the estimate of mean terminal-link duration (Subject S3 in Experiment 1; Subjects S1 and S3 in Experiment 4). Hegarty (1995) has also found partial disconfirming evidence (as well as partial support) for both the contextual choice model and delay-reduction theory when ITI values were manipulated in a self-control procedure. These findings indicate that a more explicit tactic must be taken for the contextual choice model to account for the apparent absence of ITI effects on choice proportion reported here and elsewhere.

One possible reason for the absence of effects may be that the ITI played no role in modulating choice due to the lack of any re-

response requirements: Subjects often turn away from darkened keys or engage in extraneous behavior when blackouts or ITIs are presented to them (Dunn, 1990; Goddard & Jenkins, 1987). Perhaps the ITI had no effect, in part, because the keylights and other cues associated with the ITI were not effective stimuli for the subjects. A response requirement might counteract such effects by forcing attention to the response key during the ITI. W. A. Williams and Fantino (1996) used response-dependent prechoice periods in a series of experiments analogous to the ones described above. They employed response-dependent fixed-interval schedules preceding each choice phase and manipulated terminal-link configuration across three independent studies. Our results corroborate theirs insofar as no systematic effect of prechoice delay was demonstrated, despite the response requirement. Furthermore, subjects had the opportunity to respond during the ITI in both the present Experiments 2 and 3, yet there was no significant correlation between responding during the ITI and subsequent choice. Whether subjects actively responded during the ITI had no apparent influence on choice.

It is not evident that the current findings should generalize to other procedures; clearly, behavioral effects of ITIs have been demonstrated in discrete-trial concurrent-chains (Mazur, 1993) and autoshaping preparations (Cooper, 1991). One additional difference between those studies and our own concerns our lack of differentially signaling the ITI where possible: Sensitivity to ITI manipulations may be enhanced in choice procedures by use of different ITIs (either temporally or by use of distinct stimuli) dependent upon the alternative chosen (Dunn, Williams, & Royalty, 1987), although findings are neither robust nor consistent across studies (B. A. Williams & Dunn, 1991). The stimuli correlated with the ITI in the present set of studies might have been more effective had we employed a distinct ITI following the VI 30-s versus the VI 90-s terminal link. Yet data from our laboratory indicate that sensitivity to the addition of an ITI preceding the initial links of a concurrent chain may indeed be evident without differentially signaling the ITI, under conditions in which percentage reinforcement schedules were used (unpublished data). Furthermore, Hegarty (1995) was able

to produce reliable effects on a self-control task (with humans) without differentially signaling the ITIs (Experiment 5). Thus, presuming that effects of our ITI manipulation were not observed because the ITI employed was identical across trials seems to be ill-suited to the above positive findings under circumstances similar to the present studies.

In concluding, our results suggest that a local contextual analysis of conditioned reinforcement (i.e., one that describes the value of a stimulus relative to the onset of the preceding stimulus) is more appropriate for describing performance in concurrent-chains schedules of reinforcement than a global analysis (i.e., one that considers the IRI to be critical in describing conditioned value). This does not indicate that there are no conditions under which a global temporal analysis would be appropriate, only that such a condition or conditions have not been detailed. In terms of delay reduction, however, we need not amend its basic formulation at this time, but may now be more specific with respect to its measurement. Based on the present experiments, it appears that the time intervals that determine the effectiveness of a stimulus as a conditioned reinforcer are the reduction in time to reinforcement signaled by the onset of that stimulus relative to the reduction in time to reinforcement as measured from the onset of the prior stimulus condition.

