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THE PSYCHOLOGICAL DISTANCE TO REWARD[1]

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Pigeons' responses in the presence of two concurrently available (initial-link) stimuli produced entry into one of two different and mutually exclusive terminal link stimuli according to identical but independent variable-interval schedules. In one experiment, a two-component chained fixed-interval schedule produced food in one terminal link while a simple fixed-interval schedule produced food in the other terminal link. When the interreinforcement intervals were equal in the two terminal links (*i.e.*, the simple fixed-interval was twice the size of each of the components in the chained schedule) pigeons preferred the simple fixed-interval as measured by their relative rates of responding in the concurrently available initial links. This preference increased as the duration of the terminal links increased. The preference could be reversed by making the simple fixed-interval schedule sufficiently longer than the chained schedule. In the second experiment, the terminal links consisted of two- *vs* three-component chained fixed-intervals, again with equal interreinforcement intervals. Pigeons preferred the two-component chain to the three-component chain, although these results were less consistent and less dramatic than those in the first experiment. Again, preference increased as the duration of the terminal links increased. The results show that an organism's choice for a schedule will be substantially lowered by the chaining operation even when the interreinforcement interval remains constant.

The present experiment assessed the effects on choice of segmenting the interreinforcement interval (*i.e.*, the time intervening between the choice and the reinforcement ultimately resulting from that choice). Fantino (1969*b*) argued that by segmenting one of two interreinforcement intervals (IRIs) into discriminably different component schedules, clear preferences should develop for the unsegmented IRI. One purpose of the present study was to evaluate this proposition.

There is already a substantial body of data from non-choice procedures indicating that this prediction should be borne out. The classic demonstration was reported by Gollub (1958), who compared behavior in chained and tandem schedules. In both tandem and chained schedules of reinforcement, responses in the initial component produce entry into the next component according to some schedule of reinforcement, *e.g.*, a fixed interval (FI). Responding in the terminal component produces primary reinforcement. These schedules differ in one crucial respect: the same exteroceptive stimulus is present throughout the tandem schedule, whereas a different exteroceptive stimulus is associated with each component of the chained schedule. Gollub found that although behavior was well maintained on an FI 5-min or on a tandem FI 1-min FI 1-min FI 1-min FI 1-min schedule, it disintegrated when the schedule was changed to a chained schedule composed of five successive FI 1-min components. At first, the pigeons performed well and reinforcements occurred at the same rate as on the tandem schedule. As stimulus control developed, the rates of responding in the early components dropped drastically until the organisms stopped responding altogether in the initial component. Similar results have been obtained in other non-choice studies by Findley (1962), Kelleher and Fry (1962), Fantino (1969*b*) and Lee and Gollub (1971).

A second purpose of the present experiments was to obtain a quantitative assessment of the effects of chain length (*i.e.*, the number

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of components in the chain) upon choice. To this end, concurrent-chained schedules of reinforcement were utilized as they have been in many recent studies of choice beginning with Autor (1960, 1969) and Herrnstein (1964). In this procedure, the organism responds on two concurrently available keys, each of which is illuminated by the stimulus associated with the initial link of one of the chains. Identical variable-interval (VI) schedules provide access to the mutually exclusive terminal links of the chain. In the present experiments, however, the "terminal link" often consisted of a two- or three-component chained schedule as shown in the lower portion of Figure 1. The distribution of responses in the initial links provides a measure of the organism's preference for the events occurring in the terminal links. This preference measure is generally expressed as a choice proportion: the rate of responding in the initial link of one key divided by the sum of the rates of responding in the initial links of both keys.

Experiment I, part A, studied the pigeon's choice for one- *vs* two-link FI chains in the terminal link when the total durations of each terminal link were equal (*e.g.*, FI 30-sec *vs* chain FI 15-sec FI 15-sec). Similarly, Experiment II examined the pigeon's choice for two- *vs* three-link FI chains when the total duration of each terminal link was equal (*e.g.*, chain FI 60-sec FI 60-sec *vs* chain FI 40-sec FI 40-sec FI 40-sec). These two experiments provide data on the sufficiency of the IRI as a determinant of choice since, according to that position, the pigeon's choice proportions should approximate 0.50, despite the additional response requirement and stimulus change associated with the longer chains. On the other hand, the non-choice data collected by Gollub and others suggest that pigeons will prefer the schedule containing fewer components. The degree by which choice proportions deviate from 0.50 (indifference) provides a quantitative assessment of the effects of the additional component.

In addition to investigating functional relationships between choice and chain length (*i.e.*, number of components) when the total durations of the two chains are equal, it should be possible to produce indifference (choice proportions = 0.50) between two schedules either by increasing the number of components, or by increasing the total duration of the preferred schedule. For example, if FI 10-sec is preferred to chain FI 5-sec FI 5-sec, how many seconds need be added to the FI 10-sec before the pigeon is indifferent to the two schedules? Experiment I, part B, employed this strategy in seeking to establish a relationship between the number of components and the duration of a schedule's IRI in determining the pigeon's choice for this schedule.

