

CHOICE AND BEHAVIORAL PATTERNING

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Ten pigeons pecked left and right keys in a discrete-trials experiment in which access to food was contingent upon changeovers to the right key after particular runs of left-key pecks. In each of three sets of conditions, two run lengths were reinforced according to a concurrent variable-interval schedule: reinforcement followed runs of either 1 or 2, 1 or 4, or 2 or 4 left-key pecks preceding changeovers. The intertrial interval separating successive pecks was varied from .5 to 10.0 sec, and the relative frequency of reinforcement for the shorter of the two reinforced runs was varied from 0 to .75. The contingencies established local behavioral patterning that roughly approximated that required for reinforcement. For a fixed pair of reinforced run lengths, preference for the shorter of the two frequently increased as the intertrial interval increased and therefore as the minimum temporal durations of both reinforced runs increased. Preference for the shorter of the two also increased as its corresponding relative frequency of reinforcement increased. Both of these effects on preference were qualitatively similar to corresponding effects in previous research with two different kinds of reinforced behavioral patterns, interresponse times and interchangeover times. In all these experiments, analytical units were found in the temporal patterns of behavior, not in the behavior immediately contiguous with a reinforcer. It is suggested that a particular local temporal pattern of behavior is established to the extent to which it is repeatedly remembered when reinforcers are delivered, regardless of whether the delivery of a reinforcer is explicitly contingent upon that pattern.

Key words: choice, variable-interval schedules, changeovers, differential reinforcement, behavioral patterning, pigeons

Although many studies of the temporal patterning of animal behavior focus on phylogenetic issues, as in for example studies of foraging and bird song, others focus more on ontogenetic issues. These latter experiments have focused on both the small- and large-scale temporal organization of behavior and on such conceptual issues as the efficacy of reinforcement in shaping temporal patterning and memory for behavioral patterning (Fetterman & Stubbs, 1982; Gibbon, 1977; Hulse, 1978; Marr, 1979; Schwartz, 1980; Silberberg, Hamilton, Ziriaux, & Casey, 1978; Straub, Seidenberg, Bever, & Terrace, 1979; Wasserman, Deich, & Cox, in press; Zeiler, 1979). Two types of patterns in pigeons' key pecking that have been rather systematically studied are interresponse times, the times between successive pecks, and interchangeover times, i.e., the times between successive changeovers from one key to another.

Both types of patterns are similarly affected by several experimental manipulations. First, if reinforcement is contingent upon such patterns, they become shaped and they, rather than key pecks, become analytical units (Hawkes & Shimp, 1974; Shimp & Hawkes, 1974; Shimp, 1979). Second, preference between patterns of the same type, as between two classes of interresponse times or between two classes of interchangeover times, depends in similar ways on the distribution of reinforcements across patterns (Shimp, 1979, in press). Third, preference for the shorter pattern decreases as the relative duration of that pattern increases—that is, as the two reinforced patterns become more nearly similar (Shimp, 1976, 1979, 1981b, in press).

The present experiment was designed to explore the generality of these and other empirical relations obtained previously with interresponse times and interchangeover times. Here, the generality was explored in the context of a third type of behavioral pattern, where a pattern consisted of a run of successive pecks on one of two keys preceding a changeover to the

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other key. We ask, can such patterns be chunked into new analytical units? If so, does preference conform to the empirical results with interresponse times and interchangeover times?

METHOD

Subjects

Ten White Carneaux pigeons were maintained at 80% of their free-feeding weights, plus or minus 20 g. Birds 2 and 5 were experimentally naive. The other eight birds had served in an experiment with the same contingencies as those used here, but with reinforced run lengths of 2 and 4 (Birds 1, 3, 4, and 6) or 2 and 8 (Birds 7, 8, 9, and 10) and with an intertrial interval of .5 sec (Shimp, in press).

Apparatus

Six standard two- or three-key Lehigh Valley Electronics pigeon chambers were interfaced to a Digital Equipment Corporation PDP 8/e, which arranged all experimental contingencies and recorded the data. Only the left and right keys, the operation of which required a minimum force of .1 to .2 N, were used. White noise and fans in the chambers helped to mask extraneous sounds.

Procedure

The procedure involved a discrete-trials arrangement in which reinforcement produced by a peck on the right key was contingent upon both that peck and the number of immediately preceding pecks on the left key. That is, reinforcement for a changeover to the right was contingent upon the number of immediately preceding pecks on the left. The experiment involved the manipulation of properties of the sequences of left-key pecks preceding reinforcement. The contingency was not very complicated conceptually, but did involve several parts, each of which is best described separately.

Discrete-trials contingency. Each trial began with the illumination of the white left and right keys and of the houselight. A peck on the left key turned off all the lights and initiated an intertrial interval the duration of which was varied over conditions as shown in Table 1. Such a response simply increased the current count of left-key pecks. A response on the right key also turned off all the lights and then either initiated the same intertrial interval or

initiated reinforcement, provided a variable-interval had elapsed and the computer was looking for the particular run of left-key pecks terminated by that right-key peck. Each of these contingencies is described below. A peck during the intertrial interval restarted the intertrial interval. Notice that a nonreinforced right-key peck and any left-key peck had the same immediate consequence: they both simply started the intertrial interval.

Variable-interval contingency. A constant-probability variable-interval schedule was used (Catania & Reynolds, 1968). The computer once every second calculated a quasirandom number which, when compared to a schedule parameter, gave a decision to arrange or not arrange a reinforcement. Once arranged, a reinforcer remained so until delivered. The 1-sec timer ran only during the intertrial interval to discourage long pauses when the keylights were on. The schedule parameter, and therefore the resulting variable-interval schedule, was occasionally varied, as shown in Table 1, to keep the total reinforcement rate between about 20 to 120 per hour.

Response-pattern contingencies. When a reinforcer was arranged by the variable-interval contingency, it was probabilistically allocated to one of two response patterns, a shorter and a longer run of left-key pecks. No other reinforcer was arranged until one already allocated in this manner was delivered. This feature of the contingency permitted the experimenter to control the way reinforcers were distributed between the two reinforced patterns (Shimp, 1966).

