JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1972, 18, 45-60 NUMBER 1 (JULY)

CHOICE BETWEEN TWO-COMPONENT CHAINED AND TANDEM SCHEDULES[1]

J. W. SCHNEIDER

MCMASTER UNIVERSITY

Pigeons were trained on a two-key choice procedure in which a pair of equal and concurrently available variable-interval schedules (initial links) arranged entry into one or the other of two mutually exclusive schedules (terminal links) that ended in primary reinforcement. The terminal links were two-component chained or tandem schedules. Responses during the initial links were distributed equally on the two keys whenever the terminal links were associated with the same sets of interreinforcement intervals. Whether or not the terminal-link interreinforcement intervals were the same on the two keys, initial-link responding was affected by neither the presence nor relative durations of differentially signalled components within a terminal-link schedule. The simplest interpretation of these results is that initial-link responding is maintained directly by delayed primary reinforcement, rather than conditioned reinforcement afforded by the stimuli correlated with the terminal-link schedule components. This finding suggests that aspects of chained schedule performance usually attributed to conditioned reinforcement might best be reinterpreted in terms of delayed primary reinforcement and various discriminative functions served by the component-correlated stimuli.

Many recent studies on the distribution of responses across alternatives have used concurrent and concurrent-chained schedules of reinforcement. Under concurrent schedules, reinforcement is available by each of two or more independent schedules that are simultaneously present for the animal to distribute its responses among. The concurrent-chains technique differs in that the outcome scheduled for each of the concurrent schedules consists not of primary reinforcement, but of some subsequent schedule (and its associated stimulus) according to which primary reinforcement is delivered. The procedure therefore involves two or more chained schedules whose initial links are scheduled concurrently and whose terminal links are mutually exclusive. Most studies have used a pair of equal variable-interval (VI) schedules on different keys during the initial links and have investigated the effects of differing terminal-link parameters on relative choice, measured as the proportion (or relative rate) of responses made to a key during the initial links.

A wide variety of terminal-link schedules has been used in attempts to isolate and systematically vary those factors that govern relative choice in concurrent chains. Among the conclusions that may be drawn from such studies are that the interreinforcement intervals associated with the terminal links exert strong control over relative choice, while such factors as terminal-link response rates or responses per reinforcement have little or no effect on relative choice (Herrnstein, 1964*a*, *b*; Killeen, 1968*a*, *b*, 1971; Neuringer, 1969). Although the importance of terminal-link interreinforcement intervals in determining choice is widely accepted, there is as yet no general agreement on how these intervals should be transformed to predict relative choice quantitatively. Early studies (*e.g.*, Autor, 1960; Herrnstein, 1964*a*) reported that relative choice equalled terminal-link relative rate of reinforcement, but this attractively simple relation has since been shown not to be generally true for concurrent chains (*e.g.*, Duncan and Fantino, 1970; Herrnstein, 1964*b*; Killeen, 1968*a*, 1970). The search for a transformation of general applicability remains a matter of current research interest.

[1]This research was supported by grant #33-586-63-13 from the National Institute of Mental Health to Harvard University and was conducted while the author held a National Science Foundation predoctoral fellowship. The article is based on a doctoral dissertation submitted to the Department of Psychology, Harvard University. The author wishes to thank Mrs. Antoinette Papp for her invaluable assistance in the conduct of the experiments. Reprints may be obtained from the author, Department of Psychology, McMaster University, Hamilton, Ontario, Canada.

Aside from the question of how the terminal-link intervals to reinforcement should be properly transformed to predict choice, it has not yet been demonstrated whether they affect choice directly or whether their effect on choice is mediated by the influence they may have on the relative strengths of the terminal-link stimuli as conditioned reinforcers for initial-link responding. Nearly all presently published concurrent-chains studies have arranged single-component schedules, such as variable-interval (VI) or variable-ratio (VR) schedules during the terminal links. In such cases, a single exteroceptive stimulus intervenes between the initial-link state on a key and the occurrence of primary reinforcement. Under these circumstances, one cannot say whether initial-link responding on a key should be ascribed to the action of delayed primary reinforcement or to the conditioned reinforcing properties of the intervening stimulus.

The present experiments investigated this question by studying choice between terminal-link schedules in which the conditioned reinforcing values of the stimuli might be expected to depend importantly on manipulable factors other than the intervals to primary reinforcement spanned by those stimuli. During each of four experiments, the terminal link on one or both keys consisted of a two-component chained or tandem schedule. In chained (*chain*) schedules, each component is correlated with a distinct exteroceptive stimulus. In tandem (*tand*) schedules, the same stimulus is present throughout all components. Comparisons of performance under equal-valued chained and tandem schedules have led to the conclusion that the chaining operation affects the conditioned reinforcing strengths of the component-correlated stimuli (Kelleher and Gollub, 1962).

If initial-link responding in concurrent-chains schedules is maintained directly by delayed primary reinforcement, the presence of chained components within a terminal-link schedule should have no effect on choice except insofar as their presence affects the obtained intervals to reinforcement. On the other hand, if initial-link responding is maintained in whole or in part by conditioned reinforcement, effects on relative choice attributable directly to the chaining of components within a terminal-link schedule might be expected. These effects, moreover, might suggest specific functions governing the reinforcing strengths of the component-correlated stimuli in chained schedules.

GENERAL METHOD

Subjects

A total of 12 adult, male, White Carneaux pigeons maintained at 80 to 85% of their free-feeding weights served in the four experiments. All had experimental histories on various procedures usually including concurrent or concurrent-chains schedules. Daily experimental sessions were conducted six or seven times per week except for infrequent cases of apparatus failure or excessive weight gain.

Apparatus

The two experimental chambers used in the following experiments, while differing in details of size and construction, are typical of operant conditioning chambers for pigeons as described by Ferster and Skinner (1957). One chamber was used in Experiments 1 to 3; the other chamber was used in Experiment 4. A panel at the front of each chamber contained two translucent plastic response keys separated by 3.75 or 5 in. (9 or 12 cm) and operated by pecks of at least 10g (0.098N) force. The keys could be transilluminated by various pairs of white or colored 7-w bulbs. A relay mounted behind the front panel provided an audible click for each effective peck. The reinforcer was delivered by elevating and illuminating a hopper of mixed grain. Access to the elevated hopper was provided by an opening in the front panel located below and midway between the two response keys. Several 7-w bulbs were mounted in the upper rear portions of the chambers and served as houselights to illuminate the chambers at various times with any of several colors or white light. White noise was continuously present within the chambers to mask external sounds. Scheduling and recording equipment was located in an adjoining room.

