APERIODICITY AS A FACTOR IN CHOICE¹

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Four pigeons were trained to peck at either of two response-keys. Pecks at either key occasionally produced a secondary reinforcer, in the presence of which further pecks occasionally produced food, the primary reinforcer. All pigeons showed a consistent preference for variable (as compared to fixed) interval schedules of primary reinforcement.

A variable-interval schedule of reinforcement is identified by the arithmetic mean of the individual time intervals of which it is composed. Similarly, a variable-ratio schedule is identified by the arithmetic mean of the individual ratios of unreinforced to reinforced responses. It may be, however, that the organism, when confronted with one of these schedules, does not react in a way that corresponds to the taking of an arithmetic average. An organism may, instead, be logarithmic in this respect, in which case it would be reacting to the geometric means of the schedules. Or, an organism may transform the individual elements of a schedule according to some principle not so easily defined as either the arithmetic or geometric mean. The answer to how the organism does transform these elements might have considerable importance for those who attempt parametric studies of schedules of reinforcement.

The problem of averaging is not peculiar to investigations of schedules. In many psychological experiments, a random or irregular sequence of events, characterized by an arithmetic average, is used. For example, the probability of a particular event is traditionally given by the frequency of the event divided by all the possible events in the universe of discourse. This computation tacitly involves an arithmetic average and may, therefore, be inadequate as a description of the organism's experience.

The present experiment deals with the legitimacy of using the arithmetic mean in connection with a variable-interval schedule of reinforcement. By using pigeons that are trained to choose between variable and fixed-interval schedules, the experiment shows whether or not arithmetic averaging can predict preference.

METHOD

Subjects

Four, adult, male White Carneaux pigeons, without prior experimental histories, were kept at 80% of *ad libitum* body weights.

Apparatus

A two-key chamber for pigeons (see Herrnstein, 1963) was used. All programming and recording were done automatically.

Procedure

Figure 1 shows a schematic representation of the procedure. Each key is indicated by a circle, the enclosed letter designating either left key (L) or right key (R). The box at left pictures the two keys at the start of a session, when both are transilluminated with white light, and when responding at either is reinforced on a variable-interval schedule averaging 1 min (VI 1'). The reinforcement is a change in the color of illumination, rather than a presentation of food. Thus, if the S is reinforced for responding to the right key, the result is a change from white to yellow light on the right key and a change from white to darkness on the left. Now, further responding to the right key is reinforced

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with food (the feeding device is operated for 3 sec) on a fixed-interval schedule, while further responding to the darkened left key is ineffective. After two operations of the feeding device, the procedure reverts back to its original state, with both keys white. A symmetrical sequence is arranged on the left key, with the sole difference that the food-reinforcement was, at times, delivered on a variable-interval schedule.²

Fig. 1. Diagram of one cycle of the experimental procedure. Each box represents one of the three possible states of the two response-keys. At the start of a cycle (left box), both keys are illuminated and operative. Pecking at either key leads, on a $VI 1'$, to the state represented by the box either at the upper right or lower right, during which pecking at one key leads intermittently to food (S^R), while pecking at the other, which is now darkened, has no consequences.

This procedure may be viewed as one in which S responds on two chained schedules, one for each key. Each chain comprises two links, the first one always a variable-interval schedule with an average of 1 min and the second, either a variable or a fixed interval. The first links are concurrent; the second

links, mutually exclusive. In its general features, this procedure has been used by Autor (1960), Reynolds (1963), and Herrnstein (1964) and has proved to be a convenient tool for studying preference.

Table 1 gives the order and duration of the various phases of the present experiment.

Fig. 2. Relative rate of responding during the first link as a function of relative rate of reinforcement during the second. The diagonals show the locus of perfect matching between ordinates and abscissas. Open points were taken when both second links were fixed-interval schedules; solid points, when one was fixed and the other, variable.