Table 1 gives the two reinforced patterns for each experimental condition. Over the entire experiment, there were three different pairs of reinforced runs: 1 and 2 and 2 and 4 (Group A) and 1 and 4 (Group B) where 2 and 4, for example, means the reinforced patterns consisted either of 2 or of 4 successive left-key pecks preceding a reinforced changeover to the right key. Table 1 shows the percentage of reinforcements allocated in each condition to the shorter of the two patterns.

Note that the contingency was defined in terms of the number of left-key responses in a sequence, rather than in terms of the temporal duration of the sequence, but that the number of responses in, and the minimum temporal duration of, a sequence were correlated by virtue of the intertrial interval.

Table 1
Experimental Conditions

Condi- tion Num- ber	Group A (reinforced runs of 1 and 2 or of 2 and 4 left-key pecks preceding a changeover). Group A includes Birds 1, 2, 3, 4, 5, and 6.					Group B (reinforced runs of 1 and 4 left-key pecks preceding a changeover). Group B includes Birds 7, 8, 9, and 10.				
	Rein- forced Runs	Programmed Relative Frequency of Reinforce- ment for the Shorter Run (π_s)	Intertrial Interval (ITI) (sec)	Equivalent Constant- Probability VI (sec)	Num- ber of Days	Rein- forced Runs	Programmed Relative Frequency of Reinforce- ment for the Shorter Run (π_s)	Intertrial Interval (ITI) (sec)	Equivalent Constant- Probability VI (sec)	Num- ber of Days
1	2 and 4	.75	1.0	5	20	.50	.5	20	35	
2	2 and 4	.50	1.0	5	20	.10	.5	30	20	
3	2 and 4	.25	1.0	5	23	.00	.5	30	20	
4	2 and 4	.10	1.0	5	21	.05	.5	30	20	
5	1 and 2	.25	2.0	20	20 ¹	.05	1.0	20	20 ²	
6	1 and 2	.10	2.0	30	20	.05	2.0	20	20 ³	
7	1 and 2	.10	4.0	30	20	.05	3.0	20	14 ⁴	
8	1 and 2	.25	4.0	30	20	.05	1.0	20	20	
9	1 and 2	.25	6.0	30	20 ⁵	.05	.5	20	20	
10	1 and 2	.25	8.0	5	20 ⁶					
11	1 and 2	.25	10.0	5	20 ⁷					
12	1 and 2	.10	6.0	5	20 ⁸					
13	1 and 2	.10	1.0	30	20					

¹This condition was preceded by 2 others with reinforced runs of 2 and 4, and with ITI equal to 2.0 sec.

²These 20 days were preceded by 23 days during which the ITI was slowly lengthened to 1 sec.

³These 20 days were preceded by 27 days during which the ITI was slowly lengthened to 2 sec.

⁴Approximately two and a half months intervened between Conditions 6 and 7 for Group B.

⁵These 20 days were preceded by 48 days during which the ITI was slowly lengthened to 6.0 sec.

⁶These 20 days were preceded by 24 days during which the ITI was slowly lengthened to 8.0 sec.

⁷These 20 days were preceded by 24 days during which the ITI was slowly lengthened to 10 sec.

⁸These 20 days were preceded by 15 days during which the ITI was greatly shortened and then slowly lengthened back to 6.0 sec.

Experimental conditions. Birds 1, 3, 4, and 6 in Group A began the present Condition 1 immediately after finishing the last of the conditions described in Shimp (in press), where the relative frequency of reinforcement for the shorter pattern had been manipulated, the reinforced patterns had been runs of length 2 and 4, and the intertrial interval had been .5 sec. In the present experiment, the conditions were arranged in two sets. In Conditions 1 to 4, relative frequency of reinforcement was manipulated while the reinforced patterns remained as in Shimp (in press), but the intertrial interval was slightly lengthened to 1.0 sec. In Conditions 5 to 13, the reinforced patterns were changed to runs of 1 or 2 pecks on the left key, and the intertrial interval was manipulated for each of two values, .10 and .25, of the relative frequency of reinforcement. These low values were used so that as the intertrial interval was lengthened, problems potentially resulting from a ceiling effect would be re-

duced. Group B also began the present Condition 1 immediately after finishing the last condition in Shimp's (in press) experiment where, as for Group A, the relative frequency of reinforcement had been manipulated when the intertrial interval had been .5 sec. For Group B, the reinforced patterns in Shimp (in press) had been runs of length 2 or 8. In the present experiment, they were runs of 1 or 4. The relative frequency of reinforcement for the shorter pattern was varied first, and then the intertrial interval was varied while the relative frequency of reinforcement for the shorter pattern was .05, a very low value necessitated by the same ceiling effect mentioned above.

Miscellaneous details. Each session was one hour in duration. Sessions were conducted six days per week. It was not possible to perform the analysis of sequential data on a daily basis, so decisions about changes of experimental conditions were based on duration of training

rather than on criteria of behavioral stability. Except in relatively rare cases, each condition was conducted for a standard 20 days, as shown in Table 1. Reinforcement consisted of 3-sec access to the same mixed grain provided in the home cage, Pillsbury's Pigeon Feed. During reinforcement, all lights in the box were off except for one over the hopper.

Summary of and comments on the procedure. On each of a series of discrete trials, side keys were lighted and a subject pecked either a left or a right key. A peck to the right key was reinforced if it was preceded by a suitable number of left-key pecks and if a variable-interval contingency had arranged a reinforcement. No exteroceptive stimulus signaled either the variable-interval contingency or the response-pattern contingency. It is helpful to think of the procedure as one in which behavioral patterns were reinforced, even though only right-key pecks were temporally contiguous with the delivery of a reinforcer. It is helpful, that is, to think of the procedure as one where shorter and longer patterns of behavior were reinforced.