Procedure

The concurrent-chains procedure common to Experiment 1 to 4 is shown in general schematic form in Figure 1. During the initial links both keys were white, and variable-interval (VI) 1-min schedules were independently associated with each key. Each initial-link schedule consisted of 12 intervals selected ac-

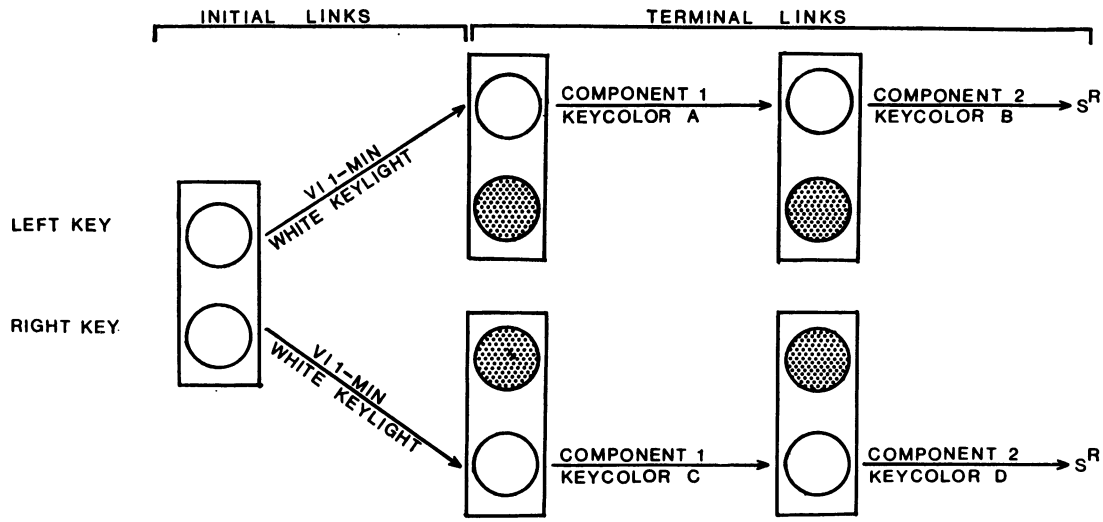

Fig. 1. Schematic diagram of the concurrent-chains procedure used in Experiments 1 to 4. Each box represents one of five possible states. During the terminal-link schedule on either key the other key was darkened and inoperative. The initial-link schedules were reinstated immediately after each reinforcement (S^R). Terminal-link schedules and key colors were varied in the four experiments.

cording to a progression (Fleshler and Hoffman, 1962) that generates VI schedules in which the probability of reinforcement is approximately constant with respect to the time elapsed since the last reinforcement (or other scheduled outcome).

The first initial-link response to occur on a key after its interval elapsed initiated the terminal link on that key and darkened the other key. The schedules and stimuli in effect during the terminal links differed from one series of conditions to the next and are described below in the context of each experiment separately. In each case, however, the concurrent-chains schedule reverted to the initial-link state immediately after each primary reinforcement.

Except where noted below, a white houselight provided general chamber illumination at all times, except during reinforcement. Reinforcement consisted of 3-sec access to mixed grain, and experimental sessions ended when 48 reinforcements occurred.

EXPERIMENT 1

During this series of conditions, initial-link responding gained entry into a *chain* VI VI schedule on one key and a *tand* VI VI schedule on the other key. The question posed by the present experiment was whether choice between the two schedules would be affected by the presence of component-correlated stimuli within one, but not the other, of those schedules.

Since the transition between components in a tandem schedule is unsignalled, a *tand* VIx VIy schedule is similar to a single-component VI(x + y) schedule, and either might have served the purpose of the present experiment. The slight advantage of using a *tand* VI VI instead of a simple VI schedule during one terminal link is that the response requirements of the *tand* VI VI may be made identical to those of the *chain* VI VI on the other key. When corresponding chained and tandem schedules are used, possible effects on choice due to the differential signalling of components within the chained schedule cannot be attributed instead to differences in the terminal-link response-reinforcement contingencies.

METHOD

Subjects

Of the 12 pigeons described earlier, four (254, 452, 255, and 325) were used.

Procedure

The concurrent-chains procedure of Figure 1 was employed. Aspects of this procedure common to Experiments 1 to 4 have been described above. In the present series, the terminal link on one key (except where noted below) consisted of a *chain* VI VI with red and green keylights correlated with the respective com-

ponents. On the other key, the terminal link was a *tand* VI VI with blue keylight during both components.

Each VI component consisted of 12 intervals occurring in a fixed irregular sequence. Intervals were selected according to the equal-probability progression described by Fleshler and Hoffman (1962). The intervals associated with the first and second components of each terminal-link schedule were ordered with respect to each other so that the overall intervals to reinforcement during the terminal link also conformed to a Fleshler and Hoffman equal probability progression. Thus, for example, a chained or tandem VIx VIy scheduled interreinforcement intervals identical to those of a VI(x + y) schedule constructed according to the Fleshler and Hoffman progression. This was accomplished by having the transitions between components within the chained or tandem schedules bisect the overall interreinforcement intervals arranged by those schedules.

Subjects were trained in the same order on six conditions. Each was continued until relative choice was judged clearly stable in all birds. The terminal-link schedules and number of sessions associated with each condition are shown in Table 1.

Conditions 1 to 4 scheduled identical sets of interreinforcement intervals for the terminal links on the two keys. A baseline value of relative choice was determined in Condition 1 by scheduling identical tandem schedules during both terminal links. Key colors during the tandem schedules were green (left key) and blue (right key). Conditions 2 to 4 employed *tand* VI x-sec VI (60-x)-sec schedules where the value of x was either 15, 30, or 45 sec. Condition 5 studied choice between a chained and a tandem schedule whose intervals to reinforcement stood in a two-to-one ratio. Condition 6 maintained this two-to-one ratio of interreinforcement intervals but scheduled tandem schedules on both keys. Terminal-link keylights during Condition 6 were red (left key) and blue (right key).

Results and Discussion

Mean relative choice in each condition is shown in Table 1. Relative choice was calculated as the responses to the left key (L) during the initial links divided by the total number of initial-link responses. Values shown are averages across subjects from the last five sessions of each condition. Table 1 also shows the obtained mean relative rates of reinforcement associated with the terminal-link schedules on the left key. Values of this measure for individual subjects are not shown because they were in all cases close to the mean values. Absolute rates of responding to each key during the initial links and during each component of the terminal links are also provided in Table 1.

When identical *tand* VI VI schedules were associated with each key in the first condition, choice was approximately equal on the two keys, although a slight bias in favor of the left key is evident from the discrepancy between relative choice and obtained relative rate of reinforcement during the terminal links (see Table 1). For Condition 2, the left-key schedule was changed from *tand* VI 30-sec VI 30-sec to *chain* VI 30-sec VI 30-sec; in other respects this condition was identical to the initial baseline condition. This introduction of differentially signalled components on the left key was accompanied by a slight increase in preference for that key. Though disproven by subsequent conditions, the magnitude of this increase (0.52 to 0.56) raised the possibility at this point that chained schedules might be preferred over equal-valued tandem schedules.