REFERENCES

- 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.
- Barnet, R. C., Grahame, N. J., & Miller, R. R. (1993). Local context and the comparator hypothesis. *Animal Learning & Behavior*, *21*, 1-13.
- Bateson, M., & Kacelnik, A. (1995). Preferences for fixed and variable food sources: Variability in amount and delay. *Journal of the Experimental Analysis of Behavior*, *63*, 313-330.
- Cooper, L. D. (1991). Temporal factors in classical conditioning. *Learning and Motivation*, *22*, 129-152.
- Cooper, L. D., Aronson, L., Balsam, P. D., & Gibbon, J. (1990). Duration of signals for intertrial reinforcement and nonreinforcement in random control procedures. *Journal of Experimental Psychology: Animal Behavior Processes*, *16*, 14-26.
- 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.
- Durlach, P. J. (1983). Effect of signaling intertrial unconditioned stimuli in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*, 9, 374–389.
- Durlach, P. J. (1984). The effect of intertrial conditioned stimuli in autoshaping. *Quarterly Journal of Experimental Psychology*, 36B, 353–369.
- Fantino, E. (1969). Choice and the rate of reinforcement. *Journal of the Experimental Analysis of Behavior*, 12, 723–730.
- 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., & Logan, C. A. (1979). *The experimental analysis of behavior: A biological approach*. San Francisco: Freeman Press.
- Fantino, E., Preston, R. A., & Dunn, R. (1993). Delay-reduction: Current status. *Journal of the Experimental Analysis of Behavior*, 60, 159–169.
- Fleshler, M., & Hoffman, H. S. (1962). A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 5, 529–530.
- Gibbon, J., Baldock, M. D., Locurto, C. M., Gold, L., & Terrace, H. S. (1977). Trial and intertrial durations in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*, 3, 264–284.
- Gibbon, J., & Balsam, P. (1981). Spreading association in time. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), *Autoshaping and conditioning theory* (pp. 219–253). New York: Academic Press.
- Goddard, M. J., & Jenkins, H. M. (1987). Effect of signaling extra unconditioned stimuli on autoshaping. *Animal Learning & Behavior*, 15, 40–46.
- Grace, R. C. (1994). A contextual model of concurrent-chains choice. *Journal of the Experimental Analysis of Behavior*, 61, 113–129.
- Hegarty, J. (1995). *Temporal context in human choice and self-control*. Unpublished doctoral dissertation, University of Otago, Dunedin, New Zealand.
- Jenkins, H. M., Barnes, R. A., & Barrera, F. J. (1981). Why autoshaping depends on trial spacing. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), *Autoshaping and conditioning theory* (pp. 255–284). New York: Academic Press.
- Kaplan, P., & Hearst, E. (1982). Bridging temporal gaps between CS and US in autoshaping. Insertion of other stimuli before, during and after CS. *Journal of Experimental Psychology: Animal Behavior Processes*, 8, 187–203.
- LaFiette, M. H., & Fantino, E. (1989). Responding on concurrent chain schedules in open and closed economics. *Journal of the Experimental Analysis of Behavior*, 51, 329–342.
- Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. In M. L. Commons, J. E. Mazur, J. A. Nevin, & H. Rachlin (Eds.), *Quantitative analysis of behavior: Vol. 5. Reinforcer value—the effect of delay and intervening events* (pp. 53–74). Hillsdale, NJ: Erlbaum.
- Mazur, J. E. (1989). Theories of probabilistic reinforcement. *Journal of the Experimental Analysis of Behavior*, 51, 87–99.
- Mazur, J. E. (1991). Choice with probabilistic reinforcement: Effects of delay and conditioned reinforcers. *Journal of the Experimental Analysis of Behavior*, 55, 63–77.
- Mazur, J. E. (1993). Predicting the strength of a conditioned reinforcer: Effects of delay and uncertainty. *Current Directions in Psychological Science*, 2, 70–74.
- Mazur, J. E. (1994). Effects of intertrial reinforcers on self-control choice. *Journal of the Experimental Analysis of Behavior*, 61, 83–91.
- Mazur, J. E. (1995). Conditioned reinforcement and choice with delayed and uncertain primary reinforcers. *Journal of the Experimental Analysis of Behavior*, 63, 139–150.
- Mazur, J. E., & Romano, A. (1992). Choice with delayed and probabilistic reinforcers: Effects of variability, time between trials, and conditioned reinforcers. *Journal of the Experimental Analysis of Behavior*, 58, 513–525.
- Reilly, S., & Schactman, T. R. (1987). The effects of ITI fillers in autoshaping. *Learning and Motivation*, 18, 202–219.
- Schactman, T. R., & Reilly, S. (1987). The role of local context in autoshaping. *Learning and Motivation*, 18, 343–355.
- 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., Mondloch, M. V., Belke, T. W., & Dunn, R. (1994). Determinants of pigeon's choice between certain and probabilistic outcomes. *Animal Learning & Behavior*, 22, 239–255.
- Squires, N., & Fantino, E. (1971). A model for choice in simple concurrent and concurrent chain schedules. *Journal of the Experimental Analysis of Behavior*, 15, 27–38.
- Williams, B. A., & Dunn, R. (1991). Preferences for conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, 55, 37–46.
- Williams, B. A., & Ploog, B. O. (1992). Extinction of stimulus element decreases the rate of conditional discrimination learning. *Animal Learning & Behavior*, 20, 170–176.
- Williams, W. A., & Fantino, E. (1996). Effects of response-dependent prechoice events on foraging-related choice. *Journal of the Experimental Analysis of Behavior*, 65, 619–641.
- Yin, H., Barnet, R. C., & Miller, R. R. (1994). Trial spacing and trial distribution effects in Pavlovian conditioning: Contributions of a comparator mechanism. *Journal of Experimental Psychology: Animal Behavior Processes*, 20, 123–134.

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