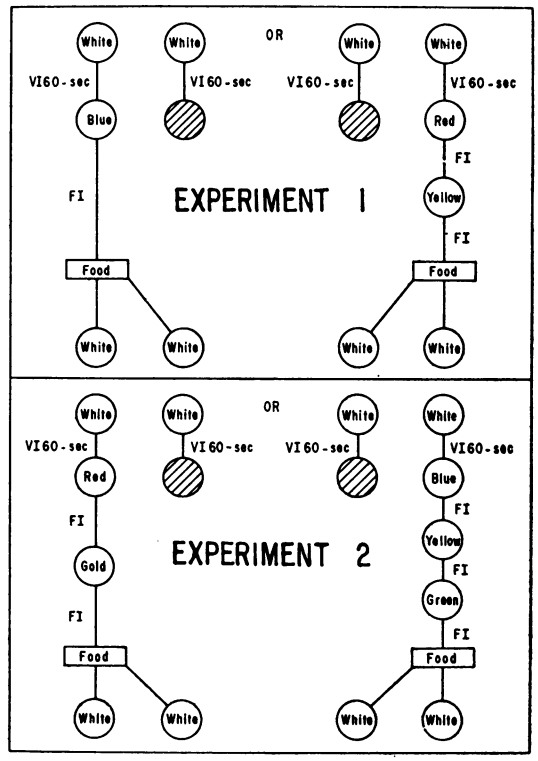

Fig. 1. Pictorial representation of the experimental procedure. The left portion of each figure indicates the sequence of events when responses on the left key were reinforced; the right portion indicates the sequence of events when responses on the right key were reinforced. The top half of the figure shows that in Experiment 1 the terminal links consisted of a simple FI schedule on one of the keys and a chain FI FI schedule on the other key. The bottom half shows that in Experiment 2 the terminal links consisted of a chain FI FI schedule on one key and a chain FI FI FI schedule on the other key.

METHOD

Subjects

Three female (N9, N10, and N11) and three male (N1, N5, and N8) White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. The females

were about six months old at the beginning of the experiment and were experimentally naive. The males were about 18 months old, and had previously been exposed to the concurrent-chains procedure, with fixed-ratio schedules in the terminal links (Duncan and Fantino, 1970).

Apparatus

The experimental chamber (Ferster and Skinner, 1957) contained two translucent response keys mounted 3 in. (7.6 cm) apart and 9 in. (27.9 cm) above the floor which could be transilluminated by white, yellow, gold, green, red, or blue lights. Each color was produced by two 28-v, 6-w light bulbs projected through color chips (One Plane Digital Display Unit, Model #10495, Industrial Electronics Engineers). A force of 10 g (0.098 N) was required to operate each response key. Each response on a lighted key produced auditory feedback by operating a 110-v ac relay. The chamber was illuminated during a session by a 6-w houselight at all times except during reinforcement, when both the house light and keylights went off, and a food magazine, centrally located between the two keys, was elevated and illuminated. Reinforcement consisted of 3.5-sec access to grain.

Procedure

Pigeons N9, N10, and N11 were magazine trained, and key pecking was conditioned with food reinforcement of successively approximate responses. N1, N5, and N8 required no further training. Three birds (N1, N8, and N11) were then exposed to the concurrent-chains procedure outlined in the upper portion of Figure 1 (Experiment I), and three birds (N5, N9, and N10) to the procedure outlined in the lower portion of Figure 1 (Experiment II). For both experiments, Figure 1 shows that in the presence of two white keylights, independent variable-interval 60-sec (VI 60-sec) schedules were associated with each key. Each time one of the schedule's interreinforcement intervals had elapsed, the next response on the appropriate key produced a colored light and the associated terminal-link schedule on that key, while the other key became dark and its associated VI schedule ceased to operate.

In Experiment I, Figure 1 shows that the terminal links consisted of a simple FI schedule on one of the keys, and a chain FI FI schedule on the other key. In Conditions 1 to 3 of Experiment I, part A, the sum of the component values of the chain schedule was equal to the FI value on the other key in each condition. In Conditions 3 to 5 of Experiment I, part B, a chain FI 5-sec FI 5-sec schedule was always associated with one key, while the value of the FI in the terminal link of the other key was varied. Table 1 presents the values of the FI and chain schedules used in each of the conditions. The schedules are presented in order of decreasing value in Part A, and in order of increasing value in Part B. Condition 3 is thus included in both Parts A and B. Except for Condition 2, the birds were exposed to each of the schedule comparisons twice, once each with the FI and chain schedules associated with different keys. The colors of the keylights that were associated with each of the chain's components were varied between the various conditions, and were different for the two replications in any given condition.

In Experiment II, the terminal links were a chain FI FI schedule on one key and a chain FI FI FI schedule on the other key. The sums of the component FIs on both keys were equal in each condition. Table 2 presents in order of increasing value the chain FI FI and the chain FI FI FI schedules for each of the conditions. Each session terminated after 60 reinforcements, or after 4 hr had elapsed in the presence of the initial links (Experiment II, condition 3). Conditions for a bird were changed when the relative rates of responding in the initial links ("choice proportions") were judged to be stable by a visual criterion, and were neither increasing nor decreasing in the final four sessions.

RESULTS

Experiment 1

All of the data in Table 1 represent median values from the last four sessions in each condition. The relative rate of responding in the initial link (choice proportion) for the FI key represents the rate of responding in the initial link on the FI key, divided by the rates of responding on both the FI and chain keys in the initial links. The observed relative rate of reinforcement on the FI key represents reinforcements per minute in the terminal link

Table 1

The values (in seconds) of the FI and chain FI FI schedules used in each of the experimental conditions in Experiment 1, parts A and B. All of the data represent median values from the last four sessions for this condition. Thus, the absolute rates of responding (responses/minute) in both the initial and terminal links on the FI and chain FI FI keys represent the median values of the last four sessions on the respective keys. Similarly, the relative rates of responding and relative rates of reinforcement on the FI key represent the median values of the last four sessions.

