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RESPONSE STRENGTH IN MULTIPLE PERIODIC AND APERIODIC SCHEDULES

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Responding in multiple periodic and aperiodic schedules of equal mean reinforcement rate was examined during extinction, satiation, and in the presence of various free-food schedules. In Experiments I and II, pigeons were trained on multiple variable-interval–fixed-interval schedules. Decreases in the rate of responding due to extinction, satiation, or food schedules were approximately equal regardless of the temporal pattern of reinforcer presentation. In Experiment III, pigeons responded on a two-component multiple schedule in which each component was a two-member homogeneous response chain terminating in a fixed-interval schedule during one component and in a variable-interval schedule during the other. The length of both terminal links was varied over a series of conditions. Initial-link responding in the fixed-interval component was reduced more by increasing terminal-link length than was initial-link responding in the variable-interval component. However, no differences in resistance to satiation and extinction were obtained across the fixed and variable components. If the relative decrease in responding produced by satiation and extinction is used as an index of the "value" of the conditions maintaining responding, then these data suggest that fixed and variable schedules of equal mean length are equally valued. This conclusion, however, is not consistent with findings of preference for variable over fixed schedules obtained in studies using concurrent-chain procedures.

Key words: fixed interval, variable interval, random interval, multiple schedules, concurrent-chain schedules, extinction, satiation, key peck, pigeons

The relative rate of responding in the initial links of a concurrent-chain schedule has frequently been used to assess the relative "value" of the terminal-link reinforcement schedules. In concurrent-chain schedules, entry into one of two terminal-link reinforcement schedules is dependent on the subject's choice of response alternative in the initial link. Equality of the rates of responding in the initial links of concurrent-chained schedules is typically found when equal rates of reinforcement are programmed in the terminal links, provided the terminal links are aperiodic or variable interval (VI) schedules (Autor, 1969; Herrnstein, 1964). If, however, a fixed-interval (FI) schedule with reinforcement interval equal to the mean reinforcement interval of the VI schedule is programmed in one of the terminal links, this relation is not obtained. Typically, strong preferences for the variable schedule are reported: that is, fewer initial-link responses are made on the key which provides access to the fixed-interval terminal-link schedule (Davison, 1969, 1972; Herrnstein, 1964; Hursh & Fantino, 1973; Killeen, 1968). Despite the generality of this finding, a consistent quantitative relation which predicts preference in all situations has not yet been defined.

The relative rates of responding in the initial links of concurrent-chain schedules with periodic and aperiodic schedules in the terminal links, have been used by a number of experimenters in an attempt to scale the "value" of aperiodic schedules in terms of periodic schedules which produce a given degree of preference. This approach has led to the notion that the average value of a sequence of variable intervals does not correspond to the arithmetic mean of those intervals, but is better represented by some other averaging rule, e.g., the harmonic mean (Kil-

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leen, 1968). The use of such a procedure rests on the assumption that the relative rate of responding during the initial link of the chain is influenced solely by the average value of the terminal-link schedule. This assumption may not be entirely accurate. Initial-link responding may be influenced by local temporal patterns of reinforcement over and above the average value of the schedule. For example, it is presumably the case that there is a discriminable period of nonreinforcement at the start of each interval in a fixed-interval schedule. It is possible that entry into a discriminated period of nonreinforcement may depress responding in the corresponding initial link in a way not adequately represented by any average measure. It is also possible that choice responses are influenced by local probabilities of reinforcement as well as average schedule value. When the average rates of reinforcement are equated in fixed and variable schedules, then, early in the inter-reinforcement interval, the local probability of reinforcement is higher in the variable schedule. That is to say, the probability of obtaining a reinforcement before the average reinforcement interval has elapsed is greater in a variable than in a fixed-interval schedule. Thus, if subjects are sensitive to local reinforcement probabilities as well as average schedule value, choosing between schedule alternatives at the start of the reinforcement interval, as is typically the case in the concurrent-chains procedure, should produce a preference for the variable schedule. In order to obtain further information about the way in which subjects evaluate schedules with dissimilar patterns of reinforcement, a method of assessing "value" which does not entail a choice procedure is explored in the present research. Specifically, responding in multiple periodic and aperiodic schedules is examined from the standpoint of resistance to change or response strength (Nevin, 1974, 1979). In this approach, those conditions which are more favorable to responding are believed to produce stronger or less easily disrupted performance.

Response strength is typically assessed in the following manner: a multiple schedule is arranged such that alternating components associated with different reinforcement conditions are presented to the subject. Components might differ in frequency of reinforcement, delay of reinforcement, amount of reinforcement, etc. After behavior stabilizes, a disruptive operation such as extinction or satiation is administered in both components. The amount of disruption in behavior is assessed in terms of the relative decrease in the rate of responding in each component with respect to previous baseline performance. Nevin has demonstrated orderly relations between the resistance of behavior to change and the conditions which maintain that behavior. Specifically, he has shown that more stable or stronger performances are obtained in components correlated with higher rates of reinforcement, greater amounts of reinforcement, or less delayed reinforcement. These relations seem to hold despite differences in experimental procedures used to maintain behavior, and procedures used to suppress or disrupt behavior. Some of the procedures which have yielded this result are extinction (Gollub & Urban, 1958; Nevin, 1974), satiation (Herrnstein & Loveland, 1974), delivery of alternative sources of reinforcement (Nevin, 1974; Pliskoff, Shull, & Gollub, 1968), and conditioned suppression (Lyon, 1963). See Nevin (1979) for an extensive review of this literature.

If the strength of responding covaries with the conditions maintaining behavior, then it should be possible to use response strength as an index of the relative "value" of various schedules of reinforcement. In the present research, this procedure is used to determine the "value" of fixed and variable schedules of equal mean reinforcement rate. Specifically, pigeons respond on multiple fixed-interval–variable-interval schedules in which the average reinforcement rate is equated across components. After responding stabilizes, a disruptive operation is administered. That schedule, which is associated with a smaller decrease in response rate with respect to the previous baseline, is considered to be the more "valuable" schedule.

In previous work described by Nevin (1979), the strength of responding has typically provided an index of schedule value which is consistent with determinations of value based on preference. That is, conditions which produce stronger behavior are also found to be associated with greater degrees of preference in concurrent-chain schedules. Specifically, preferences for schedules correlated with more frequent reinforcement, larger amounts of reinforcement, and more immediate reinforcement are generally reported (Fantino & Herrnstein, 1968; Logan, 1969; Schwartz, 1969; Ten Eyck, 1970). Therefore, if the preference for aperiodic over periodic schedules reflects the average value of those schedules, then responding in aperiodic schedules should also be more resistant to the effects of some disruptive operation. An experiment reported in 1961 by Carlton suggests that this might not in fact be the case. Carlton trained one group of rats to respond on a Mult FI 2-min continuous reinforcement (CRF) schedule and a second group to respond on a Mult VI 2-min CRF schedule. Deprivation conditions were then manipulated. Decreases in rates of responding on the intermittent schedules were evaluated with respect to the associated CRF performance. Relative decreases in rates of responding were found to be quite similar in fixed and variable conditions. This finding suggests that fixed and variable schedules are equivalently valued, and, as such, it is not consistent with concurrent-chain studies which show enhanced preference for variable-interval schedules. It is possible that these discrepant results were obtained because the two procedures used were sensitive to different aspects of the conditions maintaining behavior. If so, it is not clear which procedure provides a more valid index of the average value of fixed and variable schedules. It is also possible, however, that the differences in the obtained results were related to differences in specific parameters used in each of these procedures, rather than a fundamental difference in the measurement process. Some of the procedural differences which might be important: (a) Carlton compared performance between groups of animals rather than performance within single subjects as is usually the case with the concurrent-chains procedure; (b) Carlton used rats as subjects whereas pigeons are typically used in concurrent-chains studies; and (c) Carlton trained his subjects for relatively brief periods (12 sessions) whereas most concurrent-chain procedures involve extensive training. These differences were circumvented in the present research in which pigeons' responding was assessed during extinction, satiation, and in the presence of various free-food schedules using multiple fixed and variable schedules of equal mean length. This procedure thus allowed the comparison of FI and VI performance within single subjects.

EXPERIMENT 1

The purpose of this experiment was to assess response strength in a multiple schedule composed of periodic and aperiodic schedules of equal mean length. On the basis of preferences obtained in studies using concurrent-chain schedules, it was expected that responding on the aperiodic schedule would be more resistant to the effects of extinction and the presentation of free food than was responding on the periodic schedule.

METHOD

Subjects

Four White Carneaux pigeons with extensive experimental histories of performance on operant schedules served. Subjects were maintained at 80% of their free-feeding weights. Grit and water were available in the home cage.

Apparatus

A Lehigh Valley #1519C two-key pigeon chamber and standard electromechanical programming equipment were used. A fan provided masking noise and ventilation.

The VI schedules were programmed with a punched tape in which the distribution of interreinforcement times was arranged to approximate a normal distribution. The average interval was 60 sec, the standard deviation was 27.5 sec, and the value of each interval (in seconds) with its associated frequency of occurrence was as follows: .5(1), 12(3), 24(5), 36(7), 48(9), 60(10), 72(9), 84(7), 96(5), 108(3), 120(1). The tape was constructed in this manner in order to specify variability for future experimentation, which, in fact, never transpired.

Procedure

Pigeons were trained on a two-component multiple schedule. When the left key was lighted red, reinforcement was available on the VI 60-sec schedule described above. When the right key was lighted green, reinforcement was available on an FI 60-sec schedule. Reinforcement consisted of 3-sec access to grain. Components were changed after three reinforcers had been obtained. A 30-sec intertrial interval (ITI) was scheduled between components, during which the keys were dark. A session consisted of 24 components.

