SOME EFFECTS OF INTERREINFORCEMENT TIME UPON CHOICE¹

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Pigeons' responses were reinforced on two identical and concurrently available chain variable-interval-schedules. Unlike the typical concurrent chains procedure, both links were operative throughout, thus producing three types of concurrency: (1) concurrent initial links; (2) concurrent initial and terminal links; (3) concurrent terminal links. Choice proportions in each of these three states suggested that the pigeons were sensitive to momentary likelihoods of reinforcement: choice proportions for a schedule were higher when the schedule had been operative for some time, resulting in a higher probability of reinforcement. The study also showed that the relative rates of responding did not match the relative rates of reinforcement in any of the three states of concurrency. Instead, the choice proportions in both the concurrent initial and in the concurrent terminal links were intermediate between the scheduled and the obtained relative rates of reinforcement, while the choice proportions for a terminal link concurrent with an initial link consistently overmatched the relative interreinforcement times (and were typically 1.00). These data indicate that an accurate characterization of choice may not be obtained by considering only the relative interreinforcement interval where one interreinforcement interval is segmented into a chain. Instead, the organism's choice for a schedule will be substantially lowered by the chaining operation.

Many of the variables controlling an organism's choice behavior have been studied with the concurrent-chains schedule of reinforcement (*e.g.*, Autor, 1960; Herrnstein, 1964*a,b*; Fantino, 1965, 1967, 1968, 1969*a,b*; Killeen, 1968; Duncan and Fantino, 1970; Squires and Fantino, 1971). In this procedure, the organism responds on two concurrently available keys, each of which is illuminated by the stimulus associated with the initial link of one of the chains. Responses on each key produce the stimulus associated with the terminal link of the chain on that key according to a variable-interval (VI) schedule of reinforcement. The VI schedules associated with the initial links of the chains on each key are equal. In all previous studies using this procedure, when the stimulus associated with the terminal link of one key was produced, the other key became dark and inoperative. Thus, while the stimuli of the initial links were concurrently available, those of the terminal links have been mutually exclusive; the chains are "concurrent" in the

initial links only. The present experiment deviated from the usual concurrent-chains procedure in that both chains were continuously available and operative throughout a session, thus producing three types of concurrency: (1) the usual concurrent initial links; (2) an initial link concurrent with a terminal link; (3) concurrent terminal links. This variation of the concurrent-chains procedure allowed an assessment of the effects of chain length, in the sense of the number of links in the chain, upon choice (a variable that Fantino, 1969*b*, suggested would have a profound influence upon choice); and determined whether the organism is sensitive to the momentary likelihood of reinforcement in this procedure (a question raised in the context of simple concurrent schedules by both Shimp, 1969, and Nevin, 1969). To illustrate how the present experiment provided these tests, however, it is first necessary to go over the procedure in some detail.

In this procedure, the two (two-link) chains were operative throughout. Thus, when the pigeon entered one terminal link, the stimulus lights, response key, and schedule of reinforcement of the other key's initial link remained operative and the pigeon could respond to

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the initial link of one key and to the terminal link of the other key. For example, in part of the experiment, the initial-link schedules were VI 60-sec, while the terminal-link schedules were VI 15-sec. A major interest was the behavior when the pigeon entered either terminal link. At this point it was confronted with a single VI 15-sec on this key and with the initial link of chain VI 60-sec VI 15-sec on the other key. If choice depended only upon relative rates of reinforcement (the rate of reinforcement on one key divided by the sum of the two rates of reinforcement) the pigeon would match its responses to the rates of reinforcements provided on each key as it does in simple concurrent schedules (*e.g.*, Herrnstein, 1961, 1970; Catania, 1966; Shull and Pliskoff, 1967; Silberberg and Fantino, 1970). In other words, it would respond five times as often on the VI 15-sec key as on the chain VI 60-sec VI 15-sec key. The degree by which the subject's choice proportion exceeded the 0.83 expected for the VI 15-sec if it were paired with a simple VI 75-sec measured the influence of the chaining procedure upon choice. For example, if the choice proportion obtained were 0.95, this value would correspond to a choice ratio of 19 to 1, favoring VI 15-sec. In order to produce a choice ratio of 19 to 1 for a VI 15-sec in simple concurrent schedules, the value of the competing member must be in the range of VI 285-sec. In this hypothetical case, the chain VI 60-sec VI 15-sec would have the same effect upon choice as would a simple VI 285-sec; a chain VI 60-sec VI 15-sec and a simple VI 285-sec would be apparently equivalent, at least when each is compared in this choice situation to a VI 15-sec.

