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PREFERENCE FOR LESS SEGMENTED FIXED-TIME COMPONENTS IN CONCURRENT-CHAIN SCHEDULES OF REINFORCEMENT

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A concurrent-chain procedure was used to examine choice between segmented and less segmented response-independent schedules of reinforcement. A pair of independent, concurrent variable-interval 60-s schedules were presented in the initial link, along with a 1.5-s changeover delay. A chained fixed-interval fixed-time and its corresponding tandem schedule constituted the terminal links. The length of the fixed-interval schedule in the terminal link was varied between 5 s and 30 s while that of the fixed-time schedule was kept at 5 s over conditions. The first components of both terminal-link schedules were accompanied by the same stimulus. Except in the baseline condition, the onset of the second component of the terminal-link chained schedule was accompanied by either a localized (key color) or a nonlocalized (dark houselight) stimulus change. Stimulus conditions were constant during the terminal-link tandem schedule. With three exceptions, pigeons demonstrated a slight preference for the tandem over the chained schedule in the terminal link. Furthermore, this preference varied inversely with the length of the first component. In general, these results are consistent with previous studies that reported an adverse effect on choice by segmenting an interval schedule into two or more components, but they are inconsistent with studies that reported preference for signaled over unsignaled delay of reinforcement.

Key words: preference, segmentation, fixed-time schedules, response-independent reinforcement, concurrent chains, key peck, pigeons

A simple interval schedule of reinforcement is said to be segmented if its interreinforcement interval (IRI) is divided into two or more component schedules by certain events such as a stimulus change and/or a response requirement (Duncan & Fantino, 1972; Fantino, 1969). An important example is a chain or chained schedule. The type of chained schedule that has been studied most extensively consists of two components (e.g., Kelleher & Gollub, 1962). The schedule begins with the first component (C1) that correlates with a specific stimulus (S1). In satisfying the schedule requirements in C1, a response produces the second component (C2) correlated with another stimulus (S2). The reinforcer is delivered only when the response requirements have been fulfilled in C2.

Based on the observation that laboratory animals' responding is not strongly maintained by multiple-component chains, Fantino (1969) predicted that, when given a choice between a simple and a segmented schedule, animals will prefer the simple one. For example, a simple fixed-interval (FI) schedule will be chosen more often than a chained FI FI schedule with equal time to primary reinforcement. It seems that segmenting a schedule increases the number of stages to be traversed prior to the presentation of the reinforcer, and this effectively increases the "psychological distance" to reinforcement (Fantino, 1969). The notion that segmentation has adverse effects on choice was first demonstrated in a study performed by Duncan and Fantino (1972) using the concurrent-chain (Autor, 1960, 1969) choice procedure. This procedure typically includes two phases—the initial link (choice phase) and the terminal link (outcome phase). During the initial link, two response keys are illuminated, each correlated with an independent variable-interval (VI) schedule. Meeting the schedule

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requirements on either key produces a stimulus change on that key while the other key becomes dark and inoperative; the terminal link is now in effect. Completion of the schedule requirements in the terminal link produces food, followed by reinstatement of the initial link. The relative allocation of responses on the two keys during the initial link (the choice proportion) is taken as a measure of preference for one of the two mutually exclusive terminal-link schedules. In their first experiment, Duncan and Fantino presented a simple FI $2x$-s and a chained FI x-s FI x-s in the terminal link. As expected, pigeons showed strong preference for the simple schedule over the segmented one when these had the same IRI. In addition, such preference increased as the size of the IRI in the terminal link varied from 10 s to 20 s to 30 s. The simple schedule was almost exclusively preferred when the IRI was 30 s.

