CHOICE AND THE RELATIVE IMMEDIACY OF REINFORCEMENT

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The relative immediacy of reinforcement in concurrent-chain schedules was varied while the relative reduction in the overall average time to reinforcement associated with terminal-link entry was held constant. For each of four pigeons, choice did not vary with relative immediacy of reinforcement. Subsequently, choice by the same subjects was shown to be sensitive to relative reduction in average time to reinforcement.

Key words: choice, concurrent-chain schedules, delay reduction, relative immediacy, conditioned reinforcement, key peck, pigeons

Choice on concurrent-chain schedules with unequal terminal-link durations was initially described as matching the relative immediacy of reinforcement, i.e. the reciprocal of terminal-link duration (Autor, 1969; Chung & Herrnstein, 1967; Herrnstein, 1964). This relation may be summarized by the following equation:

$$\frac{R_s}{R_s + R_l} = \frac{1/t_{2s}}{1/t_{2s} + 1/t_{2l}}, \quad (1)$$

where R_s and R_l represent the number of responses during the initial links on the keys associated with the short and long terminal links, respectively, and t_{2s} and t_{2l} represent the average durations of the terminal links (adapted from Herrnstein, 1964).

Subsequent results have supported an alternative description: Relative response rates match the relative reduction in overall delay to reinforcement associated with terminal-link entry. Overall delay includes the averages of the initial and the terminal-link durations, i.e. the average time to reinforcement from the onset of the initial links. The delay-reduction hypothesis states that the strength of a terminal-link stimulus as a conditioned reinforcer is a function of the reduction in time to reinforcement correlated with the onset of that stimulus. In terms of relative delay reduction,

$$\begin{aligned} \frac{R_s}{R_s + R_l} &= \frac{r_s(T - t_{2s})}{r_s(T - t_{2s}) + r_l(T - t_{2l})} \\ (\text{when } t_{2l} < T) & \\ &= 1.0 \\ (\text{when } t_{2l} \geq T), & \end{aligned} \quad (2)$$

when T represents the average delay to reinforcement from the onset of the initial links, and r_s and r_l represent the overall rate of primary reinforcement scheduled on the keys associated with the short and long duration terminal links (Squires & Fantino, 1971).

Although there are instances of concurrence, the two equations do offer divergent predictions. In a specific example related to the following procedure, in concurrent chains with variable-interval (VI) 200-sec initial-link schedules and VI 60-sec and VI 90-sec terminal-link schedules, both equations predict a .60 level of preference for the shorter terminal link. In the relation described by Equation 2, the overall delay to reinforcement, T , signaled by the onset of the initial links would be the sum of the 100-sec average initial-link duration (since initial links are concurrent) and the 75-sec average terminal-link duration. The delay reduction (175 to 60 sec) signaled by entry to the VI 60-sec terminal link would be greater than the delay reduction (175 to 90 sec) signaled by entry to the VI 90-sec terminal link. In Equation 2 this proportion is modified by the overall rates of primary reinforcement (initial plus terminal-link durations) on the short ($r_s = 260$ sec) and long ($r_l = 290$ sec) alternatives.

This study was supported by NIMH Grant No. 20752 to the University of California, San Diego. Address correspondence to either author at Department of Psychology C-009, University of California at San Diego, La Jolla, California 92093.

(See Appendix for details of related computations.) However, if the initial links were reduced to VI 30-sec schedules, Equation 2 would predict exclusive preference for the VI 60-sec terminal link. In the latter case, the overall delay to reinforcement, T , would be the sum of the 15-sec average initial-link duration and the 75-sec average terminal-link duration. With T equal to 90 sec, entry to the VI 90-sec terminal link no longer represents a delay reduction. On the other hand, if the initial-link schedules were greater than VI 200-sec, Equation 2 predicts preference levels less than .60. The relative immediacy (Equation 1) of the VI 60-sec terminal link is .60 regardless of the overall delay to reinforcement.

Equation 2 has been tested primarily by varying the size of either the initial or terminal links (and hence T) while holding the ratio of terminal-link durations (and hence relative immediacy) constant (Davison & Temple, 1973; Fantino, 1977; Gentry & Marr, 1980; Hursh & Fantino, 1973; Williams & Fantino, 1978). These results make clear that when relative immediacy is held constant, relative delay reduction controls choice. The generality and implications of these and related findings have recently been reviewed (Fantino, 1981).

It remains possible, however, that relative immediacy may also affect choice when relative delay reduction is held constant. In other words, does relative immediacy account for variance in choice within a context of invariant relative delay reduction? Our procedure initially varied relative immediacy while maintaining a constant relative delay reduction. In a subsequent manipulation relative delay reduction was varied while relative immediacy remained constant or varied in opposition to relative delay reduction.

