JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1985, 44, 89-101 NUMBER 1 (JULY)

PREFERENCE FOR UNSEGMENTED INTERREINFORCEMENT INTERVALS IN CONCURRENT CHAINS

JIN-PANG LEUNG AND ALAN S. W. WINTON

MASSEY UNIVERSITY, NEW ZEALAND

Five pigeons were trained under concurrent-chain schedules in which a pair of independent, concurrent variable-interval 60-s schedules were presented in the initial link and either both variable-interval or both fixed-interval schedules were presented in the terminal link. Except for the baseline, one of the terminal-link schedules was always a two-component chained schedule and the other was either a simple or a tandem schedule of equal mean interreinforcement interval. The values of the fixed-interval schedules were either 15 s or 60 s; that of the variable-interval schedules was always 60 s. A 1.5-s changeover delay operated during the initial link in some conditions. The pigeons preferred a simple or a tandem schedule to a chain. For the fixed-interval schedules, this preference was greater when the fixed interval was 60 s than when it was 15 s. For the variable-interval schedules, the preferences were less pronounced and occurred only when the changeover delay was in effect. For a given type of schedule and interreinforcement interval, similar preferences were obtained whether the nonchained schedule was a tandem or simple schedule. The changeover delay generally inflated preference and lowered the changeover rate, especially when the terminal-link schedules were either short (15 s) or aperiodic (variable-interval). The results were consistent with the notion that segmenting the interreinforcement interval of a schedule into a chain lowers the preference for it.

Key words: preference, segmentation, concurrent chains, interreinforcement interval, changeover delay, chained interval schedule, simple interval schedule, key peck, pigeons

The concurrent-chain procedure (Autor, 1960, 1969) is widely used for studying the effects of various schedule parameters on choice. In a typical experiment, pigeons are presented concurrently with two variable-interval (VI) 60-s schedules, each correlated with an illuminated key. This constitutes the initial link. Meeting the schedule requirement on either key produces a stimulus change on that key while the other key becomes dark and inoperative. The subject is now in the terminal link. Completing a terminal-link schedule requirement produces food and then reinstatement of the initial link. The relative allocation of responses on the two keys during the initial link is used as a measure of preference between the two mutually exclusive terminal-link schedules.

A brief report of this experiment was presented at the Annual Conference (1983) of the New Zealand Psychological Society. Reprints may be obtained from Jin-Pang Leung, Department of Psychology, University of Canterbury, Christchurch 1, New Zealand, or from Alan S. W. Winton, Psychology Department, Massey University, Private Bag, Palmerston North, New Zealand.

Whether events occurring in the interreinforcement interval (IRI) of a schedule affect choice for it has been the major concern of several concurrent-chain experiments (e.g., Duncan & Fantino, 1972; Fantino, 1968; Neuringer, 1969; Neuringer & Schneider, 1968; Schneider, 1972). In concurrent chains the IRI of a terminal-link schedule refers to the period from the onset of that schedule to the presentation of reinforcement. Some of these studies (e.g., Neuringer, 1969; Neuringer & Schneider, 1968; Schneider, 1972) found that preference for a schedule was unaffected by events occurring during the IRI. By contrast, results from other studies (e.g., Duncan & Fantino, 1972; Fantino, 1968) suggest that such events could affect choice. This was shown in Experiment 1 of the Duncan and Fantino (1972) study in which they examined choice between a simple fixed-interval (FI) and a chained FI FI schedule. The chained schedule (or chain) is considered to have been segmented relative to the simple schedule by conceptualizing it as a simple schedule divided into two components by two intervening events—by a response requirement between components and by the correlated stimulus change. Duncan and Fantino found that when the terminal-link schedules had equal IRIs, pigeons strongly preferred the simple schedule to the chain and that this preference increased with the size of the IRI. In other words, an unsegmented schedule was preferred to its segmented counterpart. These findings were consistent with a prediction made by Fantino (1969a) that segmenting a simple schedule into a chain would lower preference for that schedule. This prediction was based on an observation that lever-press responding by rats was well maintained under a fixed-ratio (FR) 20 schedule but that this deteriorated quickly when the ratio was broken down into a four-component chain.

If segmentation per se is responsible for these results with FI schedules, then segmenting a VI schedule should have similar effects. A study by Schneider (1972), however, provided indirect evidence against this proposition. In the first of a series of experiments, Schneider presented chained VI VI and tandem VI VI schedules in the terminal link, always with equal mean IRIs. He found that the tandem and chained schedules were equally preferred, despite the extra stimulus in the latter. Together with results from his other experiments, Schneider concluded that choice between two schedules is unaffected by events intervening within the IRI and is controlled simply by their relative IRIs.

Although Schneider's data may have been confounded by order effects inasmuch as all birds received the same sequence of conditions, this does not seem to adequately account for the difference between his results and those of Duncan and Fantino (1972). Schneider's finding of indifference could have been due to his use of tandem schedules instead of simple schedules as were used by Duncan and Fantino. Another possible explanation may lie in the different types of schedules presented in the terminal links of each study. With the FI schedules used in the Duncan and Fantino study, the fixed IRI of at least 10 s meant that reinforcement never closely followed responding in the initial link. On the other hand, Schneider used aperiodic (VI) schedules that allowed a response on one key during the initial link to be sometimes followed by a short delay to reinforcement. If responding on the other key had occurred just previously, such short delays might have been sufficient to maintain frequent switching between the keys. The equal reinforcement rates provided on both keys could have further enhanced such switching (cf. Catania, 1966). In a concurrent-schedules procedure, such adventitiously reinforced (superstitious) switching can disrupt the measure of choice so that the choice proportion is always close to .5 (e.g., Herrnstein, 1961). To separate the effects of the component schedules, a changeover delay (COD) is usually included that reduces the development of superstitious switching between keys. In accord with most concurrent-chain studies, Schneider (1972) did not program a COD during the initial link. If indifference was produced by superstitious switching, then the inclusion of a COD might have produced different results.

To explore this possibility, some conditions of the present experiment involved a comparison of a chained VI VI schedule with either a simple VI or a tandem VI VI schedule, with and without a COD. If the use of a tandem schedule rather than a simple schedule was important, then this should be demonstrated. If, however, adventitiously maintained switching was important, then preference might be obtained in conditions with a COD but not in its absence.

To determine whether a sequential pattern (e.g., superstitious switching) during the initial link was a source of variance affecting the measurement of choice, the criterion developed by Navarick (1979) was used. Based on the four basic response sequences in a choice situation (left-left, left-right, right-left, right-right), Navarick derived two conditional probabilities, one to measure any switching dependency (between keys) and the other any repetition dependency (on the same key). To indicate the overall direction of the sequential dependencies, a "dependency index" is calculated by subtracting the repetition dependency from the switching dependency.