These findings were recently replicated by Leung and Winton (1985). In some conditions, they also compared a simple FI and a chained FI FI, but the IRI was either 15 s or 60 s. Pigeons' choices invariably favored the simple schedule over the chain, and much more so in conditions using the longer IRI. In the same study, the adverse effect of segmentation on choice was extended to segmented VI schedules, despite the fact that the effect was less pronounced compared with that found in FI schedules and occurred only when a changeover delay (COD) operated during the initial link. In other conditions, Leung and Winton also examined tandem-simple and tandem-chain comparisons showing that a tandem schedule had the same effect on choice as did the corresponding simple schedule. This latter observation supplemented the finding from an experiment conducted by Fantino (1983) who, in one condition, presented pigeons with a simple FI $2x$-s and a tandem FI x-s FI x-s and found indifference. It was therefore concluded that stimulus segmentation may be solely responsible for the preference for a simple schedule over the segmented chain, and that differing response requirements may not affect choice in these situations (cf. Neuringer, 1969).

The adverse effect on choice resulting from segmentation seems rather robust in interval schedules, but its generalization to other schedule types has yet to be established. For instance, does segmenting a response-independent schedule, such as a time schedule, produce the same effect as segmenting a response-dependent schedule of food delivery? To throw some light on this question, the present experiment investigated choice between a pair of differently segmented schedules that ended with fixed-time components (i.e., a chained versus a tandem schedule) to determine whether the less segmented schedule was preferred even when the reinforcer was delivered irrespective of responding at the end of the IRI. A second purpose was to examine different patterns of segmentation and their effect on choice. Previous studies of segmentation (Duncan & Fantino, 1972; Fantino, 1983; Leung & Winton, 1985) employed segmented schedules whose interreinforcement intervals were always bisected into equal halves. In the present experiment, segmentation was made uneven by manipulating the duration of C1 over conditions while the duration of C2 remained constant. Finally, in order to look at the effect on choice of different loci of the segmentation stimulus, the stimulus correlated with S2 of the terminal-link chain was either localized (key color change) or nonlocalized (chamber light switched off).

METHOD

Subjects

Four homing pigeons of racing stock, designated P22, P25, P28, and P29, were maintained at 80% (±10 g) of their free-feeding body weights. All birds had prior experience with pecking the center key under VI schedules of reinforcement.

Apparatus

The experimental chamber was a standard three-key pigeon chamber (31 cm by 34 cm by 33 cm). The enclosure was made of sound-attenuating material, with an exhaust fan that helped mask external noise. Throughout the experiment, only the two side keys were operative. The center key was covered with black insulation tape. Each side key could be transilluminated with 1.3-W lights of various colors. A force of 0.15 N operated the microswitch behind each key. Auditory feedback for pecking was a 30-ms 1-kHz tone produced by a sine-wave generator. Reinforcement consisted of 3-s access to wheat in a raised, illuminated hopper with the houselight and keylights off. Experimental events were controlled and recorded by electromechanical and solid-state equipment.

Procedure

Pecking on the two side keys was shaped through differential reinforcement, and then the birds were exposed to concurrent VI 60-s VI 60-s schedules of reinforcement with a changeover delay (COD) of 1.5 s (Herrnstein, 1961). Both keys were illuminated white during this procedure, which continued for 15 sessions before the concurrent-chain procedure was introduced.

The initial link of this procedure resembled the concurrent schedules, having two white keys and the same COD operating. However, instead of directly producing a reinforcer (food), responding occasionally produced a schedule of response-independent food delivery. When the terminal-link schedule on a given key was accessed, a change of key color accompanied this event while the other key became dark and inoperative. Except in the baseline procedure, the terminal link consisted of chained and tandem schedules of equal IRI.

In the terminal link, the stimuli correlated with the first components (S1) of both schedules were the same—that is, either both red (Birds P22 and P28) or both green (Birds P25 and P29). For the tandem schedule, the stimulus correlated with the second component (S2) remained the same as S1. For the chained schedule, however, the onset of S2 was signaled either by a change in key color from red to green or from green to red (localized conditions) or by the turning off of the houselight without altering the key color (nonlocalized conditions).