		Terminal-Link Schedules				Rates of Responding (Resp/Min)						Relative Reinforcement Rates
						Initial Links			Terminal Links			
										Chain		
Bird No.	Condition	Key	FI	Chain FI FI	Order and No. of Sessions	FI Key	Chain Key	Choice Prop. (FI)	FI	FI(S_1)	FI(S_2)	(FI)
N1	1	L	30	15	1 32	42.3	1.0	0.98	74.4	22.5	125.0	0.53
		R	30	15	2 56	33.0	1.8	0.96	65.6	24.4	102.1	0.53
	2	R	20	10	4 23	60.1	5.8	0.92	120.9	53.2	126.3	0.53
	3	L	10	5	3 41	51.3	22.4	0.70	161.6	79.5	120.0	0.56
		R	10	5	8 17	39.5	20.7	0.66	145.6	53.0	101.8	0.58
	4	L	15	5	6 41	20.4	38.4	0.34	100.8	85.6	141.0	0.45
		R	15	5	9 59	17.1	67.0	0.21	96.6	79.6	106.3	0.45
	5	L	20	5	5 18	3.8	77.6	0.04	92.2	93.8	74.8	0.39
		R	20	5	7 16	6.8	62.4	0.09	76.7	75.0	120.9	0.39
N8	1	L	30	15	1 33	34.9	1.3	0.97	59.4	29.3	105.0	0.54
		R	30	15	2 44	30.1	0.3	0.99	41.7	33.5	85.3	0.52
	2	R	20	10	4 32	55.9	0.3	0.99	53.0	23.4	72.0	0.54
	3	L	10	5	3 43	29.4	11.8	0.72	44.8	22.3	112.7	0.59
		R	10	5	8 29	33.8	13.9	0.71	63.3	16.8	99.7	0.59
	4	L	15	5	9 32	12.5	34.7	0.26	37.6	22.9	87.6	0.47
		R	15	5	7 18	20.6	24.2	0.46	44.6	25.2	87.7	0.48
	5	L	20	5	5 16	9.9	44.7	0.17	46.1	29.1	114.4	0.40
		R	20	5	6 44	6.4	34.4	0.15	60.6	25.3	104.4	0.41
N11	1	L	30	15	1 42	29.6	0.9	0.98	125.1	73.8	187.5	0.52
		R	30	15	2 38	31.8	1.7	0.96	105.5	71.0	176.3	0.52
	2	R	20	10	4 32	40.7	7.6	0.85	138.0	83.2	143.7	0.54
	3	L	10	5	3 30	27.1	16.6	0.63	101.6	89.4	178.2	0.56
		R	10	5	8 18	33.5	27.8	0.55	176.4	132.7	185.0	0.56
	4	L	15	5	7 36	12.5	24.7	0.33	105.2	80.8	179.7	0.47
		R	15	5	6 31	28.6	40.3	0.41	103.6	133.2	184.4	0.47
	5	L	20	5	5 20	3.3	51.8	0.06	104.6	144.3	157.8	0.38
		R	20	5	9 21	4.5	42.4	0.09	63.9	77.5	47.2	0.40

on the FI key divided by reinforcements per minute on both the FI and chain keys.

In part A, with equal overall IRIs in the terminal links, the choice proportions were always higher (> 0.50) for the key associated with the FI *vs* the chain schedule. Furthermore, these choice proportions increased as the values of the terminal links increased. This finding is presented graphically in Figure 2, which shows for each bird the choice proportions on the FI key as a function of the size of the intervals in the terminal links. Since there were two determinations for FI 10-sec and FI 30-sec, Figure 2 presents the mean of the values given in Table 1. The median relative rates of reinforcement on the FI key, averaged over birds, are represented by the "x"s above each condition. Figure 2 shows that as the size of the terminal links increased, the choice proportions for the FI key also increased, while the relative rates of reinforcement on the FI key decrease.

At the conclusion of Condition 2, a chain FI 5-sec FI 5-sec was scheduled in the terminal link on one key, and different-valued FI schedules in the terminal link on the other key. The birds were exposed to each of the three comparisons twice, once each with the chain and fixed-interval schedules associated with either key. Figure 3 shows for each bird

the mean choice proportions for the key associated with the chain FI 5-sec FI 5-sec schedule as a function of the value of the FI schedule associated with the other key. The "x"s indicate the median relative rates of reinforcement on the chain FI 5-sec FI 5-sec schedule in each condition, averaged over birds. Figure 3 shows that the birds' choice proportions for the chain FI 5-sec FI 5-sec schedule increased as the value of the FI on the other key increased. The figure shows, in addition, that the birds' choice proportions for the chain were lower than the relative rate of reinforcement on this key when an FI 10-sec was scheduled in the terminal link on the other key, but that when the FI value was increased to 15 sec and to 20 sec, the choice proportions for the chain schedule exceeded the relative rates of reinforcement provided by this schedule.

The absolute rates of responding in the terminal links are presented graphically in Figure 4. These data represent the mean of the rates presented in Table 1 for each bird in each condition. The closed squares correspond to the rates of responding on the FI schedule, and the closed and open circles correspond to the rates of responding in the first and second components, respectively, on the chain FI FI schedule. The open squares show the overall rates of responding in the terminal link on the chain schedule. The figure shows that the overall rates of responding in the terminal links were fairly constant across conditions; when there were rate changes between conditions, the rates in both terminal links tended to change in the same direction. Note that the rate of responding in the second component (S_2) of the two-component chain was dramatically higher than the rate in the first component (S_1), at least in part A. The smallest increase was about 70% for Pigeon N-1 in chain FI 5 FI 5 (condition 3); the largest increases were about 500% for Pigeon N-1 in chain FI 15 FI 15 (condition 1) and for Pigeon N-8 in chain FI 5 FI 5 (condition 3). Figure 4 also shows that responding was well maintained in the first component of the terminal links, however, so that the chaining operation had little effect upon the actual interreinforcement intervals.