RESULTS

The results may be organized in terms of three questions. First, did reinforcement control the local organization of behavior so that there were two classes of patterns corresponding to the two reinforced patterns? Second, if so, how did preference for a pattern depend on structural features of the reinforced patterns, such as their absolute and relative durations? Third, how did preference depend on reinforcement parameters associated with the patterns?

The Local Organization of Behavior

If reinforcement controlled the sequential patterning of behavior, the lengths of the runs of successive pecks on a key before a changeover to the other key should have at least roughly corresponded to the lengths of the reinforced runs. On the left key, most run lengths should have approximated the two different lengths preceding reinforced changeovers, and on the right key, few runs should have been longer than one, because only runs of length one preceded reinforcement.

Runs of pecks on the left key. To what extent did changeovers to the right key follow

runs of left-key pecks that approximated the two reinforced runs? For present purposes it is sufficient simply to look at some relative-frequency distributions of interchangeover run lengths. An interchangeover run of left-key pecks is simply a sequence of successive pecks on the left key preceded and followed by pecks on the right key. The number of left-key pecks in such a run is the interchangeover run length. A relative-frequency distribution of these runs was computed for a subject for each of the last five days in a condition. A five-day average distribution was then obtained for this subject and then these five-day average distributions were averaged over the various subjects to obtain a mean distribution for a condition. Figure 1 shows nine of these mean distributions. These mean curves give a rough representation of the curves for individual subjects, which is adequate for the simple purpose of showing that the emitted runs tended to cluster near the reinforced ones. The figure suggests this was always the case. The nine average curves in the figure were selected to illustrate several important features for each of four different types of conditions, those where the reinforced run lengths were 1 and 2, 1 and 4, 2 and 4, and 2 and 8. The latter case, shown in Panels H and I, is from an earlier experiment (Shimp, in press) and is provided here so that these earlier data from the same subjects may be more conveniently compared to the present data. Consider in turn now the panels for each of the different pairs of reinforced runs.

Panels A and B are for reinforced run lengths of 1 and 2. For each of these panels, the relative frequency of reinforcement for the shorter run was .25, and the intertrial interval was 2 and 6 sec for Panels A and B, respectively. It is clear that most of the run lengths clustered near the reinforced ones and furthermore, as will be shown in a different and clearer way below, preference for the shorter reinforced run increased as the intertrial interval, and therefore the minimum duration of the runs, increased, even though their relative lengths remained unchanged.

Panels C and D are for reinforced run lengths of 2 and 4. Here, the relative frequency of reinforcement for the shorter run was .10 and the intertrial interval was increased slightly from .5 to 1.0 sec in Panels C and D, respectively. Most of the run lengths were close

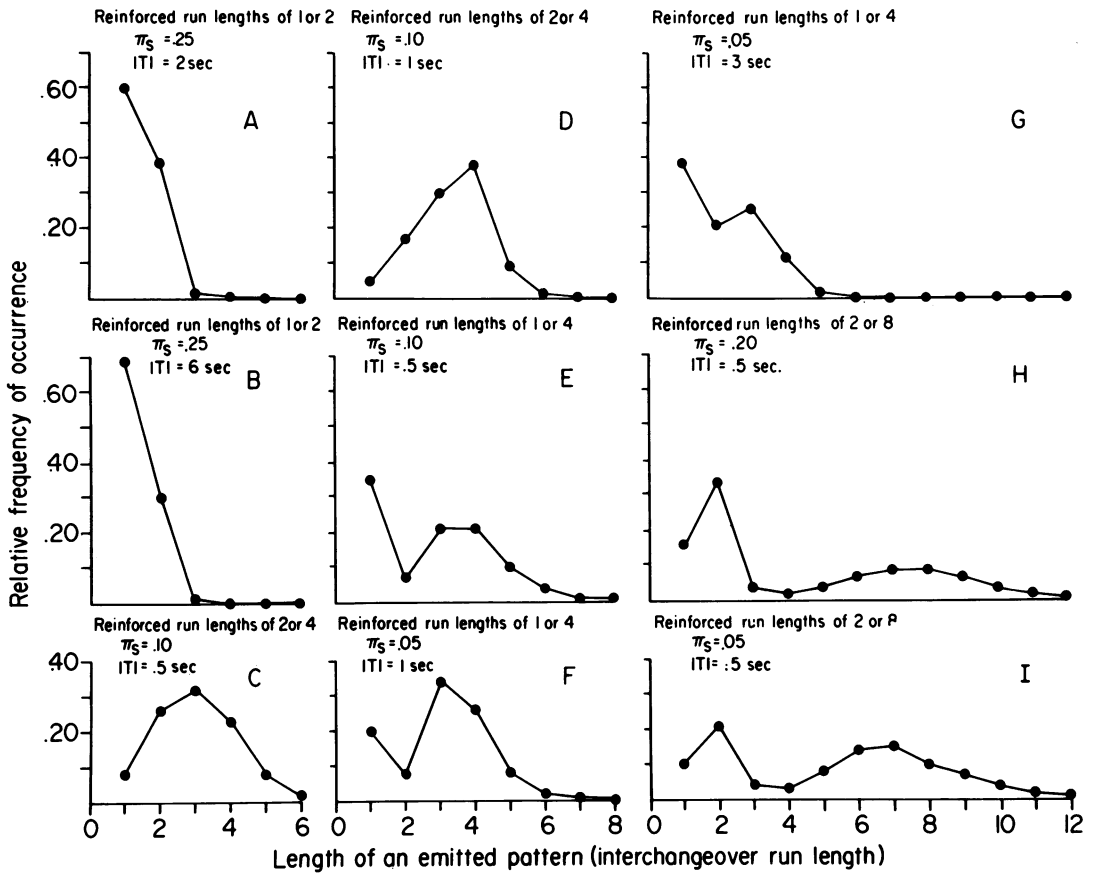


Fig. 1. The relative frequency of runs of left-key pecks preceding a changeover as a function of the lengths of those runs. Each curve is an average over the last five days of a condition and all the birds in a group. The symbols π_s and ITI refer to the relative frequency of reinforcement for the shorter pattern and the intertrial interval, respectively.

to the reinforced ones, but the two reinforced run lengths were sufficiently similar so that the interchangeover run length distributions were not bimodal.