During the baseline condition, two tandem FI 5-s FT 5-s schedules were presented and this condition lasted until responding stabilized in both links and the mean choice proportions deviated not more than ±.03 from .50. In the conditions that followed, a chain FI x-s FT 5-s was compared with a tandem FI x-s FT 5-s. Table 1 shows, for each bird, the sequence of training conditions, the component stimuli of each terminal-link schedule, and the key position correlated with the chained schedule in a condition. For Birds P22 and P28, the duration of C1 was varied from 5 s to 30 s in an ascending fashion; for Birds P25 and P29, this order was reversed. The subjects were exposed to each of the shorter C1 conditions (5 s and 10 s) twice in succession but each time having a different stimulus correlated with S2 of the chain (i.e., localized or nonlocalized). In other conditions where the C1 durations were either 15 s, 20 s, or 30 s, S2 in the chain was localized for two birds (P28 and P29) and nonlocalized for the other two (P22 and P25).

The intervals for the VI schedules were generated from progressions that scheduled events after varying times but with a constant probability (Fleshler & Hoffman, 1962). Sessions were conducted 7 days per week. Each session was terminated after the delivery of 40 reinforcers; hence, session time varied with the length of the terminal link. A new condition was introduced when the response rates in both links of the concurrent chains appeared stable by visual inspection and the mean choice proportion (initial-link response rates) computed over the last five sessions did not differ by more than 5% from that of the previous five sessions. The number of sessions for each condition is shown in Table 1.

RESULTS

In the following analysis, the reinforcement proportion refers to the ratio of reinforcement rate produced by responses on the tandem key (the key correlated with the tandem schedule) during the terminal link to the combined reinforcement rate from responding on both keys. Similarly, the choice proportion during the initial link was calculated by dividing the response rate on the key that produced the tandem schedule by the total initial-link response rate on both keys. All data presented are averaged over the last five sessions of a condition. During the baseline procedure, the choice and reinforcement proportions (with respect to the left key) were .51 and .50 (P22), .52 and .49 (P25), .50 and .53 (P28), and .47 and .49 (P29).

The choice data are summarized in Figure 1, which shows the choice proportions for each bird, as a function of the C1 duration of the terminal-link schedules. For each bird, the connected points indicate the five conditions that used the same type of stimulus for the S2 of the chains, either localized (P28 and P29)

Table 1

The schedules of the first and second components (C1 and C2), their corresponding stimuli (S1 and S2; G = green, R = red, and D = dark houselight), and the correlated key positions in the terminal link. The reinforcement proportions for the tandem schedule and the numbers of sessions for each condition are also shown.

	Component schedule in the terminal link		Component stimuli in the terminal link					Reinf. prop. for tandem key	No. of sessions
			Tandem key		Chain key				
Subj.	C1	C2	S1/S2	(Position)	S1	S2	(Position)		
P22	FI5-s	FT5-s	R	(Right)	R	G	(Left)	.50	25
	FI5-s	FT5-s	R	(Right)	R	R + D	(Left)	.49	28
	FI10-s	FT5-s	R	(Left)	R	G	(Right)	.51	28
	FI10-s	FT5-s	R	(Left)	R	R + D	(Right)	.51	30
	FI15-s	FT5-s	R	(Left)	R	R + D	(Right)	.50	27
	FI20-s	FT5-s	R	(Right)	R	R + D	(Left)	.50	32
	FI30-s	FT5-s	R	(Left)	R	R + D	(Right)	.50	35
P25	FI30-s	FT5-s	G	(Left)	G	G + D	(Right)	.48	30
	FI20-s	FT5-s	G	(Right)	G	G + D	(Left)	.50	31
	FI15-s	FT5-s	G	(Right)	G	G + D	(Left)	.48	25
	FI10-s	FT5-s	G	(Left)	G	G + D	(Right)	.51	40
	FI10-s	FT5-s	G	(Right)	G	R	(Left)	.50	29
	FI5-s	FT5-s	G	(Right)	G	R	(Left)	.50	35
	FI5-s	FT5-s	G	(Left)	G	G + D	(Right)	.50	36
P28	FI5-s	FT5-s	R	(Left)	R	G	(Right)	.49	42
	FI5-s	FT5-s	R	(Right)	R	R + D	(Left)	.49	37
	FI10-s	FT5-s	R	(Right)	R	R + D	(Left)	.51	38
	FI10-s	FT5-s	R	(Left)	R	G	(Right)	.50	33
	FI15-s	FT5-s	R	(Right)	R	G	(Left)	.50	40
	FI20-s	FT5-s	R	(Left)	R	G	(Right)	.50	41
	FI30-s	FT5-s	R	(Left)	R	G	(Right)	.52	34
P29	FI30-s	FT5-s	G	(Left)	G	R	(Right)	.50	27
	FI20-s	FT5-s	G	(Right)	G	R	(Left)	.50	28
	FI15-s	FT5-s	G	(Right)	G	R	(Left)	.49	27
	FI10-s	FT5-s	G	(Right)	G	R	(Left)	.49	26
	FI10-s	FT5-s	G	(Left)	G	G + D	(Right)	.51	29
	FI5-s	FT5-s	G	(Left)	G	R	(Right)	.48	22
	FI5-s	FT5-s	G	(Right)	G	G + D	(Left)	.49	25