For two of the pigeons, N-1 and N-11, the difference between the response rates in the first and second components decreased sharply in condition 5 (part B). This was presumably an instance of behavioral contrast (Catania, 1963; Reynolds, 1961) since the schedule in the other terminal link had been increased to

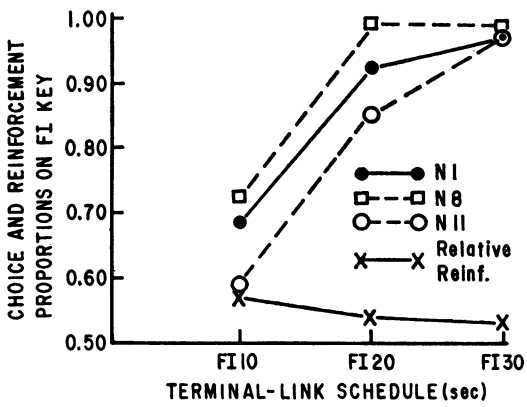

Fig. 2. The mean choice proportions for each bird in Experiment 1, part A, on the FI key as a function of the size of the intervals in the terminal links. The "x"s indicate the relative rate of reinforcement on the FI key.

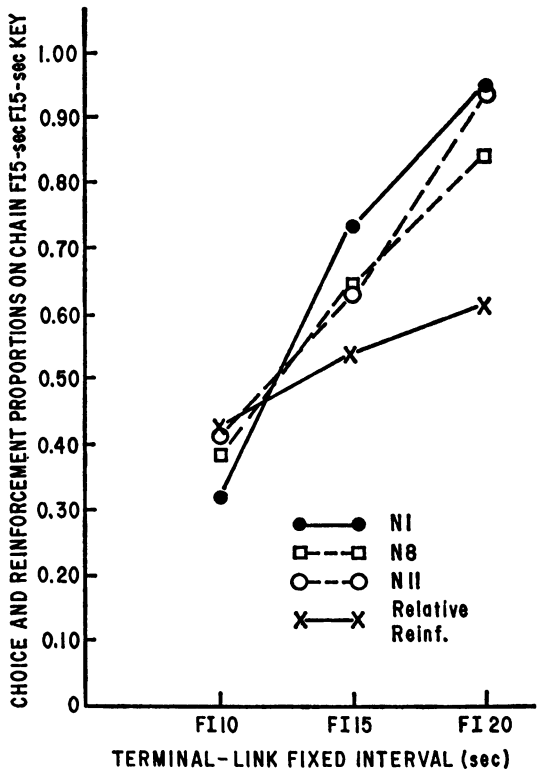

Fig. 3. The mean choice proportions for each bird in Experiment 1, part B on the chain FI 5-sec FI 5-sec key as a function of the size of the fixed-interval associated with the other key. The "x"s indicated the relative rate of reinforcement on the chain key.

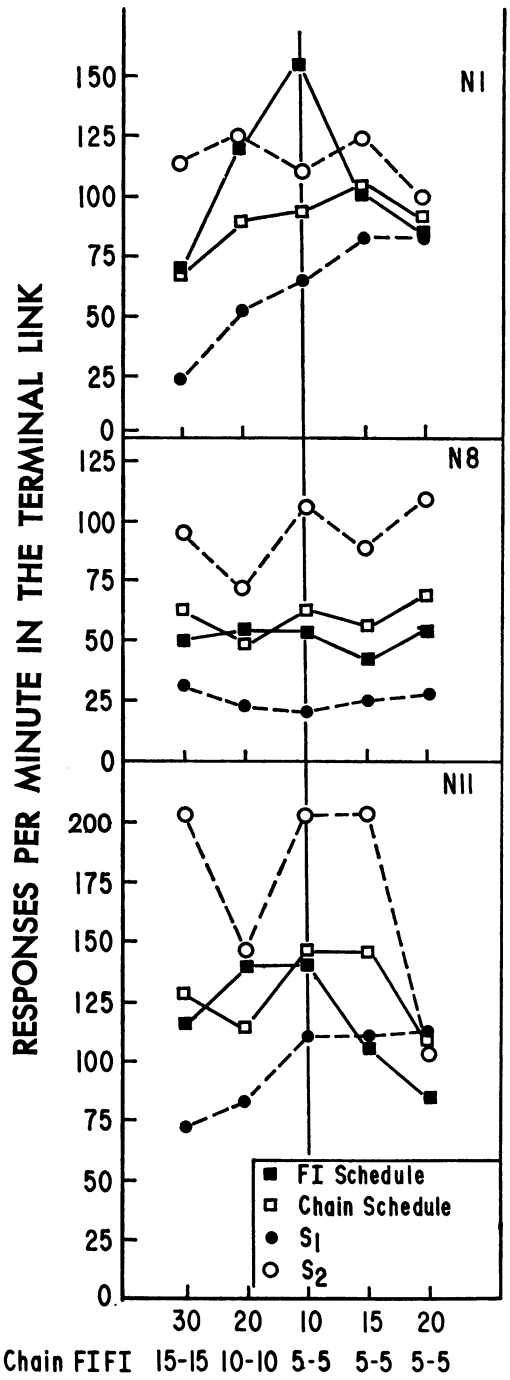

Fig. 4. Responses per minute in the terminal links for each bird in Experiment 1. The closed squares show the rates of responding on the FI schedule. Closed and open circles correspond to the rates of responding in the first and second components, respectively, on the chain FI FI schedule. The open squares show the overall rates of responding on the chain schedule.