Table 1

Median and range of response rate and cumulative response latency for two five-day blocks of baseline training.

		Response rate (r/min)		*Response latency (in sec)*	
Subject	*Component*	*Median*	*Range*	*Median*	*Range*
53	FI	16.9	12.6-18.4		
	VI	29.0	15.5-34.2		
	FI	11.9	9.7-12.4	1088.7	963.2-1286.4
	VI	32.4	24.6-37.0	347.9	296.3- 442.7
54	FI	46.2	45.7-48.2		
	VI	62.6	55.1-65.0		
	FI	47.2	43.9-49.1	376.7	285.1- 483.7
	VI	62.8	52.9-63.9	113.8	147.5- 198.2
19	FI	27.9	27.6-30.5		
	VI	56.3	49.3-65.1		
	FI	23.6	22.2-28.0	1076.4	1034.2-1213.4
	VI	64.4	57.9-70.4	272.0	270.5- 292.1
20	FI	30.7	24.8-39.8		
	VI	27.8	26.8-30.4		
	FI	32.5	32.0-37.8	621.0	612.0- 808.2
	VI	28.8	26.2-32.1	310.8	259.2- 350.4

After 45 days of training, free-feeding sessions were instituted for a single session every 7 sessions. During free-feeding sessions, the grain magazine was presented during the ITI for 3 sec according to the following arithmetic variable-time (VT) schedules: 10 sec, 30 sec, or 1 min. The order of VT schedule presentation was as follows: 30 sec, 10 sec, 1 min, 10 sec, 1 min, 10 sec, 1 min, 10 sec.

After the last free-feeding session, baseline training was continued for 6 days. Extinction was then instituted for 6 consecutive daily sessions. During these sessions, reinforcement was withheld, and components were changed every 3 min.

Results and Discussion

At the end of training, performance was relatively stable for all subjects. The median and range of baseline responding on the last 5 days of training and on the third baseline determination after free feeding had been initiated are shown in Table 1. For all but Bird 20, the rate of responding in the VI component was generally higher than the rate in the FI component, despite occasional overlap in the case of Bird 53. During the third baseline determination, the latency between the onset of either a new component or a reinforcement presentation and the next response was recorded in order to be certain that FI and VI performances were differentiated in terms of the temporal patterns of responding. The median and range of cumulative pause times for this baseline period are shown in columns 3 and 4 of Table 1. Pause times in the FI component were two to four times as long as in the VI component, indicating differential schedule control. The ranges in pause times show no overlap for any subject.

Figure 1 shows the rate of responding for each baseline condition and each subsequent free-feeding condition for all subjects. Response rate is plotted on logarithmic coordinates which facilitates the assessment of relative change in each schedule, an essential feature of Nevin's approach. That is, if the slopes of the functions relating FI and VI performance are the same, the relative degree of change is equal regardless of the baseline rate. Steeper slopes indicate relatively more rapid decreases in response rate. For Birds 54, 19, and 20, VI performance was generally more affected by free feeding than was FI performance. For Bird 53, no consistent difference emerges.

Figure 2 shows the rate of responding on logarithmic coordinates during extinction. No differences between slopes in the fixed and variable components are apparent.

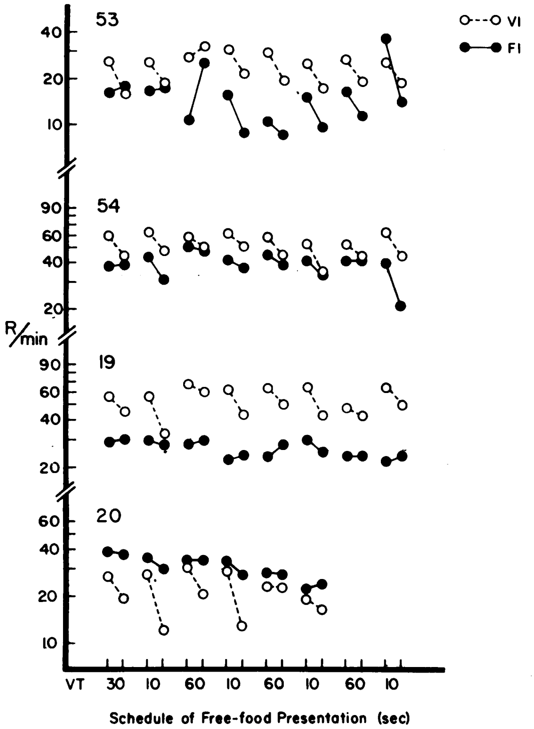

Fig. 1. Response rate on a logarithmic scale during free-feeding sessions. The first point in each function represents the mean of five preceding baseline sessions.

Because fixed-interval performance can be viewed as consisting of two components, an initial pause followed by a period of rapid responding, it was felt that an analysis of each of these components separately, rather than on the average, might reveal consistent patterns of differences in the disruptibility of performance maintained by FI and VI schedules. It is possible, for example, that free food might decrease both pause length and run rate in the FI component with the result that overall response rate would remain the same. It might also be noted that although response strength theory makes no explicit predictions about the effects of disruptive operations on periods of non-responding, it is not implausible to suggest that pauses are themselves operants, and therefore amenable to such analyses. That is, the degree to which pause times are altered by a disruptive operation may reflect something about the value of the conditions which maintain pausing.

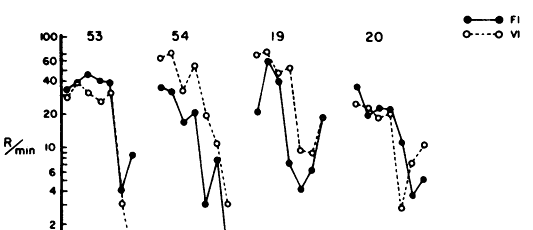

Fig. 2. Response rate on a logarithmic scale during extinction sessions. The first point in each function represents the mean of five preceding baseline sessions.

In Figure 3, the length of the cumulative pause time during free-feeding sessions is plotted as a proportion of the median pause time during the last 5 days of baseline. This proportion was determined by dividing the cumulative pause time on a given session by the sum of that pause time plus the median pause time during the last five days of baseline. A proportion of .5 represents no change in pause length on a given session, from pause length obtained during baseline. Proportions above .5 represent increases in total pause time, and, conversely, proportions below .5 represent decreases in total pause time. Relative changes in latency during the fixed components are plotted as a function of relative changes in latency during the variable component. In all but five cases, pause times in the VI components were increased by satiation by a factor of at least 1.2. In 7 out of 16 cases, pause times in the FI component were reduced by satiation; in 6 they were increased; and in 2 they were unchanged. Thus, taken

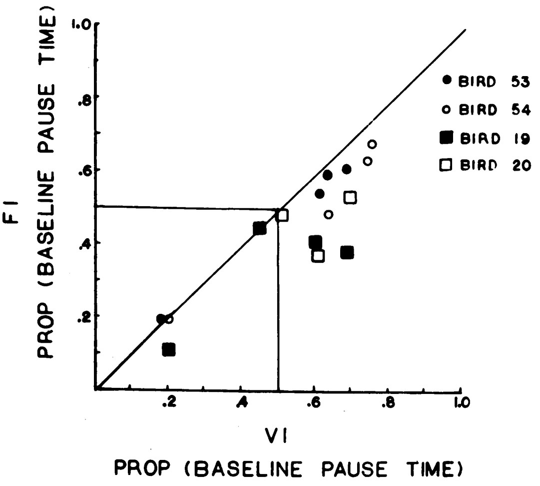

Fig. 3. Proportion of median cumulative pausetime during last five sessions of baseline [pausetime$_{(\text{session } x)}$/(pausetime$_{(\text{session } x)}$ + median baseline pausetime)] for FI component as a function of the proportion of cumulative pausetime for VI component. Each point represents one session of free feeding.

as a whole, relative pause times in the FI component were affected in a less consistent manner by manipulations in satiation than were relative pause times in the VI component. These data do not support the suggestion that relative changes in average response rate during the FI component were produced by systematic interaction of changes in pause time and run rate.

In summary, then, there is a suggestion that VI responding is more easily disrupted than FI responding, both in terms of decreasing response rates and in increased latencies to respond, but there is no evidence of any consistent differences in the rate of response reduction during extinction. This analysis then, did not reveal any indication that FI performance was weaker than VI performance, as might have been expected from the concurrent-chain preference literature. These data are consistent, however, with Carlton's work, described above. In order to further check the reliability of this finding, additional experimentation was undertaken to determine whether it was possible to produce a situation in which FI responding would show lower resistance to disruption than VI responding.

EXPERIMENT 2

The purpose of this work was to establish a set of conditions which reliably produced differences in response strength between FI and VI schedules of equal mean length. To this end, Experiment 1 was repeated with a number of modifications selected on the basis of a priori notions about the relations between response strength and the conditions which maintain behavior. Specifically, the following changes were made: (a) the average value of the terminal links was shortened in order to increase the number of exposures to the schedule contingencies; (b) because the properties of the normally-distributed VI schedule were largely unknown, this schedule was abandoned and replaced with a random-interval schedule. (The random-interval schedule is produced by making reinforcement available after a fixed time (*t*) with some probability (*P*). Such a schedule has the advantage that changes in P and t enable relatively easy manipulation of the distributions of inter-reinforcement intervals.); (c) ITI length was increased to produce maximal separation between FI and VI components; (d) component length was decreased. Shimp and Wheatley (1971) and Todorov (1972) have demonstrated that, when the components of a multiple schedule are shortened, relative response rate differences between components are enhanced. If relative response rate and response strength are influenced by similar factors, then shortening components would increase the chances of producing reliable differences in response strength.

In addition to the partial replication of Experiment 1, a concurrent-chains procedure was administered. This was intended to determine whether the typical preference for VI schedules would be obtained using parameters identical to those used in the response-strength assay.