The question of the extent to which the pigeon is sensitive to momentary changes in the likelihood of reinforcement is of general interest to students of choice (*e.g.*, Shimp, 1969; Nevin, 1969) and has also been raised in the context of the conventional concurrent-chains procedure (Fantino, 1969a). The present procedure provided several tests of the sensitivity of the pigeon's choice behavior to changes in likelihood of reinforcement. Consider, as a first example, the case in which the subject entered a terminal link on one key while the terminal link of the other key is already in effect and the scheduled values on each key are equal, *e.g.*, VI 15-sec. However, the probability of reinforcement was slightly

higher for the terminal link that was entered first. Hence, if the pigeon were sensitive to this increased likelihood of reinforcement, it would respond at a higher rate in the terminal link first produced. A second test concerned cases in which primary reinforcement occurred after responding in two terminal links. In this case, after reinforcement, the subject was confronted with a chain VI 60-sec VI 15-sec on the key that had just provided reinforcement and was still in the terminal link (VI 15-sec) on the other key. The hypothesis under discussion requires that the subject respond more often in the terminal link than would be expected had time not already elapsed on that schedule. Conveniently, the procedure included a contrasting case. The subject arrived in this situation (initial link of one key, terminal link of the other) by a different route: when it entered one terminal link after responding in the two initial links. In this case, relatively more responding would occur on the initial-link key because time had elapsed on the initial-link schedule but not in the terminal-link schedule. Comparison of choice behavior for the two cases in which the subject responds on concurrent terminal and initial links was relevant to this point. If these choice proportions were substantially different (and in the right direction) when the situation arose after primary reinforcement than when it arose after responding on two initial links, it would suggest that the pigeon's choice behavior is sensitive to momentary changes in effective VI values.

It is well established that the mean interreinforcement interval (the reciprocal of reinforcement rate) is a crucial determiner of choice. Thus, the present experiment had two main purposes: (1) to see whether or not the interreinforcement interval provided an accurate characterization of choice even when chain length *i.e.*, the number of links in the chain, was varied; (2) to see if an improved description of choice was obtained by considering momentary changes in the value of the interreinforcement interval.

METHOD

Subjects

Two male and two female White Carneaux pigeons were maintained at about 80% of their free-feeding body weights. The males (D

and F) were approximately 18 months old at the beginning of the experiment and had previously been exposed to the concurrent-chains procedure (Fantino, 1969a). The females were approximately six months old and were experimentally naive.

Apparatus

The experimental chamber (Ferster and Skinner, 1957) contained two 6-w lamps for general illumination, and a solenoid-operated grain hopper centrally located between two translucent response keys mounted 3 in. (7.62 cm) apart and 9 in. (22.9 cm) above the floor. The left key was transilluminated by either a white or green light, the right key by either a white or red light. Transillumination was accomplished by stimulus lights mounted behind the response keys (Westinghouse Christmas bulbs). A minimum effective force of 10 g (0.098N) was required to operate each response key. Each response produced auditory feedback by operating a 110-v ac relay. Standard scheduling and recording equipment was located in an adjacent room.

Procedure

After magazine training, Birds B and P were trained to respond in the presence of green and red key lights. All birds were then exposed to the first experimental condition.

Identical two-link chain VI schedules of reinforcement were arranged on each key and were operative throughout. Thus, when an initial-link response on one key produced entry into the terminal link on this key, both the keylight and schedule associated with the other key remained operative. Throughout a session, therefore, the organism could be exposed to each of three schedule pairs: (1) concurrent initial-link schedules; (2) a terminal-link schedule on one key concurrent with an initial-link schedule on the other key; (3) concurrent terminal-link schedules. In the initial links, each key was illuminated with white lights and the values of the VI schedules were equal. In the terminal links, each key was illuminated with colored lights and the values of the VI schedules were also equal to each other but differed from the initial-link values. Column ii, Table 1, presents the initial- and terminal-link schedules used in each condition, in the order of their occurrence for the individual bird.