RESULTS

The major finding of the experiment can be seen in Fig. 2. The ordinate is the relative frequency of responding to the left key during the first link. Thus, a value of .5 would mean that responding was equally distributed between the two keys during the first links; a value of .67 would mean that there were twice as many responses to the left key as to the right, and so on. The abscissa shows the relative rate of primary reinforcement associated with the left key during the second link. A value of .5 would mean that primary reinforcements occurred at equal rates during the two second links; .67 that a given number of reinforcements occurred in half the time during the second link on the left key as it did during that on the right, and so on. This measure, it should be noted, is based on the rate of primary reinforcement, rather than

Table 1
Order and Duration of Experimental Conditions

Left Key		Right Key		No. of Sessions
First Link	Second Link	First Link	Second Link	
VI 1'	VI 15"	VI 1'	FI 15"	33
VI 1'	VI 15"	VI 1'	FI 4"	48
VI 1'	VI 15"	VI 1'	FI 8"	30
VI 1'	FI 15"	VI 1'	FI 4"	60

²The sequence of programmed intervals in this schedule was, in seconds: 15, 2, 5, 25, 3, 80, 5, 10, 5, 27, 10, 3, 10, 5, 20.

the number. It, therefore, is virtually independent of responding during the first links. Earlier work (Autor, 1960; Herrnstein, 1963) has shown that pigeons will match ordinate with abscissa (the diagonal line) if the two second links are both schedules that deliver reinforcements aperiodically. In the present experiment, the pigeons deviate markedly from this diagonal. The three filled points for each *S* are 15-session medians that summarize the portions of the experiment when the second link on the right key was a fixed-interval schedule, while the second link on the left was a variable interval. The open circles are 15-session medians taken when both second links were fixed-interval schedules.

Fig. 3. Absolute rate of responding during the second link as a function of absolute rate of reinforcement, also during the second. Open points for the variable-interval schedule; solid points for fixed-interval schedules.

When the pigeon chooses between a fixed and a variable-interval schedule, it is consistently biased in favor of the variable-interval schedule. This is shown by the fact that the filled circles are, in every case, above the diagonal line. That this bias is based on the schedules, and not some peculiarity of the key itself is shown by the open circles. Here, the pigeon is choosing between two fixed-interval schedules, and if there is any bias resulting from the key, it is opposite in direction to that which might have been suspected.

The bias toward the variable-interval schedule is evident in the behavior during the second links of the chain as well as during the first. Figure 3 shows the absolute rate of responding during the second link as a function of the absolute rate of primary reinforce-

ment. A direct comparison between the effects of fixed and variable-interval schedules is possible at only the one value of the abscissa that the two schedules had in common. In each case, the variable-interval schedule produced the faster responding, but not by so large a factor as to account for the magnitude of the preference shown during the first links (see Fig. 2). As the rate of reinforcement on the fixed-interval schedule was increased, the rates of responding of three of the four *Ss* also increased. However, the one atypical *S*, No. 405, was similar to the other three as regards the first-link performances plotted in Fig. 2. This useful discrepancy suggests a moderate correlation at best between the responding during the first and second links.

DISCUSSION

While the present findings show that the assumption of arithmetic averaging is inappropriate for a pigeon receiving food on a variable-interval schedule, they do not reveal any specific alternative. A variable-interval schedule with arithmetic average of 15 sec is much preferred over a fixed interval of the same value, thus suggesting that the pigeon's method of averaging tends to weight the shorter intervals of the variable interval more than the longer. A logarithmic transformation of the variable-interval schedule may seem to be suggested, but the geometric mean of the actual intervals used here did not predict the results with notable success. One is forced, therefore, to conclude that the pigeons are not only non-linear in their averaging, but also non-logarithmic. Unhappily, the task of discovering the correct principle of transformation, while certainly worthwhile, seems forbidding.

In regard to human behavior, it may prove to be useful to consider the possibility of a similar non-linearity. The gambler, for example, often plays in games in which his statistical expectation is negative; in the long run, he will lose. Although such behavior is irrational in one sense, it may still be lawful in the sense of obeying some principle of transformation that makes the particular schedule of pay-off imply a positive expectation. The gambler may be like the pigeons in the present experiment; they were "placing their bets" consistently, if not wisely.

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