Panels E, F, and G are for reinforced run lengths of 1 and 4. Here the two reinforced run lengths were sufficiently dissimilar so that the distributions were bimodal. A comparison of Panels F and G shows that preference for the shorter reinforced run increased as the duration of the runs was increased even though, as in Panels A and B, their relative lengths remained unchanged.

Panels H and I are for reinforced run lengths of 2 and 8 and are data from conditions in Shimp (in press) for which the relative frequency of reinforcement for the shorter run was .05 and .20 and the intertrial interval was .5 sec. Preference for the shorter reinforced run increased as it received a greater percent-

age of reinforcement. Here the curves were very clearly bimodal. In summary, Figure 1 shows that the lengths of the runs on the left key depended on the reinforced ones and that a changeover from the left to the right key tended to occur when the preceding run more nearly resembled a reinforced one.

Runs of pecks on the right key. Behavior on the right key conformed sufficiently well to that specified by the reinforcement contingency to obviate the need for a graphic presentation of the data. Recall that the contingency was such that only changeovers to the right key were contiguous with a reinforcer: a peck to the right key was never reinforced unless it was preceded by a suitable number of left-key pecks. Accordingly, behavior under the control of the contingency would involve right-key runs of only one peck. The obtained behavior was, to a first approximation, of the appropri-

ate type: for example, in Group A, 85% or more of the runs of pecks to the right key were of length one on each of the last five days in a condition for most of the subjects in most of the conditions. In particular, for Birds 1 and 2, right-key runs of length one never made up less than 85% of all the right-key runs. For Bird 3, there was only one condition in which on one or more of the last five days the percentage of right-key runs of length one was less than 85. Birds 5 and 6 each had three such conditions and Bird 4 had 4. The lowest percentage for any of the last five days, across all conditions, was 83, 74, 79, and 76 for Birds 3, 4, 5, and 6, respectively. For Group B, the worst cases were 74, 61, and 79 for Birds 7, 8, and 9. For Bird 10, this percentage was never less than 85. The bulk of the runs that were not of length one were of length two. In summary, run lengths on the right key approximated the reinforced run length.

Preference as a Function of Structural Properties of the Two Alternatives

There are two preliminaries requiring attention before preference can be described. First, Figure 1 showed that changeovers tended to occur when they were more likely to be reinforced. There were two runs after which changeovers were reinforced, so one may ask about preference between these two reinforced run lengths. (Notice that although we wish to examine the results in terms of two-choice behavior, the two alternatives are not pecks at the two keys; they are the two different, shorter and longer, reinforced patterns each consisting of a run followed by a changeover.) Figure 1 showed further that changeovers did not perfectly conform to the schedule contingency: not all runs were exactly of a reinforced length. Therefore, when one wants to dichotomize the distribution of runs into shorter and longer ones, some criterion is essential. For example, one needs to know if a run of length 4 is a shorter or a longer run, or neither, in a case where runs of length 2 and 8 are reinforced. The criterion adopted here has adequately served in corresponding situations in the past and satisfies various conventions about the nature of a behavioral unit (Shimp & Hawkes, 1974; Zeiler, 1977). The criterion is to equate shorter and longer alternatives with the corresponding shorter and longer reinforced alternatives. Thus, if runs of length 2

and 4 are reinforced, our measurement of preference will involve just those runs of length 2 and length 4, discarding all other runs. Specifically, preference for the shorter pattern will be the mean of the last five daily relative frequencies of the shorter pattern, where each daily relative frequency is the frequency of occurrence of the shorter reinforced run divided by the sum of the frequencies of runs in either shorter or longer reinforced categories.

The second and last preliminary to a description of preference is a description of the total reinforcements per hour. Some evidence from previous experiments on preference between behavioral patterns indicates that it may depend on the total reinforcements per hour (Shimp, 1970, 1974). In particular, preference may move toward indifference if the total reinforcements per hour drops much below 20, but above this number, it appears to remain reasonably constant. An effort was therefore made in the present experiment to ensure that total reinforcements per hour stayed above approximately 20. For Group A, the reinforcements per hour, averaged over the last five days of a condition and all 6 birds, ranged from a low of 31 (Condition 11) to 114 (Condition 4), with an overall average reinforcements per hour of 62. For Group B, the corresponding value ranged from a low of 20 (Condition 7) to 82 (Condition 8), with an overall average of 49. It is reasonably safe to assume, therefore, that the preference measures displayed below were not importantly affected by variations in the total reinforcements per hour.

Due to a programming error, pecks during the intertrial interval were recorded incorrectly and are therefore not available.

With these preliminaries out of the way, it can now be asked how preference depended on parameters of the two behavioral alternatives.

Consider the effects of the minimum time required to emit the two reinforced runs. This minimum time was manipulated by varying the intertrial interval so that, for example, the minimum times to emit runs of 2 and 4 responses were 1 and 2 sec with an intertrial interval of .5 sec, but were 2 and 4 sec with an intertrial interval of 1 sec. There were practical limitations on how much one could manipulate the temporal duration of a run by varying the intertrial interval. If this interval were very short, run duration would be determined not so much by it as by the latency with which a

subject responded after the keys were lit. On the other hand, if the intertrial interval were very long, subjects would fail to emit a sufficient number of the longer patterns and the total reinforcements per hour would fall below the desired level (see above). Therefore, the practical range over which the intertrial interval could be manipulated here was limited in the case of Group B to only .5 to 3 sec.