The magnitude of an effect on choice due to differentially signalled components might be expected to depend on the relative durations of those components. To explore this possibility, the schedule on the left key was changed to *chain* VI 45-sec VI 15-sec (Condition 3a) while an equal-valued tandem schedule was maintained on the other key. This change failed to affect initial-link responding; as in Condition 2, relative choice on the left key was 0.56. To assess the extent to which this preference might be attributable to a position bias rather than to the chaining of terminal-link components on the left key, the chained and tandem schedules (and their stimuli) of Condition 3a were reversed with respect to keys in Condition 3b. This reversal did not produce a corresponding reversal in preference: relative choice on the left key was about the same as in the earlier conditions. This result strongly suggests that the deviation from indifference in Conditions 2, 3a, and 3b was due to an unexplained position bias favoring the left key (as noted in lesser degree for Condition 1), not to differences in the terminal-link schedules on the two keys. Relative choice in Condition 4

Table 1

The conditions and data of Experiment 1 are summarized in this table. The data for each condition represent averages over the final five sessions. For each condition the upper row of values pertains to the left key (L), and the lower row to the right key (R). Schedule values are in seconds. Relative choice and terminal-link relative rates of reinforcement are provided for the left key and are averages across subjects. Individual response rates during the initial links are shown, as well as individual and mean response rates during the terminal-link components. For terminal-link response rates, the column headings S2 and S1 refer respectively to the first and second (final) components within the terminal-link schedule. All response rates are given as responses per minute.

Condition	*Key*	*Terminal-link schedules*	*Mean relative choice*	*Initial-link response rates*				*Terminal-link response rates*										*Terminal-link relative rate of reinforcement*	*Sessions*
								#254		*#452*		*#255*		*#325*		*mean*			
				#254	*#452*	*#255*	*#325*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*		
1	L	tand VI 30 VI 30	0.52	23.9	36.1	35.9	28.8	52.4	51.7	65.7	69.2	89.9	97.4	84.3	88.8	73.1	76.8	0.49	35
	R	tand VI 30 VI 30		23.7	26.2	35.2	31.5	54.5	56.1	68.4	71.1	88.7	92.5	86.5	84.0	74.5	75.9		
2	L	chain VI 30 VI 30	0.56	26.1	35.9	43.9	29.4	48.1	53.6	60.5	68.6	87.4	89.9	82.2	89.1	69.6	75.3	0.50	38
	R	tand VI 30 VI 30		19.6	28.0	30.2	26.2	55.6	56.7	64.9	64.5	91.2	91.0	95.2	99.3	76.7	77.9		
3a	L	chain VI 45 VI 15	0.56	26.5	38.7	43.0	37.1	50.9	66.3	58.7	76.5	84.7	108.3	86.7	113.0	70.2	91.1	0.50	25
	R	tand VI 45 VI 15		22.8	27.8	27.4	32.7	54.1	55.9	60.9	58.4	86.5	86.4	77.7	80.9	69.8	70.4		
3b	L	tand VI 45 VI 15	0.54	26.3	39.3	40.6	30.2	53.6	51.8	61.4	60.1	81.2	78.9	76.3	77.1	68.1	67.0	0.50	25
	R	chain VI 45 VI 15		25.5	26.0	33.1	27.0	43.0	67.1	60.0	62.8	76.4	98.1	77.6	99.8	64.3	82.0		
4	L	tand VI 15 VI 45	0.54	25.2	35.5	43.2	30.3	50.4	51.0	68.2	69.5	89.2	90.1	79.0	72.6	71.7	70.8	0.50	28
	R	chain VI 15 VI 45		23.6	24.6	36.9	30.1	46.1	51.8	72.9	74.8	93.3	99.8	89.9	85.9	75.6	78.1		
5	L	chain VI 30 VI 30	0.38	22.0	29.6	31.9	23.4	49.3	53.6	61.9	70.2	83.6	89.2	75.3	72.2	67.5	71.3	0.34	42
	R	tand VI 15 VI 15		31.7	37.9	51.9	51.9	55.7	55.9	73.4	72.4	92.5	92.7	86.9	90.0	77.1	77.8		
6	L	tand VI 30 VI 30	0.36	25.9	17.8	28.8	21.8	53.2	49.1	67.6	68.0	87.8	87.1	74.3	73.4	70.7	69.4	0.34	32
	R	tand VI 15 VI 15		24.9	50.9	51.2	48.4	57.6	58.3	75.2	76.9	93.0	89.8	91.0	98.5	79.2	80.9		

lends additional support to this conclusion (see Table 1).

Taking position bias into account, Conditions 1 to 4 support the view that subjects are indifferent in choice between chained and tandem schedules that span the same obtained intervals to reinforcement. In two subsequent conditions, the terminal-link interreinforcement intervals on the right key were half those on the left key. Although choice was between a chained and tandem schedule in one case (Condition 5) and between two tandem schedules in the other (Condition 6), relative choice on the left key was nearly the same in both conditions (0.38 and 0.36).

Although choice in this series appeared to be governed only by the interreinforcement intervals spanned by the terminal-link schedules, the patterns of responding within the terminal-link chained and tandem schedules were not identical. Throughout the chained *vs* tandem conditions, the difference in mean rates of responding between successive terminal-link components was consistently greater in the chained than in the tandem schedules (Table 1). While the stimuli correlated with each component in the chained schedules did typically control different response rates, the degree to which they did so differed from one bird to the next. These individual differences do not show a consistent relation to individual differences in relative choice.

EXPERIMENT 2

In this series, *chain* VI VI schedules were arranged on both keys following the initial links. The experiment was designed to investigate the possible effects on choice of differentially signalled components within each terminal-link schedule and to separate these effects, if any, from the effects on choice of terminal-link interreinforcement intervals.

Method

Subjects

Three pigeons (346, 457, 480) served.

Procedure

The basic concurrent-chains procedure diagrammed in Figure 1 was employed. Except where noted below, the terminal-link schedule on each key was *chain* VI VI. The first and second components of the terminal-link chain on the left key were correlated with red and green keylights respectively; on the right key, keylights were yellow and blue respectively. As in Experiment 1, the initial-link and terminal-link VI components were each constructed of 12 intervals selected according to the Fleshler and Hoffman (1962) equal probability progression, and the intervals associated with the first and second components of each terminal link were ordered with respect to each other so that the overall terminal-link interreinforcement intervals also conformed to the equal probability progression.

Subjects were trained in the same order on six conditions. Conditions were changed when relative choice appeared clearly stable in all birds. Table 2 shows the terminal-link schedules used in the various conditions and the number of sessions associated with each. Conditions 1 to 4 investigated choice between pairs of chained schedules having identical sets of overall intervals to reinforcement. In Conditions 5 and 6, the terminal-link interreinforcement intervals on one key were half those on the other. Condition 6 employed a tandem schedule on the left key with red key color during both components.

Results and Discussion

Mean relative choice and terminal-link relative rate of reinforcement obtained in each condition are shown in Table 2. Absolute rates of responding to each key during the initial links and during each terminal-link component are also provided in Table 2.