or nonlocalized (P22 and P25). In general, the choice proportions from various conditions did not seem to deviate substantially from .50 (i.e., indifference), ranging from .45 to .62. However, this deviation from the .50 level can be considered fairly consistent across birds and it is not shared by the obtained reinforcement proportions, which, as indicated in Table 1, have values virtually equal to .50. In 25 of the 28 occasions, the birds preferred the tandem schedule over the chain (i.e., the choice proportions were above .50). The three exceptions are found in Birds P25 and P29, the training of which began with the longest C1 duration. Both of these birds slightly preferred the chained schedule (.45 for P25 and .47 for P29) when the C1 duration equaled 30 s; further, P25 showed indifference when the duration of C1 was 20 s. The effect of the type of delay stimulus (S2) on choice can be assessed by comparing data across localized and nonlocalized stimulus conditions. Within-subject comparisons are possible only with conditions using the shorter C1s. For C1 of 5-s duration, the choice proportions for all birds were consistently greater in conditions when S2 was nonlocalized (averaged .59) than when it was localized (averaged .56), whereas for C1 of 10-s duration, no systematic difference between these conditions was observed. Between-subject comparisons over all five durations did not show any substantial differences. In fact, the functions, as shown in Figure 1, had virtually the same form across the two types of stimulus conditions. In general, these functions indicated a negative relationship between preference for the tandem schedule and the C1 duration, although their slopes were relatively gradual. On the other hand, the order of training affected the values of the preference being assessed. Compared point by point, birds trained under a descending sequence of C1 durations (P25 and P29) tended to show less preference for the tandem schedules than their ascending-ordered counterparts (P22 and P28). As mentioned above, choice in P25 and P29 actually favored the chained schedule in the 30-s condition.

A summary of the absolute rates of responding on both keys during the initial links and the terminal links of the concurrent chains appears in the Appendix. Figure 2 depicts the absolute rates of responding in each component of the chained and tandem schedules as a function of the duration of C1. The data presented in Figure 2 include, for each bird, only those conditions using the same type of S2 over all five conditions—that is, nonlocalized conditions for P22 and P25 and localized conditions for P28 and P29. The absolute rates of responding during the terminal link varied according to the type of schedule and, within the chained schedule, the type of S2. In the tandem schedule, response rate under C1 was always lower than that under C2. This rate difference between components was demonstrated in all subjects except on one occasion (for P25 when C1 was 5 s). Apart from individual variations, responding in both components showed a general decreasing trend with the increasing C1 duration. Under the chained schedule, the relationship between C1 and C2 rates depended on the type of S2. When S2 was localized (P28 and P29), the C2 rate was clearly higher than the C1 rate, especially in P28; but the C1 and C2 rates showed no consistent trend with the length of C1. When S2 was nonlocalized (P22 and P25), the rate differences between components showed little consistency across conditions and subjects. As shown in Figure 2, P22 had similar C1 and C2 rates in one condition (C1 = 30 s); however, in three other conditions, the C1 rates were lower than the C2 rates, and in yet another condition (C1 = 5 s), the rate difference was reversed. On the other hand, P25 had virtually indistinguishable component rates in four of the five conditions shown and, on two occasions, the C1 rate was higher than the C2 rate. According to cumulative records not presented here, in the tandem schedule performance under the FI component (C1) exhibited a scalloped or break-and-run pattern; near the end of the interval, the steady run of responses tended to "spill over" into the FT component (C2) until reinforcement. During the chained schedule, similar patterns were observed, although responding often slowed very briefly following the transition from C1 to C2, which, unlike the tandem schedule, was accompanied by a stimulus change; the high rate in C2 tended to be even higher when S2 was localized.