According to Navarick's criterion, a positive index indicates overall switching tendency and a negative index indicates overall repetition tendency. Hence, if superstitious switching occurred when there was no COD, the index should be more positive than that obtained when there was a COD.

An additional purpose of the present experiment was to attempt to replicate the major findings of Duncan and Fantino (1972). To this end, some conditions compared choice between simple and chained FI schedules but with IRIs different from those used by Duncan and Fantino. To determine whether a tandem schedule had effects differing from those of simple schedules, conditions were also included that compared a tandem FI FI with an equivalent chain.

METHOD

Subjects

Five homing pigeons of racing stock, designated P12, P16, P21, P33, and P38, were maintained at 80% (± 10 g) of their free-feeding body weights. All birds had had prior experience with chained schedules of reinforcement scheduled on the center key.

Apparatus

The experimental chamber was a standard three-key pigeon enclosure (31 cm by 34 cm by 33 cm) made of sound-attenuating material, with an exhaust fan that helped mask external noise. The keys could be transilluminated with 1.3-W lights of various colors. Throughout the experiment, only the two side keys were operative and the center key was covered with black insulation tape. A force of 0.15 N operated the microswitch behind each key. Reinforcement was 3-s access to wheat in a raised, illuminated hopper with houselight and keylights off. Experimental events were controlled and recorded by electromechanical and solid-state equipment located some distance away from the experimental chamber.

Procedure

After initial shaping of pecking the two side keys, key pecking was maintained under concurrent VI 60-s VI 60-s schedules of reinforcement for 15 sessions with the two side keys illuminated white. The pigeons were then exposed to the concurrent-chains procedure. During the initial link, the two side keys remained white and responding on either key occasionally produced a change in key color on that key and the respective terminal-link schedule. Two independent VI 60-s schedules always operated during the initial link. For the baseline, during the terminal link one of two identical tandem FI 7.5-s FI 7.5-s schedules was correlated with a purple left key and the other with a green right key. A COD was in effect during the initial link. Other conditions then were introduced successively. Table 1 shows for each condition the terminal-link schedules and whether a COD was programmed during the initial link. For all conditions, in the terminal link a chained schedule was correlated with one key and either a tandem or simple schedule of the same IRI with the other. Each bird was exposed to the conditions in the numerical order shown. Conditions 1-8 were identical for all birds, and in each of these conditions preference was determined twice in succession, designated as *a* and *b*, with the terminal-link schedules reversed with respect to the two keys on the two occasions. Conditions 9-11 varied for each bird and were run to evaluate possible effects of order and color bias. Except for Condition 11 for P21 and Condition 10 for P33 that were new due to the absence of a COD, each of these conditions replicated one of Conditions 1-8, but with key colors varied. In Table 1, for each bird, a 1-8 Condition that was replicated later is marked by an asterisk; these earlier conditions being replicated are further designated in parentheses after the condition number of Conditions 9-11.

The terminal-link schedules for Conditions 1-3 were VI 60-s schedules. The same chained schedule was compared with a simple schedule (Condition 1), a tandem schedule with a COD (Condition 2), and the same tandem schedule with no COD (Condition 3). The terminal-link schedules in Conditions 4-8 were FI schedules with an IRI of 15 s in Conditions 4-6 and of 60 s in Conditions 7 and 8. The

Table 1

The order of conditions, the terminal-link schedules, the presence of a COD, and the number of sessions for each subject. The choice and reinforcement proportions for the nonchain key, the absolute rates of responding on each key during both the initial link and each component of the terminal-link schedules, and the changeover (CO) rate are also shown, with each entry being an average based upon the last five sessions of a condition. C1 and C2 refer to the first and second components of chained and tandem schedules in the terminal link. A simple schedule is also referred to as C2. In Conditions 1-8, each condition (a) was replicated immediately or (b) with each of the terminal-link schedules correlated with a different key. Some conditions, indicated by asterisks, were replicated in Conditions 9-11. In Conditions 9-11, the terminal-link schedules were different for each subject and the conditions being replicated are shown in parentheses. Key colors in Conditions 10 and 11 differed from those in Conditions 1-9 and across subjects.

