

CHOICE AND NUMBER OF REINFORCERS

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Pigeons were exposed to the concurrent-chains procedure in two experiments designed to investigate the effects of unequal numbers of reinforcers on choice. In Experiment 1, the pigeons were indifferent between long and short durations of access to variable-interval schedules of equal reinforcement density, but preferred a short high-density terminal link over a longer, lower density terminal link, even though in both sets of comparisons there were many more reinforcers per cycle in the longer terminal link. In Experiment 2, the pigeons preferred five reinforcers, the first of which was available after 30 sec, over a single reinforcer available at 30 sec, but only when the local interval between successive reinforcers was short. The pigeons were indifferent when this local interval was sufficiently long. The pigeons' behavior appeared to be under the control of local terminal-link variables, such as the intervals to the first reinforcer and between successive reinforcers, and was not well described in terms of transformed delays of reinforcement or reductions in average delay to reinforcement.

Key words: choice, concurrent chains, number of reinforcers, delay of reinforcement, key peck, pigeons

Much recent work investigating the manner in which reinforcers control behavior has been carried out with pigeons in a choice procedure known as concurrent chains. In this procedure, the pigeon is presented with two concurrently available response keys, each illuminated by a stimulus associated with the initial link of a chain. Occasionally, a peck on one key produces a terminal-link stimulus, and the other key becomes dark and inoperative. Further responding on the illuminated key achieves food; at the completion of the terminal link, the initial links are reinstated, and the cycle begins anew. The independent variable in this research is typically some difference between

the ways in which food is presented in the terminal links, and the dependent variable is the distribution of responding in the concurrent initial links, called the choice proportion. The choice proportion is generally expressed as a ratio in the form $R_L/(R_L + R_R)$. The pigeons are said to be indifferent between the terminal links when choice proportions approximate .50 and to exhibit a preference when proportions in favor of a terminal link reliably exceed .50.

One of the more interesting issues that has been addressed using this procedure is the effect of multiple terminal-link reinforcers upon choice. Briefly stated, the question is: What is the effect of arranging a comparatively large number of reinforcers in one terminal link but only a few reinforcers (e.g., 1) in the other? Three principal studies have reported data relating to this issue: Fantino and Herrnstein (1968), McDiarmid and Rilling (1965), and Squires and Fantino (1971).

Fantino and Herrnstein (1968) presented pigeons with a choice between different numbers of reinforcers where the reinforcers were made available by variable-interval (VI) 15-sec schedules. That is, in one terminal link the pigeons would receive one reinforcer according to a VI 15-sec schedule, and in the other, some larger number of reinforcers, such as five, all arranged by a VI 15-sec schedule. Their data

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suggested that the pigeons preferred the terminal link associated with the greater number of reinforcers, and that preferences increased as the number of reinforcers increased.

Similarly, Squires and Fantino (1971) examined choice between concurrent chains where a long initial link was followed by a terminal link with multiple reinforcers (e.g., 10) on one key, and a shorter initial link was followed by a terminal link with a single reinforcer on the other key. As in Fantino and Herrnstein, the reinforcers in the terminal links were arranged by identical VI schedules. Their data suggested that choice proportions were higher on a given key when there were multiple reinforcers in the terminal link as compared to when there was only a single reinforcer in the terminal link. Taken together, the data from this study and from Fantino and Herrnstein's study appear to indicate that a terminal link yielding a large number of reinforcers is more attractive than one yielding a small number.

However, other data suggest that the generality of such an effect is unclear. For example, McDiarmid and Rilling (1965) examined choice between a large and small number of reinforcers in three conditions: (A) when reinforcers in one terminal link were available after 6 sec and 66 sec (2 reinforcers), and in the other after 24, 54, 84, and 114 sec (4 reinforcers); (B) when reinforcers in one terminal link were available after 6 sec and 114 sec (2 reinforcers), and in the other after 24, 30, 36, and 42 sec (4 reinforcers); and (C) when the only reinforcer in one terminal link was available after 6 sec, and in the other after 12, 18, 24, 30, and 36 sec (5 reinforcers). Inasmuch as the terminal links were always of equal overall duration, if number of reinforcers contributes to preference, then presumably the pigeons should have preferred the latter alternative—the one associated with the greater number of reinforcers—in each of the three comparisons. However, McDiarmid and Rilling found that, although the pigeons did prefer the latter alternative in Condition C, they preferred the first alternative in Conditions A and B. In these two conditions, then, if one wishes to relate choice to number of reinforcers, the preferences were directed away from, rather than toward, the greater number of reinforcers. Accordingly, it seems difficult to formulate a generalization on the effects of number of

reinforcers that is consistent with the available data.

In view of these ostensibly conflicting data and interpretations, it may be that it is incorrect to consider the independent variable in such large scale terms, e.g., by appealing to number of reinforcers per se. More specifically, it may be that multiple reinforcers exert two effects: (a) One effect is a function of the interval to the first reinforcer, and (b) a second effect is a function of the interval between successive reinforcers. For example, it may be that the preferences noted in Fantino and Herrnstein (1968) and Squires and Fantino (1971) are instances of the second effect in the sense that the VI schedules by their very character almost certainly arranged successive reinforcers with short local interreinforcement intervals, and any effect may have been attributable to a variable more like amount of the reinforcer than number. This variable may also have been operative in Condition C of McDiarmid and Rilling (1965). In Conditions A and B, however, the preferences may have been instances of the first kind of effect, since there the intervals to the first reinforcer were substantially different, i.e., 6 sec versus 24 sec in each case.