In Condition 1, where *chain* VI 30-sec VI 30-sec schedules were scheduled on both keys, birds showed a slight preference for the left key. The schedule on the right key remained unchanged during Conditions 2 and 3, but the relative durations of the components within the terminal-link chain on the left key were varied. This variation was not accompanied by important changes in relative choice. The slight deviations from equal choice in Conditions 1 to 3 are probably attributable to a small position bias in favor of the left key and to slight differences in obtained relative rates of reinforcement during the terminal links (Table 2). In Condition 4, the transition between components within the terminal-link schedule occurred, on the average, 30 sec earlier on the right key than on the left key, although the schedules provided identical

Table 2

The conditions and data of Experiment 2 are summarized in this table. The data for each condition represent averages over the final five sessions. For each condition the upper row of values pertains to the left key (L), and the lower row to the right key (R). Schedule values are in seconds. Relative choice and terminal-link relative rates of reinforcement are provided for the left key and are averages across subjects. Individual response rates during the initial links are shown, as well as individual and mean response rates during the terminal-link components. For terminal-link response rates the column headings S2 and S1 refer respectively to the first and second (final) components within the terminal-link schedule. All response rates are given as responses per minute.

Condition	*Key*	*Terminal-link schedules*	*Mean relative choice*	*Initial-link response rates*			*Terminal-link response rates*								*Relative rate of reinforcement*	*Sessions*
							#346		*#457*		*#480*		*mean*			
				#346	*#457*	*#480*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*		
1	L	chain VI 30 VI 30	0.51	35.1	28.3	31.9	73.7	75.1	74.3	63.0	89.1	87.8	79.0	75.3	0.49	30
	R	chain VI 30 VI 30		32.4	27.3	31.3	69.4	79.8	63.2	52.9	86.5	80.6	73.0	71.1		
2	L	chain VI 15 VI 45	0.54	43.9	27.1	43.4	83.9	64.3	60.4	55.3	83.1	94.7	75.8	71.4	0.51	28
	R	chain VI 30 VI 30		36.0	28.1	33.2	80.6	80.4	61.6	67.5	80.2	80.3	74.1	76.1		
3	L	chain VI 45 VI 15	0.52	31.6	29.5	39.2	78.1	86.6	60.4	72.5	90.9	109.8	76.5	89.6	0.51	20
	R	chain VI 30 VI 30		34.2	24.2	36.6	86.2	82.8	68.4	67.7	91.0	93.0	81.9	81.2		
4	L	chain VI 45 VI 15	0.50	36.9	26.7	44.4	98.3	101.1	56.9	70.5	81.3	126.6	78.8	99.4	0.49	23
	R	chain VI 15 VI 45		35.9	30.3	41.7	97.0	94.4	67.9	60.3	93.0	94.1	86.0	82.9		
5	L	chain VI 30 VI 30	0.35	16.3	20.0	36.1	70.2	72.0	70.7	68.3	86.3	87.9	75.7	76.1	0.34	42
	R	chain VI 15 VI 15		54.8	37.2	42.2	85.6	92.2	74.8	78.1	89.6	92.1	83.3	87.5		
6	L	tand VI 30 VI 30	0.34	10.9	18.2	38.0	80.2	84.1	73.2	73.8	84.3	83.0	79.2	80.3	0.34	31
	R	chain VI 15 VI 15		56.5	36.9	41.0	86.9	95.5	75.6	78.1	90.9	92.7	84.5	88.8		

overall interreinforcement intervals. As in the earlier comparisons, birds were approximately indifferent between the terminal-link chains. In Conditions 5 and 6, the interreinforcement intervals of one terminal link were half those of the other, though schedules were *chain* VI VI *vs chain* VI VI in one case and *chain* VI VI *vs tand* VI VI in the other case (c.f. Conditions 5 to 6 of Experiment 1). Relative choice was virtually identical in the two conditions.

Mean rates of responding in the first and second components of each terminal link were similar when the successive components were equal (*e.g., chain* VI 30-sec VI 30-sec). When the components were unequal, response rates were consistently greater in the shorter component. The magnitude of this difference was greater when the shorter followed the longer component. This systematic pattern of response rates provides evidence that the subjects discriminated the component-correlated stimuli of the terminal link schedules.

As in Experiment 1, relative choice was not affected by the presence or relative durations of differentially signalled components within a terminal-link schedule. Choice did depend, however, on the terminal-link interreinforcement intervals. In all conditions, relative choice on a key was approximately equal to the obtained relative rate of reinforcement provided by the terminal link on that key.

EXPERIMENT 3

Experiments 1 and 2 revealed no effect on relative choice uniquely attributable to conditioned reinforcement in the terminal-link chains. Initial-link responding was controlled by the intervals to primary reinforcement associated with the terminal links, but not by the subdivision of those intervals into differentially signalled components.

In single-key studies of chained schedules, effects attributed to conditioned reinforcement have typically been exhibited most strongly when components are fixed-interval (FI) schedules (*e.g.,* Gollub, 1958). The present series investigated choice between pairs of *chain* FI FI schedules. An effect on relative choice arising from terminal-link conditioned reinforcement was sought by varying the relative durations of the terminal-link components while the overall intervals to reinforcement on each of the keys remained equal as well as constant.

METHOD

Subjects

Seven pigeons (254, 452, 255, 325, 346, 458, and 480) served.

Procedure

The basic concurrent-chains procedure of Figure 1 was used. In all conditions, the successive terminal-link components were FI 20-sec FI 20-sec on one key and FI x-sec FI (40-x)-sec on the other key. Table 3 shows the terminal-link schedules of the four conditions. Each was continued until relative choice was stable in all birds. The successive terminal-link key colors were yellow and blue on the right key, and red and green on the left key, except

Table 3

The conditions and data of Experiment 3 are summarized in this table. The data for each condition represent averages over the final five sessions. For each condition the upper row of values pertains to the left key (L), and the lower row to the right key (R). Schedules values are in seconds. Relative choice and terminal-link relative rates of reinforcement are provided for the left key and are averages across subjects. Individual response rates during

Condition	*Key*	*Terminal-link schedules*	*Mean relative choice*	*Initial-link response rates*						
				#254	*#452*	*#255*	*#325*	*#346*	*#457*	*#480*
1	L	chain FI 20 FI 20	0.52	24.5	28.3	29.6	35.0	37.1	24.4	34.8
	R	chain FI 20 FI 20		19.0	26.9	33.4	29.1	34.4	26.2	26.0
2a	L	chain FI 38 FI 2	0.56	25.5	29.3	31.1	38.8	44.9	25.4	40.7
	R	chain FI 20 FI 20		18.7	24.9	36.5	25.2	29.2	27.3	24.9
2b	L	chain FI 20 FI 20	0.54	26.5	25.4	32.8	36.8	38.5	24.7	37.5
	R	chain FI 38 FI 2		19.1	25.9	34.2	25.3	32.4	24.9	26.2
3	L	tand FI 20 FI 20	0.55	23.7	30.1	35.7	34.7	43.4	28.5	41.0
	R	chain FI 38 FI 2		19.5	26.6	34.9	27.4	32.8	23.2	27.0

for Condition 3 in which both left-key components were red.