				Initial-Link Response Rate (Per Min.)			*Terminal-Link Response Rate (Per Min.)*						
	Terminal-Link Schedules						*Chain Key*		*Nonchain Key*				
Condition	*Left Key*	*Right Key*	*COD*	*Nonchain Key*	*Chain Key*	*Choice Prop.*	*C1*	*C2*	*C1*	*C2*	*Reinf Prop.*	*CO Rate (Per Min.)*	*No. of Sess.*
P12													
1 a	chain VI30 VI30	VI60	yes	26.3	18.3	0.59	35.3	46.8	–	43.7	0.52	11.2	28
1 b	VI60	chain VI30 VI30	yes	28.6	22.5	0.56	37.7	48.5	–	45.6	0.52	12.7	21
2 a*	chain VI30 VI30	tand VI30 VI30	yes	27.8	22.7	0.55	40.6	48.2	44.4	46.7	0.51	13.0	18
2 b	tand VI30 VI30	chain VI30 VI30	yes	29.5	23.2	0.56	38.6	50.0	45.9	47.3	0.50	13.5	19
3 a	chain VI30 VI30	tand VI30 VI30	no	29.9	27.6	0.52	39.9	50.7	38.7	42.1	0.53	17.7	30
3 b	tand VI30 VI30	chain VI30 VI30	no	32.5	28.8	0.53	38.7	48.5	42.4	45.0	0.53	19.2	25
4 a	tand FI7.5 FI7.5	chain FI7.5 FI7.5	yes	35.5	7.2	0.83	53.0	111.8	81.3	96.4	0.53	5.8	20
4 b	chain FI7.5 FI7.5	tand FI7.5 FI7.5	yes	23.0	7.8	0.75	50.1	104.6	77.3	90.3	0.54	5.7	28
5 a*	FI15	chain FI7.5 FI7.5	no	40.5	10.8	0.79	49.3	120.4	–	77.1	0.52	9.5	30
5 b	chain FI7.5 FI7.5	FI15	no	41.5	10.4	0.80	52.7	108.7	–	86.0	0.52	9.2	31
6 a	FI15	chain FI7.5 FI7.5	yes	36.1	7.9	0.82	50.2	113.8	–	68.9	0.53	5.8	25
6 b*	chain FI7.5 FI7.5	FI15	yes	40.1	8.8	0.82	44.3	95.0	–	77.7	0.52	7.1	22
7 a	FI60	chain FI30 FI30	yes	29.9	0.3	0.99	24.0	51.5	–	30.6	0.52	0.2	32
7 b	chain FI30 FI30	FI60	yes	44.9	0.5	0.99	22.6	45.1	–	34.7	0.52	0.4	25
8 a	FI60	chain FI30 FI30	no	30.0	0.6	0.98	22.7	60.0	–	48.3	0.52	0.4	27
8 b	chain FI30 FI30	FI60	no	31.2	0.6	0.98	18.7	56.7	–	50.9	0.53	0.4	30
9(2a)	chain VI30 VI30	tand VI30 VI30	yes	25.5	19.6	0.60	45.0	70.2	46.6	52.0	0.50	12.9	35
10(5a)	FI15	chain FI7.5 FI7.5	no	38.3	12.0	0.76	47.6	100.4	–	85.3	0.49	10.8	40
11(6b)	chain FI7.5 FI7.5	FI15	yes	45.2	8.5	0.84	48.5	97.6	–	84.7	0.51	8.0	36
P16													
1 a	chain VI30 VI30	VI60	yes	30.7	21.3	0.59	19.6	28.4	–	20.9	0.48	14.1	22
1 b*	VI60	chain VI30 VI30	yes	27.0	20.4	0.57	15.8	18.7	–	15.8	0.51	12.7	30
2 a	chain VI30 VI30	tand VI30 VI30	yes	30.6	21.2	0.59	32.1	36.1	19.5	20.9	0.51	12.9	20
2 b	tand VI30 VI30	chain VI30 VI30	yes	30.5	22.0	0.58	28.4	35.6	30.4	32.0	0.51	13.5	20
3 a	chain VI30 VI30	tand VI30 VI30	no	34.1	24.7	0.49	22.7	30.5	18.2	19.0	0.48	20.8	22
3 b	tand VI30 VI30	chain VI30 VI30	no	33.7	29.9	0.53	18.0	20.1	22.3	21.8	0.50	21.4	19
4 a	tand FI7.5 FI7.5	chain FI7.5 FI7.5	yes	27.1	14.0	0.66	30.1	121.8	62.5	111.5	0.53	9.2	27
4 b	chain FI7.5 FI7.5	tand FI7.5 FI7.5	yes	22.5	10.6	0.68	21.7	99.2	77.2	123.7	0.52	7.1	33
5 a	FI15	chain FI7.5 FI7.5	no	25.4	16.2	0.61	43.1	127.6	–	67.8	0.53	10.7	21
5 b	chain FI7.5 FI7.5	FI15	no	22.7	15.8	0.59	26.5	106.4	–	63.7	0.52	10.4	18
6 a	FI15	chain FI7.5 FI7.5	yes	26.3	10.7	0.71	24.7	89.3	–	68.9	0.55	7.0	35
6 b	chain FI7.5 FI7.5	FI15	yes	25.7	11.0	0.70	36.5	89.7	–	66.3	0.55	7.7	30
7 a	FI60	chain FI30 FI30	yes	31.0	0.4	0.99	20.4	47.1	–	39.2	0.52	0.3	27
7 b*	chain FI30 FI30	FI60	yes	28.1	0.6	0.95	17.0	59.4	–	47.4	0.52	0.5	25
8 a	FI60	chain FI30 FI30	no	37.5	1.6	0.98	24.0	58.6	–	52.7	0.52	1.4	29
8 b*	chain FI30 FI30	FI60	no	35.9	1.5	0.99	22.3	60.1	–	50.8	0.51	1.2	28
9(1b)	VI60	chain VI30 VI30	yes	32.1	22.8	0.63	33.0	45.6	–	88.2	0.51	13.5	33
10(8b)	chain FI30 FI30	FI60	no	40.0	1.2	0.97	18.7	70.7	–	50.1	0.52	1.0	35
11(7b)	chain FI30 FI30	FI60	yes	39.8	0.6	0.99	16.9	69.3	–	52.4	0.53	0.5	35