This kind of interpretation may be contrasted with that found in recent quantitative treatments of responding in concurrent chains. In particular, two treatments may be identified as prominent: (a) the Squires and Fantino (1971) equation, and (b) the transformed delay interpretation. Consider first the Squires and Fantino equation:

$$\frac{R_L}{R_L + R_R} = \frac{r_L(T - t_{2L})}{r_L(T - t_{2L}) + r_R(T - t_{2R})} \quad (1)$$

This equation suggests that the proportion of left key responses is described by the reduction in average delay to reward (T) with which the left terminal-link stimulus (t_{2L}) is associated. Squires and Fantino have derived the terms, and they will not be repeated here (for a review, see also Fantino, 1977). Suffice it to note that r_L is the overall rate of reinforcement on the left key, defined as $r_L = n_L / (t_{1L} + n_L t_{2L})$, where n_L is the number of primary reinforcers obtained on one entry into the terminal link on the left key. Thus, there is a unidimensional role assigned to terminal link reinforcers: They act in a molar sense, through the

overall rate of reinforcement. Moreover, this role is assigned to the terminal-link reinforcers irrespective of whether there is one per cycle or whether the numbers of terminal-link reinforcers are equal or unequal. Indeed, Squires and Fantino applied their equation to Fantino and Herrnstein (1968) and to certain of their own data, which involved multiple and unequal numbers of reinforcers. They found that the predicted choice proportions were in the appropriate direction, although they did exceed the obtained choice proportions somewhat. Now, the equation is primarily used with VI schedules in the initial and terminal links. A problem arises when the logic of the equation, with its unidimensional role for terminal-link reinforcers, is applied to other situations, such as McDiarmid and Rilling (1965). The overall rate of reinforcement is not a reliable predictor of preference. Accordingly, there is a limitation on the generality of the principle by which reinforcers are assumed to strengthen behavior.

Consider a second kind of quantitative treatment which suggests that the interval from the last choice response to the subsequent reinforcer(s) be transformed according to a power function, $f(y) = y^r$. The choice proportion is then calculated, using the transformed terminal link intervals. Killeen (1968, p. 269) suggested that these intervals could simply be summed. The straightforward implication of this approach is as follows:

$$V_L = \sum_{i=1}^N y_i^r; \frac{R_L}{R_L + R_R} = \frac{V_L}{V_L + V_R}. \quad (2)$$

A more recent study in this tradition, Hursh and Fantino (1973), found a better fit by summing and then averaging:

$$V_L = \frac{1}{N} \cdot \sum_{i=1}^N y_i^r; \frac{R_L}{R_L + R_R} = \frac{V_L}{V_L + V_R}. \quad (3)$$

In any case, a unidimensional role for reinforcers is postulated: Each reinforcer strengthens responding in proportion to some transformation of its delay. Now, both Equations 2 and 3 can handle equal numbers of reinforcers, when n is one or greater than one. However, Equation 3 makes markedly inaccurate predictions in some cases when unequal

numbers of reinforcers are involved. For example, if applied to Fantino and Herrnstein (1968), the equation predicts preference for a single reinforcer over any number of multiple reinforcers. Equation 2 is very consistent with the data of Fantino and Herrnstein and, accordingly, would seem to be the more general treatment. The r value required to fit the data varies with the size of the interval that is transformed. For short intervals, such as those with VI schedules, ($r = -1$) is appropriate, and for longer intervals, such as with longer FI schedules, ($r = -4$) or greater is required (see Duncan & Fantino, 1970, Figure 8). For convenience, the type of treatment described by Equation 2 may be designated as the transformed delay interpretation where it is understood that the parameter of transformation is proportional to the interval that is being transformed. This treatment also yields predictions that are consistent in principle with the data of Squires and Fantino (1971) and McDiarmid and Rilling (1965). However, there is somewhat of a problem in the latter study. To account for these data, the transformation parameter that is required to fit the data ($r = -1$) is not the same as that required with similar intervals in other studies (cf. Duncan & Fantino, 1970), again suggesting a limitation on the generality of the approach.

Squires and Fantino (1971, pp. 36-37) did suggest that, in their study, later reinforcers in the sequence may have had less effect than did the first few, which is in keeping with the spirit of the transformed delay approach. However, they report that the nontransformed, arithmetic intervals actually yielded a better fit than did transformed intervals. Accordingly, it is difficult to discern what general approach is adequate, and again there is the continuing problem with the generality of the treatments.

The present research sought to shed light on these problems. Additional instances of choice between different numbers of reinforcers were examined, with the intent to assess the role of the interval to the first reinforcer (Experiment 1) and the interval between successive reinforcers (Experiment 2). It was thought that, after the effects of these variables had been assessed, a better understanding of the complex controlling relations could be achieved, especially as the controlling relations pertain to the adequacy of recent quantitative treatments of choice.

EXPERIMENT 1

In Experiment 1, different numbers of reinforcers were arranged according to a variation of Autor's (1969; Note 1) procedure. That is, in Autor's procedure, the pigeon produced a terminal link that remained in effect for a predetermined period of time. During that time, reinforcers were made available by an associated VI schedule. In the present variation of this procedure, one terminal link was in effect for a longer period of time than the other, and hence yielded a greater number of reinforcers per cycle than did the other. This procedure is not a special case inasmuch as Squires and Fantino (1971) have already shown that data from this procedure compare favorably with other data. Behavior in the present experiment was examined in four conditions. In two conditions, the terminal-link VI schedules were equal, as in Fantino and Herrnstein (1968) and Squires and Fantino (1971); in the other two conditions, the VI schedules were unequal. The latter comparisons had not been reported before and constituted a test of whether a small number of reinforcers, presented over a short period according to a rich VI schedule, could counteract a larger number of reinforcers, presented over a longer period but by a leaner VI schedule.