Results and Discussion

Mean relative choice and terminal-link relative rate of reinforcement in each condition are shown in Table 3. Table 3 also provides the absolute rates of responding for individual subjects during the initial links and during the terminal-link components.

The first condition established a baseline performance with *chain* FI 20-sec FI 20-sec on each key. After choice became stable and approximately equal on the two keys, the left-key schedule was changed to *chain* FI 38-sec FI 2-sec (Condition 2a). Relative choice on the left key increased to 0.56, a change whose magnitude suggested a weak effect due to the changed values of the left-key schedule. Condition 2b tested this possibility by reversing the terminal-link schedules with respect to the two keys. The reversal did not produce a corresponding reversal in relative choice (see Table 3). These results imply that the slight preference for the left key in Condition 2a was due not to differences in the terminal-link chains on the two keys but to the development of a weak position bias. Condition 3, identical to 2b except for the absence of differential stimuli correlated with the terminal components on the left key, produced virtually the same relative choice for the left key as had Conditions 2a and 2b.

As in Experiments 1 and 2, no effect on choice was found that could be attributed to differential strengths of conditioned reinforcement provided by the stimuli following the initial links on the two keys. Except for small deviations due to position bias, birds chose approximately equally between schedules that spanned equal intervals to primary reinforcement.

In Experiments 1 and 2, responding during the terminal-link chains showed clear evidence of being under stimulus control, but the magnitude of the difference in response rates between successive chained components was often small. In the present experiment, however, these differences were large: response rate during the second stimulus of each *chain* FI FI was typically four or five times greater than response rate during the first stimulus of the chain (see Table 3). Further evidence of strong stimulus control is provided by the patterns of responding within the individual chained FI components. These response patterns were typical of FI behavior, and generally consisted of a pause followed by an increasing rate of responding throughout the interval. This was observed within all FI components except the FI 2-sec components, where responding occurred at a high rate throughout the interval.

Condition 3 provides a case in which choice was between a chained FI FI, with responding under strong stimulus control, and a tandem FI FI, in which the same stimulus was present throughout. The difference in response rates between the successive chained FI components was much larger than between successive components in the tandem schedule. This differ-

the initial-links are shown, as well as individual and mean response rates during the terminal-link components. For terminal-link response rates, the column headings S2 and S1 refer respectively to the first and second (final) components within the terminal-link schedule. All response rates are given as responses per minute.

Terminal-link response rates																*Relative rate of reinforcement*	*Sessions*
#254		*#452*		*#255*		*#325*		*#346*		*#457*		*#480*		*mean*			
S2	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*	*S2*	*S1*		
10.7	68.9	15.4	75.7	32.4	135.1	27.2	110.3	18.5	101.5	21.3	99.7	16.8	79.9	20.3	95.9	0.51	35
12.4	61.3	20.7	71.5	40.1	119.6	34.0	110.1	16.6	86.9	22.1	90.8	20.3	87.6	23.7	89.7		
10.4	98.0	18.0	95.2	33.2	148.5	21.9	125.4	12.1	98.7	18.5	112.9	13.3	95.6	18.2	110.6	0.50	35
11.1	57.6	17.0	65.8	35.6	112.2	22.9	108.4	19.2	86.5	14.4	88.6	27.0	79.4	21.0	85.5		
10.6	52.7	13.5	68.3	30.8	113.1	27.7	92.3	16.9	81.5	21.3	90.9	24.0	82.7	20.7	83.1	0.51	25
16.1	84.3	12.3	84.7	48.0	132.6	28.5	121.3	18.8	98.5	15.1	104.1	20.5	105.9	22.8	104.5		
33.0	46.8	21.5	30.9	85.3	109.0	56.3	65.2	20.1	57.6	42.1	49.0	51.6	53.9	44.3	58.9	0.51	25
15.5	79.0	14.1	84.3	35.0	159.4	32.6	125.8	16.6	95.3	18.9	121.4	46.4	148.2	25.6	116.2		

ence in the degree of terminal-link stimulus control on the two keys apparently had no effect on relative choice, which remained about the same as in earlier conditions involving the same terminal-link intervals to reinforcement (Table 3).

EXPERIMENT 4

In each of the comparisons studied in Experiments 1 to 3, relative choice approximately equalled terminal-link relative rate of reinforcement, a relation first found by Autor (1960) and Herrnstein (1964a) when single-component schedules were employed in the terminal links. A strong deviation from this equality was found by the author in an exploratory study that preceded the experiments reported here. The study arranged *chain* VI 30-sec FT x-sec *vs chain* VI 30-sec FT y-sec schedules after the initial links. [A fixed-time (FT) schedule delivers a reinforcer independently of behavior when an interval of fixed duration elapses.] Relative choice for the chain providing the higher rate of reinforcement was consistently greater than predicted by the matching function of Herrnstein (1964*a*). It was felt that the basis for these deviations might lie in the effect of chaining on the conditioned reinforcing properties of the terminal-link stimuli, a possibility that led to the above experiments.

No comparable deviations from equality between relative choice and relative rate of terminal-link reinforcement were found in Experiments 1 to 3 despite the use of chained schedules in these experiments. The following experiment was undertaken to replicate and extend the findings of the initial exploratory study and to investigate the causes of deviations from matching, if any, when both terminal links are *chain* VI FT schedules.

Subjects

Five pigeons (244, 247, 248, 472, 292) served.

Procedure

The concurrent-chains procedure of Figure 1 was used, with *chain* VI FT schedules during the terminal links in most of the 12 conditions. Table 4 shows the terminal-link schedules, subjects, and number of sessions associated with each condition.

The terminal VI components on the left key were correlated with red keylight; on the right key, with green keylight. During FT components, both response keys were darkened and pecks, though recorded, had no scheduled consequences. Fixed-time components on the left key were associated with yellow chamber illumination (colored houselight); on the right key with blue chamber illumination. During all VI components, the chamber was illuminated only by keylights.

Conditions 1 to 9 studied choice between *chain* VI FTx *vs chain* VI FTy schedules. In the first four of these conditions, the terminal-link VI components on each key were VI 15-sec schedules; in Conditions 5 to 9 they were VI 30-sec schedules. Fixed-time values ranged from 1-sec *vs* 11-sec to 6-sec *vs* 6-sec in these conditions. Condition 10 involved choice between a *chain* VI 30-sec FT 10-sec schedule and a VI 30-sec schedule. Condition 11 involved choice between two simple VI schedules (VI 40-sec *vs* VI 30-sec) whose interreinforcement intervals were identical to those of Condition 10. Finally, Condition 12 involved a *chain* VI 38-sec FT 2-sec schedule on one key having the same interreinforcement intervals as those of a *chain* VI 30-sec FI 10-sec schedule on the other key.

Each VI component appearing in a terminal link consisted of 12 intervals selected according to the Fleshler and Hoffman (1962) equal probability progression, except in the cases of the VI 40-sec component in Condition 11 and the VI 38-sec component of Condition 12.

Results and Discussion

Mean relative choice and terminal-link relative rates of reinforcement are shown in Table 4 together with individual rates of responding to each key during the initial and terminal links.