Figures 2 and 3 shows the individual and average data for Group A, and Figures 4 and 5 show the individual and average data for Group B. The figures show preference for the shorter pattern as a function of the intertrial interval. For Group A, the reinforced run lengths were 1 and 2, the corresponding minimum durations of shorter and longer reinforced runs ranged from 2 and 4 sec to 10 and 20 sec, and the relative frequency of reinforcement for the shorter pattern was either .10 or .25. Figures 2 and 3 show a tendency toward greater preference for the shorter reinforced run when the intertrial interval was lengthened. The individual data are noisy, but this

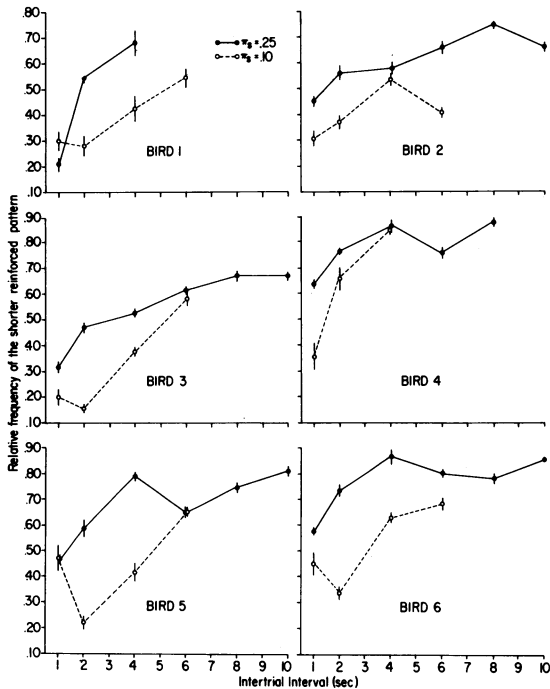


Fig. 2. The relative frequency of the shorter reinforced pattern (a run of left-key pecks) as a function of the intertrial interval separating the successive trials in those runs. Each curve is for an individual bird in Group A, and each point is an average over the last five days of a condition. The vertical lines represent plus and minus one standard error. When no line is visible, its length is less than the diameter of the symbol.

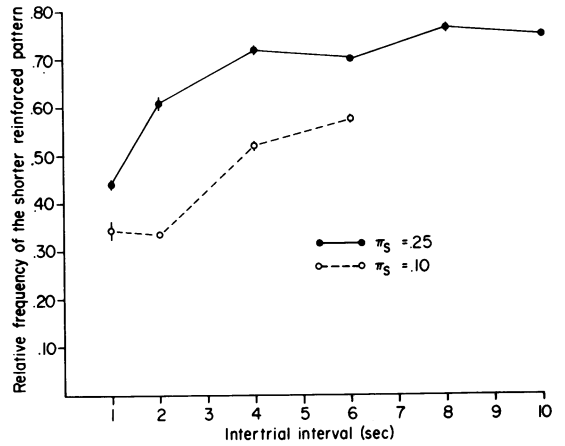


Fig. 3. The relative frequency of the shorter reinforced pattern as a function of the intertrial interval separating the successive trials in those runs. The curves are averages of the corresponding curves in Figure 2. The vertical lines represent plus and minus one standard error.

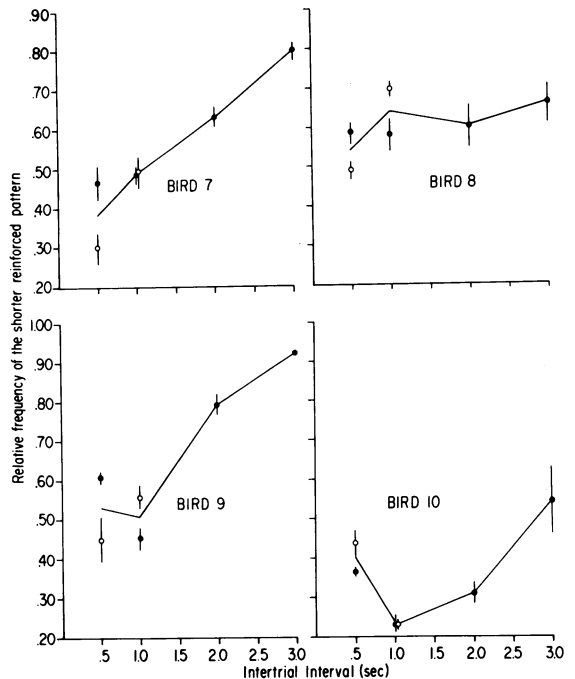


Fig. 4. The relative frequency of the shorter pattern as a function of the intertrial interval. Each curve is for an individual bird in Group B, and each point is an average over the last five days of a condition. The vertical lines represent plus and minus one standard error. The relative frequency of reinforcement for the shorter reinforced run was .05. Replications are indicated by unfilled circles. The line has been drawn through the average of original and replicated conditions.

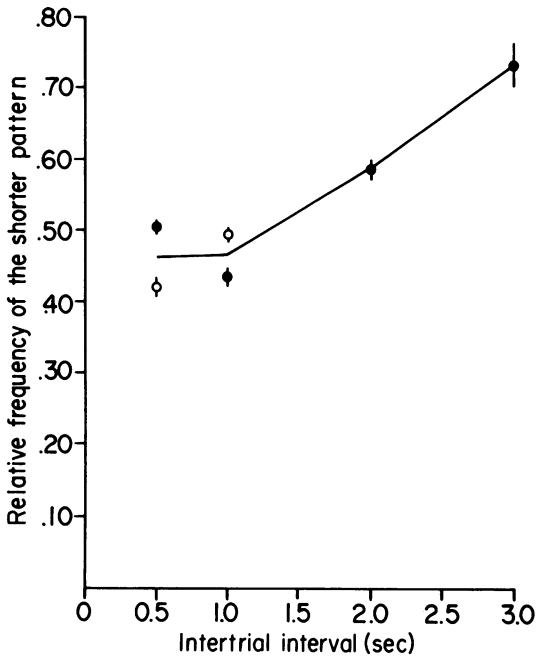


Fig. 5. The relative frequency of the shorter reinforced pattern as a function of the intertrial interval separating the successive trials in those runs. The curve is an average of the curves in Figure 4. The vertical lines represent plus and minus one standard error.

general tendency is nevertheless visible. The averaged data in Figure 3 more clearly reveal the same effect. Note that the points in Figure 3 are not all averages over the same number of subjects; as is apparent in Figure 2, different birds were deleted in different conditions as the intertrial interval was increased. A bird was deleted as its total reinforcements per hour dropped significantly below about 20 reinforcements per hour. Figures 2 and 3 display also, of course, a larger effect of the relative frequency of reinforcement, with preference for the shorter pattern generally being greater when it collected 25% of the reinforcers than when it collected only 10%.