METHOD

Subjects

Four adult male white Carneaux pigeons (P-1, P-2, P-3, and P-4), maintained at approximately 80% of their free-feeding weights, served. All pigeons had experience with a variety of experimental schedules, including concurrent chains.

Apparatus

A two-key version of the standard experimental chamber for pigeons was used (Ferster & Skinner, 1957). Conventional electromechanical programming apparatus, located in a room adjacent to the experimental chambers, controlled events within the chambers and recorded the data.

Procedure

The initial links were nonindependent VI 240-sec schedules (Stubbs & Pliskoff, 1969). Each terminal link lasted for a predetermined duration. During that period, reinforcers were

made available by an associated VI schedule. At the conclusion of the terminal link, the initial links were reinstated automatically. The terminal-link duration timer ran also during reinforcement cycles. If a reinforcer was made available but not collected, that reinforcer remained available on the next entry into the terminal link. The specifications of the terminal links were as follows.

1. In Condition 1, identical VI 20-sec schedules were in effect in the terminal links. One terminal link was in effect for 20 sec (VI 20/20, 1 reinforcer), and the other for 180 sec (VI 20/180, 9 reinforcers).

2. In Condition 2, identical VI 60-sec schedules were in effect in the terminal links. One terminal link was in effect for 60 sec (VI 60/60, 1 reinforcer), and the other for 180 sec (VI 60/180, 3 reinforcers).

3. In Condition 3, a VI 20-sec schedule was in effect for 40 sec in one terminal link (VI 20/40, 2 reinforcers), and a VI 45-sec schedule was in effect for 270 sec in the other (VI 45/270, 6 reinforcers).

4. In Condition 4, a VI 20-sec schedule was in effect for 40 sec in one terminal link (VI 20/40, 2 reinforcers), and a VI 60-sec schedule was in effect for 360 sec in the other (VI 60/360, 6 reinforcers).

The particular initial- and terminal-link schedules were chosen because current accounts (e.g., Squires & Fantino, 1971) suggest that particular results should obtain in each condition. Also, the terminal link offering the fewer number of reinforcers was twice as long as the average interreinforcement interval in Conditions 3 and 4, meaning that it arranged two reinforcers per cycle on the average. This feature of the terminal links made these conclusions even more closely comparable with earlier studies (e.g., Autor, 1960, 1969) and also minimized any potential complications brought about by the omission of a reinforcer on a terminal-link entry.

In the initial links, both keys were white. The left terminal-link stimulus was a green keylight, and the right, a red keylight. The unconditioned reinforcer was 3-sec access to mixed grain. All VI tapes were constructed according to Segal's (1964) method. Sessions were conducted 6 days per week, and were 1 hr in duration.

A stability criterion was used to assess steady-state performance. This criterion required that

Table 1

The schedules and data are presented for each pigeon in Conditions 1, 2, 3, and 4 of Experiment 1. Included are the schedules (preceding the slash) and duration of access (following the slash) in the left (L) and right (R) terminal links, the choice proportion for the shorter duration terminal link with the standard deviation (except for Condition 4), the absolute rate of response (resp/min) in the initial link on the shorter duration key, and the number of sessions. The initial links were VI 240-sec. All terminal link VI values and durations are in sec. The choice proportions and absolute response rates are averages from the last nine sessions of each determination.

Pigeon	Terminal-link schedules		Choice proportion for shorter duration	Initial-link resp/min on shorter duration key	Sessions
	L	R			
<i>Condition 1</i>					
P-1	VI 20/20	VI 20/180	.43 (.02)	18	19
	VI 20/180	VI 20/20	.37 (.10)	5	33
	VI 20/20	VI 20/180	.52 (.07)	5	33
	VI 20/180	VI 20/20	.56 (.05)	2	16
	VI 20/20	VI 20/180	.44 (.06)	3	17
P-2	VI 20/20	VI 20/180	.47 (.03)	39	19
	VI 20/180	VI 20/20	.50 (.07)	20	19
P-3	VI 20/180	VI 20/20	.53 (.04)	20	15
	VI 20/20	VI 20/180	.35 (.05)	10	36
	VI 20/180	VI 20/20	.60 (.05)	18	16
P-4	VI 20/180	VI 20/20	.54 (.06)	21	15
	VI 20/20	VI 20/180	.49 (.06)	18	15
<i>Condition 2</i>					
P-1	VI 60/60	VI 60/180	.53 (.03)	27	20
	VI 60/180	VI 60/180	.46 (.06)	21	17
P-3	VI 60/180	VI 60/60	.53 (.03)	31	16
	VI 60/60	VI 60/180	.45 (.03)	25	32
	VI 60/180	VI 60/60	.50 (.03)	22	15
<i>Condition 3</i>					
P-1	VI 20/40	VI 45/270	.65 (.04)	14	33
	VI 45/270	VI 20/40	.54 (.01)	8	28
P-2	VI 20/40	VI 45/270	.66 (.05)	18	34
	VI 45/270	VI 20/40	.56 (.04)	28	30
P-3	VI 20/40	VI 45/270	.57 (.05)	20	27
	VI 45/270	VI 20/40	.61 (.01)	23	30
P-4	VI 20/40	VI 45/270	.69 (.03)	35	24
	VI 45/270	VI 20/40	.52 (.02)	15	42
<i>Condition 4</i>					
P-2	VI 60/360	VI 20/40	.65*	31	20
	VI 20/40	VI 60/360	.68*	37	28
P-3	VI 20/40	VI 60/360	.59*	15	16
	VI 60/360	VI 20/40	.56*	26	28
P-4	VI 20/40	VI 60/360	.63*	14	15
	VI 60/360	VI 20/40	.59*	16	32