The interreinforcement intervals (IRIs) for the VI 60-sec schedule were generated according to Segal's (1964) method for constructing VI tapes. This produces a sequence of variable intervals with a relatively flat IRI per opportunity ("IRIs/Op") distribution, *i.e.*, the probabilities with which intervals at each length terminate in reinforcement are fairly constant within the range of IRI values used. However, in the present schedules the probability of reinforcement is zero until 30% of the mean value of this VI has elapsed (*i.e.*, 4.5 sec, 9 sec, and 18 sec for the VI 15-sec, VI 30-sec and VI 60-sec schedules, respectively). This feature of the tapes permits some interesting tests, discussed in the Results section, of the sensitivity of the pigeon's choice behavior to momentary changes in the relative value of the interreinforcement interval. The VI 30-sec and VI 15-sec schedules used in the study were generated by taking one-half and one-quarter, respectively, of each of the VI 60-sec IRIs.

Figure 1A-D provides a pictorial representation of the four schedule combinations ("states") that are possible on the two keys and illustrates that each may be entered from two of the other states (upper boxes) and that each may lead to two of the other states (lower boxes). For example, each session begins with concurrent initial links on both keys (Figure 1A). Responding on either the left or the right key produces this key's terminal link, according to identical VI schedules, and initiates one of the states shown below (and in Figures 1B and 1C). In the presence of an initial- and terminal-link schedule (Figures 1B and 1C) a terminal-link response may produce food, which is followed by concurrent initial links (Figure 1A), while an initial-link response may produce concurrent terminal links (Figure 1D).

A changeover delay (COD) has usually been used in experiments involving simple concurrent schedules of reinforcement (*e.g.*, Herrnstein, 1961). A COD prevents a response on a key from producing primary reinforcement unless a specified time has elapsed since switching to this key from the other key. CODs have generally not been used with the conventional concurrent-chains procedure (*e.g.*, Autor, 1960; Herrnstein, 1964a; Fantino, 1969a,b) since, with mutually exclusive terminal links, responses on one key may not be followed by a response producing primary

Fig. 1. Pictorial representation of the schedule combinations ("states") that are possible on the two keys. Each is entered from one of the two states pictured in the upper boxes, and each leads to one of the two states pictured in the lower boxes.

reinforcement on the other key. In the present experiment, however, since the terminal links are not mutually exclusive, it would seem that a COD would be desirable. In two recent experiments (Davison, 1969; Neuringer, 1969), CODs were also utilized in the initial links of conventional concurrent chains. Such a requirement insures that responses on a key cannot produce entry into the terminal link of that key unless a specified time has elapsed since switching to this key. In two of the five conditions of the present experiment (column iii of Table 1), a COD was in effect for responding in either initial link. In those two procedures, as well as in two additional ones, a COD was utilized for responding in the terminal links (column iv of Table 1). In the remaining condition, no COD was employed. Throughout the experiment, COD duration was 1.5 sec. Three of the conditions, the one with no COD throughout, and the two with a COD throughout, are procedurally straightforward. A few sentences will elucidate the procedure when the COD is in effect only for responding in the terminal links. In this case, there is a COD when both terminal links are available but not when both initial links are available. When a terminal link is available concurrently with an initial link, the COD is in effect only for terminal-link responding. In other words, when the organism switches from the terminal-link key to the initial-link key, immediate reinforcement may occur by entry into the other terminal link; primary reinforcement may not occur, however, by switching from responding on the initial-link key to re-

sponding on the terminal-link key until the COD requirement is met.

The first condition was studied for a period of several months, during which time modifications were made in data collection. The subsequent conditions were altered for an organism when the initial-link response proportions satisfied the following stability criterion: each pigeon remained at a given schedule for a minimum of 14 sessions; on the fourteenth day and every day thereafter until stability had been reached, the last nine sessions were divided into three blocks of three consecutive sessions, and the means of the choice proportions for those three blocks of sessions were computed (m_1 , m_2 , m_3). The behavior was considered stable when the means of the three blocks differed by 0.05, or less, and there was no trend in the choice proportions, *i.e.*, neither $m_1 > m_2 > m_3$ or $m_1 < m_2 < m_3$.