METHOD

Subjects

Four adult male White King pigeons were maintained at approximately 80% of their free-feeding weights. All had previous experience on simple FI and VI schedules. The birds were weighed after each experimental session and fed measured amounts of grain to maintain weight levels. Water and grit were available in the home cages.

Apparatus

Two standard two-key operant conditioning chambers were used. The translucent response keys were mounted 8.6 cm apart and 23 cm above the floor. Each key required a minimum force of about .15 N to be activated. The operation of a relay solenoid provided auditory feedback for key pecks. Keys could be transilluminated with various colors. A solenoid-operated grain hopper was centrally located below the keys and provided 3.5-sec access to grain. General chamber illumination was provided except during operation of the hopper. White noise was present continuously. Standard electromechanical scheduling equipment was located in an adjacent room.

Procedure

In all conditions, the initial links of the concurrent-chain schedules (cf. Autor, 1960, 1969; Herrnstein, 1964) were independently programmed variable-interval (VI) schedules. The mutually exclusive terminal links consisted of VI schedules of food delivery. Intervals were determined according to the method suggested by Segal (1964). During the initial links, the left key was illuminated red and the right key green. The terminal links were signaled by blue illumination of the left key and white on the right key.

Initial- and terminal-link schedule values were manipulated to vary either the relative immediacy of reinforcement or the reduction in delay associated with entry into the terminal link. The Appendix shows how Equations 1 and 2 may be applied to these schedule values. Table 1 (first two columns) presents the schedule values in each condition and in the order of presentation. Each condition continued for a minimum of 20 sessions and until the following stability criterion had been satisfied: After 20 sessions, the relative rates of responding in the initial links for the previous nine sessions were divided into blocks of three sessions. Performance was considered stable when the means of the three blocks neither differed by more than ± 0.05 nor exhibited a trend, i.e. neither $\bar{X}_1 > \bar{X}_2 > \bar{X}_3$ nor $\bar{X}_1 < \bar{X}_2 < \bar{X}_3$. The number of sessions to stability in each condition is presented in the last column of Table 1. In all conditions, sessions continued for 40 food presentations and occurred daily.

Table 1

Schedule values and results in each condition in the order of presentation. R_s and r_s represent the response and obtained reinforcement rate, respectively, on the key associated with the shorter delay to reinforcement. The calculations of relative immediacy (Equation 1) and relative delay reduction (Equation 2) are presented in the appendix.

Bird	Initial link VI left/right	Terminal link VI left/right	R_s $R_s + R_l$	Eq. 1	Eq. 2	r_s $r_s + r_l$	Initial link R/min	Terminal link R/min left/right	Sessions to stability
G21	30/30	60/90	0.99	0.60	1.00	0.84	32.2	61/49	22
	30/30	90/60	0.98	0.60	1.00	0.75	39.7	61/69	50
	75/75	10/85	1.00	0.89	1.00	0.97	41.7	115/47	32
	75/75	85/10	0.93	0.89	1.00	0.66	39.0	61/156	56
	240/240	5/30	0.58	0.86	0.58	0.48	40.1	156/89	30
	240/240	30/5	0.54	0.86	0.58	0.52	37.8	52/181	36
G23	75/75	10/85	1.00	0.89	1.00	0.95	36.4	66/38	22
	75/75	85/10	1.00	0.89	1.00	0.92	26.0	72/102	43
	30/30	60/90	0.99	0.60	1.00	0.91	25.8	84/63	53
	30/30	90/60	0.99	0.60	1.00	0.94	19.1	86/75	41
	240/240	5/30	0.64	0.86	0.58	0.49	38.2	95/93	32
	240/240	30/5	0.68	0.86	0.58	0.48	52.4	74/120	32
Y47	30/30	60/90	0.91	0.60	1.00	0.65	39.9	47/35	30
	30/30	90/60	0.82	0.60	1.00	0.55	47.0	36/41	43
	75/75	10/85	0.97	0.89	1.00	0.64	43.7	73/43	30
	75/75	85/10	0.68	0.89	1.00	0.48	34.4	46/130	42
	240/240	5/30	0.65	0.86	0.58	0.52	33.8	70/46	25
	240/240	30/5	0.46	0.86	0.58	0.49	38.9	59/52	29
G69	75/75	10/85	1.00	0.89	1.00	0.83	36.8	56/47	27
	75/75	85/10	0.99	0.89	1.00	0.72	30.6	61/39	46
	30/30	60/90	1.00	0.60	1.00	0.96	62.1	66/63	41
	30/30	90/60	0.99	0.60	1.00	0.85	51.2	63/42	30
	240/240	5/30	0.64	0.86	0.58	0.49	55.7	67/46	29
	240/240	30/5	0.56	0.86	0.58	0.53	45.3	41/63	24