FI 20-sec. In both replications of condition 5, the one pigeon (N-8) that continued to show large differences in response rates across the two components of the chain FI 5 FI 5 (see Figure 4) also showed less preference than did N-1 and N-11 for the chained schedule (see Figure 3).

Experiment 2

Table 2 shows the absolute rates of responding (responses per minute) in both the initial links and in each component of the terminal links on the chain FI FI and the chain FI FI FI keys for each condition. The table also indicates the relative rate of responding (choice proportion) and the relative rate of reinforcement on the chain FI FI key.

Table 2 shows that there was sometimes considerable variability between the choice proportions for the chain FI FI schedule in each condition when the keys associated with the two- and three-component chains were reversed. Because of apparent key biases, the birds' choice proportions in each condition were also evaluated in terms of a particular key (the left). For example, N-10's choice proportions on the left key in condition 2 were 0.52, 0.55, and 0.90. The first two choice proportions were for the chain FI 10-sec FI 10-sec FI 10-sec schedule and the 0.90 was for the chain FI 15-sec FI 15-sec schedule. Similar comparisons performed in each condition for each bird showed that, as in this example, choice proportions were usually higher when the chain FI FI was scheduled in the left key's terminal link than when the chain FI FI FI was scheduled in the left key's terminal link. This was true for N-10 in all conditions, and for N-5 and N-9 in conditions 1 and 3. The results for these birds were equivocal in condition 2.

Figure 5 presents the choice proportions for the chain FI FI key for each bird in each condition. Each value represents the mean of those shown in Table 2 for this bird in this condition. Figure 5 shows that in eight of the nine cases, the average choice proportions were higher (*i.e.*, > 0.50) for the two- *vs* the three-component terminal link. These results also suggest that the choice proportions for the two-component schedule tend to increase as the duration of the terminal links increases. For two of the three birds, the choice proportions in condition 2 were greater than those

Table 2

The values (in seconds) of the chain FI FI and chain FI FI FI schedules used in each of the experimental conditions in Experiment 2. All of the data represent median values from the last four sessions for this condition. Thus, the absolute rates of responding (responses/minute) in both the initial and terminal links on the chain FI FI and chain FI FI FI keys represent the median values of the last four sessions on the respective keys. Similarly, the relative rates of responding and relative rates of reinforcement on the chain FI FI key represent the median values of the last four sessions.

						Rates of Responding (Resp/Min)								
						Initial Links								
			Terminal-Link Schedules					*Choice*	*Terminal Links*					*Relative*
Bird			*Chain*	*Chain*	*Order &*	*Chain*	*Chain*	*Prop.*	*Chain*		*Chain*			*Reinforcement*
No.	*Condition*	*Key*	*FI FI*	*FI FI FI*	*No. of Sessions*	*FI FI*	*FI FI FI*	*Chain FI FI*	*FI*	*FI*	*FI*	*FI*	*FI*	*Rate (Chain FI FI)*
N5	1	L	6	4	4 17	22.4	16.0	0.59	69.8	154.8	17.9	86.0	109.8	0.54
		R	6	4	5 20	19.1	20.6	0.47	18.1	83.4	18.1	115.1	61.5	0.54
	2	L	15	10	2 79	9.2	19.4	0.33	15.3	119.7	24.7	60.0	101.8	0.51
		R	15	10	1 87	9.7	1.5	0.85	15.5	81.7	6.0	54.5	132.1	0.55
		R	15	10	3 27	5.9	4.7	0.55	14.0	121.7	6.7	55.4	120.0	0.56
	3	L	60	40	6 30	2.3	1.7	0.63	18.2	61.3	6.7	19.4	53.6	0.50
		R	60	40	7 37	0.14	0.3	0.97	15.7	57.1	3.2	26.8	55.2	0.55
N9	1	L	6	4	6 17	20.4	28.0	0.43	23.5	71.7	26.3	74.5	102.0	0.53
		R	6	4	7 15	26.5	17.3	0.63	31.3	83.6	20.2	83.8	42.6	0.57
	2	L	15	10	2 39	15.0	12.7	0.55	12.2	81.6	7.0	28.2	94.4	0.55
		R	15	10	1 110	10.3	15.5	0.39	12.4	89.8	19.4	64.2	132.8	0.52
		R	15	10	3 36	19.7	16.4	0.54	25.7	57.7	10.5	48.6	92.7	0.53
	3	L	60	40	4 61	0.2	0.04	0.88	21.4	29.0	4.3	33.3	26.8	0.45
		R	60	40	5 18	0.8	0.1	0.91	23.5	55.8	3.7	43.8	53.8	0.54
N10	1	L	6	4	6 40	27.2	34.4	0.45	25.9	135.0	14.9	144.0	150.2	0.55
		R	6	4	5 40	43.7	25.7	0.63	49.9	172.1	37.7	134.0	130.5	0.52
	2	L	15	10	2 26	58.6	6.4	0.90	35.1	90.0	6.5	84.8	72.7	0.54
		R	15	10	1 110	36.4	39.8	0.48	13.8	52.6	14.0	60.1	48.5	0.52
		R	15	10	3 66	10.7	11.4	0.45	11.6	61.6	8.4	22.5	100.3	0.55
	3	L	60	40	4 22	4.9	0.1	0.98	15.2	52.1	6.8	45.5	44.0	0.53
		R	60	40	7 21	0.2	0.9	0.16	38.7	73.8	6.9	37.2	57.1	0.57