METHOD

Subjects

Three White Carneaux pigeons with extensive experimental histories served. Food and water maintenance conditions were as in Experiment 1.

Apparatus

As in Experiment 1.

PROCEDURE

Subjects were trained to peck keys on a two-component multiple schedule. When the left key was red, reinforcement (3-sec access to grain) was available on an FI 15-sec schedule. When the right key was green, reinforcement was available on a random-interval (RI) 15-sec schedule of the type designed by Millenson (1963). In this schedule, a 3-sec time base was used, and a probability generator established the availability of reinforcement with a probability of .20.

The length and number of components and the length of the ITI were changed three times during the study. A summary of conditions is presented in Table 2. In Condition 1, component length was 3.5 min, and the ITI was 30 sec. In Condition 2, the ITI duration was increased to 2.5 min. In both these conditions, eight components completed a session. In Condition 3, component length was reduced to 1 min, ITI length to 30 sec, and component number was increased to 30.

After 65 sessions of training in Condition 1, three free-feeding sessions were administered

Table 2

Experiment 2: Summary of Conditions

Condition	*No. of days*	*Schedule value*	*ITI length*	*Component length*	*No. of components*	*Schedule class*
I	65	15 sec	30 sec	3.5 min	8	mult
	1	Free feeding—7 day intervals—VT 3 min				
	1	Free feeding—7 day intervals—VT 1 min				
	1	Free feeding—7 day intervals—VT 10 sec				
IIA	12	15 sec	2.5 min	3.5 min	8	mult
	9	Free feeding—VT 10 sec				
B	15	15 sec	2.5 min	3.5 min	8	mult
	variable	Extinction				
C	6	15 sec	2.5 min	3.5 min	8	Conc-chain
IIIA	42	15 sec	30 sec	1 min	30	mult
	3	Free feeding—7 day intervals—VT 10 sec				
	3	Free feeding—7 day intervals—FT 1 sec				
B	5	15 sec	30 sec	1 min	30	mult
	variable	Extinction				

at 7-day intervals. On these sessions, the grain magazine was presented during the ITI, for 3 sec, according to the following schedules: VT 3-min, VT 1-min, and VT 10-sec.

Training in Condition 2 was then given for 12 days, following which 9 consecutive free-feeding days were programmed. Free food was administered during the ITI on a VT 10-sec schedule. During these 9 sessions, a gradual increase in the subjects' body weights occurred.

Following 15 additional days of training, extinction was instituted. During extinction, sessions were conducted as usual, but reinforcement was withheld. Extinction continued until 1 hr had elapsed with no responses emitted.

Between Conditions 2 and 3, a concurrent-chain schedule was instituted for six sessions. The terminal-link schedules were identical to those previously programmed in the multiple schedule in Condition 2. Access to either of the two terminal links depended on responding during the initial link of the chain, in which both keys were illuminated with white light. During the initial link, responses on the left key produced the FI 15-sec schedule, and responses on the right key produced the RI 15-sec schedule. Access to either terminal link was available on two independent VI 20-sec schedules for pecks on the two keys during the initial links.

In Condition 3, free-feeding sessions were immediately instituted at 7-day intervals. On free-feeding sessions, the grain magazine was presented during the ITI according to either a VT 10-sec or a fixed time (FT) 1-sec schedule. Three determinations were made at each schedule value. After 5 additional days of training, extinction was administered as in Condition 2.

RESULTS AND DISCUSSION

At the end of training, performance was relatively stable for all birds. In Table 3, the median and the range of responding during 5-day blocks of training (a) prior to free feeding in Condition 1, (b) prior to free feeding in Condition 2 and, (c) at the start of Condition 3 are shown. For Birds 82 and 85, VI response rate was generally higher than FI response rate, although this was not true of Bird 82 in Condition 3. For Bird 90, FI response rate was consistently higher than VI response rate. In columns 3 and 4 of Table 3, the median and range of the latency to respond at the start of a component and following a reinforcer are presented. There was at least a fivefold difference in cumulative pause time between the FI and VI schedules. This demonstrates clear differentiation between the temporal patterns of responding controlled by the schedules.

In Figure 4, the rates of responding are shown on a logarithmic scale during the free-feeding sessions and the preceding baseline sessions of Conditions 1 and 3. In most cases,

Table 3

Median and range of response rate and cumulative response latency for three five-day blocks of baseline.

		Response rate (R/min)		*Response latency (in sec)*	
Subject	*Component*	*Median*	*Range*	*Median*	*Range*
82	FI	95.9	79.1-108.6	488.5	422.1-553.6
	VI	109.3	96.7-120.1	67.0	45.0- 87.8
	FI	97.1	71.5-102.2	481.8	445.5-518.2
	VI	123.3	102.7-129.7	82.3	72.4-103.2
	FI	137.0	124.2-146.1	370.7	293.1-455.8
	VI	137.0	134.4-142.9	64.7	55.7- 74.0
85	FI	59.5	50.2- 65.6	567.5	512.7-615.5
	VI	90.0	77.4-101.7	76.3	61.9- 89.5
	FI	66.5	51.9- 79.6	588.6	537.5-643.0
	VI	92.9	84.0-101.1	82.8	75.7- 93.5
	FI	60.4	54.7- 68.6	432.3	369.2-549.3
	VI	93.8	77.0-102.7	82.0	78.0-100.8
90	FI	106.2	92.9-116.6	548.2	512.6-606.9
	VI	94.6	81.9-120.1	66.1	54.6- 76.1
	FI	109.0	102.6-116.6	539.8	457.2-625.9
	VI	80.0	71.4- 89.9	84.5	81.7- 96.0
	FI	119.1	113.2-130.6	512.3	473.6-548.4
	VI	100.1	91.9-172.1	78.4	57.1- 91.5

free feeding resulted in a decrease in rate, which was greater in the VI component for Bird 82 and nondifferential for Bird 85. Bird 90 showed slightly larger changes in the FI component.

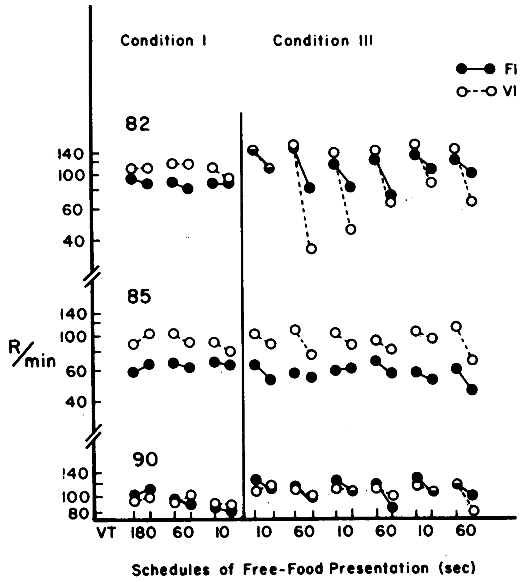

Fig. 4. Response rate during free-feeding sessions for Conditions 1 and 3 on a logarithmic scale. The first point in each function represents the mean of five preceding baseline sessions.

In Figure 5, the absolute rates of responding are plotted for the consecutive free-feeding sessions of Condition 2. Birds 82 and 90 show a more rapid decrease in FI than VI response rate. That is, the slopes of the functions are steeper for FI than for VI performance. For Bird 85, however, VI responding was reduced more drastically than was FI responding.

Figure 6 represents the absolute rate of responding during the extinction phases of Conditions 1 and 3. For Bird 90, FI performance extinguished faster than VI performance. For Birds 82 and 85, however, no consistent differences in resistance to extinction are apparent.

In Figure 7, the relative change in the length of the postreinforcement pause in the FI component is shown as a function of the relative change in pause time in the VI component during the free-feeding sessions of Conditions 1 and 3. As in Experiment 1, increases in pause length are generally observed in the VI components whereas changes in FI pause length are very small and less consistent in direction. Thus, satiation does not seem to have had a separate effect on pause length and run rate in the fixed-interval schedule.

Finally, in Figure 8, the relative rates of responding in the initial and terminal links of the concurrent-chain schedule are presented.

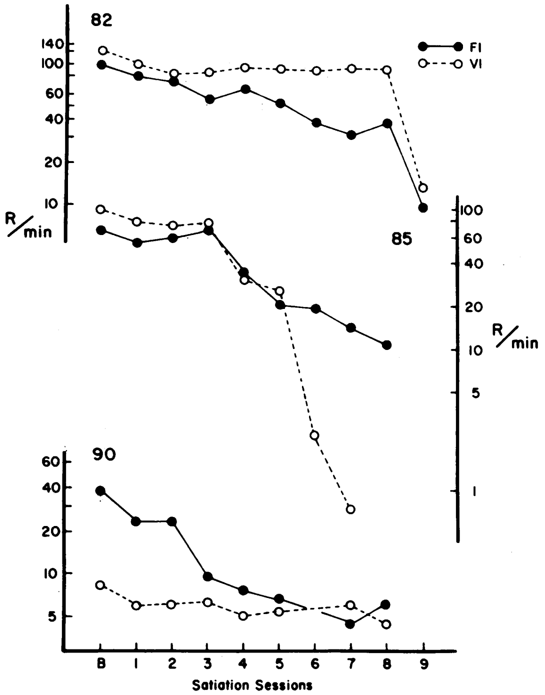

Fig. 5. Response rate, on a logarithmic scale, during satiation sessions in Condition 2. The first point in each function represents the mean of five preceding baseline sessions. Bird 90 emitted no responses on session 6.