RESULTS AND DISCUSSION

The relative rates of responding in the initial links in each condition are presented in Table 1. These data are averages of the last nine sessions in each condition. For all birds, preference does not vary substantially with changes in relative immediacy. Variation in preference is generally consistent with variation in relative delay reduction. This result is particularly clear in Figure 1. The mean data approximate relative delay reduction and do not vary with relative immediacy. Although there are quantitative differences, this pattern is consistent across all birds.

Although relative immediacy did not affect choice, it may have affected how quickly preference developed and stabilized. For example, did preference develop more rapidly when the terminal-link durations were more disparate (i.e., in the 10/85-sec vs. the 60/90-sec conditions)? There are at least two points of analysis relevant to this question. First, at the outset

of the experiment all four birds were naive to concurrent-chain schedules. Two birds (G23 & G69) were initially assigned to the 10- vs. 85-sec condition; the other two (G21 & Y47) were assigned to the 60- vs. 90-sec condition. Those birds initially exposed to 10- vs. 85-sec terminal links developed preference at about the same rate as those initially in the 60- vs. 90-sec condition (24.5 and 26 sessions to stability, respectively; the individual data are in Table 1). Furthermore, the upper plot of Figure 2 suggests that the course of acquisition was not different in the two initial conditions. The pattern of acquisition for the birds in the 60- vs. 90-sec condition, G21 and Y47, did not differ systematically from the pattern for the birds in the 10- vs. 85-sec condition. Second, if resistant to change once preference has been established can be considered a measure of response strength (an assumption somewhat analogous to Nevin, 1979), then the transition to the last pair of conditions is of interest. The last set of two comparisons (5 vs. 30 and 30 vs. 5) was the

Fig. 1. Relative rates of responding (averaged over reversals) on the short-delay key in each comparison. The relative rates predicted by relative immediacy (Equation 1) and relative delay reduction (Equation 2) are also plotted. Note that Birds G23 and G69 were exposed to these conditions in the order presented here; G21 and Y47 had the first two comparisons presented in the reverse order.

same for all four birds. Two birds, G21 and Y47, were in the 85- vs. 10-sec condition immediately prior to the transition to 5 vs. 30 sec. Birds G23 and G69 were previously in the 90- vs. 60-sec condition. Both pairs of birds developed stable preference for the 5-sec terminal link in approximately the same number of sessions (27.5 and 31 sessions, respectively). The lower plot of Figure 2 shows that variations in the pattern of transition were not systematically correlated with the prior terminal-link conditions. Thus, there is no evidence from the acquisition, transition, or asymptotic data that suggests relative immediacy affects choice when relative delay reduction is held constant.

Absolute response rates in the initial and terminal links and relative reinforcement rates are presented in the last three columns of Table 1. Absolute response rates in the initial links did not vary systematically across conditions. Response rates were generally higher in the shorter terminal link. Four of the five exceptions to this relation occurred in the data from Y47 and G29. Finally, at extreme preference values, the nonpreferred alternative was sampled infrequently.

Fig. 2. Relative rates of responding on the short-delay key. A. Acquisition in the initial condition. The circles denote birds in the 60- vs. 90-sec condition. The other two birds (triangle and asterisk) were in the 10- vs. 85-sec condition. B. The transition to the last pair of conditions. The isolated data on the far left represent stable levels of preference in the preceding conditions. Circles denote birds in transition from the 85- vs. 10-sec condition. The triangle and asterisk refer to birds in transition from the 90- vs. 60-sec condition.

Hineline (1981), in his analysis of negative reinforcement, has distinguished between two modes of reinforcement: "reinforcement by change in density of events within a behavioral situation, and reinforcement by change of situation" (Hineline, 1981, pp. 239-240). The delay-

reduction hypothesis primarily implicates reinforcement by change of situation, e.g., the terms $(T - t_{2s})$ and $(T - t_{2l})$. Baum (1973) has also stressed that transition from one situation to another can serve as a potent reinforcing event. The present results support this view by showing that choice is sensitive to changes in the overall delay to reinforcement between the start of a trial and onset of a stimulus rather than simply being sensitive to the rate of reinforcement in the presence of that stimulus. As such, choice appears sensitive to temporal events throughout a trial, not just temporal events during the outcomes chosen. The density of temporal events during the outcomes chosen affects choice in two ways. For example when the rate of reinforcement is increased for one outcome only (say the one with the short duration terminal link) both r_s and $(T - t_{2s})$ in Equation 2 increase. Since the corresponding terms for the other outcome do not increase— r_l remains the same and $(T - t_{2l})$ decreases—Equation 2 requires a larger choice proportion. Thus, by increasing the relative rate of reinforcement during the one outcome relative delay reduction is increased. The present results suggest that the relative rate of reinforcement has no effect on choice independent of its effect on relative delay reduction.