Relative choice is displayed as a function of obtained relative rate of reinforcement in Figure 2. Each point represents a value from an individual subject. The graph reveals systematic deviations from equality between relative choice and relative rate of reinforcement. Relative choice for a schedule was greater than its relative rate of reinforcement if that schedule provided the higher rate of reinforcement; if it provided the lower rate, relative choice was less than relative rate of reinforcement. Deviations of this nature also appeared, though in lesser degree, when relative

Table 4

The conditions and data of Experiment 4 are summarized in this table. The data for each condition represent averages over the final five sessions. For each condition the upper row of values pertains to the left key (L), and the lower row to the right key (R). Schedule values are in seconds. Relative choice and terminal-link relative rates of reinforcement are provided for the left key and are averages across subjects. Individual response rates during the initial links are shown, as well as individual and mean response rates during the terminal-link components. For terminal-link response rates, the column headings S2 and S1 refer respectively to the first and second (final) components within the terminal-link schedule. All response rates are given as responses per minute.

Condition	Key	Terminal-link schedules	Mean relative choice	Initial-link response rates					Terminal link response rates												Relative rate of reinforcement	Sessions
									#244		#247		#248		#472		#292		mean			
				#244	#247	#248	#472	#292	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1		
1	L	chain VI 15 FT 2	0.66				26.1	38.9							41.3	7.2	69.8	9.5	55.6	8.4	0.60	40
	R	chain VI 15 FT 10					9.6	26.0							30.7	0.6	67.8	4.4	49.2	2.5		
2	L	chain VI 15 FT 7	0.44		26.3	17.5	11.1	31.0			72.0	2.1	25.7	7.7	31.2	5.5	60.4	6.2	47.3	5.4	0.48	26
	R	chain VI 15 FT 5			34.9	14.3	22.9	34.9			75.2	1.9	26.2	5.6	38.1	1.7	65.5	3.6	51.2	3.2		
3	L	chain VI 15 FT 8	0.27		18.2	6.5	4.1	25.4			68.6	2.0	28.3	6.2	31.8	4.4	54.1	6.3	45.7	4.7	0.44	45
	R	chain VI 15 FT 3			38.7	26.1	25.2	38.1			80.5	5.7	31.5	11.2	40.6	5.4	69.3	14.0	55.5	9.1		
4	L	chain VI 15 FT 11	0.21		15.2	2.6	7.6	17.8			63.3	1.2	25.6	5.2	29.4	3.0	47.5	3.5	41.4	3.2	0.38	28
	R	chain VI 15 FT 1			54.0	25.9	21.7	45.9			76.4	8.5	36.8	10.9	50.7	5.8	63.2	6.1	56.8	7.8		
5	L	chain VI 30 FT 6	0.47	32.0	25.7	13.8			57.1	8.1	69.5	2.3	36.2	8.0					54.3	6.1	0.50	20
	R	chain VI 30 FT 6		21.3	45.6	16.2			40.9	2.2	60.9	4.5	32.7	5.4					44.8	4.0		
6	L	chain VI 30 FT 5	0.50	31.4	31.7	11.8			60.7	12.1	68.9	3.8	37.4	11.4					55.7	9.1	0.51	20
	R	chain VI 30 FT 7		17.6	38.7	17.0			49.1	4.1	54.9	1.4	30.5	6.3					44.8	3.9		
7	L	chain VI 30 FT 3	0.69	33.5	38.4	18.6			54.0	11.1	67.5	4.5	31.8	12.1					51.1	9.2	0.54	20
	R	chain VI 30 FT 9		7.4	30.1	8.4			54.7	2.0	43.8	0.2	20.7	2.9					39.7	1.7		
8	L	chain VI 30 FT 4	0.61	27.8	31.8	16.5			54.4	3.6	67.2	2.1	33.3	9.4					51.6	5.0	0.53	34
	R	chain VI 30 FT 8		9.8	28.2	12.4			58.4	1.9	44.5	0.2	23.7	5.3					42.2	2.5		
9	L	chain VI 30 FT 2	0.78	43.7	31.4	24.7			58.3	2.0	69.3	3.6	38.0	8.6					55.2	4.7	0.56	41
	R	chain VI 30 FT 10		0.2	21.8	7.8			53.2	0.3	42.6	0.1	23.2	2.9					39.7	1.1		
10	L	chain VI 30 FT 10	0.24		9.5	4.9	8.8	22.4			69.0	0.4	37.2	4.8	28.5	3.1	59.6	4.8	48.6	3.3	0.43	28
	R	VI 30			50.1	25.8	22.8	38.1			—	48.3	—	36.7	—	50.6	—	66.3	—	50.5		
11	L	VI 40	0.27		16.6	1.9	11.0	25.7			—	70.7	—	34.6	—	33.5	—	59.7	—	49.6	0.43	27
	R	VI 30			44.7	26.6	21.3	37.0			—	50.5	—	38.4	—	49.0	—	66.9	—	51.2		
12	L	chain VI 38 FT 2	0.49		29.1	14.3	15.9	25.6			68.1	4.3	30.4	10.1	36.1	5.2	60.3	5.3	48.7	6.2	0.50	34
	R	chain VI 30 FT 10			31.9	13.8	14.1	31.2			56.0	0.8	33.1	3.8	54.1	6.8	69.9	4.9	53.3	4.1		

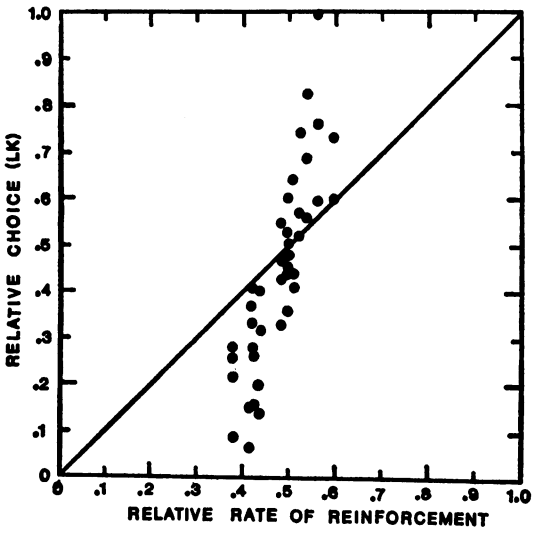

Fig. 2. Relative rate of responding (relative choice) on the left key during the initial links as a function of obtained relative rate of reinforcement on the left key during the terminal links in Experiment 4. Each point represents data from an individual subject averaged across the last five days of a condition. The diagonal line shows where points would fall if relative choice matched relative rate of reinforcement.

choice was compared with relative harmonic rate of reinforcement, a measure of reinforcement frequency described by Killeen (1968*a*).

Since the VI components of the terminal links were equal on the two keys during Conditions 1 to 4 and 5 to 10, the striking changes in relative choice within these sets of conditions must be attributed to the variation in the short but unequal FT components. It was not clear from these conditions alone whether the FT components exerted their control over relative choice through their effect on the overall interreinforcement intervals of each chain or whether their effect on choice required an explanation in terms of terminal-link conditioned reinforcement. Subsequent conditions (11 and 12) were conducted to investigate this question.