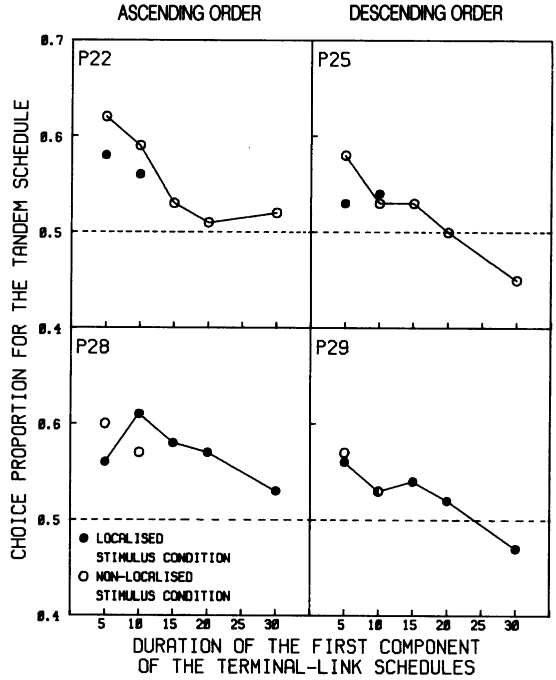

Fig. 1. Proportion of initial-link responding (choice proportion) on the key that produced a tandem schedule as terminal link, as a function of the duration of the first component in the terminal link for each bird, during exposure to a concurrent-chains procedure with equal-duration tandem and chained schedules in the alternative terminal links. The connected points are from conditions that had the same type of delayed stimulus (either all localized or all nonlocalized).

DISCUSSION

The present results show that pigeons, except in three of the 28 conditions, preferred a tandem schedule that terminated with response-independent food delivery to its equivalent chain. The preference, although small, cannot be accounted for by the distributions of reinforcers produced by responding on the two keys, because the reinforcement proportions, in all conditions, stayed close to .50 (see

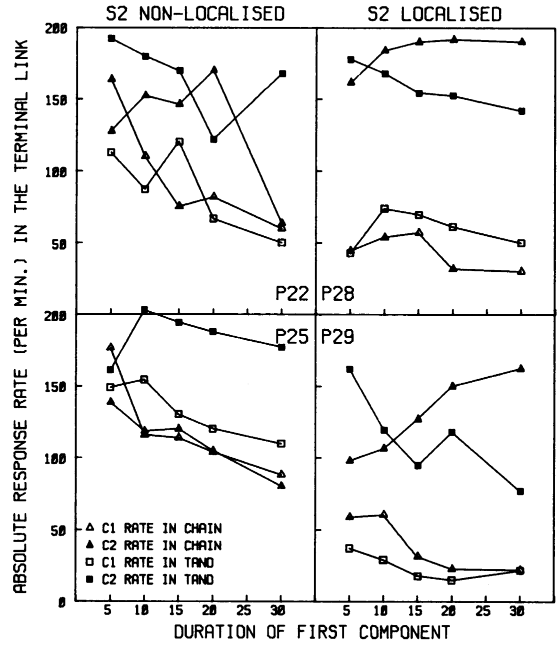

Fig. 2. Absolute response rates for each bird in both first and second components of the terminal-link schedules, as a function of the duration of the first component of the terminal links of concurrent-chains procedures.