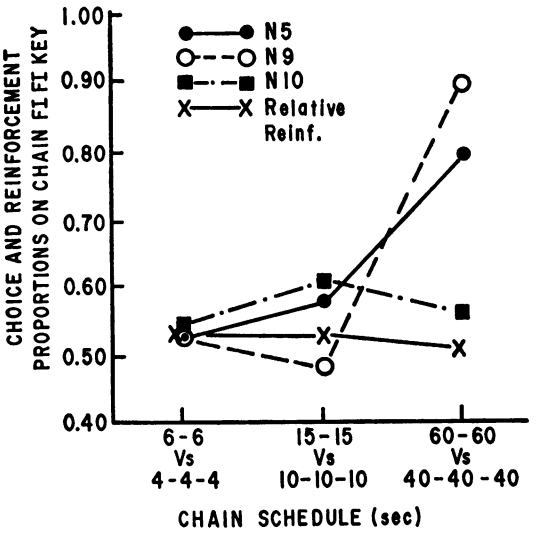

Fig. 5. The mean choice proportions for each bird in Experiment 2 on the chain FI FI key as a function of the overall size of the intervals in the terminal links. The "x"s indicate the relative rate of reinforcement on the chain FI FI key.

in condition 1, and for two of the three birds, the choice proportions in condition 3 were greater than those in condition 2. For all of the birds, the choice proportions in condition 3 were greater than those in condition 1. Thus, these results, though less impressive due to variability, are consistent with those in Experiment I, part A, in two respects: the choice proportions on a key are greater for a terminal-link schedule composed of fewer components; and these choice proportions tend to increase as the values of the terminal-link schedules increase.

Figure 6 shows for each bird the absolute rates of responding (responses per minute) in the terminal links in each condition on the keys associated with the chain FI FI (closed circles) and the chain FI FI FI (open circles) terminal-link schedules. These data represent the means of the values presented in the appropriate columns of Table 2 for each bird in each condition. The rates of responding in the successive components of the terminal-link schedules are indicated above S_1, S_2, and S_3 (where S_3 is the component terminating in reinforcement in the three-component chain and S_2 in the two-component chain). The overall rates of responding in each of the terminal-links are indicated by the unconnected points above S_1 in each condition. As

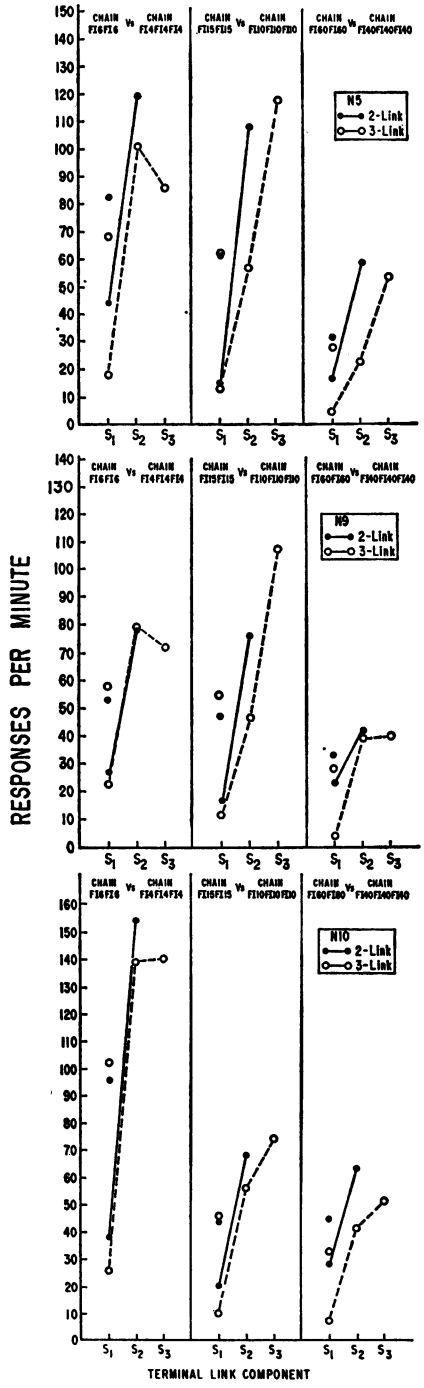

Fig. 6. Responses per minute in the successive components of the terminal-link schedules for each bird in Experiment 2. S_3 is the component terminating in reinforcement in the chain FI FI FI schedule (open circles); S_2 is the component terminating in reinforcement in the chain FI FI schedule (closed circles). The overall rates of responding in each terminal link are indicated by the unconnected points above S_1 in each condition.

in Experiment I, the response rates increased dramatically across the two component terminal-link chain. Indeed, this increase tended to be comparable to the increase across the entire three-component chain of the other terminal link. It is argued below that these comparisons may account for the smaller effects upon choice in Experiment II relative to those obtained in Experiment I.

Figure 6 shows that the overall rates of responding in the terminal links decreased as the size of the terminal links increased. Table 2 shows that the rates of responding in the initial links were also drastically reduced. In fact, in condition 3, where the terminal-link schedules totalled 120 sec, responding in the initial links sometimes ceased entirely, and sessions were terminated when a bird had spent more than 4 hr in the initial links. Figure 7 shows a representative cumulative record of condition 3, from the final session in this condition for N-5. The chain FI 60-sec FI 60-sec and chain FI 40-sec FI 40-sec FI 40-sec schedules are represented in the upper and lower records, respectively. Each pip marks the occurrence of a successive component in the chain, and the final pip, designated "S^R", indicates reinforcement. Only the first and final hour from this session are included. Figure 7 shows that the length of the pauses in the initial links on both keys tended to increase for this bird as the session progressed, but that longer pauses occurred sooner on the key associated with the three-component chain.