All three birds show extremely low relative rates of responding on the initial-link key which gives access to the FI schedule. This is in accord with earlier literature, although the magnitude of this effect is somewhat greater

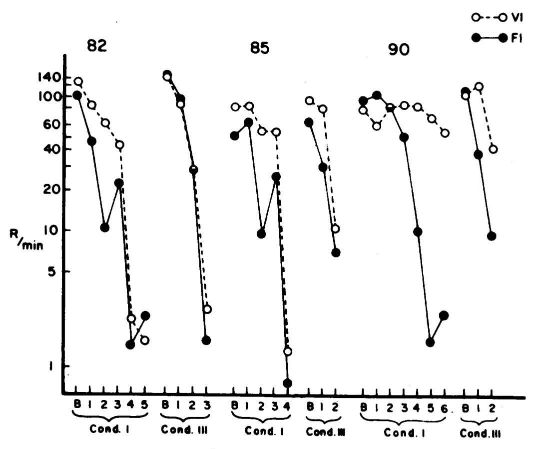

Fig. 6. Response rate, on a logarithmic scale, during extinction for Conditions 1 and 3. The first point in each function represents the mean of five preceding baseline sessions.

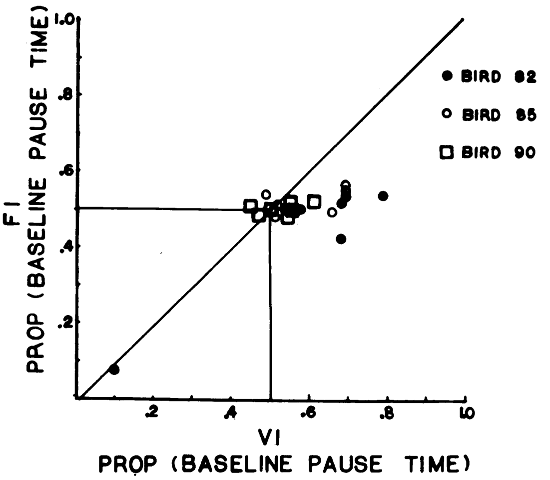

Fig. 7. Proportion of median cumulative pausetime during last five sessions of baseline [pausetime$_{(\text{session } x)}$/(pausetime$_{(\text{session } x)}$ + median baseline pausetime)] for FI component as a function of the proportion of cumulative pausetime for VI component. Each point represents one session of free feeding.

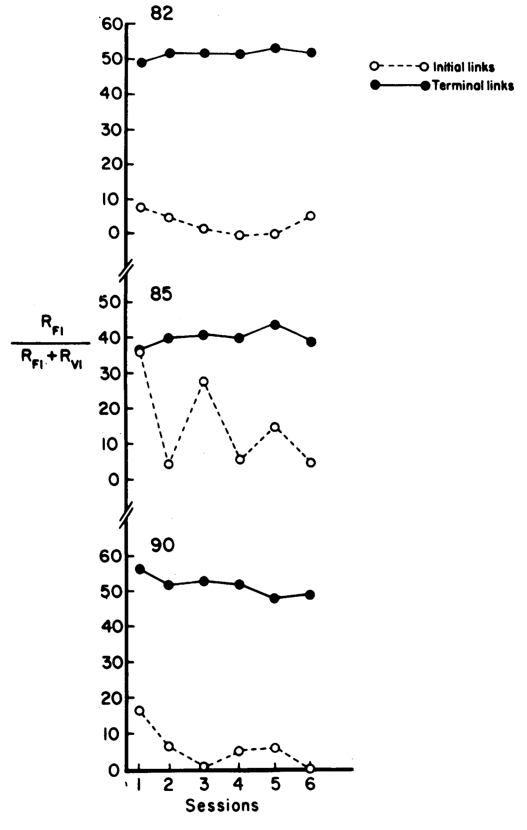

Fig. 8. Relative response rate in FI component during initial and terminal links of a concurrent-chain schedule.

than previously reported (e.g., Herrnstein, 1964) perhaps because of differences in initial-link lengths in earlier and the present work (cf. Fantino, 1969). Terminal link response rates, however, were approximately equal.

An examination of the resistance-to-change measure across subjects and operations shows no consistent differences despite the clear-cut differentiation in temporal patterns of responding (i.e., pause time) and despite the very strong preferences demonstrated for the VI schedule during the initial link of the concurrent chain. These data suggest that when the average rate of reinforcement is constant across fixed and variable schedules, the two schedules are equally "valued." This result is not consistent with the results obtained in studies of preference which would lead one to expect lower "value" and consequently weaker performance in the fixed-interval component. It is possible, however, that the failure to demonstrate consistent differences in response strength between FI and VI schedules in the two previous experiments occurred because comparisons were made across schedule types which support different temporal patterns of responding. Nevin (1974) reported differences in resistance to change using differential-reinforcement-of-low-rate (DRL) and differential-reinforcement-of-high-rate (DRH) schedules in which the frequency of reinforcement was equated. Therefore, in Experiment 3 a situation was arranged in which chain schedules terminating in FI and VI schedules of equal mean length were presented successively. Rather than comparing response strength across asymmetrical schedules, response strength was examined in the identical initial-link schedules.

EXPERIMENT 3

In order to eliminate the possibility that differences in response strength were obscured by differences in response patterns, Experiment 3 examined response strength in the initial links of chain schedules terminating in fixed and variable interval schedules of equal mean length. This procedure entails the assumption that initial-link responding which is maintained by less favorable conditions of reinforcement in the terminal link will show less resistance to change than initial-link responding maintained by more favorable conditions in the terminal link. The plausibility of this assumption is suggested by several studies in which simple chain schedules are disrupted by some operation such as satiation (Ferster & Skinner, 1957; Fischer & Fantino, 1968; Malott, 1966) or extinction (Catlin & Gleitman, 1973; Fantino, 1965). In the simple chain schedule, initial-link responding is presumably maintained in part by the reinforcing consequences produced during the terminal link. Initial-link responding might be supposed to be weaker than terminal-link responding because the delay of reinforcement is greater in the initial link than in the terminal link. All but two of the studies reported above support this assumption. The exceptions were (a) a study by Fischer and Fantino (1968) in which satiation was found to produce equivalent rates of disruption in the initial and terminal links of a chain schedule after prolonged training; and (b) a study by Fantino (1965) in which schedules of different types (ratio and interval) were used in the terminal and initial links, respectively.

The research described above simply shows that initial-link responding is proportionately more affected by disruptive operations than is terminal-link responding, consistent with notions about delay of reinforcement in general or Nevin's theory of response strength in particular. It does not address the question of whether the degree of disruption in the initial link is indeed a function of the maintaining conditions in the terminal link. Research on this question, in which chain schedules terminating in different rates and amounts of reinforcement are presented successively to subjects, suggests that this is the case. This research is currently being conducted by Nevin and me and has been presented, in part, at the meetings of the Eastern Psychological Association (Note 1) and in Nevin's review (1979). Presently, we assume that the relative degree of disruption in the initial links of two chain schedules would covary with the relative value of the maintaining conditions in the terminal links.

It is important, at this point, to consider the rationale for the use of sequentially arranged rather than concurrently arranged chain schedules. Although it is possible to assess shifts in response strength in concurrent schedules, the analysis is complicated by the fact that exposures to the contingencies of reinforcement are not necessarily equal in the concurrent schedule because they are determined by the subject rather than the experimenter. Moreover, the computation of response rate in concurrent schedules is less straightforward than in multiple schedules because both local response rates and time engaged in responding vary simultaneously in the former. Therefore, for the sake of ease in analysis as well as a desire to relate the present work to earlier work on response strength, multiple rather than concurrent-chain schedules were employed.

In Experiment 3, response strength in multiple-chain schedules was analyzed with four terminal-link schedules (20, 40, 80, 160 sec). Using concurrent-chain schedules, Duncan and Fantino (1970) and McEwen (1972) report that when the absolute length of two terminal-link schedules is increased while the relative length is held constant, an enhancement of preference for the shorter schedule results. This result is consistent with Fantino's (1969) model of choice in concurrent-chain schedules. In this model, the relative rate of initial-link responding is seen as dependent on the relative amount of reduction in total time to reinforcement produced by entry into the terminal links. As terminal-link schedules assume a larger proportion of the total time to reinforcement (that is, as the absolute length is increased while initial-link length remains constant), the ratio of terminal-link schedule values becomes an increasingly potent determiner of the relative rate of initial-link responding.

In the present research, relative response rate in the initial links of multiple-chain schedules is examined to determine whether the rate of responding in the initial link providing access to the FI schedule is lower than that in the initial link providing access to the VI schedule, as is customarily the case with concurrently arranged chain schedules. Moreover, differences in initial-link response rates are expected to increase with increasing terminal-link schedule value, as in the concurrent-chain schedule. Finally, response strength is assessed in the initial links of the chain schedules. If preference in a concurrent-chain situation and response strength are indeed related, then observed differences in response strength should be enhanced with increasing schedule length.

In the final condition of this experiment, a signaled period of nonreinforcement was inserted during the first two-thirds of each interval of the VI schedule. That is, following each reinforcement in the VI component the keylight was illuminated with a yellow light, which signaled a period of nonreinforcement. The duration of this period was precisely two-thirds of the duration of the programmed interreinforcement interval. At the completion of the nonreinforcement period, the keylight was illuminated with green light. The green light remained on until the next reinforcer was collected. The value two-thirds was chosen to approximate the average pause length on FI schedules (Schneider, 1969). It was believed that the addition of a discriminable period of nonreinforcement at the start of each VI reinforcement interval would produce patterns of responding which approximated those obtained on FI schedules. In this manner, the contribution of response pattern to the relative initial-link response rate could be assessed.

METHOD

Subjects

Four Silver King pigeons with experimental histories of autoshaping served. Maintenance conditions were as in Experiments 1 and 2.

Apparatus

A Lehigh Valley #1519c three-key pigeon chamber and standard electromechanical programming equipment were used. A fan provided masking noise and ventilation.