Table 1). Nor could it be due to response biases inasmuch as baseline performance indicated little key bias in all birds, and possible color bias had been controlled by using the same stimulus for S1 in both terminal-link schedules. The preference for the less segmented schedule is in accord with findings from previous research on segmentation and choice. Both Fantino (1983) and Leung and Winton (1985) found that pigeons preferred a tandem schedule terminating with response-dependent food delivery over its corresponding chained schedule. In some conditions of an experiment, Wallace (1973) assessed choice between equal length simple and chained schedules of response-independent food delivery (i.e., chained FT x-s FT x-s and simple FT $2x$-s). A clear and consistent preference for the unsegmented schedule was also found. All of these results suggest that segmenting a response-independent IRI and segmenting a response-dependent IRI are likely to produce similar effects on choice.

One purpose of the present study was to examine the effect of the locus of the segmentation stimulus on choice by using either a localized or nonlocalized stimulus as S2. Except when C1 was 5 s, the locus of S2 did not seem to affect the magnitude of preference in other conditions using longer C1s. The choice functions depicted in Figure 1 have similar shapes and are comparable across individual birds whether S2 was localized or not. Such results suggest that the locus of the stimulus signaling the latter component in a segmented schedule is not crucial so long as the segmentation gains control over behavior.

Three aspects of the present data appear inconsistent with previous research findings. The first aspect is the low preference obtained for the less segmented tandem schedule, which ranged only from .45 to .62. Taking into consideration the IRI durations employed by the present experiment, these choice proportions are small compared with those found by Duncan and Fantino (1972) and by Leung and Winton (1985). For instance, in their first experiment, Duncan and Fantino reported choice proportions of values well above .70 when the IRI was either equal to or greater than 20 s. A second differing aspect of the present results is that preference for the less segmented IRI decreased when the C1 duration of the terminal-link schedules increased. In other words, preference was a negative function of the size of the terminal-link IRI that was directly proportional to the C1 duration. Again, this is inconsistent with the result obtained both by Duncan and Fantino and by Leung and Winton, who reported a generally positive relationship between preference and the IRI size. The third and most puzzling differing aspect of the results is the reversal of preference for the chained schedule exhibited by 2 birds when the IRI was 30 s. Illustrating this inverse relationship between preference and C1 duration, P25 showed indifference when C1 was 20 s and both P25 and P29 slightly preferred the chained to the tandem schedule when C1 was 30 s. The reversal is unexpected in that previous studies always found choice favoring the less segmented IRI over the segmented one.

These discrepancies could have been the outcome of the particular terminal-link schedules employed in the present experiment. Unlike Duncan and Fantino (1972), we presented response-independent instead of response-dependent reinforcers in the terminal links of the concurrent chains. This arrangement may have lowered the preference for the less segmented schedule. Similarly low values were found by Wallace (1973), who compared a pair of time schedules (i.e., simple FT 2x-s versus chain FT x-s FT x-s). However, Wallace did not observe any reversal of preference favoring the segmented schedule of response-independent food delivery. Hence, although the response-independent characteristic of the present procedures may acount for the weak preference observed, it cannot resolve the reversal of preferences. Another possibility was the failure of the schedules to control appropriate behavior in the terminal link, which might in turn have affected choice in the initial link. Evidence favoring this interpretation can be seen in the response-rate data presented in Figure 2. It is obvious that responding during the terminal link was not consistent across birds. For example, although both Birds P22 and P25 (S2 nonlocalized) showed a decreasing trend in responding during C1 of the chained schedule, they exhibited different trends during C2. Specifically, in four of the five conditions shown, P25 responded at approximately equal rates in both components of the chain, indicating that the components may not have been discriminated. As for the other 2 birds, P28 and P29 (S2 localized), although C1 and C2 rates can be clearly distinguished, there is no clear trend in responding that distinguishes the chained and the tandem schedules. However, even if these inconsistencies in terminal-link responding were responsible for the weak preference and reversal, they may not be able to account for the negative functions shown in Figure 1. It appears that other factors not yet identified have contributed to our findings.