*Standard deviation not available.

the pigeon perform in at least 15 sessions. After the 15th session, or every session thereafter if the criterion was not satisfied, the choice proportions from the last 9 sessions were then considered in 3 blocks of 3 sessions each. When the mean choice proportions of the blocks differed by no more than .05 and showed neither a monotonically increasing nor decreasing

trend, performance was judged stable. An initial determination and at least one reversal, wherein the former left terminal-link alternative was presented in the right terminal link and vice versa, were conducted with each set of terminal-link conditions. Table 1 presents the details of the conditions to which the pigeons were exposed in Experiment 1.

RESULTS AND DISCUSSION

The data of interest are the choice proportions as a function of the number of terminal-link reinforcers in each of the four conditions. Table 1 presents the choice proportions for individual pigeons in each determination. The choice proportions are also graphed in Figure 1. For simplicity, the figure presents the choice proportions as simple averages of the determinations in each of the conditions; the determinations are taken from Table 1. The choice proportions in Figure 1 are expressed in terms of the shorter duration terminal link. Thus, a choice proportion appreciably in excess of .50 means that preferences were directed toward that terminal link. Similarly, a choice proportion less than .50 means that the pigeons preferred the terminal link of longer duration, yielding the larger number of reinforcers.

As seen in Figure 1, the pigeons were generally indifferent in Conditions 1 and 2, when

the densities of the VI terminal-link schedules were equal. With respect to Condition 1, inspection of the individual determinations in Table 1 shows that P-2 and P-4 were indifferent in both initial and reversal determinations. P-1 at first seemed to prefer the greater number of reinforcers, but its behavior on subsequent determinations failed to indicate any systematic control by number of reinforcers. P-3 was indifferent in the initial determination, then seemed to adopt a right-key bias that was not systematically affected by further terminal link manipulations. With respect to Condition 2, P-1 and P-3 were indifferent on all determinations.

The pigeons in Conditions 3 and 4 generally preferred the richer density terminal link. With respect to Condition 3, Table 1 reveals that P-2 and P-3 preferred VI 20/40 over VI 45/270 in both initial and reversal determinations. P-1 and P-4 preferred VI 20/40 in the initial determination, but it is not clear why the choice proportions in the reversal were not

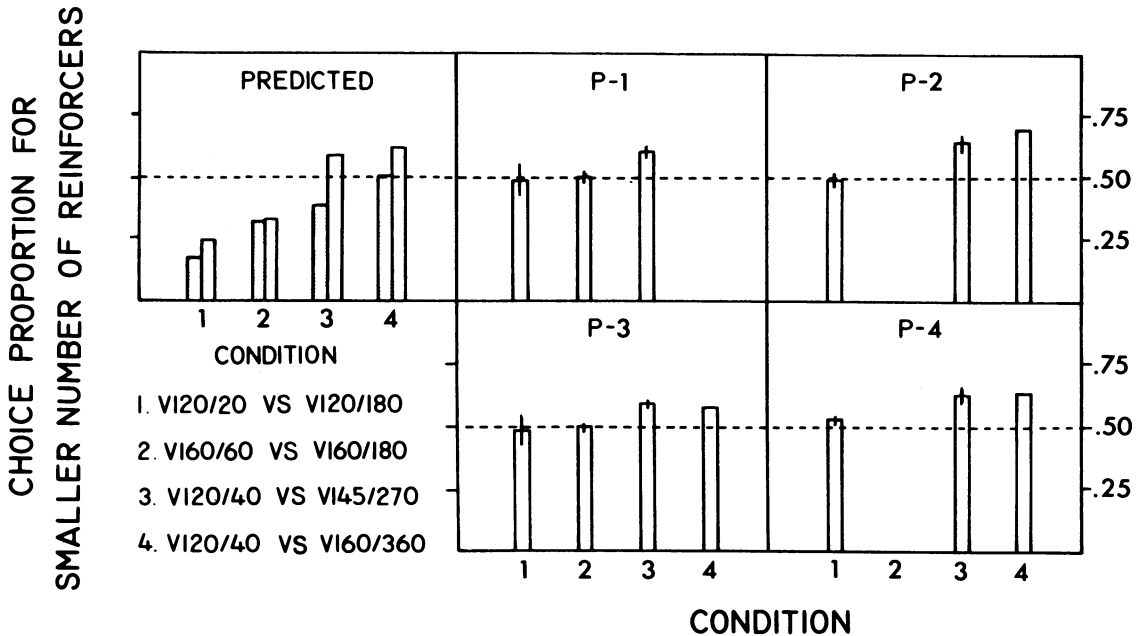


Fig. 1. The choice proportions are shown for individual pigeons in Experiment 1. The data are averages of the determinations listed in Table 1 with the standard deviations, and are expressed in terms of the terminal link with the shorter duration. Thus, bars in the range of .50 (dotted horizontal line) indicate indifference between the terminal links; bars less than .50 indicate preference in favor of the longer terminal link, hence for the larger numbers of reinforcers. Bars above .50 indicate preference in favor of the alternative terminal link, which was of a shorter duration and yielded fewer reinforcers per cycle. The predicted choice proportions are from the Squires and Fantino (1971) equation (left bar) and the transformed delay interpretation (right bar, see Equation 2 above) with a transformation parameter of ($r = -1$). All initial links were VI 240-sec. Note that position bias, evident in Table 1, for P-1 and P-3 in Condition 1, gives the impression of great intersession variability.

as great. With respect to Condition 4, all pigeons preferred VI 20/40 over VI 60/360 on each determination.