Table 1 Continued

Condition	Terminal-Link Schedules: Left Key	Terminal-Link Schedules: Right Key	COD	Initial-Link Response Rate (Per Min.): Nonchain Key	Initial-Link Response Rate (Per Min.): Chain Key	Choice Prop.	Terminal-Link Response Rate (Per Min.): Chain Key C1	Terminal-Link Response Rate (Per Min.): Chain Key C2	Terminal-Link Response Rate (Per Min.): Nonchain Key C1	Terminal-Link Response Rate (Per Min.): Nonchain Key C2	Reinf Prop.	CO Rate (Per Min.)	No. of Sess.
P21													
1 a	chain VI30 VI30	VI60	yes	19.2	14.5	0.57	40.9	53.6	–	44.1	0.50	8.2	22
1 b	VI60	chain VI30 VI30	yes	17.6	15.5	0.54	40.3	72.8	–	58.2	0.50	8.3	23
2 a	chain VI30 VI30	tand VI30 VI30	yes	19.5	15.3	0.56	40.2	78.4	66.8	72.3	0.54	8.5	22
2 b	tand VI30 VI30	chain VI30 VI30	yes	20.2	14.5	0.58	36.0	84.6	60.2	76.6	0.53	8.6	20
3 a	chain VI30 VI30	tand VI30 VI30	no	23.7	22.8	0.51	50.8	66.6	40.1	44.3	0.51	15.6	26
3 b	tand VI30 VI30	chain VI30 VI30	no	22.0	20.3	0.52	40.8	60.6	48.5	52.9	0.50	16.4	18
4 a*	tand FI7.5 FI7.5	chain FI7.5 FI7.5	yes	22.6	10.1	0.69	100.9	132.3	90.2	113.6	0.51	7.0	25
4 b	chain FI7.5 FI7.5	tand FI7.5 FI7.5	yes	23.9	9.3	0.72	84.4	54.7	93.8	72.4	0.53	7.2	24
5 a*	FI15	chain FI7.5 FI7.5	no	22.9	12.3	0.65	50.2	34.5	–	46.4	0.52	9.7	23
5 b	chain FI7.5 FI7.5	FI15	no	21.8	12.8	0.63	82.4	19.4	–	45.3	0.49	9.2	19
6 a	FI15	chain FI7.5 FI7.5	yes	18.0	6.7	0.73	39.5	29.2	–	42.1	0.52	4.5	30
6 b	chain FI7.5 FI7.5	FI15	yes	20.2	7.4	0.73	49.0	27.8	–	32.7	0.52	5.4	28
7 a	FI60	chain FI30 FI30	yes	38.4	0.4	0.98	35.8	78.8	–	38.6	0.50	0.2	30
7 b	chain FI30 FI30	FI60	yes	39.7	0.4	0.97	30.8	66.2	–	28.8	0.51	0.3	22
8 a	FI60	chain FI30 FI30	no	42.0	1.9	0.66	25.6	66.6	–	42.7	0.54	0.9	24
8 b	chain FI30 FI30	FI60	no	44.6	1.4	0.99	21.3	61.4	–	50.8	0.52	0.9	25
9(5a)	FI15	chain FI7.5 FI7.5	no	22.8	1.7	0.68	40.5	112.7	–	86.4	0.51	8.9	30
10(4a)	tand FI7.5 FI7.5	chain FI7.5 FI7.5	yes	29.6	11.0	0.73	37.1	124.6	50.8	74.5	0.50	8.3	35
11	chain FI7.5 FI7.5	tand FI7.5 FI7.5	no	25.3	13.2	0.66	40.6	118.5	61.9	70.2	0.52	9.9	35
P33													
1 a*	chain VI30 VI30	VI60	yes	19.7	13.1	0.60	55.3	71.7	–	64.0	0.51	7.8	33
1 b	VI60	chain VI30 VI30	yes	16.2	11.5	0.62	60.9	79.5	–	74.3	0.50	7.2	24
2 a	chain VI30 VI30	tand VI30 VI30	yes	16.3	11.5	0.58	52.6	70.2	67.2	65.5	0.49	6.8	21
2 b	tand VI30 VI30	chain VI30 VI30	yes	16.5	12.0	0.58	62.5	69.1	60.4	65.5	0.52	6.9	20
3 a	chain VI30 VI30	tand VI30 VI30	no	18.7	18.5	0.50	66.2	91.5	74.3	68.2	0.50	14.3	26
3 b	tand VI30 VI30	chain VI30 VI30	no	19.3	17.1	0.53	63.8	81.5	68.8	72.1	0.50	13.9	25
4 a*	tand FI7.5 FI7.5	chain FI7.5 FI7.5	yes	16.5	10.6	0.61	60.1	122.2	88.6	97.5	0.53	6.5	23
4 b	chain FI7.5 FI7.5	tand FI7.5 FI7.5	yes	14.9	9.8	0.60	52.4	132.7	98.3	118.0	0.53	5.9	21
5 a	FI15	chain FI7.5 FI7.5	no	15.5	12.2	0.56	62.9	112.3	–	100.6	0.51	9.1	32
5 b	chain FI7.5 FI7.5	FI15	no	16.8	12.7	0.57	70.3	124.7	–	110.4	0.52	8.7	30
6 a	FI15	chain FI7.5 FI7.5	yes	16.4	10.5	0.61	87.5	126.6	–	122.1	0.54	6.4	19
6 b	chain FI7.5 FI7.5	FI15	yes	16.9	11.0	0.61	69.5	121.2	–	111.7	0.54	6.6	18
7 a	FI60	chain FI30 FI30	yes	26.0	1.4	0.95	44.3	92.5	–	104.8	0.51	1.1	29
7 b	chain FI30 FI30	FI60	yes	22.0	1.2	0.95	47.4	90.9	–	89.3	0.51	0.9	28
8 a	FI60	chain FI30 FI30	no	28.3	1.8	0.94	48.1	92.6	–	88.2	0.50	1.5	22
8 b	chain FI30 FI30	FI60	no	33.3	2.1	0.94	38.6	80.3	–	90.5	0.50	1.7	22
9(4a)	tand FI7.5 FI7.5	chain FI7.5 FI7.5	yes	24.6	15.3	0.62	50.7	113.6	77.9	86.5	0.52	7.9	29
10	chain VI30 VI30	VI60	no	18.3	17.5	0.51	51.9	83.4	–	70.0	0.50	15.5	34
11(1a)	chain VI30 VI30	VI60	yes	20.5	15.4	0.57	60.3	85.7	–	74.7	0.51	8.9	31

Table 1 Continued

Condition	Terminal-Link Schedules: Left Key	Terminal-Link Schedules: Right Key	COD	Initial-Link Response Rate (Per Min.): Nonchain Key	Initial-Link Response Rate (Per Min.): Chain Key	Choice Prop.	Terminal-Link Response Rate (Per Min.): Chain Key C1	Chain Key C2	Nonchain Key C1	Nonchain Key C2	Reinf Prop.	CO Rate (Per Min.)	No. of Sess.
P38													
1 a	chain VI30 VI30	VI60	yes	32.0	26.1	0.55	61.1	80.9	–	61.0	0.48	16.2	23
1 b	VI60	chain VI30 VI30	yes	26.9	22.1	0.55	63.4	74.4	–	76.0	0.51	14.3	30
2 a	chain VI30 VI30	tand VI30 VI30	yes	31.4	26.3	0.56	75.9	91.3	70.1	73.7	0.50	16.0	35
2 b*	tand VI30 VI30	chain VI30 VI30	yes	28.9	23.4	0.55	57.1	70.7	80.5	77.6	0.49	14.5	32
3 a*	chain VI30 VI30	tand VI30 VI30	no	32.5	31.2	0.51	60.6	78.2	50.1	53.7	0.51	25.8	23
3 b	tand VI30 VI30	chain VI30 VI30	no	34.1	31.5	0.52	64.4	76.8	56.6	52.5	0.51	27.1	21
4 a	tand FI7.5 FI7.5	chain FI7.5 FI7.5	yes	27.5	12.9	0.68	42.7	131.8	60.0	110.1	0.52	9.0	33
4 b	chain FI7.5 FI7.5	tand FI7.5 FI7.5	yes	28.8	14.8	0.66	42.8	123.1	63.7	102.4	0.51	9.7	40
5 a	FI15	chain FI7.5 FI7.5	no	32.9	14.9	0.69	32.7	157.9	–	32.7	0.54	12.6	25
5 b	chain FI7.5 FI7.5	FI15	no	35.7	17.6	0.67	25.3	155.9	–	85.6	0.54	13.0	25
6 a	FI15	chain FI7.5 FI7.5	yes	33.0	12.2	0.74	25.1	159.3	–	80.8	0.55	10.1	21
6 b	chain FI7.5 FI7.5	FI15	yes	35.4	12.4	0.74	28.5	140.6	–	94.9	0.55	9.8	27
7 a*	FI60	chain FI30 FI30	yes	46.5	1.5	0.97	65.1	108.9	–	60.2	0.53	1.2	33
7 b	chain FI30 FI30	FI60	yes	35.9	1.9	0.95	78.8	107.2	–	55.3	0.52	1.5	19
8 a	FI60	chain FI30 FI30	no	40.2	2.2	0.95	42.7	90.8	–	77.9	0.54	2.0	31
8 b	chain FI30 FI30	FI60	no	45.6	2.1	0.96	62.5	98.7	–	68.0	0.54	1.7	30
9(7a)	FI60	chain FI30 FI30	yes	40.3	0.4	0.99	55.3	100.6	–	70.1	0.49	0.7	29
10(3a)	chain VI30 VI30	tand VI30 VI30	no	32.0	31.5	0.50	60.0	85.1	–	80.6	0.51	23.1	35
11(2b)	tand VI30 VI30	chain VI30 VI30	yes	36.1	25.1	0.59	59.7	85.9	–	78.3	0.50	16.2	35

nonchain key involved a simple FI schedule, except in Condition 4, which had a tandem schedule with a COD. Conditions 5 and 6 were identical except that only Condition 6 had a COD. Similarly, Conditions 7 and 8 were identical except that only Condition 7 had a COD.