RESULTS

All data represent the median values of the last four sessions for each bird, in each of the experimental conditions.

Columns v-xvi, Table 1, show both the absolute rates of responding (in responses per minute) and the relative rates of responding (responses on one key/sum of responses on both keys) on the keys indicated, in the presence of the concurrent schedules shown at the top of the columns. These concurrent schedules represent the four possible ones confronting the organism as shown in Figure 1. A zero

indicates that no responses occurred on this key in the presence of these schedules; dashes indicate that the bird never entered the condition shown at the top of this column. For example, if the organism never responded in an initial link when it was concurrently available with a terminal link, then the condition in which both terminal links were in effect (columns xiv-xv) would never arise. Table 1 also shows that the COD tended to increase the absolute rates of responding in the initial links (Conditions 2 and 3), while it had no apparent effect upon the relative rates of initial-link responding (column vii, Table 1). On the other hand, though the COD did not alter the absolute rates of responding in the terminal link (Conditions 2-5), it tended to increase the relative rates of terminal- *vs* initial-link responding when first instituted in Condition 2 (*cf.* columns x and xiii, Table 1). Subsequent COD manipulations in Conditions 2 to 5 did not noticeably affect the relative rates of terminal- *vs* initial-link responding. Our primary interest in the COD concerned its effects upon choice responding (*i.e.*, the relative rates), which it did not appreciably alter; hence, COD manipulations are not discussed further.

The first experimental question concerning the effects of chaining upon choice responding is straightforward and may be answered by examining the choice proportions in the presence of concurrent initial- and terminal-link schedules (cols. x and xiii, Table 1). If the choice proportions are determined by the interreinforcement intervals alone, they should correspond to values of 0.83 and 0.56 for the chain VI 60-sec VI 15-sec and chain VI 15-sec VI 60-sec schedules, respectively (Birds B and D), and to 0.75 and 0.60 for the chain VI 60-sec VI 30-sec and VI 30-sec VI 60-sec schedules, respectively (Birds P and F). The choice proportions shown in columns (x) and (xiii) indicate that for all procedures the subjects did not match their relative rates of responding to the relative rates of reinforcement; instead, they seldom responded on an initial-link key when it was concurrently available with a terminal link. This effect of chaining upon choice was striking whether the concurrent terminal-initial state was preceded by concurrent initial or by concurrent terminal links.

As shown in Figure 1, each experimental state is entered from either of two preceding

states. Due to the distribution of IRIs on each of the VI tapes (the probability of reinforcement is zero until 30% of the mean VI value has elapsed) the expected time to reinforcement for responding on each of the concurrent schedules is different, depending upon which experimental state preceded it. Thus, the sensitivity of the pigeon's choice behavior may be assessed for each experimental state by comparing choice proportions following entry from each of the two preceding states.

For example, consider first the experimental state shown in Figure 1A (concurrent initial links). The organism enters this state following reinforcement in a terminal link concurrent with an initial link. One initial link has been operative for some time, while the other is beginning from the position that had scheduled the previous terminal-link entry. Thus, the expected or average, time to the next terminal-link entry is lower for the former initial link. This difference in expected-time-to-reinforcement is greatest immediately following primary reinforcement, becoming minimal when elapsed time exceeds 30% of the mean VI value. If the organism's choice behavior reflects these differences in expected-time-to-reinforcement, it should respond at a higher rate during the initial link that had been in effect longest. Moreover, this difference should be maximal immediately after reinforcement. Two types of measures were taken in the present study to assess whether the organism's choice behavior demonstrated a sensitivity to these different expected-times-to-reinforcement: (1) rates of responding in concurrent initial links were recorded on different counters, depending upon whether the prior reinforcement had been on the right key (Figure 1C) or on the left key (Figure 1B); (2) the location of the first response on concurrent initial links after primary reinforcement was recorded.

Figure 2 presents the relative rates of responding in the initial links during the conditions indicated on the abscissa according to which of the initial-link schedules had been operative longer. The closed bars indicate the proportion of left-key responses that occurred in the initial links when the left initial link had been operative longer. The open bars indicate the proportion of left-key responses that occurred in the initial links when the right initial link had been operative longer.