Figures 4 and 5 show for Group B the effects on preference of changes in the intertrial interval when the two reinforced run lengths were 1 and 4. The individual panels in Figure 4 are plainly different in shape. However, an increase in preference for the shorter run can be seen for Birds 7 and 9. If one excludes the unaccountable results for Bird 10 at an intertrial interval of .5 sec, then three of the four subjects display an increasing preference for the shorter run as the intertrial interval was lengthened.

The average data in Figure 5 more clearly show this greater preference for the shorter run when the intertrial interval was longer.

Preference as a Function of a Reinforcement Parameter

Figures 6 and 7 show individual and group data for Group A when the relative frequency of reinforcement for the shorter pattern was varied from .10 to .75, whereas the intertrial interval remained constant at 1 sec. The reinforced run lengths were 2 and 4. The figures show that preference for the shorter run was a monotonically increasing, negatively accelerated function of the percentage of reinforcement delivered for that run. The average curve is a good summary of the individual curves. A rough frame of reference is provided in the

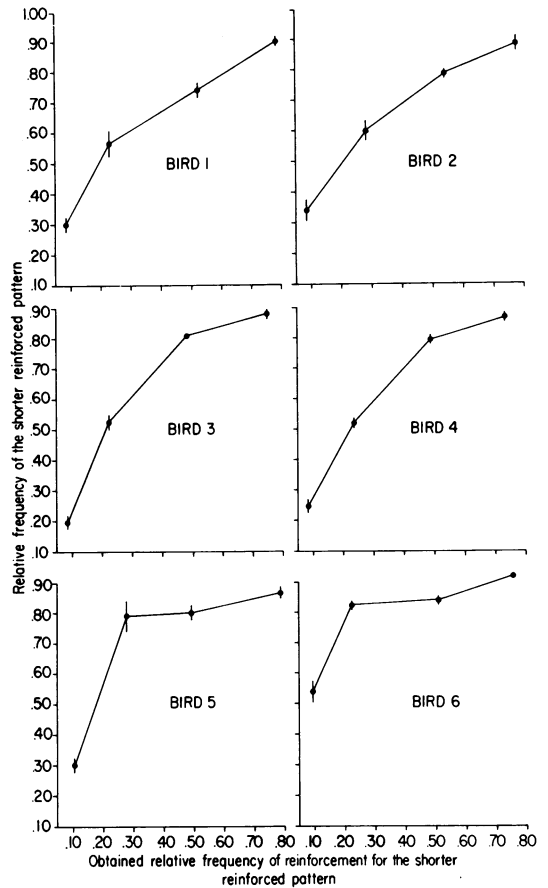


Fig. 6. The relative frequency of the shorter pattern as a function of the relative frequency of reinforcement for the shorter pattern. Each curve is for an individual subject in Group A, and each point is an average over the last five days of a condition. The vertical lines represent plus and minus one standard error.

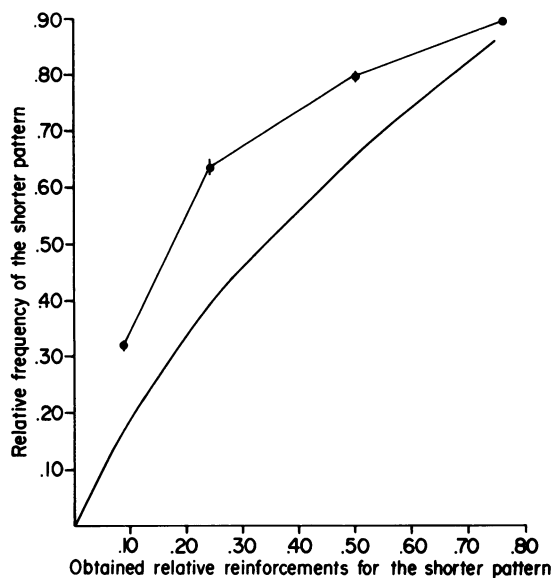


Fig. 7. The relative frequency of the shorter pattern as a function of the relative frequency of reinforcement for the shorter pattern. The empirical curve is an average of the curves in Figure 6. The smooth curve represents a form of time-allocation matching (see text).

panel for the average data: the smooth curve derives from a kind of time-allocation matching, according to which a subject is assumed to allocate to a particular behavioral pattern a percentage of the session duration equal to the percentage of reinforcers allocated to that pattern. In drawing the curve, it was assumed for simplicity that the duration of a pattern was the sum of the intertrial intervals within it, i.e., that the latencies were 0 sec in duration. With this assumption, preference for the shorter pattern was always greater than would be expected from time-allocation matching.

Figures 8 and 9 show the results for Group B corresponding to those in Figures 6 and 7 for Group A: it shows that preference for the shorter reinforced run was a monotonically increasing, negatively accelerated function of the percentage of reinforcers delivered for that run. Again the average curve is a good description of the individual curves and preference for the shorter pattern exceeded that expected from time-allocation matching. A comparison of Figure 9 with Figure 7 shows that for any given percentage of reinforcements allocated to the shorter run, a run of length one was preferred over a run of length four more than a run of length two was preferred over a run of length four.