In summary, preference did not vary with relative immediacy of reinforcement when relative delay reduction was constant. This result, in conjunction with several reports of control by relative delay reduction (see Fantino, 1977, 1981; Fantino & Logan, 1979; and the last two conditions of this procedure), suggests that relative immediacy is not an independent determinant of choice in concurrent chains.

REFERENCES

- Autor, S. M. *The strength of conditioned reinforcers as a function of frequency and probability of reinforcement*. Unpublished doctoral dissertation, Harvard University, 1960.
- Autor, S. M. The strength of conditioned reinforcers as a function of frequency and probability of reinforcement. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Ill.: Dorsey Press, 1969.
- Baum, W. M. The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 137-153.
- Chung, S., & Herrnstein, R. J. Choice and delay of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 67-74.
- Davison, M. C., & Temple, W. Preference for fixed-interval schedules: An alternative model. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 393-403.
- Fantino, E. Conditioned reinforcement: Choice and information. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- Fantino, E. 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*. Chichester and New York: Wiley, 1981.
- Fantino, E., & Logan, C. A. *The experimental analysis of behavior: A biological perspective*. San Francisco: Freeman, 1979.
- Gentry, G. D., & Marr, M. J. Choice and reinforcement delay. *Journal of the Experimental Analysis of Behavior*, 1980, 33, 27-37.
- Herrnstein, R. J. Secondary reinforcement and rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 27-36.
- Hineline, P. N. The several roles of stimuli in negative reinforcement. In P. Harzem & M. D. Zeiler (Eds.), *Advances in analysis of behaviour* (Vol. 2). *Predictability, correlation, and contiguity*. Chichester and New York: Wiley, 1981.
- Hursh, S. R., & Fantino, E. Relative delay of reinforcement and choice. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 437-450.
- Nevin, J. A. Reinforcement schedules and response strength. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour* (Vol. 1). *Reinforcement and the organization of behaviour*. Chichester and New York: Wiley, 1979.
- Segal, E. F. A rapid procedure for generating random reinforcement intervals on VI and VR tapes. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 20.
- Squires, N., & Fantino, E. A model for choice in simple concurrent and concurrent-chains schedules. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 27-38.
- Williams, B. A., & Fantino, E. Effects on choice of reinforcement delay and conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 77-86.

Received August 24, 1981

Final acceptance June 23, 1982

APPENDIX

In this procedure:

- a) When the initial links are both VI 75-sec schedules and the two terminal-link schedules are VI 10-sec and VI 85-sec,

In Equation 1:

$$\frac{.10}{.10 + .012} = .89$$

In Equation 2:

$$T = \frac{75}{2} + \frac{10 + 85}{2} = 85$$

$$r_s = \frac{1}{75 + 10} = .012$$

$$r_t = \frac{1}{75 + 85} = .006$$

$$\frac{.012(85 - 10)}{.012(85 - 10) + .006(85 - 85)} = 1.0$$

($t_{2t} = T$)

- b) With VI 30-sec initial-link schedules and VI 60-sec and VI 90-sec terminal-link schedules,

In Equation 1:

$$\frac{.016}{.016 + .011} = .60$$

In Equation 2:

$$T = \frac{30}{2} + \frac{60 + 90}{2} = 90$$

$$r_s = \frac{1}{30 + 60} = .011$$

$$r_t = \frac{1}{30 + 90} = .008$$

$$\frac{.011(90 - 60)}{.011(90 - 60) + .008(90 - 90)} = 1.0$$

($t_{2t} = T$)

- c) With VI 240-sec initial-link schedules and VI 5-sec and VI 30-sec terminal-link schedules,

In Equation 1:

$$\frac{.20}{.20 + .033} = .86$$

In Equation 2:

$$T = \frac{240}{2} + \frac{35}{2} = 137.5$$

$$r_s = \frac{1}{240 + 5} = .0041$$

$$r_t = \frac{1}{240 + 30} = .0037$$

$$\frac{.0041(137.5 - 5)}{.0041(137.5 - 5) + .0037(137.5 - 30)} = .58$$