Fig. 2. Overall choice proportions for the left key in the initial links when the right initial link (open bars) or left initial link (closed bars) has been operative longer. Open and closed circles show the analogous proportions for only the first response after initial-link entry. The numbers in parentheses above the open and closed bars indicate the relative (obtained) frequencies of conditioned reinforcement on the left key when the right and left initial links had been operative longer.

This figure shows that all birds in all conditions responded relatively more on the left key when its initial link had been operative longer than when the right initial link had been operative longer. The overall initial-link choice proportion in this condition (shown in column vii of Table 1) thus represents a composite of two proportions that are sometimes quite discrepant. The open and closed circles in each condition show the analogous data for only the first response in the concurrent initial links when the left (closed circles) or the right (open circles) initial links had been operative longer. These data show that in 38 of 40 cases, the first initial-link response occurred more frequently on the key on which the schedule had been operative longer (open circles, below 0.50; closed circles, above 0.50), and that in many conditions it did so with a relative frequency of 1.0 (open circles near 0.0; closed circles near 1.0).

In addition to the relative response measures presented in Figure 2, the relative frequencies of obtaining the terminal links (by definition, the relative frequency of conditioned reinforcement) were also recorded, though only in Conditions 4 and 5. The values shown in parentheses above each of the bars in these conditions are the relative frequencies of conditioned reinforcement on the left key, *i.e.*, the number of terminal links produced on the left key divided by the number of terminal links produced on both keys in the presence of concurrent initial links. The numbers above the open bars give the values when the right initial link had been operative longer; those above the closed bars give the values when the left initial link had been operative longer. As expected, the relative frequency of conditioned reinforcement was always higher on the key on which the schedule had been operative longer (values above open bars, less than 0.50; values above closed bars, greater than 0.50). In addition, Figure 2 shows that all open bars correspond to values on the ordinate that are greater than those shown above in parentheses. In other words, the relative rate of responding on the right key was less than the relative frequency of conditioned reinforcement on this key. Likewise, with a single exception (Bird P, Condition 4), all closed bars correspond to values on the ordinate that are less than those shown above in parentheses, indicating that the relative rate of responding on

the left key was less than the relative rate of conditioned reinforcement on this key. Thus, the relative rates of responding in the initial links (open and closed bars) tended to lie between the scheduled relative rate of reinforcement (*i.e.*, 0.50) and the obtained relative frequency of conditioned reinforcement (*i.e.*, values in parentheses).

A similar analysis is presented for concurrent terminal and initial links (Figures 1B and 1C). Is the organism's choice behavior dependent upon whether it enters these states from concurrent initial links or from concurrent terminal links? This question may be meaningfully answered only when the birds enter these states from concurrent terminal links with some regularity (arbitrarily set at a mean of eight entries per session), namely, for Bird D in Condition 4 and for Bird P in Conditions 1, 3, and 4. In the remaining conditions for these birds, and in all conditions for Birds B and F, responses were emitted almost exclusively in the terminal link in the concurrent terminal-initial-link comparison; hence, the concurrent terminal links were rarely entered.

Figure 3 presents terminal-link choice proportions on each key separately for Birds D and P in all conditions that met the criterion. The closed bars represent the relative rate of terminal-link responding in the concurrent

Fig. 3. Choice proportions for concurrent terminal and initial links for a terminal-link that has just been produced (open bars) or has already been operative (closed bars). Only those conditions for which these events occurred with some regularity are presented.

terminal-initial-link state when that state followed concurrent terminal links, *i.e.*, when the terminal-link timer had been operative since it last scheduled a reinforcer. The open bars represent the relative rate of responding on the terminal-link key when the concurrent terminal-initial-link state followed concurrent initial links, *i.e.*, when the terminal link had not been operative since last scheduling a reinforcement. Is choice for the terminal-link key higher when it had been previously operative? Figure 3 shows that although the height of every bar is above 0.50 (indicating more responding in the terminal link than in the initial link), in six of seven comparisons the closed bar is indeed higher than the open bar (in the seventh comparison, they are equal). These data are again consistent with the notion that the organism's choice behavior is influenced by expected time to reinforcement.