In Conditions 1-9, red and green stimuli were always correlated with the first and second components, respectively, of the chained schedules, and a purple stimulus was always correlated with the simple or tandem schedule. In Conditions 10 and 11 different colored stimuli were used (blue, orange, and pink), varying across birds. The stimuli correlated with the first component of the chain, the second component of the chain, and the simple schedule, respectively, were: blue, pink, and orange for P12; blue, orange, and pink for P12; orange, pink, and blue for P21; pink, orange, and blue for P33; and orange, blue, and pink for P38.

The intervals for the VI schedules were generated from progressions that scheduled events after varying times but with a constant probability (Fleshler & Hoffman, 1962). When the COD was operative, a response on either key could initiate a scheduled terminal link only if at least 1.5 s had elapsed since the first response on that key after responding on the other key or after primary reinforcement (Herrnstein, 1961).

Sessions were conducted 7 days a week. Each session was terminated after the delivery of 40 reinforcers; hence the session duration varied with the size of the terminal-link IRI. A new condition or a reversal was introduced when the performances appeared stable by visual inspection and the mean choice proportion of the last five sessions did not differ by more than 5% from that of the previous five sessions.

RESULTS

Table 1 presents, for each bird, under each condition, the choice and reinforcement proportions on the nonchain key, the absolute response rates on each key during the initial link, the absolute rate of responding in each component of the terminal link, and the changeover (CO) rate in the initial link. Each value is the mean from the last five sessions of a condition. The two keys were designated "chain key" and "nonchain key" based on the type of schedule of reinforcement given for responding on that key in the terminal link. The choice proportion is the ratio of responses made on the nonchain key to the total responses made on both keys during the initial link. The reinforcement proportion is the rate of reinforcement obtained by responding on the nonchain key divided by the overall rate of reinforcement obtained on both keys during the terminal link. The CO rate is the total number of changeovers from the nonchain to the chain key divided by the total time (in minutes) spent in the initial link.

In the baseline phase, the choice proportions, with respect to the left key for P12, P16, P21, P33, and P38, were .52, .50, .49, .53, and .48, respectively, and the reinforcement proportions were either equal or very close to .50. Allowing for extraneous variances and measurement errors, the replications in Conditions 9-11 produced data similar to those obtained in Conditions 1-8 with the same stimuli (Condition 9) or different stimuli (Conditions 10 and 11), and despite differing numbers of intervening conditions. Of the 13 intrasubject replications, in only 4 instances (each involving a different bird) did the choice proportion vary by more than 5% from that originally obtained, with the biggest difference being 11% (from P16 in Condition 9). Hence, these within-subject comparisons provided no evidence that preferences obtained in Conditions 1-8 were the outcome of either order effects or color biases. For this reason, the results from the replications were combined with those from the relevant earlier condition when the group data were considered.

In general, the effects produced by the various conditions were consistent across birds. Hence the results are described mainly in terms of the group means. Figure 1 presents the mean choice proportion (upper panels) and CO rate (lower panels) as a function of the schedule associated with the nonchain key (simple or tandem), the size of the IRI, and whether or not a COD operated in the initial link. The data for the VI schedules (Panels A and C) and FI schedules (Panels B and D) are presented separately. Each mean value is plotted with a vertical bar indicating one standard deviation on each side of the mean. For the VI schedules, the choice data (Panel A) showed little variability either within or between birds. In Condition 1 in which a COD was present, the simple VI schedule was preferred to the chain (mean choice proportion = .58). This preference was very similar to the .57 when the simple schedule was replaced by a tandem schedule in Condition 2. However, this preference disappeared to near .5 in Condition 3 where a COD was absent. Indifference also occurred with P33 in Condition 10 with a simple VI versus a chain and no COD scheduled. The mean CO rates in Conditions 1 and 2 (Panel C) were very similar (11.3 and 11.9, respectively). The removal of the COD in Condition 3 increased the amount of switching during initial links as indicated by the high mean CO rate of 19.8. Without a COD, a comparable high CO rate (15.5) was produced by P33 in Condition 10 although it was lower than the mean rate in Condition 3. The relatively low CO rate from this bird is consistent with its having had the lowest individual CO rate in most conditions. In general, the removal of the COD produced indifference and an increase in the amount of changeover responding.

The COD under these conditions also affected the direction of the sequential dependency. Table 2 presents the dependency index calculated for each bird in each condition by using the absolute response rates on both keys and the CO rate, during the initial links. To recapitulate, a positive value indicates an overall switching dependency, a negative value indicates an overall repetition dependency, and a value near zero indicates no predominant sequential dependency. Superstitious switching would be expected to produce more positive values. With the FI schedules and a COD programmed (Conditions 1 and 2), the indices were near zero or slightly positive. In the absence of a COD in Condition 3 and Condition 10 for P33, however, the indices were highly positive, indicating that ex-