Condition 11 employed single-component schedules in the terminal links (VI 40-sec *vs* VI 30-sec). Choice in this condition may be compared with choice in Condition 10, whose corresponding terminal-link schedules (*chain* VI 30-sec FT 10-sec *vs* VI 30-sec) provided the same overall interreinforcement intervals. The two conditions generated essentially the same distribution of initial-link responses, which suggests that choice in Condition 10 was affected by the interreinforcement intervals but not the chaining of components within the terminal link. Relative choice in Conditions 10 and 11 did not equal the terminal-link relative rate of reinforcement, a finding consistent with the other deviations from equality shown in Figure 2.

Condition 12 investigated choice between a pair of *chain* VI FT schedules whose sets of interreinforcement intervals were identical but whose VI and FT components were of different relative durations (*chain* VI 38-sec FT 2-sec *vs chain* VI 30-sec FT 10-sec). Initial-link responses were equally distributed on the two keys.

The results of Conditions 10, 11, and 12 argue that the FT components in this experiment influenced choice only through their contributions to the interreinforcement intervals associated with the terminal-link schedules. As in Experiments 1 to 3, the present conditions provide no evidence that choice depends on aspects of the terminal links other than their associated sets of interreinforcement intervals.

Rates of responding during the FT components were low in all conditions, averaging between 1 and 10 responses per minute. Since moderate or high response rates were maintained in the terminal-link VI components (Table 4), it is clear that the birds discriminated between the chained terminal-link components on each key. Condition 10 provided a case in which chained, highly discriminated components were present in one terminal link, while the other terminal link consisted of a single-component schedule. The difference in degrees of stimulus control involved in the two terminal links had no apparent effect on choice (*cf.* Condition 11).

GENERAL DISCUSSION

The present findings imply that relative choice is directly governed by the intervals to primary reinforcement associated with the terminal-link schedules. Other studies have demonstrated that choice is not affected by whether responses intervene between the initial-link state and reinforcement (Killeen, 1968*b;* Neuringer, 1969). The experiments reported here suggest that choice is also not affected by intervening sequences of stimuli and schedule components. More precisely, it appears that terminal-link stimuli and schedule components affect choice only insofar as they

affect the terminal-link intervals to reinforcement actually obtained.

The observation that relative choice does not depend on stimulus arrangements within the terminal-link schedules casts doubt on the notion that these stimuli have reinforcing value in their own right. Although behavior under chained schedules has often been interpreted in terms of conditioned reinforcing properties of the chained stimuli (Kelleher and Gollub, 1962), the present data on preference for chained schedules provides no evidence that these stimuli serve reinforcing functions. One can imagine at least two plausible ways in which choice might have been affected had the chained stimuli acquired reinforcing values. One possibility is that their reinforcing values would have added to that of the primary reinforcer terminating the chain, thus determining a net reinforcing value for that schedule. On this view, the first chained stimulus, the second (final) chained stimulus, and the delayed primary reinforcer would each contribute in varying degrees to the maintenance of initial-link responding on that key. As another possibility, one might assume that initial-link responding on a key is maintained only by its immediate consequence—the production of a terminal-link stimulus. If so, the reinforcing value of that stimulus, and hence choice, should depend on whether the stimulus is directly paired with the primary reinforcer, as in a tandem schedule or a single-component schedule, or is paired with yet another stimulus presumed to be a conditioned reinforcer, as in a chained schedule.

Either possibility implies that preference for a chained schedule should depend on factors above and beyond the interval to primary reinforcement alone. Furthermore, one would expect the reinforcing values of the chained stimuli, and choice, to vary with the relative durations of the components within the chain when the overall time to reinforcement remains constant. Instead, comparisons involving chained schedules during one or both terminal links showed choice to be independent of these factors and to depend only on the associated intervals to primary reinforcement. Whenever a pair of terminal-link schedules had the same overall interreinforcement intervals, choice was equal; and in cases where the interreinforcement intervals differed on the two keys, choice was not affected by the presence or relative durations of chained stimuli within either terminal link.

Although the distribution of initial-link responses was shown to depend on the terminal-link intervals to reinforcement, it is not yet clear how these intervals should be transformed to yield accurate predictions of relative choice. Early studies suggested that relative choice in concurrent chains equalled terminal-link relative rate of reinforcement (Autor; 1969, Herrnstein, 1964*a*), but subsequent research has shown that this is not generally the case (*e.g.,* Fantino, 1969; Herrnstein, 1964*b;* Killeen, 1968*a,* 1970). In Experiment 4 of the present study, relative choice did not equal relative rate of reinforcement, and the data imply that the deviations were not due to the types of schedules used in the terminal links but to their associated sets of interreinforcement intervals. As with most other studies that have reported differences between relative choice and relative rate of reinforcement, the direction of the deviations suggests that birds weight smaller intervals to a greater degree than would be predicted on the basis of terminal-link rates of reinforcement. Accordingly, preference is often more extreme than predicted by matching to relative rates of reinforcement (see Figure 2). Several recent studies (*e.g.,* Fantino, 1967; Killeen, 1968*a;* Schneider, 1970; Duncan and Fantino, 1970) have been directly concerned with finding transformations appropriate to the prediction of relative choice, and the reader is referred to these studies for a more thorough treatment of this problem. The suggestion arising from the present results is that any transformation that adequately predicts choice between the single-component schedules usually studied will also apply successfully to cases involving two-component terminal-link schedules.

It has already been noted that the present results raise serious doubts about whether the stimuli of the chained schedules served reinforcing functions, since preference appeared to be governed only by the intervals to primary reinforcement spanned by the chained components. Although it is doubtless possible to mold a theory of conditioned reinforcement mediation into a form compatible with this finding, the most parsimonious interpretation of the data is that responding during the initial links was maintained directly by delayed terminal-link primary reinforcement.

On the basis of this hypothesis, it is possible to suggest a role for the stimuli in chained schedules that differs from that based on joint discriminative and conditioned reinforcing properties. This possibility arises from the fact that many aspects of chain schedule performance usually attributed to conditioned reinforcing functions of the stimuli may be accounted for with equal ease without recourse to the notion of conditioned reinforcement.

Behavior in the early components of extended chains is typically characterized by low rates and prolonged pauses. While this has often been assumed to reflect weak conditioned reinforcing properties of the early stimuli (Gollub, 1958; Kelleher and Gollub, 1962), it may instead reflect merely the greater times to reinforcement associated with the early stimuli. The level of performance during a chained stimulus is as easily attributed to the intervals to reinforcement associated with the stimulus as to the conditioned reinforcing properties of the subsequent stimulus. The literature on chained schedules does support the notion that response rate during a chained component with a given response requirement is a decreasing function of the temporal distance between that component and reinforcement (Gollub, 1958; Findley, 1962; Kelleher and Fry, 1962).