DISCUSSION

According to several recent formulations of choice behavior in the concurrent chains procedure (Neuringer, 1969; Rachlin and Herrn-

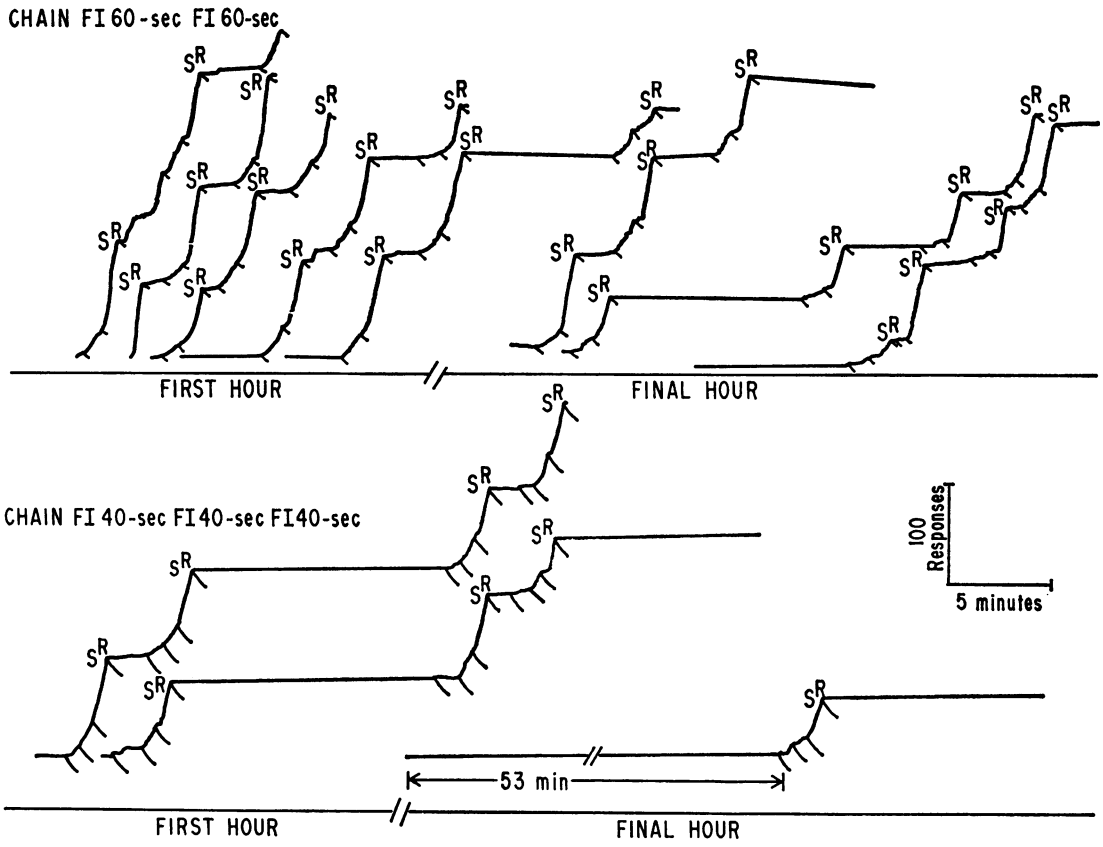

Fig. 7. Cumulative records of the first and last hours of the final session of condition 3 for N5. The upper record represents responses on the key associated with the chain FI 60-sec FI 60-sec terminal-link schedule. The lower record represents responses on the key associated with the chain FI 40-sec FI 40-sec FI 40-sec schedule. Each pip marks the occurrence of a successive component in the chain. Pips designated "S^R" indicate food reinforcement.

stein, 1969; Schneider, 1970), organisms should be indifferent to two terminal links whose overall durations (interreinforcement intervals) are equal. In other words, the organisms' choice proportions in the equal initial links should equal 0.50. On the other hand, Fantino (1969*b*) suggested that if two schedules of equal duration are segmented differently, the organism should prefer the one composed of fewer discriminable components. The present results clearly demonstrate that considerations of the value of the IRI alone do not permit an adequate characterization of choice. This basic finding is illustrated in Figures 2 and 5 for Experiment I, part A, and Experiment II, respectively. These figures show that the pigeons' choice proportions did not approximate 0.50, even though the IRIs in the terminal links in these experiments were relatively equal (*i.e.*, the "x"s are close to 0.50) in each condition. This deviation from indifference produced by the chaining operation is consistent with both Gollub's (1958) single-key results, and with Fantino's (1969*b*) prediction that segmenting a schedule's IRI should have a profound effect upon the organism's choice for this schedule. It is possible, of course, that deviations between choice proportions and matching are due to either or both aspects of chaining: the stimulus change and the additional response requirement. These aspects should be isolated in future research by comparing tandem and single-component schedules of equal duration (to evaluate the effects of the response requirement) and by comparing tandem and chained schedules composed of equal components (to evaluate the effects of the stimulus change).