One possible factor is the relative duration between C1 and C2, which we conveniently labeled "segmentation ratio." To investigate the effects of different methods of segmentation on choice, we varied the length of C1 over conditions while keeping C2 constant, and a negative relationship between preference and the C1 duration was obtained. This finding, however, might be attributable to two variables that were incidentally varied as a result of manipulating the duration of C1. These were the IRI size and the segmentation ratio. Available evidence suggests that the former factor is unlikely to be responsible. In fact, according to the studies by Duncan and Fantino (1972) and by Leung and Winton (1985), increasing IRI size should produce high or even extreme preference for the tandem schedules. The latter factor, segmentation ratio, however, has not yet been evaluated appreciably with respect to its effect on choice, for all previously reported studies of segmentation and choice have bisected the IRI, leaving the segmentation ratio at 1:1. This was not the case in the present experiment, as the C1 duration was either longer or equal to the C2 duration, leading to segmentation ratios greater than 1:1 in all conditions except when C1 had a value of 5 s. The incentive theory of choice proposed by Killeen (1982) predicts that the magnitude of preference for a less segmented schedule may vary with the C1 duration in the segmented schedule. To assess whether the segmentation ratio affects choice between segmented and less segmented schedules, future research must control for the size of the IRI in addition to manipulating the relative durations of C1 and C2.

Formally, the segmented FT schedules used in the present experiment resemble schedules that have been used to study delayed reinforcement. Moreover, the delay in the chained schedule was signaled, whereas that in the tandem schedule was not. From such a perspective, our procedure is comparable to that employed by Marcattilio and Richards (1981), who presented pigeons with two VI 60-s schedules of delayed reinforcement in the terminal link. The delay, ranging from 0 to 10 s in different conditions, was unsignaled for one schedule, and was signaled (by simultaneously switching off the keylight and houselight and turning on a yellow pilot light) for the other. Consistent with other studies on signaled-delay reinforcement (e.g., Badia, Ryan, & Harsh, 1981; Lewis, Lewin, Muehleisen, & Stoyak, 1974), these authors reported that the schedule of delayed reinforcement was chosen more often when the delay was signaled than when it was unsignaled. In other words, Marcattilio and Richards' results suggest that a segmented schedule is preferred to its less segmented counterpart. This is generally inconsistent with the present findings and with those of Duncan and Fantino (1972), Fantino (1983), Leung and Winton (1985), and Wallace (1973). A detailed comparison between Marcattilio and Richards' experiment and these segmentation studies reveals one major feature that may be responsible for their finding of preference for the segmented schedule over the less segmented one. In their terminal link, Marcattilio and Richards employed segmented schedules of different component periodicity–that is, C1 was aperiodic (VI) whereas C2 was periodic (FT). By contrast, other segmentation studies have used schedules of the same periodicity—that is, either both periodic (e.g., Duncan & Fantino, 1972; Fantino, 1983) or both aperiodic (e.g., Schneider, 1972). One direct consequence of the procedure adopted by Marcattilio and Richards is that the cycle-to-cycle duration of C1 in the terminal link varied due to the use of a VI schedule. In each entry, the terminal link varied due to the use of a VI schedule. In each entry, the terminal link would have presented an IRI and a segmentation ratio that differed from the previous entry. Perhaps such molecular variation in the terminal link affected choice responding in the initial link. Exactly why component periodicity could produce a positive segmentation effect on choice is not clear. According to some preliminary work in this laboratory, it appears that the periodicity of the component schedules could have affected the averaged segmentation ratio that may in turn influence choice. Systematic research on the effect of periodicity of segmented schedules on choice should clarify this issue.