Variable-interval tapes were based on an arithmetic progression of intervals. In the VI 20-sec schedule, the intervals ranged from 5 to 35 in 5-sec steps. In the 40-, 80-, and 160-sec conditions, each interval was multiplied by the appropriate constant value. Each tape contained three randomized blocks of intervals.

PROCEDURE

Subjects were trained on a two-component multiple schedule. Each component consisted of a two-member homogeneous response chain, performed either on the left key (FI component) or on the right key (VI component). Initial links were signaled by red keylights, and terminal links by green keylights. Responding during an initial link gave access to the associated terminal link according to two independent VI 20-sec schedules. Responding in the terminal link produced reinforcement (3-sec access to grain) on either an FI schedule on the left key or a VI schedule on the right key. The average value of the terminal-link schedules was varied, while the mean length of the schedule intervals was maintained, over a series of conditions as follows: 20, 40, 80, 160, and 80 sec. A session was composed of 40 components presented in regular alternation. Completion of the chain, followed by receipt of a reinforcer, terminated the component. During the 160-sec condition, a time limit of 120 min was imposed on session length.

Each condition consisted of 30 experimental sessions, a test for resistance to satiation (see below), 6 additional experimental sessions, and a test for resistance to extinction (see below). The following exceptions to this pattern were made: in the 40-sec condition, an additional test for resistance to satiation was administered, separated from the first by six experimental sessions. Neither test was administered after the final 80-sec condition.

Resistance to Satiation

During testing, subjects were continuously exposed to the maintenance schedule conditions until 1 hr had elapsed with no responses emitted. Data were recorded after each set of 40 components, or, in the 160-sec condition, after 120 min had elapsed. Beginning with the second test in the 40-sec condition and continuing thereafter, 25 g of grain were given in the home cage 1 hr before testing. It was hoped that this procedure would shorten the testing period and produce more gradual changes in response rate.

Resistance to Extinction

Sessions were conducted daily, exactly as in training, with the exception that reinforcement was withheld and session length was limited to 120 min. That is, completion of each link of the chain depended on responding just as in training. Component changes were scheduled as before. Testing was continued until 1 hr had elapsed with no responses emitted.

Signaled Reinforcement

In the final condition, the availability of reinforcement in the terminal link of the VI component was signaled by a change in key color from yellow to green, two-thirds through each programmed interval. The average value of the terminal-link reinforcement schedule during this condition was 80 sec. Twenty-eight experimental sessions were completed and no further tests were run.

Table 4

Median cumulative latency to respond (in sec) in terminal links of multiple chain schedule.

	20		*40*		*80*		*160*	
S	*VI*	*FI*	*VI*	*FI*	*VI*	*FI*	*VI*	*FI*
1	1	17	2	20	24	277	123	296
2	0	7	4	28	73	103	17	24*
3	9	34	19	91	100	118	123	420
7	1	53	11	162	38	410	62	135

*This subject completed very few sessions, thus these points are based on only 2 or 3 exposures.

RESULTS AND DISCUSSION

At the end of each training condition, responding appeared stable for all subjects. Differential control by the terminal-link schedule was evidenced in the longer latency to respond at the start of the FI terminal links. Table 4 shows the median cumulative pause length during the last five days of training in each of the first four conditions. Latencies were computed by recording the time from the onset of the terminal link to the occurrence of the first response. Occasionally, a burst of responding which began in the initial link would carry over to the terminal link and disenable the latency timer. For this reason, latency data might be regarded as somewhat attenuated. Nonetheless, in every condition pause times are considerably greater in the FI component than in the VI component.

In Figure 9, the average rates of responding for the last five days of each training condition are plotted on a logarithmic scale as a function of terminal-link schedule value. The replication data for the 80-sec condition are plotted separately and circled. Initial-link responding is shown in the lower panel and terminal-link responding in the upper panel. In all cases, response rate is lower in the initial link than in the corresponding terminal link. In most cases, reducing the reinforcement density in the terminal links resulted in a reduced rate of responding in both components. (Several reversals of this trend can be seen in this figure.) Terminal-link responding does not appear to be affected differentially by this operation, and initial-link responding shows a far greater reduction in the FI component. This is

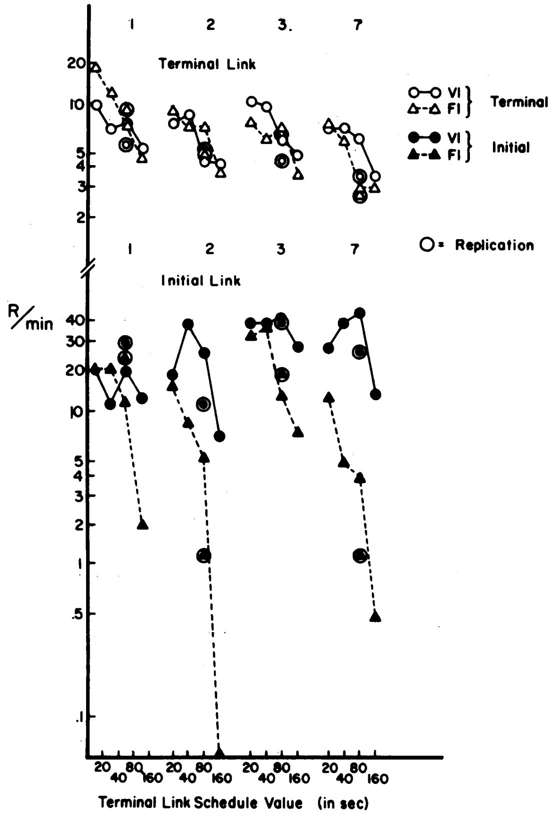

Fig. 9. Response rate, on a logarithmic scale, in initial and terminal links of a multiple chain schedule, as a function of terminal link value. Each point represents last five days of training at each schedule value. Circled points represent replication of 80-sec condition.

consistent with data obtained using concurrent-chain schedules. In Figure 10, rate of responding in the FI component relative to total responding is plotted for initial and terminal links, as a function of schedule value. Since the relative rate of reinforcement remained constant in all conditions, relative rates of responding in the initial links should be constant if a single multiplicative relation exists between schedules. Clearly this is not the case for initial links, which show a negative slope, although it may be the case for terminal links. Such a finding is consistent with data relating relative rate of initial-link responding to terminal-link schedule value in concurrent-chain schedules (Duncan & Fantino, 1970; McEwen, 1972) and with Fantino's (1969) model of choice performance in the initial links of concurrently-arranged chain schedules.

In Figure 11, the results of the resistance-to-satiation test are presented. The first point in each function represents the average rate of response on the last five days of training. Although 5 to 10 sessions were required before the response criterion was reached, only on the last 2 to 3 were systematic reductions in response rate obtained. The remaining three points in each function, therefore, represent the three final sessions in which at least four components were completed. The number of sessions given is shown on the abscissa. In all but the 20-sec condition (see Birds 3 and 7), satiation consistently disrupted initial-link performance (lower panel) more than terminal-link performance (upper panel). While satiation did not disrupt terminal-link performance differentially, in the initial links, FI responding seemed more reduced than VI responding. Exceptions to this are seen in data for Bird 3 (Conditions 1 and 2) and Bird 7 (Conditions 1 and 2).

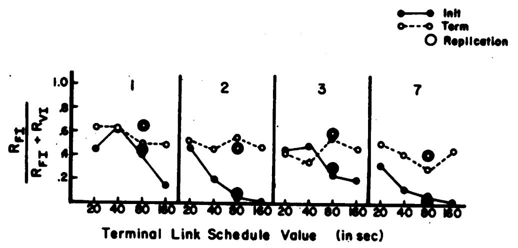

Fig. 10. Response rate in FI component relative to total responding in the initial and terminal links of a chain as a function of schedule value. Each point represents last five days of training at each schedule value. Circled points represent replication of 80-sec condition.

Figure 12 presents the results of the resistance to extinction tests. The first point of each function represents the average rate of responding on the five days of baseline preceding the extinction test. The other points represent the subsequent extinction sessions. Unlike satiation, extinction produced considerable disruption in terminal-link as well as initial-link responding. Extinction, however, produced no differential changes in fixed- or variable-interval performance in either the initial or the terminal links of the chain.

In Figure 13, relative changes in latency produced by satiation and extinction are shown for all conditions. On the ordinate, the proportion of baseline pause time in the FI condition is plotted as a function of the proportion of baseline pause time for the VI condition. In Conditions 1 and 2, satiation generally produced increases in pause time for both FI and