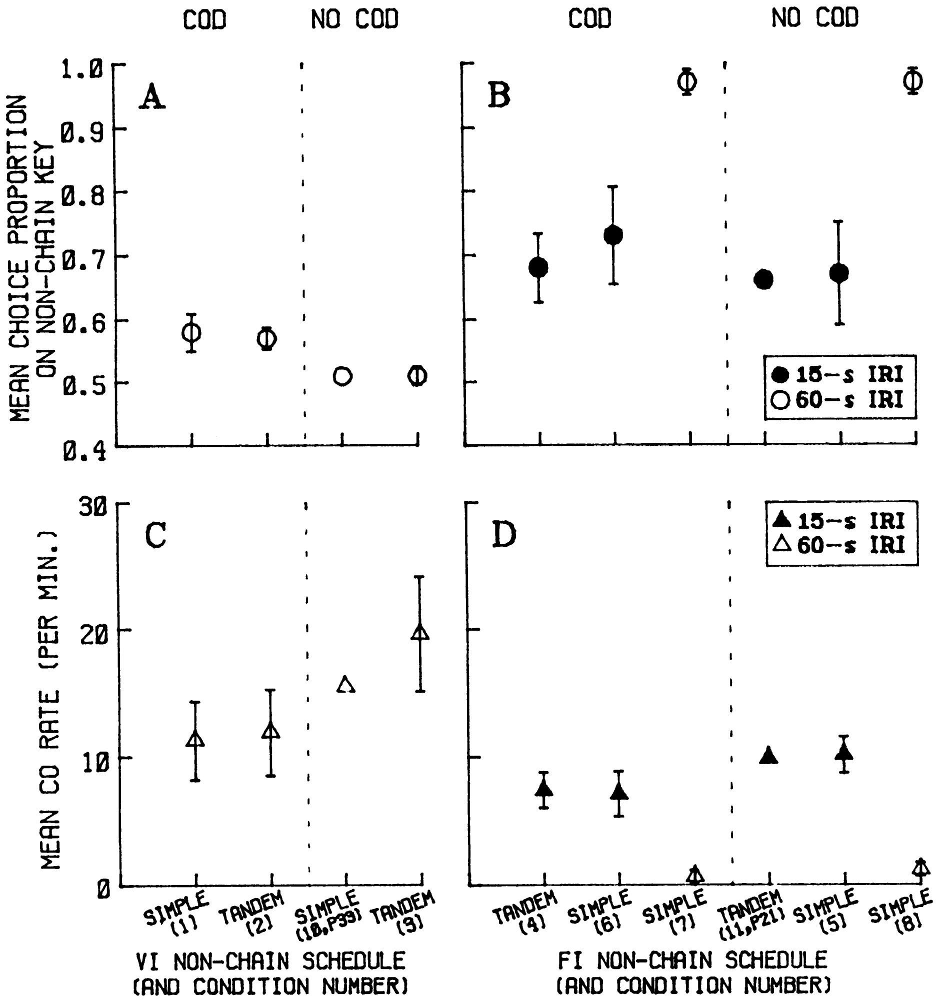

Fig. 1. Mean choice proportion for the nonchain key and the mean changeover rate from the nonchain key to the chain key as a function of the schedule programmed on the nonchain key (with the condition number shown in parenthesis), the size of the interreinforcement interval (IRI), and whether or not a COD operated in the initial link. Panels A and C are for VI schedules and Panels B and D are for FI schedules. Vertical bars indicate one standard deviation above and below the means. Note that the data points for the simple VI 60-s with no COD were from a single bird, P33 (Condition 10), and those for the tandem FI 7.5-s FI 7.5-s with no COD were from a single bird, P21 (Condition 11).

cessive switching occurred during the initial link.

In the conditions involving FI schedules, the nonchained (simple or tandem) schedule was always preferred to a chained schedule (Panel B, Figure 1). Further, these preferences were always greater than those obtained with the VI 60-s schedules, except for P33 whose choice proportions for the FI 15-s were very similar to those for the VI schedules. There was moderate intersubject variability when the IRI was 15 s but very little when the IRI was 60 s. Condition 4 compared a tandem and a chain of 15-s IRI with a COD, and the mean choice proportion was .69. This was slightly higher than the .66 obtained in a tandem/chain comparison without a COD, using only P21 (Condition 11). The simple/chain comparison with no COD (Condition 5) resulted in a slight drop in the mean preference (.67), although P38 showed a minimal increase. With the same schedules and a COD in Condition 6, the preference for the nonchained schedule rose to a mean of .73. This is somewhat higher than that obtained in Con-

Table 2

The dependency index for each subject in each condition. Positive values indicate a predominant switching dependency, negative values a predominant repetition dependency, and zeros no sequential dependency. Terminal-link schedules are not shown for Conditions 9-11 as they varied across subjects. The replicated condition is shown underneath the corresponding dependency index in parentheses.

Con-	*Terminal-Link Schedules*		*Dependency Index*				
dition	*Left Key*	*Right Key*	*P12*	*P16*	*P21*	*P33*	*P38*
1a	chain VI30 VI30	VI60	0.04	0.12	−0.01	−0.01	0.12
1b	VI60	chain VI30 VI30	0.01	0.09	0.02	0.07	0.18
2a	chain VI30 VI30	tand VI30 VI30	0.04	0.03	−0.01	0.01	0.12
2b	tand VI30 VI30	chain VI30 VI30	0.04	0.06	0.02	−0.01	0.12
3a*	chain VI30 VI30	tand VI30 VI30	0.23	0.45	0.34	0.54	0.62
3b*	tand VI30 VI30	chain VI30 VI30	0.25	0.35	0.55	0.53	0.66
4a	tand FI7.5 FI7.5	chain FI7.5 FI7.5	−0.03	0.00	0.00	0.01	0.02
4b	chain FI7.5 FI7.5	tand FI7.5 FI7.5	−0.02	−0.01	−0.08	0.00	−0.01
5a*	FI15	chain FI7.5 FI7.5	0.11	0.08	0.21	0.33	0.23
5b*	chain FI7.5 FI7.5	FI15	0.11	0.11	0.14	0.20	0.10
6a	FI15	chain FI7.5 FI7.5	−0.11	−0.08	−0.08	0.00	0.13
6b	chain FI7.5 FI7.5	FI15	−0.02	0.00	0.00	−0.09	0.07
7a	FI60	chain FI30 FI30	−0.25	−0.22	−0.49	−0.17	−0.17
7b	chain FI30 FI30	FI60	−0.21	−0.15	−0.24	−0.21	−0.17
8a*	FI60	chain FI30 FI30	−0.32	−0.09	0.02	−0.11	−0.04
8b*	chain FI30 FI30	FI60	−0.32	−0.17	−0.33	−0.14	−0.15
9	–	–	0.16	0.01	0.15	−0.16	−0.21
			(2a)	(1b)	(5a)	(4a)	(7a)
10	–	–	0.18	−0.17	0.03	0.70	0.46
			(5a)	(8b)	(4a)		(3a)
11	–	–	0.12	−0.15	0.14	0.01	0.09
			(6b)	(7b)		(1a)	(2b)

*Condition without a COD.

dition 4 (tandem versus chain, with a COD), although the preferences of two birds (P21 and P33) did not differ across these two conditions. The difference in mean preference, however, was not statistically significant ($p>.05$) according to the sign test (Siegel, 1956). In Condition 7, the simple/chain comparison with an IRI of 60 s and a COD produced preferences close to 1.0 for all birds. These preferences were maintained in Condition 8 with identical schedules but no COD.

From Figure 1 (Panel D) it can be seen that the amount of switching that occurred during the initial link was much higher overall when the IRI was 15 s than when it was 60 s. When the IRI was 15 s, the slight lowering of preference produced by having no COD correlated with an increase in the changeover rate. For the longer IRI, where there was little change in preference when the COD was removed, there was also little effect on the changeover rate.

The dependency indices for conditions with FI schedules in the terminal link (Table 2) differed from those obtained with VI schedules. For the short IRI, the indices were close to zero or slightly negative when a COD was present (Conditions 4 and 5) but were more positive when a COD was introduced (Condition 6). On the other hand, for the longer IRI, the indices were often highly negative indicating a repetition dependency, and the COD had very little effect on these values. This is in accord with the preference and changeover rate results.