Finally, consider the case of concurrent terminal links (Figure 1D). Are higher response rates maintained on the key on which the terminal link had been operative longer?

Fig. 4. Choice proportions for the left key in the terminal links when the right (open bars) or left (closed bars) terminal link has been operative longer. Only those conditions for which these events occurred with some regularity are presented.

This analysis requires a comparison of response rates after entry from each of the two preceding states, again requiring a mean of eight such entries (from each of the two states) per session. The data from Bird P in Conditions 1 and 4, and for Bird D in Condition 4, meet this criterion. Figure 4 shows that for each of these three comparisons, the relative rate of responding is higher on the left key when its terminal link has been operative longer. The relative (obtained) frequencies of reinforcement on the left key in each condition are shown in parentheses. These values represent the number of reinforcements on the left key divided by the number of reinforcements on both keys when either the right terminal link (values above open bars) or the left terminal link (values above closed bars) had been operative longer. The values above the open bars are all less than 0.50, while those above the closed bars are all greater than 0.50, indicating that the relative frequency of reinforcement was always higher on the key on which the terminal-link schedule had been operative longer. Note that the relative rates of responding on this key are less than the relative frequencies of reinforcement on this key in five of the six cases. Thus, the results in these few cases are consistent with those from both the initial-initial- and the initial-terminal-link conditions: choice proportions on a key tend to be higher when this key's schedule has been operative longer, *i.e.*, when this key's expected-time-to-reinforcement has decreased; but this effect is not as large as might be predicted from the obtained rates of reinforcement.

DISCUSSION

The effects of chain length upon choice were assessed by comparing the choice proportions in the presence of concurrent initial- and terminal-link schedules (columns x and xiii of Table 1) to the relative rates of reinforcement. If relative reinforcement rates alone permitted an accurate description of choice, the organism's choice proportions should match these relative rates of reinforcement as they would on simple concurrent schedules (*e.g.*, Herrnstein, 1961, 1970). In other words, choice proportions for a terminal-link VI 15-sec schedule concurrently available with the initial link of a chain VI 60-sec VI

15-sec schedule should equal 0.83, since the VI 15-sec and the chain VI 60-sec VI 15-sec schedules provide 4 reinforcements per minute and 0.8 reinforcements per minute, respectively, and $4/(4 + 0.8) = 0.83$. Thus, the amount by which the choice proportions differ from the relative rates of reinforcement (here 0.83) provides a measure of the effects upon choice of segmenting the behavior requirements. The comparisons of the values in columns x and xiii of Table 1 demonstrate that the choice proportions for the terminal link exceed that expected if the chaining procedure had no effect upon choice: chaining clearly weakens preference. Thus, these results argue against the sufficiency of the interreinforcement interval in characterizing choice, a sufficiency suggested by Rachlin and Herrnstein (1969) and by Neuringer (1969).

In addition, given the choice proportions, the value of a VI schedule that is "functionally equivalent" to the chain schedule may be specified. This would be a VI that would produce the same choice proportion if pitted against the terminal-link schedule in a simple concurrent situation. Table 2 presents these values for each pigeon. For Birds B and F, the average terminal-link choice proportions are 1.00, and the value of the equivalent VI is

indefinitely large. Column ii of Table 2 shows the values of the chain schedules associated with both keys, and column iii gives the average terminal- *vs* initial-link choice proportions as determined on both keys over all conditions indicated in column ii. Column iv gives the value of that VI schedule that is equivalent to the chain schedule. To illustrate how the values in column iv may be derived from the choice proportions in column iii, consider the following example. The terminal-link choice proportions for the VI 60-sec terminal-link schedule were 0.94 for both Birds D and P. This corresponds to a choice ratio of slightly more than 15 to 1 for the VI 60-sec schedule. To produce the same choice ratio with simple concurrent schedules, the schedule on the other key must therefore be about 15 times the value on the terminal-link key, or 940 sec.