Thus, this experiment found results inconsistent with both Fantino and Herrnstein (1968) and Squires and Fantino (1971). When the interreinforcement intervals in the terminal links were equal, the pigeons were generally indifferent despite a 9-to-1 advantage in number of reinforcers favoring the longer terminal link. When they were unequal, the pigeons generally preferred the short access, richer density terminal link despite a 3-to-1 advantage in number of reinforcers favoring the longer terminal link. The direction of preference is best interpreted as a simple function of which terminal link was more likely to yield a reinforcer sooner after onset. A greater number of reinforcers in one terminal link failed to control preference. An obvious question now is: Why are the present results inconsistent with the earlier results?

One procedural difference between the present study and both Fantino and Herrnstein (1968) and Squires and Fantino (1971) is the use of nonindependent initial links in the present study. However, it is questionable to try to account for the present results in terms of this difference because there is no systematic research on whether this procedure—which is essentially a control procedure to guard against overexposure to one of the choice alternatives—will affect choice. In fact, Schneider (1973) has argued persuasively that, although there are strong intuitive reasons to suppose the procedure should affect choice, few data if any support that it actually does. (For one possible exception to Schneider's argument, see MacEwen, 1972).

A second procedural difference involves the manner in which terminal-link reinforcers were arranged. It is likely that this difference is the key to interpreting the present results. The present procedure made possible massed presentations (i.e., presentations with short local interreinforcement intervals) of reinforcers in both terminal links rather than in just the one with the larger number of reinforcers, as in Fantino and Herrnstein (1968) and Squires and Fantino (1971). Thus, massed reinforcers presumably did not exert a differential effect in the present study because they were possible in both terminal links. That this terminal-link scheduling procedure produces results that are

different from those of Fantino and Herrnstein and Squires and Fantino is precisely the point, and adds support to the suggestion in the introduction to this experiment, i.e., that two different classes of independent variables are operating, rather than just number of reinforcers per se.

EXPERIMENT 2

Experiment 2 sought to clarify the effect of the local interreinforcement interval associated with the greater number of reinforcers, where local interreinforcement interval is defined as the interval between successive reinforcers. Figure 2 is a graphic display of the terminal links in Experiment 2. Essentially, the pigeons were always choosing between one and five terminal-link reinforcers. The first of the five reinforcers was made available by a schedule that was equal in length to the single schedule in the other terminal link. The remaining four schedules, which were equal but shorter, were varied parametrically.

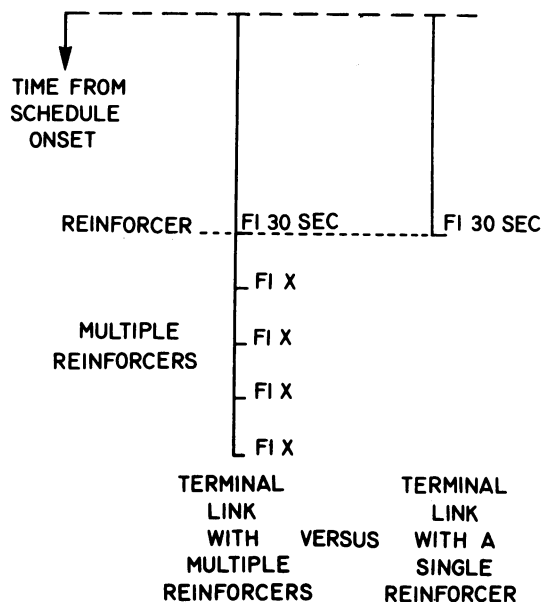


Fig. 2. The temporal distribution of reinforcers is shown for the terminal links in Experiment 2. The lines are time lines, as measured from onset of the terminal link schedule. The marks along the lines indicate the occurrence of reinforcers. In the single reinforcer terminal link, there was one reinforcer according to a single FI 30-sec schedule. In the terminal link with multiple reinforcers, there were five reinforcers. The first was always according to an FI 30-sec schedule. Each of the next four reinforcers was according to an FI x -sec schedule.

METHOD

Subjects

Three adult male white Carneaux pigeons (P-5, P-6, and P-7), maintained at approximately 80% of their free-feeding weights, served. All pigeons had previous experience with a variety of experimental procedures, including concurrent chains.

Apparatus

Same as in Experiment 1.

Procedure

The initial links were nonindependent VI 60-sec schedules (Stubbs & Pliskoff, 1969). The time to the first reinforcer was always the same in each terminal link, fixed-interval (FI) 30-sec. The values of the initial and terminal links were comparable with those used in earlier studies investigating related issues (Davison, 1968; Fantino & Herrnstein, 1968; Hursh & Fantino, 1973). In the multiple reinforcer terminal link, each of the next four food presentations was according to an FI x -sec schedule. The length of the FI x -sec schedule, i.e., the local interreinforcement interval, was then

manipulated parametrically between 3 sec and 20 sec. The lengths were chosen in a quasi-random manner with the aim of identifying which lengths produced preference and which produced indifference. In addition, reversals were frequently conducted to clarify whether there was preference with a given local interreinforcement interval. Table 2 presents the details of the schedules to which the pigeons were exposed in Experiment 2.