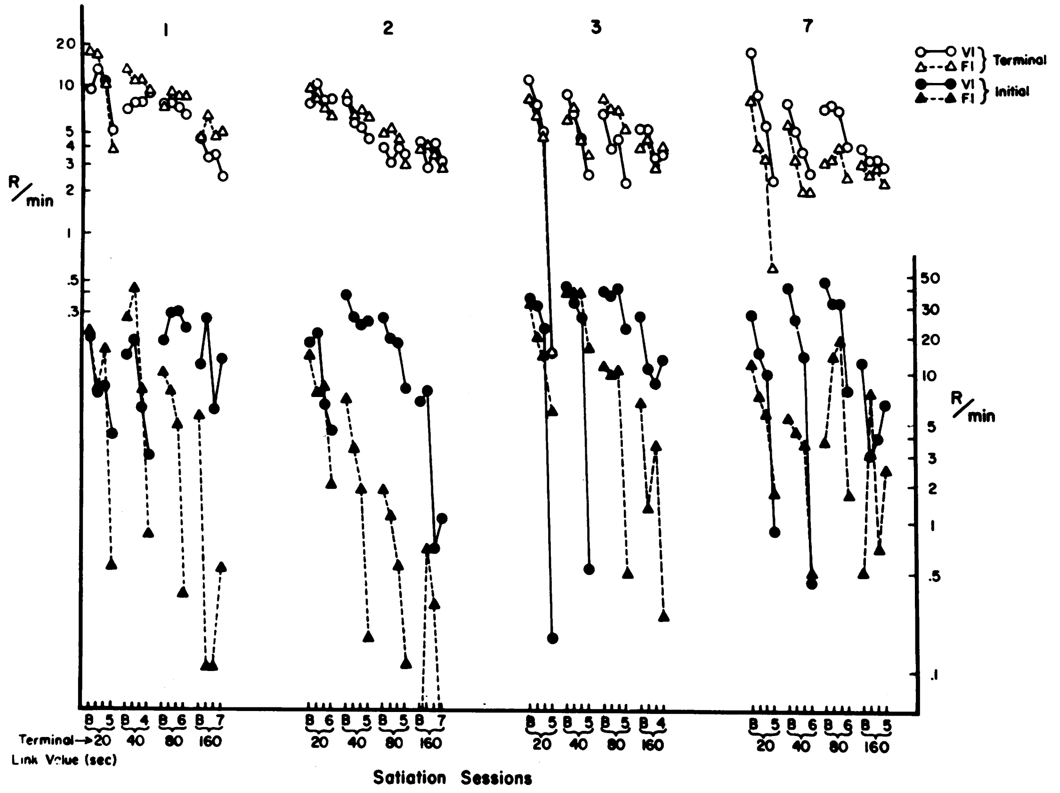

Fig. 11. Response rate, on a logarithmic scale, in initial and terminal links of a multiple chain schedule during satiation. The first point in each function represents the mean of five preceding baseline sessions. The number of sessions run is indicated on the abscissa under the last point in each function.

VI performances. Unlike the studies reported above, this increase was approximately equal for the FI and VI components. In the later conditions, however, the effect of satiation on pause time was more variable, showing occasional reductions in both FI and VI components. By comparing the number of points below .5 in the FI component with the number of points below .5 in the VI component, one can see that in more cases the FI pause time was reduced. This is an indication, perhaps, of a deterioration of schedule control on the longer schedules. During extinction, increases in pause times were consistently observed in the 20-sec condition for FI responding. The effect of extinction on VI pause length was to produce some increases and some decreases. With increasing schedule length, reductions of pause latency were observed. Again, if the number of points falling below equality is compared for each condition, a slightly greater number of reductions is found for the FI condition.

These data might suggest that under some conditions, terminal-link FI performance is somewhat more disruptible than VI performance, with decreases in pause length accompanying decreases in run speed. However, this effect is small and it would not account for the failure to find differences in initial-link response strength.

In view of the failure to obtain consistent differential reductions in response strength between schedule components, a comparison of resistance-to-change was made across conditions in order to ascertain whether the results of this study were at all consistent with predictions based on Nevin's theory of response strength. That is to say, if orderly relations in resistance to change and schedule value were observed across conditions, then the procedure presumably was not insensitive to schedule manipulations and greater confidence could be placed in the negative finding between fixed and variable components. Figure 14 presents the relative change in initial-link

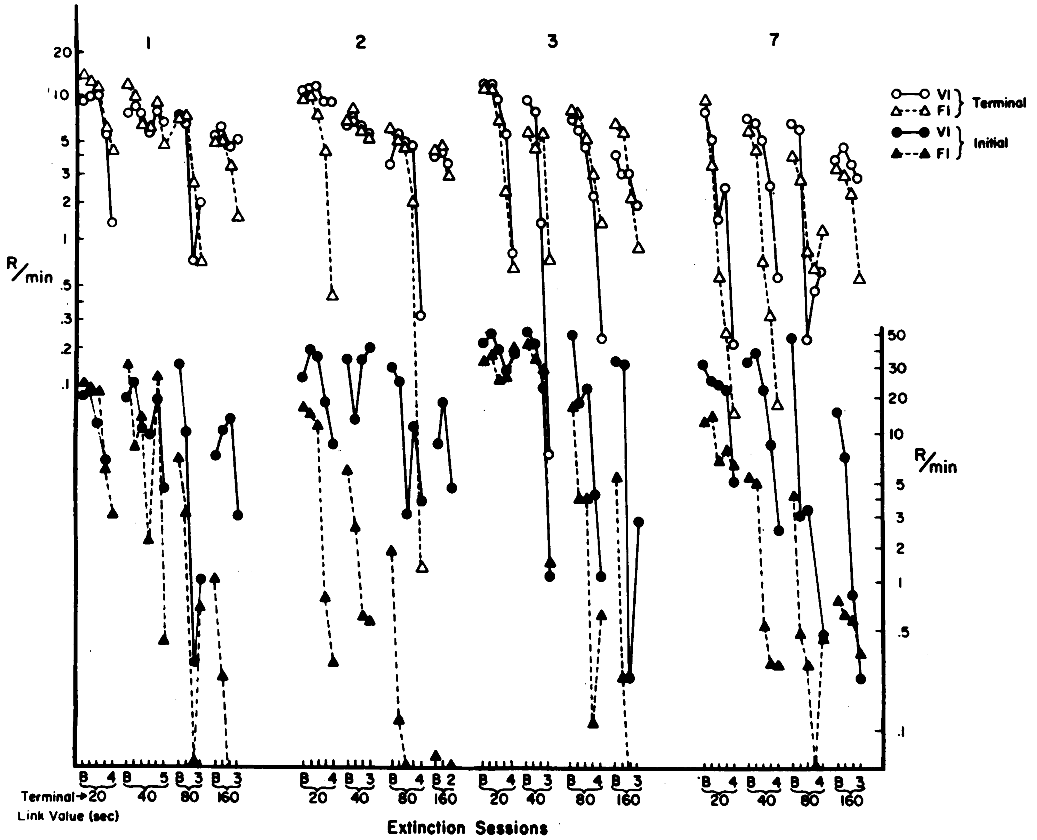

Fig. 12. Response rate, on a logarithmic scale, in initial and terminal links of a multiple chain schedule during extinction. The first point in each function represents the mean of five preceding baseline sessions. The number of sessions run is indicated on the abscissa.

responding from baseline over sessions of extinction. Solid, dotted, and dashed functions represent the 20-, 40-, and 80-sec conditions, respectively. With no exceptions, the dashed functions (80 sec) fall below the solid functions (20 sec), indicating relatively less resistance to extinction. The relation between the 40-sec condition and the other two is less consistent but, for most comparisons, falls between the other two. This is the ordering which would be anticipated if resistance to disruption is related to terminal-link schedule value. The unconnected triangles represent the 160-sec condition. As a result of the extremely low rates of responding in this condition, these data are somewhat less reliable. Very small absolute deviations in rate produce large relative changes in the ratio of extinction to baseline responding. It might be noted, however, that for three of the four pigeons, fewer sessions were required to reach the criterion of nonresponding in this condition than in the others. For Bird 1, both the 80- and 160-sec conditions required fewer sessions to criterion than the 20- or 40-sec conditions. Thus, although such an analysis was not originally intended, it demonstrates that resistance to change is related to terminal-link schedule value in a reasonably orderly way, as Nevin's theory would suggest.

Finally, the 80-sec condition was repeated, and a signaled period of nonreinforcement was added to the terminal link of the VI component. It was believed that this signaled period of nonreinforcement would make the VI schedule more comparable to the FI schedule and produce a relative decrease in VI initial-link performance. Good stimulus control was attained by key color in the terminal link. The rates of responding in the signaled and unsignaled portions of the terminal link [labeled (1) and (2), respectively] are presented in columns 8 and 9 of Table 5.

Despite the decrease in response rate during the initial portion of the terminal-link VI component, no consistent increase in relative