Comparison of the intra-organism values in column iv for the two subjects that did not maximize—Pigeons D and P—suggests that the chain schedule may function as a larger-valued schedule when the larger component of the chain—here VI 60-sec—is scheduled in the terminal link rather than when the shorter component of the chain—here either VI 15-sec or VI 30-sec—is scheduled in the terminal link (*e.g.*, 940 sec *vs* 360 sec for Pigeon D and 940

Table 2

The terminal- *vs* initial-link choice proportions for the schedules indicated in column ii were averaged over all conditions for each bird and are presented in column iii. Column iv shows what the value of the chain schedule should be in a simple concurrent situation if the birds matched choice proportions to the relative rate of reinforcement in the terminal links.

i Pigeon	ii VI vs Chain VI VI	iii Choice Proportion for VI	iv VI "equivalent" to Chain VI VI
B	VI 15-sec <i>vs</i> Chain VI 60-sec VI 15-sec	1.00	indefinitely large
	VI 60-sec <i>vs</i> Chain VI 15-sec VI 60-sec	1.00	indefinitely large
D	VI 15-sec <i>vs</i>		
	Chain VI 60-sec VI 15-sec	0.96	360 sec
	VI 60-sec <i>vs</i> Chain VI 15-sec VI 60-sec	0.94	940 sec
P	VI 30-sec <i>vs</i>		
	Chain VI 60-sec VI 30-sec	0.92	345 sec
	VI 60-sec <i>vs</i> Chain VI 30-sec VI 60-sec	0.94	940 sec
F	VI 30-sec <i>vs</i>		
	Chain VI 60-sec VI 30-sec	1.00	indefinitely large
	VI 60-sec <i>vs</i> Chain VI 30-sec VI 60-sec	1.00	indefinitely large

sec vs 345 sec for pigeon P). This suggestion is consistent with Fantino's (1969a,b) finding that the strength of the stimulus, as determined in the choice situation, is a function of the reduction in expected time to reinforcement signified by the onset of one stimulus relative to reduction in the expected time to reinforcement signified by the onset of the other stimulus. One property of this formulation (and of a modified formulation by Squires and Fantino, 1971) is the prediction that whenever chains of the type chain VI x-sec VI y-sec are presented for choice concurrent with chain VI y-sec VI x-sec, then more choice responding will be maintained in the initial link of the chain VI x-sec VI y-sec when x is greater than y. This prediction has been tested only once. Fantino (1969a) compared chain VI 90-sec VI 30-sec to chain VI 30-sec VI 90-sec and found substantially higher choice proportions for the chain VI 90-sec VI 30-sec. The present results definitely suggest that similar confirmation would follow if chain VI 60-sec VI 15-sec were compared directly with chain VI 15-sec VI 60-sec and if chain VI 30-sec VI 60-sec were compared with chain VI 60-sec VI 30-sec.

This study provides some indication that the pigeons are sensitive to momentary likelihood to reinforcement in this procedure. First, Figure 2 shows that in the presence of concurrent initial links the relative frequency of reinforcement was higher on the key on which the schedule had been operative longer and that the choice proportions on this key were also higher. This relation was most clear-cut for the first response after reinforcement on one key; this response generally occurred on the other key. The results described in Figures 3 and 4 were also consistent with the notion that the organism is sensitive to the momentary probabilities of reinforcement. However, it is also clear that the pigeon is not maximizing its rate of reinforcement in these situations, a general possibility raised by Shimp (1969). In the first place, if the pigeon were maximizing, its first response after reinforcement should always be on the key that had not produced reinforcement; this was not the case. In the second place, immediately after entering a terminal link from concurrent initial links, the organism should always respond in the initial link because the terminal link has a zero probability of providing rein-

forcement for some time. Instead, some pigeons responded exclusively on the terminal link. This does not mean that maximizing does not occur when the contingencies are clear to the organism; rather, some, or even all, of the failure to maximize in the present study may represent some forgetting as to which state had preceded the present one. Unfortunately, the present data do not permit an assessment of this speculation.

In summary, the present study supports the notion that the pigeons are sensitive to the momentary likelihood of reinforcement, at least in the procedures studied. On the other hand, they do not appear to maximize their rates of reinforcement by entirely shunning response alternatives that have zero probability of reinforcement. The data also suggest that an accurate characterization of choice may not be obtained by considering only the interreinforcement interval where the interreinforcement interval is segmented into a chain. Instead, the organism's choice for a schedule will be substantially lowered by the chaining operation.

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