Other details of the procedure (colors of the keylights, stability criterion, calculation of the choice proportions, session length) were the same as in Experiment 1.

RESULTS AND DISCUSSION

The data of interest are again the stable choice proportions engendered by each value of the local interreinforcement interval. Table 2 presents the choice proportions for individual pigeons in each determination. The choice proportions are also graphed in Figure 3. For simplicity, the figure presents the choice proportions as simple averages of the determinations listed in Table 2. Thus, the data points at 3 sec, 6 sec, etc. are averages of the determinations when the pigeons chose be-

Table 2

The schedules and data are presented for each pigeon in Experiment 2. Included are the schedules in the left (*L*) and right (*R*) terminal links (FI values are in sec), the choice proportions for the multiple reinforcers with the standard deviation, the absolute rate of response (resp/min) in the initial link on the multiple reinforcer key, and the number of sessions. The initial links were all VI 60-sec. The choice proportions and absolute response rates are averages from the last nine sessions in each determination.

Pigeon	Terminal-link schedules		Choice proportion for multiple reinforcer	Initial-link resp/min on multiple reinforcer key	Sessions
	<i>L</i>	<i>R</i>			
P-5	FI 30	FI 30 + 4 @ FI 9	.72 (.05)	32	20
	FI 30 + 4 @ FI 12	FI 30	.64 (.07)	35	30
	FI 30	FI 30 + 4 @ FI 15	.65 (.05)	36	32
	FI 30 + 4 @ FI 20	FI 30	.50 (.03)	24	15
	FI 30	FI 30 + 4 @ FI 20	.51 (.03)	24	15
	FI 30	FI 30 + 4 @ FI 15	.75 (.06)	38	15
	FI 30 + 4 @ FI 20	FI 30	.49 (.04)	29	30
	FI 30 + 4 @ FI 6	FI 30	.83 (.06)	40	28

Table 2 *continued*

Pigeon	Terminal-link schedules		Choice proportion for multiple reinforcer	Initial-link resp/min on multiple reinforcer key	Sessions
	L	R			
P-6	FI 30	FI 30 + 4 @ FI 3	.65 (.06)	32	30
	FI 30 + 4 @ FI 9	FI 30	.65 (.03)	39	18
	FI 30	FI 30 + 4 @ FI 6	.65 (.02)	47	30
	FI 30 + 4 @ FI 12	FI 30	.50 (.06)	25	16
	FI 30 + 4 @ FI 9	FI 30	.68 (.05)	47	15
	FI 30 + 4 @ FI 12	FI 30	.55 (.06)	21	16
	FI 30	FI 30 + 4 @ FI 12	.52 (.02)	22	17
	FI 30 + 4 @ FI 20	FI 30	.45 (.10)	16	44
	FI 30 + 4 @ FI 6	FI 30	.61 (.05)	26	19
	FI 30 + 4 @ FI 15	FI 30	.46 (.06)	13	15
P-7	FI 30	FI 30 + 4 @ FI 3	.66 (.08)	41	15
	FI 30 + 4 @ FI 3	FI 30	.64 (.06)	29	37
	FI 30	FI 30 + 4 @ FI 9	.73 (.04)	36	28
	FI 30	FI 30 + 4 @ FI 6	.65 (.03)	31	19
	FI 30 + 4 @ FI 12	FI 30	.50 (.03)	30	18
	FI 30	FI 30 + 4 @ FI 9	.65 (.04)	27	17
	FI 30	FI 30 + 4 @ FI 15	.68 (.05)	43	19
	FI 30 + 4 @ FI 15	FI 30	.35 (.06)	20	22

tween FI 30-sec in one terminal link, and FI 30-sec plus four FI 3-sec (or FI 30-sec plus four FI 6-sec, etc.) in the other terminal link. The reader will recall that all determinations involved a stability criterion and may consult Table 2 for details of the individual determinations.

With the exception of the single data point for P-5 when FI x -sec was 6 sec, the common feature of the choice proportions in Figure 3 appears to be a two-state effect, where the pigeons preferred the five reinforcers at more or less a consistent level until the local inter-

reinforcement interval reached some critical temporal value. This value was 15 sec for P-5 and 9 sec for P-6 and P-7. Beyond this value, indifference prevailed.

In general, the behavior seemed to be quite systematic with respect to the local interreinforcement interval. For example, consider the behavior of Pigeon P-5 as indicated in Table 1. When the local interreinforcement interval was 15 sec (i.e., when the five reinforcers were made available according to an FI 30-sec schedule followed by four FI 15-sec schedules), there was preference for the five reinforcers. When