One implication of this view is that responding in an early component should not depend on the number of subsequent components as long as the obtained time to reinforcement is held constant. Unfortunately, most experiments involving chained schedules have confounded these two variables. In the present experiments, however, it was indeed found that initial-link responding on a key was not affected by whether the subsequent interval to reinforcement was divided into two differently signalled components.

The thrust of the view proposed here is that behavior during a component-correlated stimulus depends both on the schedule in effect during the stimulus and on the intervals to reinforcement associated with the stimulus. But one must also consider that behavior in one component of a chain may be affected by the subsequent component. While the production of a stimulus correlated with one component may not maintain behavior in the preceding component in the sense that a primary reinforcer does, it may indeed influence behavior in the earlier component by serving what might be called a "contingency-delimiting" function. A stimulus change reliably occurring at the end of a given component may function simply to indicate the completion of that schedule requirement, thereby allowing the pattern of behavior characteristic of that schedule to develop. Without correlated stimulus changes, discrimination of successive schedule components would be impaired and behavior within the separate components would be under less precise control of the individual schedule requirements.

It has long been known that equal-valued chained and tandem schedules often generate markedly different patterns of responding. Gollub (1958), for example, studied performance under five-component chained and tandem schedules with FI 1-min in each component. Under the chained schedule, the accelerated pattern of responding characteristic of FI schedules was observed in each component, while responding under the tandem schedule tended to be positively accelerated throughout the schedule, with little or no separate scalloping within the individual components. The absence of characteristic FI patterns within the tandem components may be attributed to the absence of stimulus changes marking the transition between each FI component and the next. In the absence of stimulus events correlated with the onset and termination of the separate components, it is not surprising that behavior in the various components was not under precise control of the successive response contingencies. This difference in performance under equal-valued chained and tandem schedules might therefore be attributed to the absence in tandem schedules of stimulus feedback delimiting the successive contingencies.

The other major difference in performance between extended chained and tandem schedules—the low rates and long pauses in the early components of chained, but not tandem, schedules—is also interpretable in terms of informative, or signalling, functions of the stimuli involved. While the stimulus initially encountered in an extended chained schedule is always associated with relatively long intervals to primary reinforcement, this is not true in the case of equivalent tandem schedules. In a tandem schedule, the stimulus present during the first component of the schedule is also present in the later components; it is corre-

lated not only with the intervals to reinforcement associated with the first component, but also with the shorter intervals to reinforcement associated with the subsequent components. Thus, the presence of the stimulus provides less precise information about the current time to reinforcement, and, to the extent that behavior is under control of the stimulus, this correlation of the stimulus with short as well as long intervals to reinforcement should favor higher response rates in the early components than would be the case under an equal-valued chained schedule.

If the long times to reinforcement signalled by the early chained stimuli result in low response rates in their presence, these low rates may moreover interact with the schedule requirements to produce yet longer obtained intervals to reinforcement, and therefore yet lower rates. Few studies comparing performance under chained and tandem schedules have equated the obtained, as opposed to scheduled, overall intervals to reinforcement. Yet when the obtained interval sets are not equal for the two schedules it is not possible to determine the extent to which the lower rates in early chained than tandem components are due to the differences in obtained intervals to reinforcement under the two schedules and the extent to which they are due to the fact that the components are differentially signalled in the chained, but not the tandem schedule. Effects due to the latter factor could be interpreted in terms of either reinforcing functions or non-reinforcing functions served by the chained stimuli, as indicated earlier.

The present study found, however, that choice between pairs of two-component schedules was not affected by the presence of component-correlated stimuli within either schedule when effects due to overall times to reinforcement were controlled. Apparently the stimuli in the chained and tandem schedules studied here did not have important reinforcing values of their own. If so, then their effects on performance within those schedules must be accounted for in terms of non-reinforcing functions of the stimuli. The discussion above suggests various ways in which such an account might tentatively proceed. Nonetheless, the possibility of explaining certain aspects of chained schedule performance without recourse to conditioned reinforcement does not preclude the possibility that chained stimuli may sometimes serve genuine reinforcing functions. Although none were evidenced in the present study, it remains to be shown whether other procedures would yield results that could not be adequately accounted for without assuming that the stimuli were reinforcing.

One must be cautious, however, about attributing reinforcing values to stimuli that may, under certain conditions, show reinforcing-like effects. Schuster (1969) discussed this problem in detail and also questioned the role of conditioned reinforcement in schedule-maintained behavior. One of Schuster's experimments involved a concurrent chains schedule in which birds chose between pairs of equal-valued VI schedules during one of which responding also produced presentations of a brief stimulus on a superimposed fixed-ratio schedule. Every occurrence of the primary reinforcer was paired with the brief stimulus. Although this arrangement should have resulted in the brief stimulus becoming a potent conditioned reinforcer, the data on choice between the schedule pairs did not favor this interpretation. Instead, his results supported the notion that an arbitrary stimulus paired with a primary reinforcer does not itself become a reinforcer, though it may have reinforcing-like effects on prior responding under certain circumstances. Schuster argued that such effects may be predicted from the reinforcing consequences cued by the stimulus without assuming that the stimulus strengthens behavior in the sense that primary reinforcers do. The present results lend additional support to the view that stimuli often presumed to act as conditioned reinforcers may in fact exert their effects on behavior through various non-reinforcing functions.

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. Hendry, (Ed.), *Conditioned reinforcement,* Homewood, Ill.: The Dorsey Press, 1969. Pp. 127-162.

Duncan, B. and Fantino, E. Choice for periodic schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1970, **14,** 73-86.

Fantino, E. Preference for mixed- *versus* fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior,* 1967, **10,** 35-43.

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

Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement.* New York: Appleton-Century-Crofts, 1957.

Findley, J. D. An experimental outline for building and exploring multi-operant behavior repertoires. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 113-166.

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

Gollub, L. R. *The chaining of fixed-interval schedules.* Unpublished doctoral dissertation, Harvard University, 1958.

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

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

Kelleher, R. T. and Fry, W. T. Stimulus functions in chained fixed-interval schedules. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 167-173.

Kelleher, R. T. and Gollub, L. R. A review of positive conditioned reinforcement. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 543-597.

Killeen, P. R. On the measurement of reinforcement frequency in the study of preference. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 263-269. (*a*)

Killeen, P. R. Response rate as a factor in choice. *Psychonomic Science,* 1968, **12,** 34. (*b*)

Killeen, P. R. Preference for fixed-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1970, **14,** 127-131.

Killeen, P. R. Response patterns as a factor in choice. *Psychonomic Science,* 1971, **22**(1), 23-24.

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

Schneider, J. W. *Conditioned reinforcement and delay of reinforcement in concurrent-chain schedules.* Unpublished doctoral dissertation, Harvard University, 1970.

Schuster, R. H. A functional analysis of conditioned reinforcement. In D. Hendry (Ed.), *Conditioned reinforcement.* Homewood, Ill.: The Dorsey Press, 1969. Pp. 192-234.

Received 22 July 1971.
(Final acceptance 4 April 1972.)