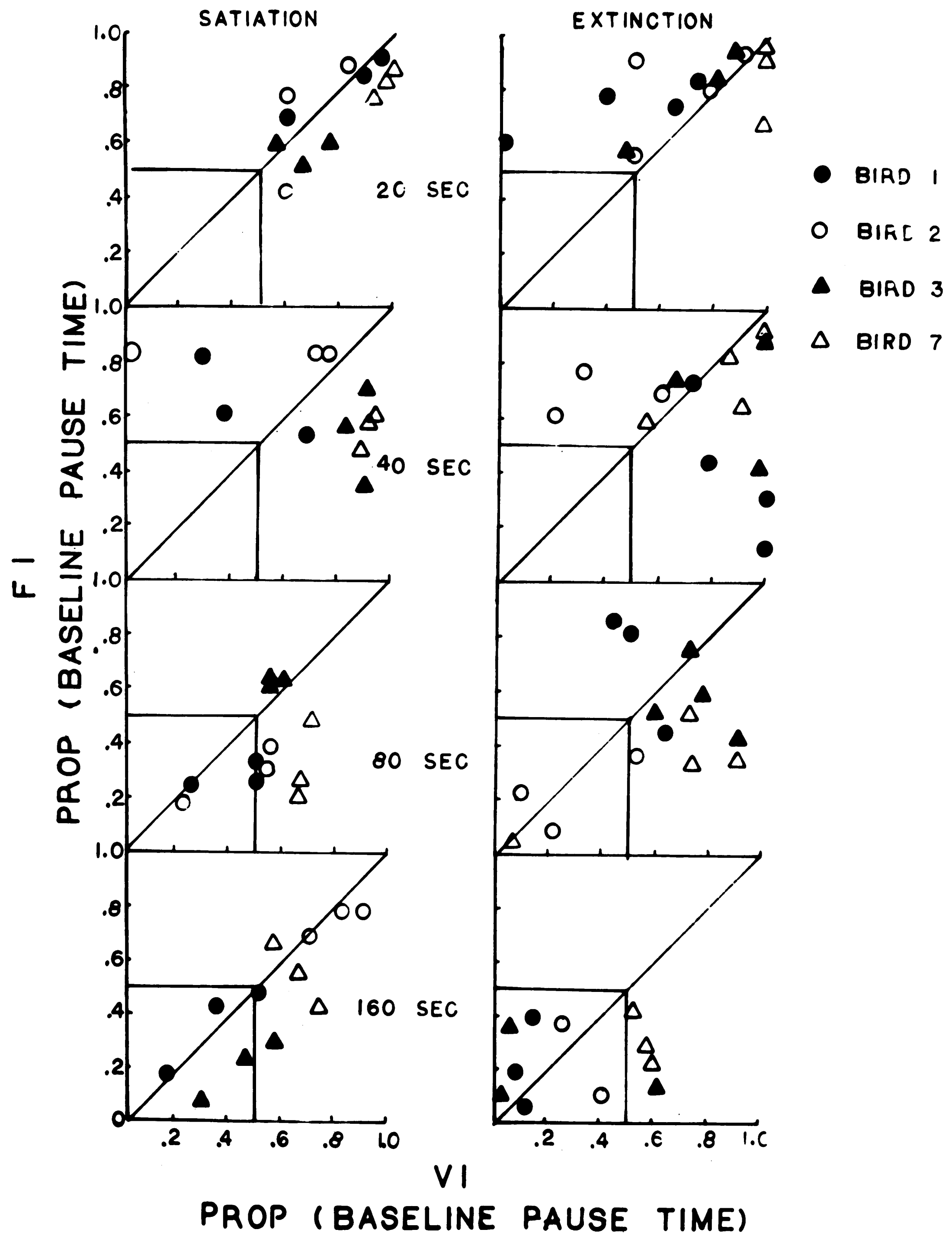

Fig. 13. Proportion of median cumulative pause time during last five sessions of baseline [pause $time_{session}$ x/ ($pausetime_{session}$ x + median baseline pausetime)] for FI component as a function of the proportion of cumulative pausetime during baseline for VI component for each session of free feeding (left column) and extinction (right column).

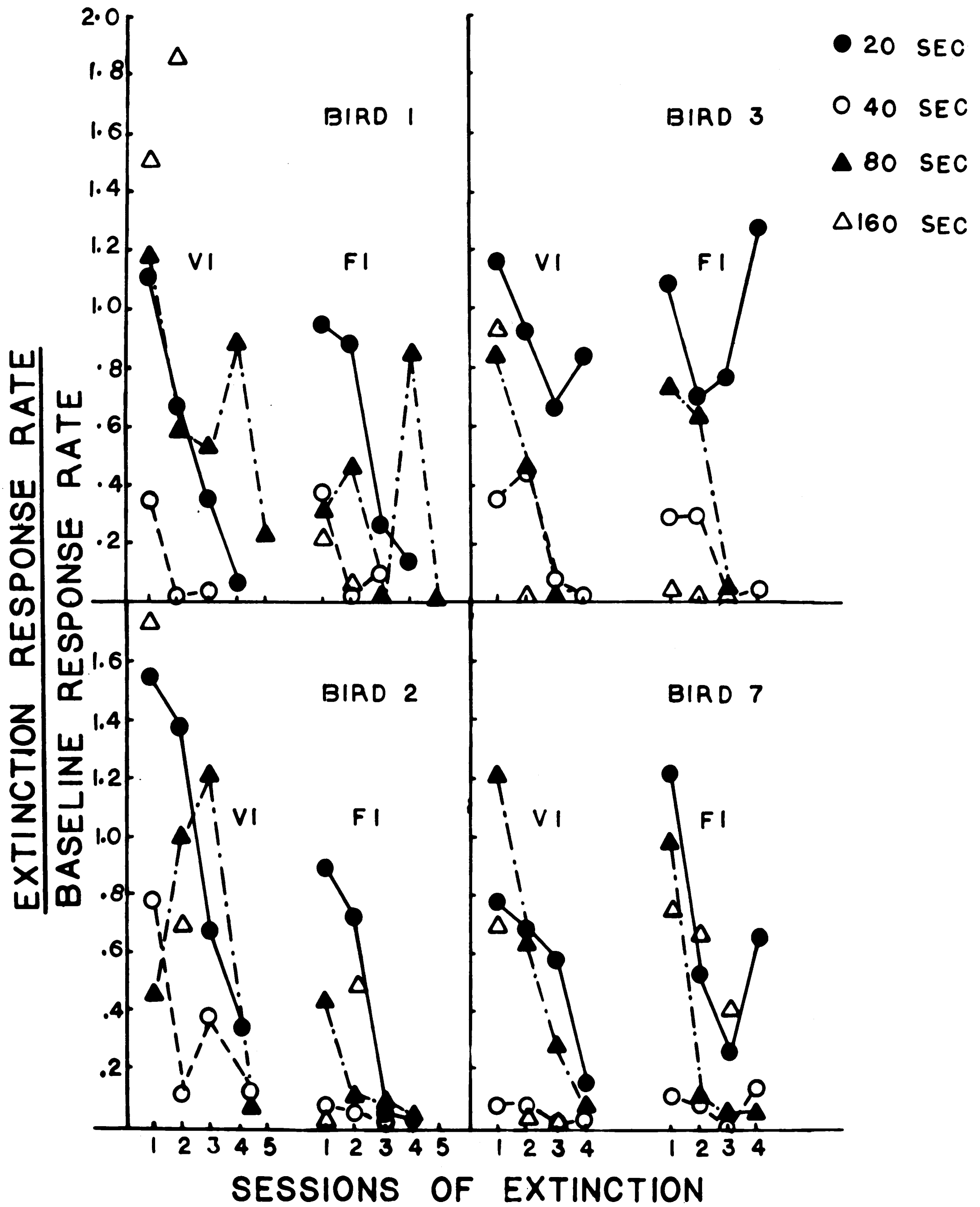

Fig. 14. Initial-link response rate during extinction expressed as a ratio of the response rate on the last five sessions of baseline for each schedule condition.

initial-link FI response rate occurred (see columns 6 and 11 of Table 5). These findings may be related to earlier work by Duncan and Fantino (1972) and Schneider (1972). Duncan and Fantino found that pigeons preferred a simple FI schedule to one which was composed of two chained FI components, despite the fact that overall component length was equivalent. This suggests that, in the present study, converting the VI into a two-member schedule should have resulted in a reduction of the relative rate of VI initial-link responding with respect to the previous unsignaled condition. The present results, however, are more com-

Table 5

Rate of response (R/min) during equivalent unsignaled and signaled reinforcement conditions. Relative response rate in FI components during initial links is shown in columns 6 and 11.

	UNSIGNALED					SIGNALED					
	VI		*FI*			*VI*			*FI*		
Subject	*Init.*	*Term*	*Init.*	*Term*	*Init.FI* / *FI + VI*	*Init.*	*Signaled Term*		*Init.*	*Term*	*Init.FI* / *FI + VI*
							(1)	(2)			
1	28.8	55.0	23.4	98.4	.45	27.0	.6	129.0	4.8	102.0	.15
2	12.0	54.0	1.2	46.8	.09	24.6	1.8	70.2	1.8	45.0	.07
3	40.2	44.4	18.0	67.8	.31	28.8	.6	57.6	9.0	77.4	.23
7	26.0	36.0	1.2	27.0	.04	7.8	1.8	70.2	1.9	34.2	.19

patible with J. W. Schneider's work, in which no preference was reported between chain and tandem schedules. Schneider compared chain and tandem schedules in which the individual components were of variable length. Both schedules were composed of two links, the second of which produced primary reinforcement. Only in the chain schedule, however, was the initial link signaled by a discriminative stimulus. Following Schneider's results, then, the addition of an initial period of nonreinforcement should not alter the rate of responding in the initial link of the VI chain with respect to the previous unsignaled condition, as was, in fact, the case.

In summary, the present data provide no strong evidence that differences in temporal patterns of reinforcement produce differences in the resistance of responding to disruption in either the initial or terminal links of a multiple chained schedule. This is consistent with the results reported in Experiments 1 and 2. These data suggest that FI and VI schedules with equal mean reinforcement rates are equally "valued."

Although the patterns of behavioral disruption obtained in tests are not consistent with expectations based on preference data, the patterns of initial-link responding obtained with multiple-chain schedules are very similar to those obtained in concurrent-chain schedules. Specifically, increases in terminal-link schedule length reduced initial-link responding relatively more when reinforcement was made available on a fixed- rather than a variable-interval schedule. Despite the constant ratio in the relative rate of reinforcement over the four schedule values, the relative rate of responding in the component giving access to the fixed schedule decreased. These results are compatible with Fantino's (1969) model which suggests that schedule preferences are enhanced as the absolute schedule length increases. Finally, this result appears to be unaffected by the addition of an initial period of signaled nonreinforcement in the VI schedule.

In the two earlier studies, analyses of changes in response latency indicate that latencies during the FI conditions are more stable and relatively less susceptible to systematic increases than are latencies in the VI condition. This may indicate that the pause in the FI component is actually a conditioned property of the behavior whereas pausing in the VI component may represent time engaged in unspecified behaviors which compete with pecking. Thus, pausing in the VI component might be more susceptible to motivational manipulations than is pausing in the FI component. It should be noted, however, that in previous research involving simple FI schedules, increases in pause time have been reported in response to satiation (Ferster & Skinner, 1957). This pattern was reversed in some conditions of Experiment 3, indicating, perhaps, a greater deterioration of schedule control in the FI component.