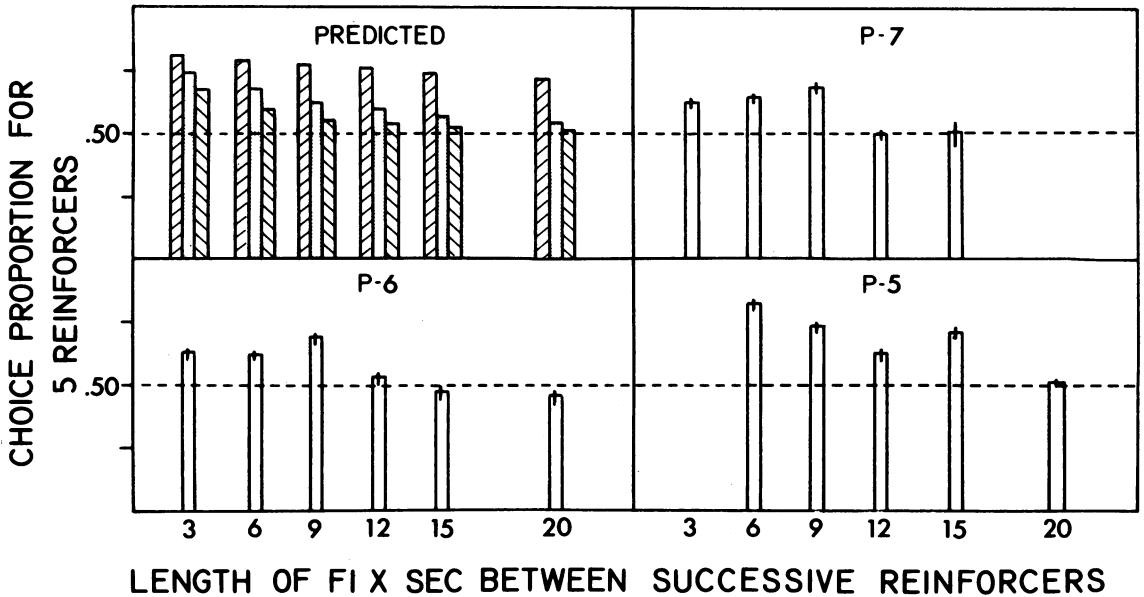


Fig. 3. The choice proportions are shown for individual pigeons in Experiment 1 as a function of the local interreinforcement interval separating the last four reinforcers. The data are averages of the determinations with standard deviations listed in Table 2 and are expressed in terms of the terminal link yielding five reinforcers. Thus, bars in the range of .50 (dotted horizontal line) indicate indifference between one and five terminal-link reinforcers; bars extending above .50 indicate preference for the multiple reinforcers. All initial links were VI 60-sec, and the time to the first reinforcer was FI 30-sec in each terminal link. Thus, the data at 3 sec represent the choice proportion for (FI 30-sec + FI 3-sec + FI 3-sec + FI 3-sec + FI 3-sec) versus (FI 30-sec). Also shown for each local interreinforcement interval are three predicted choice proportions of the transformed delay interpretation, based on 3 different transformation parameters [r : -1 (left bar), -4 (center bar), -7 (right bar)]. The predicted choice proportions were derived from Equation 2 above. Note that position bias, evident in Table 1 for P-7 at a local interreinforcement interval of 15 sec, gives the impression of great intersession variability.

the local interreinforcement interval was increased from 15 sec to 20 sec, there was indifference, even through a reversal. When the local interreinforcement interval was decreased to 15 sec, there was again preference, and with an increase to a local interreinforcement interval of 20 sec, indifference. Thus, the choice behavior tracked the terminal link manipulations fairly well.

The behavior of pigeon P-6 was also fairly consistent and reflected control by the local interreinforcement interval in the terminal link. There was uniform preference until the local interreinforcement interval reached 12 sec, at which level the pigeon became indifferent. The preference was recovered, and then the indifference was replicated, with local interreinforcement intervals of 9 sec and 12 sec. There was an additional finding of preference at 6 sec, and another finding of indifference with a local interreinforcement interval of 15 sec. The last three determinations from this pigeon are particularly interesting. The five re-

inforcers were always on the left terminal link, yet the behavior reliably indicated indifference, preference, and then indifference with changes in the local interreinforcement interval. The changes in the choice proportions here were about .15 in each case.

Pigeon P-7 also tracked the terminal link manipulations until the local interreinforcement interval reached 15 sec. At this level, the pigeon adopted what is usually described as a key or position bias, in favor of the right key. The bias did appear first to favor the five reinforcers, but since the behavior failed to reverse with a reversal of the terminal links, it is difficult to conclude that there was systematic control by the terminal links, especially when the indifference at a 12-sec local interreinforcement interval is considered. It is noteworthy that key bias was a problem in Fantino and Herrnstein (1968) as well.

In summary, the pigeon's choice between one and five reinforcers was related to the local interreinforcement interval among the five

reinforcers, rather than to the larger number per se. When the local interreinforcement interval was short, there was preference. However, when it was long, there was indifference. Moreover, this indifference held even though the overall rate of reinforcement as well as the number of reinforcers was higher in the terminal link yielding five reinforcers. For example, with a local interreinforcement interval of 20 sec, the overall average time between successive reinforcers was about 22 sec, which compares with the fixed time of 30 sec in the other terminal link. Thus, as in Experiment 1, a central finding was that preferences were not generally directed toward what is ordinarily considered the more favorable terminal link, measured in terms of the number of reinforcers or simple arithmetic rate of reinforcement.

GENERAL DISCUSSION

The present two experiments examined pigeons' choices between unequal number of reinforcers. The preferences were found to be a function of the interval to the first reinforcer and the interval between successive reinforcers. Their preferences were not generally directed toward the greater number of reinforcers per se.

The importance of the interval to the first reinforcer was shown in Experiment 1. When the VI schedules were equal, meaning that on the average the intervals from schedule onset to the first reinforcer were equal, the pigeons were indifferent. When the schedules were unequal, meaning that one schedule provided a reinforcer sooner after onset than did the other, the pigeons preferred that schedule. These findings obtained despite a clear net advantage, in terms of more reinforcers, favoring the longer terminal link.