Figures 2 and 5 also show that the choice proportions for the schedule composed of fewer components tended to increase as the duration of these schedules increased. The median choice proportions for the FI 10-sec, FI 20-sec, and FI 30-sec schedules for all birds were 0.60, 0.92, and 0.97 in conditions 1 to 3, respectively. A similar, though less-impressive effect is shown in Figure 5 for Experiment II. For terminal link durations of 10 sec, 30 sec, and 120 sec, the median choice proportions for the two- *vs* three-component chains for all birds were 0.53, 0.54, and 0.90, respectively. These results are similar to those of Duncan and Fantino (1970) with fixed schedules. They found that when a constant difference separated the two schedules, choice proportions for the smaller of the two schedules increased as the schedules' IRIs increased, even though the relative rates of reinforcement were approaching 0.50. Both of these studies qualify the generality of extant choice models for concurrent-chains schedules by demonstrating schedule-produced deviations from matching: choice proportions in the initial links tend to exceed the relative rates of reinforcement scheduled in the terminal links, both when these schedules are of fixed duration (Duncan and Fantino, 1970; Killeen, 1970) and when the schedules are segmented into different numbers of discriminable components. In addition, both experiments demonstrate that deviations from matching (*i.e.*, the difference between choice and reinforcement proportions) increase as the durations of the schedules' IRIs increase.

The results shown in Figures 2 and 5 are consistent with the findings from non-choice studies that have typically demonstrated that responding on chained schedules becomes progressively weaker as the number of links in the chain is increased. While both the duration and the number of components in a schedule are important, there has not been any quantitative assessment of the independent contributions of each of these variables. The most extensive treatment of the conditions that establish the stimuli in a chain as conditioned reinforcers is Gollub's (1958) finding that the largest number of FI components that could maintain responding on a chain depended upon the duration of the intervals. In other words, the strength of a conditioned reinforcer is apparently determined by an exchange between the IRI and the number of components within it. The purpose of Experiment I, part B, was to examine the relationship between the number of components in a schedule and its overall duration in determining the organism's choice for this schedule, by increasing the value of a single- *vs* a two-component chain schedule.

Figure 3 shows that the choice proportions for the chain FI 5-sec FI 5-sec schedule never matched the relative rates of reinforcement provided by this schedule. In addition, these results suggest that the detrimental effects of segmenting the 10-sec IRI into two 5-sec components are rapidly offset by the relatively higher rate of reinforcement which this schedule provides.

The detrimental effects of chaining upon choice were both less consistent and less dramatic when two-component chains were compared with three-component chains. This smaller effect is instructive and may depend upon two interrelated factors:

(1) Two-component and three-component chains are similar in that the first component of each is reliably distant from food. Numerous studies have shown that a stimulus that is even occasionally associated with food is a powerful conditioned reinforcer (*e.g.,* Kelleher and Fry, 1962; Kelleher, 1966; deLorge, 1967; Byrd and Marr, 1969). Thus, in addition to having one fewer component than the chain FI FI schedule, the FI is also directly associated with food, which probably enhances its strength as a conditioned reinforcer. Presumably, if VI schedules had been used instead of FI schedules, the chaining operation would have produced a smaller choice decrement, since with chained VIs the first component would occasionally be in close temporal association with primary reinforcement. Indeed, Gollub (1958) found that behavior was well maintained in five-component VIs in his single-key experiment.

(2) There was markedly less difference between stimulus control produced by the terminal-link chain on one key and the terminal-link chain on the other key. The difference in response rates within the two-component chain was only slightly less than the difference in response rates within the three-component chain. For example, whereas the differences in the absolute rates of responding across the two components of chain FI FI were dramatic in Experiment I, part A (ranging from 70 to 500%), they were only slightly more dramatic when the third component was added in Experiment II. Another reflection of stimulus control is the response rate during the first component (S_1) of each terminal-link chain. Where the difference in these response rates is large between the two keys (as in the one- *vs* two-component comparison) the terminal link with the higher response rate is strongly preferred. Where these differences are relatively small (as in the two- *vs* three-component comparison) the effects upon choice should be correspondingly small.

Schneider's (1970) results support these interpretations. He found essentially no difference between choice for chain and tandem schedules composed of VI components (our first point), and only minor differences in stimulus control across the components of the chain (our second point). Unfortunately, neither Schneider's nor the present study directly compared chained FIs with equivalent tandem FIs. It may be that the three sets of results—those from Experiment I, part A, and from Experiment II and Schneider's—fall on a continuum from large differences between stimulus control in the terminal links at one extreme (Experiment I, part A) to trivial differences between stimulus control in the terminal links at the other extreme (Schneider's). The choice data fit in nicely with this analysis: large and consistent detrimental effects of chaining upon choice in Experiment 1, part A, smaller and less-consistent effects in Experiment 2, and no apparent effect in Schneider's experiment.

A more definitive assessment of the stimulus control analysis, however, must await results from tandem schedule comparisons. For example, the additional response requirement in the chain schedule might also be sufficient to account for the simple FI preference, a prediction also consistent with Schneider's results. While Fantino (1968) found that the addition of a response requirement weakens preference for interval schedules, choice proportions in his experiment were less extreme than in the present experiment. It should be stressed that whether the present results are due to stimulus or response aspects of the chaining procedure (or both), they argue against the sufficiency of the size of the IRI in determining choice. In this respect, they are consistent with findings from several studies (*e.g.,* Fantino, 1968, 1969*a;* Duncan and Fantino, 1970; Squires and Fantino, 1971).

In summary, the present results show that the pigeons' choice proportions were always higher (> 0.50) for an unsegmented interval *vs.* a two-component chain of equal duration, and were generally higher for a two- *vs* a three-component chain of equal duration. Furthermore, in both cases the choice proportions for the schedule with fewer components tended to increase as the schedules' durations increased. These results also suggest that choice for a segmented schedule can be characterized by an exchange between the duration and the number of components that separate the schedule from the primary reinforcer. All of the present results demonstrate that a con-

sideration of a schedule's IRI alone will not permit an accurate characterization of choice when these IRIs are segmented into discriminable schedule components.

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