The chained schedules in the terminal link always controlled absolute response rates that were higher during the second component than during the first component except for P21 during Conditions 4, 5, and 6, where they were higher in the first component (Table 1). Observations of P21 during these conditions revealed that in the second component, often the rim rather than the key was pecked. This topography disappeared, however, with the longer IRIs in Conditions 7 and 8. The differences in response rates between the two components were more pronounced with the FI schedules than with the VI schedules. Patterns of responding within each component of the chained schedules were typical of those produced by the component schedule alone (i.e., scalloping was observed with the longer FI schedules such as FI 60-s), and constant rates of responding occurred with the VI schedules. The response rates under the tandem VI VI schedules were steady throughout both components and resembled those maintained by the simple VI schedule. The tandem FI FI schedules also seemed to control behavior resembling that under the simple FI schedule of equal IRI.

DISCUSSION

The major findings in the present experiment were: (1) For both VI and FI schedules, a simple (unsegmented) schedule always was preferred to a chained (segmented) schedule of the same interreinforcement interval. (2) With VI schedules, the relative preferences were considerably smaller than with FI schedules, and preferences were observed only when a COD was in effect. (3) With FI schedules, much larger preferences occurred with the long (60-s) FI than the short (15-s) one, and the COD had little effect and only with the short FI. (4) For a given type of schedule and IRI, similar results were obtained whether the nonchained schedule was a tandem or a simple schedule. (5) A COD during the initial link produced decreases in the CO rate, especially with the VI and shorter FI schedules. These findings cannot be explained by the relative distributions of reinforcement produced by responding on the two keys, because throughout the experiment the reinforcement proportions remained very close to .50. The observed deviations from matching therefore can be attributed to the segmentation of one of the two schedules in the terminal link.

Condition 3 using VI schedules replicated Schneider's (1972) finding of indifference in the absence of a COD. However, a preference for the less segmented (simple or tandem) schedule was obtained when a COD was included in Condition 2. These results suggest that Schneider's finding was not due to presenting the tandem (instead of simple) or VI (instead of FI) schedules in the terminal link. This conclusion is supported by the virtually identical results obtained when a simple, rather than a tandem, schedule was used in Condition 1 and Condition 10 for P33. The exceptionally high change-over rate and the positive dependency indices found in Condition 3 and Condition 10 for P33 without a COD, compared with Conditions 1 and 2 (with a COD), apparently support the interpretation of Schneider's (1972) results on the basis of superstitious switching maintained by aperiodic terminal-link schedules.

Of course it could be argued that the preference obtained with VI schedules was an artifact produced by the COD. However, no study has provided evidence that a COD actually produces a preference when there is none, even though the addition of a COD has been known to inflate the choice proportion for a preferred component within concurrent schedules (e.g., Herrnstein, 1961; Schroeder & Holland, 1969; Shull & Pliskoff, 1967). The dependency indices shown in Table 2 also indicate that when a COD was not present there was a large amount of switching that probably disrupted the assessment of choice. Because the preferences for the nonchain VI schedules were relatively weak even with a COD (Conditions 1 and 2), they could be expected to be more vulnerable to the influence of sequential patterning—in this case, superstitious switching between keys. Hence, under such circumstances the COD becomes relatively important for maintaining the independence of the choice alternatives.

Unlike studies of concurrent schedules, a COD is rarely included in concurrent-chain procedures, although there is some evidence that it can affect choice (Davison, 1969, 1972). The present results show that whether a COD affects choice can depend on the nature of the terminal-link schedules. With the FI schedules it had relatively little effect, but with the VI schedules, where rapid switching occurred without a COD, its inclusion produced choice data consistent with those obtained with FI schedules. This observation, however, may not appropriately generalize to choices between two interval schedules of unequal IRIs. Nevertheless, the present results confirm Duncan and Fantino's (1972) observation with segmented FI schedules, and extend its generality to segmented VI schedules, that chaining an interval schedule makes it less preferred.

Comparing Panels A and B of Figure 1 reveals that segmenting a VI affects choice less than segmenting an FI. This may be due to the different temporal control of behavior exerted by the two types of interval schedules. Unlike the variable delays in a VI schedule, the fixed delay to reinforcement in an FI schedule provides clear temporal cues for reinforcement. This has clear differential effects on the patterns of responding maintained by each of these schedules and could be expected to affect choice. For instance, Herrnstein (1964b) found that pigeons preferred a VI (aperiodic) schedule to an FI (periodic) schedule. He suggested that subjects weighted the short intervals of the VI schedule more than longer intervals. In other words, in affecting choice, a VI schedule could be considered functionally equivalent to a shorter FI. Because segmenting a shorter FI has less effect on preference (Duncan & Fantino, 1972), segmenting a VI should similarly affect choice less than segmenting an FI schedule of the same IRI. With very short VI schedules, pigeons might show little or no preference for a simple schedule over a chain.

The preference for a tandem interval schedule over a chain was similar to that for an equivalent simple schedule. In addition, the cumulative records showed the patterns of responding under the simple and the tandem schedules to be largely indistinguishable. This is consistent with observations from nonchoice research that the behavior maintained under a tandem schedule is comparable to that maintained under a simple schedule (e.g., Catania, Yohalem, & Silverman, 1980; Gollub, 1958). Together these results imply that an extra response requirement imposed during an IRI does not necessarily affect choice (cf. Neuringer, 1969). However, a simple versus tandem comparison might produce results different from those obtained with the indirect comparisons performed in the present study, since choice in concurrent chains may not be transitive (Navarick & Fantino, 1972).

The findings to date have not identified precisely why a simple or a tandem interval schedule should be preferred to a chain of equal time between reinforcers. Fantino (1969a) suggested that because segmenting a schedule increased the number of stages to be traversed before the presentation of reinforcement, the "psychological distance" to reinforcement was increased—that is, segmentation functionally lengthened the IRI with a consequent adverse effect on preference for that schedule.

Among the several models of choice (e.g., Davison, 1983; Fantino, 1969b; Herrnstein, 1964a; Killeen, 1982a, 1982b; Squires & Fantino, 1971), the only one that specifically attempted to account for Duncan and Fantino's (1972) data is Killeen's "incentive theory." According to this theory, responding on each key during the initial link of concurrent chains is maintained by the incentive values produced by the overall rate of reinforcement, the delayed primary reinforcement, and the immediate conditioned reinforcer of the terminal-link stimulus on that key. The effect of each of these factors can be expressed in mathematical terms (for details see Killeen, 1982b), and the resulting equations can describe most published concurrent-chain data. To deal with chained terminal-link schedules, Killeen (1982b) further assumes that the first component does not contribute to the maintenance of responding in the initial link but only acts to delay access to the conditioned reinforcer, that is, the second-component stimulus that is correlated with food. Using this assumption, the model predicts preference for a simple over a chained schedule. By invoking the relevant equations (Equations 5, 7, and 14, Killeen, 1982b), he derived choice proportions that generally agreed with those obtained by Duncan and Fantino.