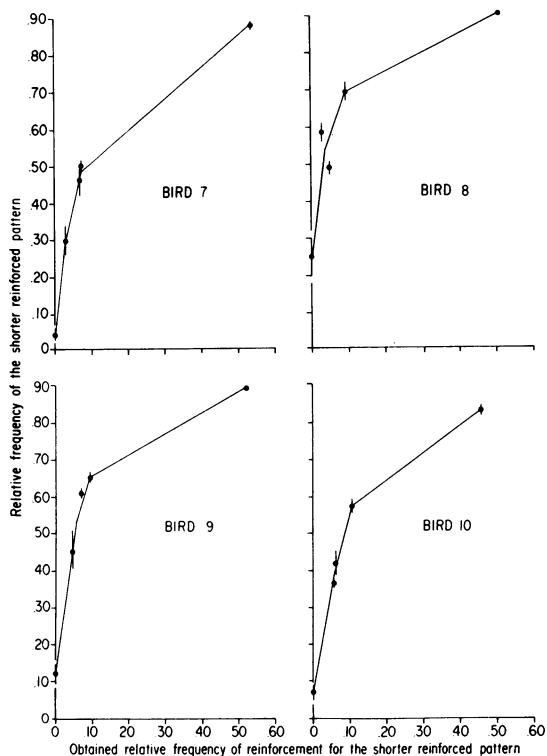


Fig. 8. The relative frequency of the shorter pattern as a function of the relative frequency of reinforcement for the shorter pattern. Each curve is for an individual subject in Group B, and each point is an average over the last five days of a condition. The vertical lines represent plus and minus one standard error.

Table 2 and Figure 10 summarize an alternative description of the data for conditions over which the relative frequency of reinforcement was varied. This description is based on a ratio equal to the number of shorter patterns divided by the number of longer patterns and a corresponding ratio of reinforced patterns. The logarithms of each of these ratios, for each of the last five days in a condition, were averaged and then the five-day averages were used to calculate least-squares best-fitting straight lines. The resulting equations are shown in Table 2. For Group A, with reinforced run lengths of 2 and 4, the y-intercept ranged across birds from .51 to .77, and the slope ranged from .56 to 1.02. For Group B, with reinforced run lengths of 1 and 4, the y-intercept ranged from .79 to 1.06, and the slope ranged from .77 to 1.14.

The chief features of Table 2 are graphically summarized in Figure 10, which shows the lines for the two group averages. The slope

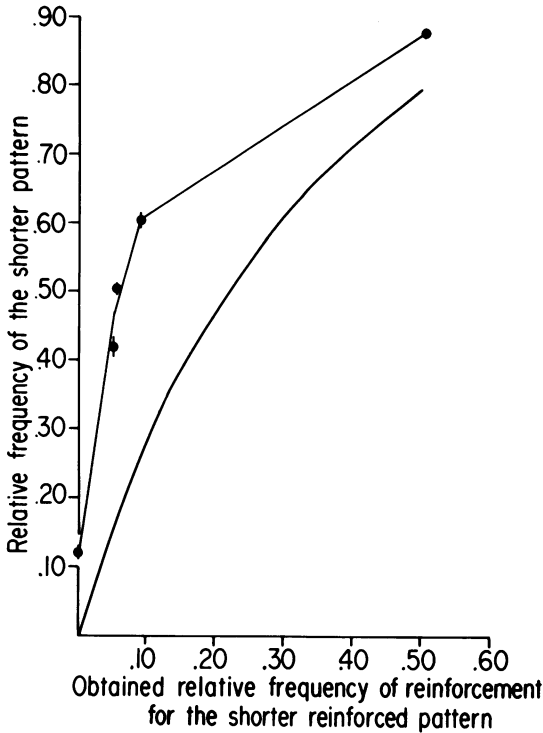


Fig. 9. The relative frequency of the shorter pattern as a function of the relative frequency of reinforcement for the shorter pattern. The empirical curve is an average of the curves in Figure 8. The smooth curve represents a form of time-allocation matching (see text).

for Group A appears slightly greater than the slope for Group B, but more clearly apparent is the larger y-intercept for Group B.

Table 2 and Figure 10 also give the correlation coefficient between the two log ratios: it is apparent that at a practical level a straight line does a good job of summarizing the relation between the two log ratios.

DISCUSSION

The data give a provisional answer to a question concerning the generality of previous data on the local organization of behavior. Specifically, it was asked if pattern length and relative frequency of reinforcement would affect interchangeover runs in a discrete-trials setting in generally the same way as they have affected two other kinds of behavioral patterns in free-responding settings. The provisional answer is yes. This similarity in controlling relations for three different kinds of behavioral patterns is consistent with the hypothesis that there is a general tendency for reinforcement to shape the local temporal organization of behavior (Morse, 1966; Shimp, 1976).

With each of the three types of behavioral pattern investigated so far, it has been the pattern itself that has evolved into an analytical

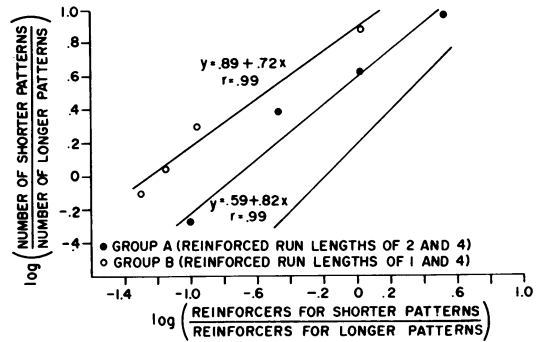


Fig. 10. The logarithm of the ratio equal to the frequency of shorter patterns divided by the frequency of longer patterns, as a function of the logarithm of the corresponding ratio for reinforced shorter and longer patterns. Each point is an average for either Group A or Group B. Also shown are the best-fitting straight lines and a line of slope one for comparison purposes.

Table 2

Best-fitting linear functions for individual subjects, where $x = \log \frac{r_s}{r_l}$, $y = \log \frac{R_s}{R_l}$, r_s and r_l are the frequencies of reinforcement for the shorter and longer patterns and R_s and R_l are the frequencies of the shorter and longer patterns.

Group A (Conditions 1 through 4)						
	B1	B2	B3	B4	B5	B6
y =	.51 + .82x	.58 + .82x	.54 + 1.02x	.51 + .94x	.59 + .76x	.77 + .56x
r =	1.00	1.00	.97	.99	.86	.93
Group B (Conditions 1, 2, 4, and 9)						
	B7	B8	B9	B10		
y =	.82 + .77x	1.01 + .96x	1.06 + 1.14x	.79 + .79x		
r =	1.00	.75	.86	.99		

unit; response or operant; in none of the cases does the relation between behavior and reinforcement appear meaningful when behavior is described in terms of key pecking rather than patterns of key pecking. For instance, in the present experiment most key pecks were to the left key, yet only right-key pecks were contiguous with reinforcement. Reinforcement was operating not on a key peck but on a pattern of behavior that consisted mostly of left-key pecks.