REFERENCES

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

Autor, S. M. (1969). The strength of conditioned reinforcers as a function of frequency and probability of reinforcement. In D. P. Hendry (Ed.), *Conditioned reinforcement* (pp. 127-162). Homewood, IL: Dorsey Press.

Badia, P., Ryan, K., & Harsh, J. (1981). Choosing schedules of signaled appetitive events over schedules of unsignaled ones. *Journal of the Experimental Analysis of Behavior,* **35,** 187-195.

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

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

Fantino, E. (1983). On the cause of preference for unsegmented over segmented reinforcement schedules. *Behaviour Analysis Letters,* **3,** 27-33.

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

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

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

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

Leung, J. P., & Winton, A. S. W. (1985). Preference for unsegmented interreinforcement intervals in concurrent chains. *Journal of the Experimental Analysis of Behavior,* **44,** 89-101.

Lewis, P., Lewin, L., Muehleisen, P., & Stoyak, M. (1974). Preference for signalled reinforcement. *Journal of the Experimental Analysis of Behavior,* **22,** 143-150.

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

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

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

Wallace, R. F. (1973). *Conditioned reinforcement and choice.* Unpublished doctoral dissertation, University of California, San Diego.

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APPENDIX

Absolute rates of responding on both keys during the initial link and the terminal links of the concurrent chains. The first and second components of the segmented schedule are signified as C1 and C2. Nonlocalized conditions are indicated by (N).

		Initial-link response rate (per/min.)		Terminal-link response rate (per/min.)			
				Chain key		Tandem key	
Subj.	C1 of the chain	Chain key	Tandem key	C1	C2	C1	C2
P22	*FI 5-s	47.8	65.7	170.7	179.2	126.6	187.7
	FI 5-s (N)	42.2	68.9	163.8	127.9	112.9	192.2
	*FI 10-s	40.5	52.2	94.0	170.9	86.4	187.4
	FI 10-s (N)	38.6	55.6	110.1	152.4	87.3	179.7
	FI 15-s (N)	27.2	30.7	75.3	146.5	120.5	169.8
	FI 20-s (N)	23.3	24.2	82.0	170.0	66.9	122.2
	FI 30-s (N)	20.0	21.7	60.0	63.6	50.3	167.8
P25	FI 30-s (N)	19.1	15.6	88.3	80.4	110.0	177.2
	FI 20-s (N)	22.0	21.6	104.1	105.1	120.4	187.9
	FI 15-s (N)	21.9	24.7	114.1	120.3	130.3	194.6
	FI 10-s (N)	29.3	33.0	116.2	118.8	154.6	203.1
	*FI 10-s	24.0	28.2	147.3	145.1	158.9	177.1
	*FI 5-s	35.6	40.2	166.8	129.1	146.1	166.4
	FI 5-s (N)	31.7	43.8	176.8	138.7	149.1	161.1
P28	FI 5-s	25.6	32.6	44.5	161.7	42.8	177.7
	*FI 5-s (N)	22.8	34.2	54.0	151.9	77.2	182.8
	*FI 10-s (N)	20.7	27.5	60.5	151.9	74.6	153.5
	FI 10-s	16.3	25.5	54.1	183.9	74.0	167.9
	FI 15-s	13.5	18.6	57.4	189.9	69.7	154.4
	FI 20-s	12.2	16.2	32.0	191.6	61.5	152.6
	FI 30-s	9.7	10.9	30.2	190.1	50.3	142.0
P29	FI 30-s	13.5	12.0	22.0	162.3	21.7	77.2
	FI 20-s	26.3	28.5	22.7	150.1	14.8	118.1
	FI 15-s	31.0	36.4	31.4	127.1	17.7	94.8
	FI 10-s	35.5	40.0	60.5	106.7	29.0	119.7
	*FI 10-s (N)	36.1	40.7	87.2	154.7	59.7	152.0
	FI 5-s	43.7	55.6	58.9	98.0	37.1	161.9
	*FI 5-s (N)	39.8	52.7	43.0	140.5	77.4	145.1

* Terminal-link response rate not shown in Figure 2.