The importance of the interval between successive reinforcers was shown in Experiment 2. Here, the choice was always between one and five reinforcers, yet there was preference for the five reinforcers only when the local interreinforcement interval was sufficiently short. This pattern of preference suggests that the behavior may have been a function of some variable like amount of the reinforcer, as suggested earlier. The specific parameters that indicate just how short the local interreinforcement interval must be to exert an effect like amount are then defined in Figure 3. That pi-

geons do prefer the greater of two amounts of the reinforcer has, of course, been previously documented (Catania, 1963; Neuringer, 1967; Schwartz, 1969; Ten Eyck, 1970). Moreover, it has long been known that multiple food presentations are a highly effective means of facilitating behavior, even when the overall amount of the reinforcer is constant (Grindley, 1929; Wolfe & Kaplon, 1941). Thus, the present data suggest that the effects of reinforcers following the first must be interpreted cautiously. So far as present data indicate, it appears that one effect of reinforcers after the first is to enhance the strength of the first, when they are close enough in time to the first (but see Kendall, 1967). In this sense, the effect noted here seems to parallel that of increasing the amount of the reinforcer.

It is instructive to consider the predictions of the two quantitative treatments, the Squires and Fantino (1971) equation and the transformed delay interpretation, as they relate to the present data. First, consider Experiment 1. Figure 1 presents the predictions of both the Squires and Fantino equation and the transformed delay account. The Squires and Fantino equation requires preference for the larger number of reinforcers in both Conditions 1 and 2. Similarly, the transformed delay account predicts preference for the larger number of reinforcers in Conditions 1 and 2. The transformation parameter is ($r = -1$), suggested by Duncan and Fantino (1970), Hursh and Fantino (1973), and Killeen (1968) as appropriate to VI schedules. As shown in Figure 1, the predictions do not well describe the obtained data, which suggest indifference in both conditions.

The predictions in Conditions 3 and 4 are particularly interesting. The Squires and Fantino equation predicts preference for the greater number of reinforcers in Condition 3 and indifference in Condition 4. The transformed delay interpretation, with a transformation parameter of ($r = -1$), predicts preference for the higher density schedule in each condition. Of particular interest is the theoretical discordance between the predictions of the models in Condition 3, where one model predicts preference in one direction and the other in the opposite direction. In any case, as seen in Figure 1, the pigeons preferred the higher density alternative in each condition. In summary then, neither model can accom-

modate both the indifference in Conditions 1 and 2 and the preferences in Conditions 3 and 4.

In Experiment 2, FI terminal-link schedules were used. Presumably, the transformed delay interpretation is more appropriate here, rather than the Squires and Fantino equation. Figure 3 presents the predicted data from Equation 2 with three representative transformation parameters. The predicted data do not appear to conform to the obtained data when compared on the basis of either the overall shape of the function or any set of points derived with a given transformation parameter.

It appears then that current treatments do not well describe the present data. This discrepancy between predicted and obtained data is important because these treatments have postulated specific roles for reinforcers in FI and VI schedules in cases where there are both single and multiple reinforcers per terminal link. Thus, the data do not support the manner in which the treatments say reinforcers act. The underlying issue here, of course, is how to characterize the manner in which reinforcers over time control behavior, and involves far more than, say, any particular version of how a VI schedule can be converted to its FI equivalent. The reader will undoubtedly recognize that a conspicuous trend in the literature for at least 10 years has been to try to express mathematically the reinforcing effectiveness of certain schedules. Probably the most familiar attempt has been to express the effectiveness in terms of some common denominator dimension, such as "value." The net result of this trend has been an incredible proliferation of special feature equations, each of which claims some measure of generality but works only in restricted circumstances. In any case, one general property that ties together this entire trend of research, irrespective of the particular experimental issue with which the research is concerned, is an assumption of comparatively large-scale controlling relationships. That is, virtually all accounts implicitly endorse the notion that the effectiveness of the reinforcers is to be subsumed under one general heading; reinforcers are not recognized as having different classes of effects over time. For example, in the Squires and Fantino equation, all reinforcers contribute to one variable: average overall rate of reinforcement. Similarly, in the transformed delay equation (e.g.,

Equation 2 above), all reinforcers contribute to the transformed sum of the intervals from schedule onset to their occurrence. There is no recognition that the reinforcers might function in any other manner. Consider the following quotation (Baum, 1973), which captures rather nicely the spirit of the assumption of large-scale controlling relationships:

[control by events over a substantial period of time] implies an averaging or integrating capability on the part of the organism. Such integrating must [sic] be commonplace in an organism's reactions to its environment. . . . [A]n organism may be viewed as collecting time samples of significant events in its environment (e.g., reinforcers and punishers), which it then uses to control its behavioral output. The exact nature of this integrating or averaging process has been the subject of some recent research (Killeen, 1968; Davison, 1969; Duncan and Fantino, 1970; Schneider, J. W., 1970). (p. 148)

In principle, of course, the position expressed in the quotation above is not new. It presumably derived from the reactions of Thorndike, Holt, Tolman, and Skinner to classical muscle-twitch behaviorism. Historical issues aside, the position does not appeal solely to contemporary concurrent chains research for support, but there is a good deal of mutual support between the concurrent chains literature and the theoretical position asserted above. In fact, all the references in the quotation above are concurrent chains studies. In any case, it now appears time to consider alternative approaches to characterizing the manner in which reinforcers over time strengthen behavior. The very fact that so many equations are required should have been a warning signal; the conflicting theoretical predictions in Experiment 1, Condition 3, where one can choose an existing model to support preference for either alternative, is just one symptom of the larger problem. So far as present data indicate, the independent variables operate in a much different time frame than current accounts have suggested.

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