Although it is a commonplace to see the local organization of behavior adapting, as it did here, to a temporal contingency, how best to interpret such adaptations remains problematical. From the full range of proposed interpretations, two major classes can be identified. A first way is to assume that local patterning does not occur except, perhaps, when it is forced by a temporal contingency; that is, when the delivery of a reinforcer is explicitly contingent upon the occurrence of a behavioral pattern, as in differential-reinforcement-of-low-rate, synthetic, and paced schedules. One seldom if ever encounters an explicit statement of this assumption. However, one very frequently encounters it operationalized in experimental methods and methods of data analysis. In particular, one is likely to encounter this assumption in treatments of variable-interval and concurrent variable-interval variable-interval schedules. In much of the literature on these schedules, key pecks per minute, averaged over all local behavioral patterning, is interpreted as entering into a causal relation with reinforcements per hour, averaged over all local reinforcement contingencies (Baum, 1973; Herrnstein, 1970; Rachlin, 1978). These theories, sometimes called molar theories, are not designed to answer questions about temporal patterning, and the data to which they are applied are nearly always collected with contingencies that do not require patterning. The data analyses are in terms of statistics that are averages over whatever local patterns appear. These theories therefore share the assumption that various "pattern-free" analyses are appropriate to situations that do not force patterning to occur. Situations requiring patterning are sometimes specifically excluded from the domain of applicability of molar theories (e.g., Herrnstein, 1970).

This first way of dealing with the local patterning of operant behavior may be discrimi-

nated from a second way, which is to assume that local patterning appears quite generally, whether reinforcement contingencies force it or not (Shimp, 1966, 1969). This assumption motivates us to set up various kinds of temporal contingencies, to see what kinds of behavioral patterns they maintain, and then to explore the consequences of the possibility that such patterns occur even when not forced (Shimp, 1975, 1978, 1979). This view of operant behavior has much in common with similar views on organization in verbal learning and memory (Shimp, 1976). This view, which in the experimental analysis of behavior is often called a molecular view, is given credibility by a steadily growing body of data (Hinson & Staddon, 1981; Menlove, 1975; Platt, 1979; Schwartz, 1980; Silberberg et al., 1978). One potential advantage of this molecular view is that it does not concede at the outset an essential difference between situations where temporal patterning is or is not forced; instead, it encourages the view that the same psychological processes are at work in both. One such possibility is that the behavior reinforcement operates on is the same as the behavior an organism remembers having recently emitted (Shimp, 1975, 1976, 1978, 1979, 1981a, 1981b; Wasserman, Deich, & Cox, in press).

The distinctions between molar and molecular analyses sometimes seem of a type that suggests if either is right, the other must be wrong (Shimp, 1975, 1976). Nevertheless, a worthwhile undertaking is to see if there are ways in which the two are complementary rather than incompatible. Nevin (in press) has undertaken to do just this. He suggests that molecular analyses deal with questions pertaining to the nature of behavioral units, whereas molar analyses deal with the strength of, and preference among, those units. This suggestion appears to be related to Morse's (1966) proposal that there are two separate properties of reinforcement, a shaping and a strengthening property. To illustrate his point, Nevin (in press) replotted results from an experiment (Shimp & Hawkes, 1974) in which two classes, a shorter and a longer class, of interresponse times were differentially reinforced. He plotted the log of the ratio of shorter to longer interresponse times as a function of the log of the ratio of reinforced shorter to reinforced longer interresponse times. The resulting function was for practical purposes adequately described as a

straight line. Staddon (1968) earlier displayed a similar function, and it will be noted that the present Table 2 and Figure 10 indicate the same function applies also to the present experiment. This linear function is very widely obtained and has become one of the defining characteristics of a molar analysis (e.g., see Baum, 1974). The similarity between the present function and earlier ones extends to the numerical values of the obtained slopes; both here and elsewhere, these slopes tend on the average to be less than the matching value of unity (Davison, 1981; McCarthy & Davison, 1981; Myers & Myers, 1977). Nevin's (in press) suggestion would lead us to describe the present experiment in the following way: a molecular run-length contingency established behavioral patterns as analytical units, and a molar contingency determined the strengths of these units.

Nevin's (in press) characterization of molar and molecular analyses surely is worth serious consideration, but at least two problems already can be identified. First, his characterization of the molar strengthening property may confound at least two different reinforcement properties; there seem to be separable effects attributable to overall reinforcement frequency and to relative reinforcement frequency (Shimp, 1970, 1974). Second, his characterization of the molecular shaping property would seem to demand that all temporal patterning be ascribable to the patterning of operants themselves. Yet, it surely is unsafe to assume that in general temporally patterned operants emerge in the behavior stream in an unpatterned sequence. In the case of simple patterns such as interresponse times, sequential dependencies exist when none is demanded (Shimp, 1973), as they do also in many discrete-trials experiments (Shimp, 1966, in press; Silberberg et al., 1978).

Suppose that in the present experiment, sequences of runs had been recorded. It clearly is in the realm of possibility that dependencies would have been observed. At least, it is consistent with a molecular point of view to consider the possibility that these dependencies would occur and would show behavioral adaptation to local reinforcement contingencies. Indirect evidence supports this possibility. The present experiment used a modified concurrent variable-interval variable-interval schedule; accordingly, the longer a subject persisted

in making runs of the shorter length, the greater the probability of a reinforcer for a run of the longer length. If the sequence of run lengths adapted to this contingency, one would expect undermatching (Shimp, 1969; Staddon, Hinson, & Kram, 1981). As noted above, undermatching was in fact obtained, thereby indirectly supporting the idea that patterns were produced here in an adaptive, nonrandom sequence.

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