When we applied the same set of equations to the FI schedules used in the present experiment, the predicted choice proportions were .66 and 1.0 for the IRI of 15 s and 60 s, respectively. These agree well with the mean proportions obtained when there was no COD (.67 and .97, respectively) but underestimated the value for the shorter IRI (.73) when there was a COD. As Killeen (1982b) pointed out, the same set of equations can be used for VI schedules although the incentive values of the delayed primary reinforcer and the conditioned reinforcer of the terminal link must be evaluated separately for each interval of the VI and then averaged. When this was done with the present 12-interval VI schedules, the predicted choice proportion was .80 in favor of the unsegmented schedule, which is much higher than the mean values obtained in Conditions 1 and 2 (.58 and .57, respectively).

Thus, Killeen's (1982a, 1982b) theory successfully predicted choice for unsegmented FI schedules but overestimated the preference for unsegmented VI schedules. The size of this overestimation casts doubts on the adequacy of the assumption about the role of the first component of a segmented schedule in the terminal link. Nevertheless, as this model of behavior has so far proved to be comprehensive and versatile, with some revised assumptions it might more accurately predict choice between segmented and unsegmented schedules.

Little work has been done on the effects of segmentation since the Duncan and Fantino (1972) study. Their findings are clearly supported by the present results, but the exact nature and extent of the effects of segmentation await further investigation. The need for such research is suggested by seemingly contradictory data obtained from other studies of choice. For instance, in an experiment designed to investigate the preference for signaled versus unsignaled delays to reinforcement, Marcattilio and Richards (1981) presented pigeons with two VI 60-s schedules in the terminal link of concurrent chains. At the end of the schedule, the reinforcer was delayed for a short period of time. The delay was signaled by exteroceptive stimuli on one key but not on the other. It was found that pigeons preferred the signaled delay (i.e., the schedule segmented by use of two exteroceptive stimuli) over the unsignaled delay (i.e., the schedule with only one stimulus). This is inconsistent with the results of Duncan and Fantino (1972) and those of the present study, and does not seem to be readily attributable to procedural differences. It is also inconsistent with the incentive theory of choice (Killeen, 1982b), because this model would predict preference for the unsignaled delay schedule. Obviously, systematic research is required to delineate the various factors responsible for the effects on choice caused by segmenting the interreinforcement interval of a schedule.

REFERENCES

Autor, S. M. (1960). *The strength of conditioned reinforcers as a function of frequency and probability of reinforcement.* Unpublished doctoral dissertation, Harvard University.

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.

Catania, A. C. (1966). Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 213-270). New York: Appleton-Century-Crofts.

Catania, A. C., Yohalem, R., & Silverman, P. J. (1980). Contingency and stimulus change in chained schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* **33,** 213-219.

Davison, M. C. (1969). Preference for mixed-interval versus fixed-interval schedules. *Journal of the Experimental Analysis of Behavior,* **12,** 247-252.

Davison, M. C. (1972). Preference for mixed-interval versus fixed-interval schedules: Number of component intervals. *Journal of the Experimental Analysis of Behavior,* **17,** 169-176.

Davison, M. (1983). Bias and sensitivity to reinforcement in a concurrent-chain schedule. *Journal of the Experimental Analysis of Behavior,* **40,** 15-34.

Duncan, B., & Fantino, E. (1972). The psychological distance to reward. *Journal of the Experimental Analysis of Behavior,* **18,** 23-34.

Fantino, E. (1968). Effects of required rates of responding upon choice. *Journal of the Experimental Analysis of Behavior,* **11,** 15-22.

Fantino, E. (1969a). Conditioned reinforcement, choice, and the psychological distance to reward. In D. P. Hendry (Ed.), *Conditioned reinforcement* (pp. 163-191). Homewood, IL: Dorsey Press.

Fantino, E. (1969b). Choice and rate of reinforcement. *Journal of the Experimental Analysis of Behavior,* **12,** 723-730.

Fleshler, M., & Hoffman, H. S. (1962). A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior,* **5**, 529-530.

Gollub, L. R. (1958). *Conditioned reinforcement and choice.* Unpublished doctoral dissertation, Harvard University.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior,* **4**, 267-272.

Herrnstein, R. J. (1964a). Secondary reinforcement and rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior,* **7**, 27-36.

Herrnstein, R. J. (1964b). Aperiodicity as a factor in choice. *Journal of the Experimental Analysis of Behavior,* **7**, 179-182.

Killeen, P. R. (1982a). Incentive theory. In D. J. Bernstein (Ed.), *Nebraska symposium on motivation 1981: Vol. 29. Response structure and organization* (pp. 169-216). Lincoln: University of Nebraska Press.

Killeen, P. R. (1982b). Incentive theory: II. Models for choice. *Journal of the Experimental Analysis of Behavior,* **38**, 217-232.

Marcattillo, A. J. M., & Richards, R. W. (1981). Preference for signaled versus unsignaled reinforcement delay in concurrent-chain schedules. *Journal of the Experimental Analysis of Behavior,* **36**, 221-229.

Navarick, D. J. (1979). Free-operant choice behavior: A molecular analysis. *Journal of the Experimental Analysis of Behavior,* **32**, 213-232.

Navarick, D. J., & Fantino, E. (1972). Transitivity as a property of choice. *Journal of the Experimental Analysis of Behavior,* **18**, 389-401.

Neuringer, A. J. (1969). Delayed reinforcement versus reinforcement after a fixed interval. *Journal of the Experimental Analysis of Behavior,* **12**, 375-383.

Neuringer, A. J., & Schneider, B. A. (1968). Separating the effects of interreinforcement time and number of interreinforcement responses. *Journal of the Experimental Analysis of Behavior,* **11**, 661-667.

Schneider, J. W. (1972). Choice between two-component chained and tandem schedules. *Journal of the Experimental Analysis of Behavior,* **18**, 45-60.

Schroeder, S. R., & Holland, J. G. (1969). Reinforcement of eye movement with concurrent schedules. *Journal of the Experimental Analysis of Behavior,* **12**, 897-903.

Shull, R. L., & Pliskoff, S. S. (1967). Changeover delay and concurrent schedules: Some effects on relative performance measures. *Journal of the Experimental Analysis of Behavior,* **10**, 517-527.

Siegal, S. (1956). *Nonparametric statistics for the behavioral sciences.* New York: McGraw-Hill.

Squires, N., & Fantino, E. (1971). A model for choice in simple concurrent and concurrent-chains schedules. *Journal of the Experimental Analysis of Behavior,* **15**, 27-38.

Received July 3, 1984
Final acceptance April 30, 1985