GENERAL DISCUSSION

Nevin's (1974) theory of response strength provides a way to characterize schedule value and response strength. None of the studies described here, in which different parameters and disruptive operations were used, provides any conclusive evidence of differential strength in periodic and aperiodic schedules of equal length. Examinations of response strength across conditions in which the terminal link schedule was varied show some evidence of orderly relations between schedule value and response strength. Therefore, one can interpret the data in two ways: (a) there is, in fact, no difference in the "value" of FI and VI schedules of equal mean length; or (b) the response-strength procedure used to assess schedule value was insensitive to differences in the value of the schedules. Therefore, it is important to consider whether differential response strength is typically observed using schedule values similar to those used in the present studies. In Nevin's original work (1974), which covered a range of values from VI 30-sec to VI 500-sec, reliable differences in response strength were obtained with concurrently available free food and extinction. Herrnstein and Loveland (1974) obtained similar results using multiple VI 1-min VI 4-min schedules with pre-feeding. Carlton's work, described earlier, used CRF in one component of a multiple schedule. Finally, in current work on multiple chained schedules, reliable effects have been obtained using terminal-link schedules ranging from VI 320- to VI 28-sec (Nevin, 1979). Thus, it is certainly the case that reliable differences in response strength have been obtained using schedules similar to those used here, in at least one component of a multiple schedule.

The negative results presented here take on significance when evaluated against the findings obtained and reviewed by Nevin (1979). They suggest that fixed- and variable-interval schedules of equal mean-reinforcement rate may in fact have equal "value," despite the strong differences in relative rate of initial-link responding obtained in Experiments 2 and 3 and by others using the concurrent-chain procedure. How, then, are the discrepancies between these two sets of data to be resolved? If response strength is viewed as representing the average value of the schedule, then preference must be seen as having some other determinants. It might be noted that concern about the use of concurrent-chain procedures as indices of schedule value comes from other sources as well: Navarick and Fantino (1972) report a series of studies which tested for transitivity between periodic and aperiodic schedules. In their procedure 1, they equated fixed and variable schedules in terms of concurrent initial-link responding. They then compared each of these schedules to a third schedule. Preferences for the third schedule were not found to be equal. In their procedure 2, they obtained fixed and variable schedules which were equally preferred to a third schedule. They then tested to see if subjects were indifferent between these two schedules. Indifference was generally not obtained. Navarick and Fantino suggest that this absence of transitivity indicates that no single rule is used by a subject in transforming an aperiodic schedule into its periodic equivalent. But it is also possible that transitivity fails to hold because the relative rate of responding in the initial links of a concurrent chain is not a "pure" index of preference. If this is the case, then attempts to scale the value of aperiodic schedules cannot be pursued exclusively in terms of relative-response rates in concurrent-chain schedules.

If average value is not the sole determinant of schedule preference, what then are the other possible determinants? It would appear that preference is not related to the temporal patterns of responding in the terminal links of the chain inasmuch as the addition of a discriminated period of nonreinforcement in the final condition of Experiment 3 produced no change in the relative rate of initial-link responding. Alternatively, it is possible that preference is determined by local probabilities of reinforcement. This alternative has been suggested by Gibbon (1977) in his work on scalar expectancy theory of timing. Gibbon suggests that responding is determined by a comparison of local to mean estimates of time to reinforcement. When this quotient exceeds a particular threshold value, responding emerges. In the fixed-interval case, the distribution of the subject's estimates of interreinforcement intervals can be assumed to be normally distributed, although strictly speaking this assumption is not necessary. In the variable-interval case, the subject's estimates of time to reinforcement are distributed in a positively skewed manner. This occurs because of the subject's use of scalar timing. Scalar timing implies that judgments of time are scale transforms of the estimates of one unit of time. A consequence of this process is that the variance of a subject's time estimates increases with the square of the mean of the interval being estimated. While relative timing efficiency remains constant as interval size increases, the absolute accuracy of the subject's

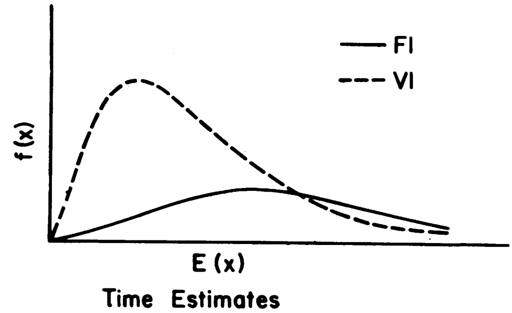

Fig. 15. Hypothetical distribution of estimates of time to reinforcement for fixed-interval (solid line) and variable-interval (dashed line) schedules. Dashed vertical lines represent individual intervals comprising variable-interval schedule. Solid vertical line represents expected value, which in this case is equal for the two distributions (from Gibbon, 1977).

timing decreases with interval size. When a series of different intervals is arranged, as in a variable-interval schedule, the resulting distribution of time estimates is a mixture of the distributions associated with each interval. Because each of these distributions becomes increasingly flatter and more variable than the next smaller one, the resulting distribution for the variable-interval schedule, as a whole, is positively skewed. (Figure 15 shows hypothetical distributions of time estimates associated with equivalent FI and VI schedules.) If the average interreinforcement interval of the VI schedule is set equal to that of the FI schedule, as was the case in the present experiments, then the expected values (or overall estimate of the time to reinforcement) of these two distributions of time estimates would be equal. The density of short estimates, however, would be far greater for the VI schedule. In Gibbon's theory, choice between schedules is seen as being determined by the ratio of two local estimates of time to reinforcement (or a likelihood ratio of times to reinforcement). Since the density of short estimates is greater for the VI schedule, a strong preference for the VI schedule should emerge. It is possible, however, that response strength, or resistance to change, is determined by the expected values of these distributions, which, in this case, are equal and should not produce differences in response strength. In other words, response strength is solely related to the average interval of reinforcement whereas choice is influenced by the form of the distribution of interreinforcement intervals.

While the application of Gibbon's account to this problem is highly speculative at this point, it serves to suggest that perhaps the determiners of choice in a concurrent-chain schedule are based, not on mean value of the terminal links, but rather on the local reinforcement contingencies. Response strength, on the other hand, may serve as a better index of the mean value of the schedule.

REFERENCE NOTE

1. Nevin, J. A., & Mandell, C. *Response strength and reinforcement value in chained schedules.* Paper presented at the meetings of the Eastern Psychological Association, April 1977.

REFERENCES

Autor, S. M. The strength of conditioned reinforcers as a function of frequency and probability of reinforcement. In D. P. Hendry (Ed.), *Conditioned reinforcement.* Homewood, Ill.: Dorsey, 1969.

Carlton, P. L. The interacting effects of deprivation and reinforcement schedule. *Journal of the Experimental Analysis of Behavior,* 1961, **4,** 379-381.

Catlin, J., & Gleitman, H. Pattern of disruption in the extinction of chain FR7 FR7 in pigeons. *Animal Learning and Behavior,* 1973, **1,** 154-156.

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

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

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

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

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

Fantino, E. Some data on the discriminative stimulus hypothesis of secondary reinforcement. *Psychological Record,* 1965, **15,** 409-415.

Fantino, E., & Herrnstein, R. J. Secondary reinforcement and number of primary reinforcements. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 9-14.

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

Fischer, K., & Fantino, E. The dissociation of discriminative and conditioned reinforcing functions of stimuli with changes in deprivation. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 703-710.

Gibbon, J. Scalar expectancy theory and Weber's law in animal timing. *Psychological Review,* 1977, **84,** 279-325.

Gollub, L. R., & Urban, J. T. The accentuation of a rate difference during extinction. *Journal of the Experimental Analysis of Behavior,* 1958, **1,** 365-369.

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

Herrnstein, R. J., & Loveland, D. H. Hunger and contrast in a multiple schedule. *Journal of the Experimental Analysis of Behavior,* 1974, **21,** 511-517.

Hursh, S. R., & Fantino, E. Relative delay of reinforcement and choice. *Journal of the Experimental Analysis of Behavior,* 1973, **19,** 437-450.

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

Logan, F. A. The role of delay of reinforcement in determining reaction potential. *Journal of Experimental Psychology,* 1952, **43,** 393-399.

Lyon, D. O. Frequency of reinforcement as a parameter of conditioned suppression. *Journal of the Experimental Analysis of Behavior,* 1963, **6,** 95-98.

Malott, R. W. The effects of prefeeding on plain and chained fixed ratio schedules of reinforcement. *Psychonomic Science,* 1966, **4,** 285-286.

McEwen, D. The effects of terminal-link fixed-interval and variable-interval schedules on responding under concurrent chained schedules. *Journal of the Experimental Analysis of Behavior,* 1972, **18,** 253-261.

Millenson, S. R. Random interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1963, **6,** 437-443.

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

Nevin, J. A. Response strength in multiple schedules. *Journal of the Experimental Analysis of Behavior,* 1974, **21,** 389-408.

Nevin, J. A. Reinforcement schedules and response strength. In M. D. Zeiler and P. Harzem (Eds.), *Reinforcement and the organization of behavior.* New York: Wiley, 1979.

Pliskoff, S. S., Shull, R. L., & Gollub, L. R. The relation between response rates and reinforcement rates in a multiple schedule. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 271-284.

Schneider, B. A. A two-state analysis of fixed-interval responding in the pigeon. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 677-687.

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

Schwartz, B. Effects of reinforcement magnitude on pigeons' preference for different fixed-ratio schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 253-259.

Shimp, C. P., & Wheatley, K. Matching to relative reinforcement frequency in multiple schedules with a short component duration. *Journal of the Experimental Analysis of Behavior,* 1971, **15,** 205-210.

Ten Eyck, R. L. Effects of rate of reinforcement-time upon concurrent operant performance. *Journal of the Experimental Analysis of Behavior,* 1970, **14,** 269-274.

Todorov, J. C. Component duration and relative response rates in multiple schedules. *Journal of the Experimental Analysis of Behavior,* 1972, **17,** 45-49.

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