

## PREFERENCE FOR FIXED-INTERVAL SCHEDULES OF REINFORCEMENT<sup>1</sup>

PETER KILLEEN

ARIZONA STATE UNIVERSITY

Pigeons were trained on a two-link concurrent chain schedule in which responding on either of two keys in the initial link occasionally produced a terminal link, signaled by a change in the color of that key and a darkening of the other. Further responding on the lighted key was reinforced with food according to a fixed-interval schedule. For one of the keys, this fixed interval was always 20 sec, while for the other it was held at values of 5, 14, 30, or 60 sec for several weeks. In the initial link, all pigeons responded relatively more often on the key with the shorter fixed interval than was predicted by the matching hypothesis. Responding in the initial link showed a large negative recency effect: pigeons responded less frequently on the key that provided their last reinforcement than predicted from the overall response rates.

There has been a recent growth of interest in the study of animals' preference for schedules of reinforcement. Using the concurrent-chain method, Autor (1960) and Herrnstein (1964a) showed that preference for a variable-interval or variable-ratio schedule equalled ("matched") the relative rate of reinforcement provided by that schedule. Herrnstein (1964b) later found, however, that pigeons preferred variable-interval (VI) schedules to fixed-interval (FI) schedules, even though the schedules provided equal average rates of reinforcement. This discrepancy might have occurred not because the pigeons preferred variable inter-reinforcement intervals *per se*, but because the method of averaging was not isomorphic with the processes it was modeling (Stevens, 1955). The average of the reciprocal of the interreinforcement intervals, for instance, gives a different number than the reciprocal of the average of the interreinforcement intervals, and the former measure may more appropriately reflect the effect of a variable delay of reinforcement in the terminal links upon the choice responses in the initial links. Indeed, Killeen (1968) showed that when the former measure, which is called the harmonic rate of

reinforcement or average immediacy of reinforcement, was equal for two schedules, pigeons would be indifferent between those schedules. When schedules had unequal immediacies of reinforcement, preference for a schedule seemed to equal the relative immediacy of reinforcement for that schedule. This finding was consistent with data from Chung and Herrnstein (1967), who found that preference for one of two fixed delays of reinforcement also equalled the relative immediacy (1/delay) of reinforcement.

The harmonic transformation did not account for all the data reported by Herrnstein (1964b). When given a choice between two FI schedules, Herrnstein's pigeons preferred the shorter FI more than predicted by the relative immediacy of reinforcement. This finding is especially paradoxical in light of pigeons' approximate indifference between equal-valued fixed-interval and fixed-delay schedules (Neuringer, 1969), and was the motivation for the present study of preference for FI schedules.

### METHOD

#### *Subjects*

Four male White Carneaux pigeons, all with previous experimental histories, were maintained at 80% of their free-feeding weight.

#### *Apparatus*

The experimental chamber contained two response keys, which required forces of 0.15 N

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to be operated, and a food hopper that occasionally provided 3.5-sec access to mixed grain. The chamber was illuminated by two 7-w white bulbs, and the response keys were trans-illuminated at different times with lights of various colors, correlated with various phases of the experiment. White masking noise was continuously present.

### Procedure

At the start of each session, both keys were illuminated with blue light. Responding on either key produced, according to independent VI 1-min schedules, a change of key-light color. A response on the left blue key was reinforced by a change of that key color to red, with the other key going dark and inoperative. Responding on the left red key was then reinforced with grain according to an FI 20-sec schedule. After one such reinforcement, the schedule reverted to the original state, with both keys blue. Similarly, responses to the right blue key were reinforced by a change of that key-light color to green, with the other key going dark and inoperative. Responding on the right green key was reinforced with grain according to an FI schedule, the value of which varied as shown in Table 1, after which the schedule reverted to the original state. All responses to illuminated keys resulted in an audible feedback click and a brief (40 msec) flicker of the key light. Sessions terminated after 48 reinforcements with grain, and schedules were changed when preference appeared stable. Table 1 gives the FI values used in the right terminal link, along with the order and duration of the experimental conditions. The intervals for the initial link VI schedules were: 13, 55, 65, 3, 34, 86, 76, 107, 44, 24, 96, and 113 seconds.

Table 1

Number of sessions, order of presentation, and preference at each experimental condition. Preference is the average relative number of responses on the right key in the initial link over the last five days at each value. FI 20-sec was always scheduled on the left key.

Bird	Fixed-Interval (sec)			
	5	14	30	60
	[number of sessions (order) preference]			
321	25 (4) 0.91	42 (2) 0.66	33 (3) 0.36	40 (1) 0.10
367	42 (3) 0.88	40 (1) 0.63	37 (4) 0.24	62 (2) 0.05
394	40 (1) 0.96	42 (3) 0.88	59 (2) 0.15	42 (4) 0.16
467	40 (2) 0.98	37 (4) 0.76	40 (1) 0.16	14 (3) 0.01

## RESULTS

Table 1 gives the relative number of responses on the right key (responses on right key/responses on both keys) in the initial link for each of the conditions. In all cases, this measure of preference was more extreme than predicted from the relative immediacy of reinforcement (0.79, 0.60, 0.40, 0.25); the average values were 0.93, 0.73, 0.23, and 0.08. Absolute response rates in the initial and terminal links are given in Table 2.

For two pigeons (321 and 367), the ordinal pattern of responding in the initial link was recorded during the last three days of the FI 20-sec vs. FI 14-sec condition. There was no marked change in the proportion of responses on either key in the initial link as a function of the number of responses emitted in the initial link. When, however, the data were separated into two classes—responses following a reinforcement on the right key and responses following a reinforcement on the left key—a striking pattern was found. Figure 1 shows the relative frequency with which the  $N^{\text{th}}$  response in the initial link occurred on the left key as a function of the number of responses since the last reinforcement ( $N$ ). The circles represent relative rates of responding following a reinforcement on the right key, while the triangles represent the relative rates of responding following a reinforcement on the left key. Each point is based on 25 to 50 responses, with the sample size decreasing as  $N$  increases. The solid lines join running five-point means. After a reinforcement on one key, the pigeons showed an increase in the relative rate of responding on the other. This negative recency effect lasted for 20 responses for 367 and for more than 30 responses for 321. There was no systematic change in the rate of switching from one key to the other as a function of time in the initial link.

The amount of sequential constraint in response sequences was measured with the technique described by Miller and Frick (1949). Knowledge of the preceding response reduced the uncertainty of the locus of the following response by 8% for both birds. Knowledge of the two preceding responses effected an additional reduction of no more than 2%. This amount of sequential constraint is less than that found in printed English (Newman and Gerstman, 1952). Much of the uncertainty

Table 2

Interreinforcement intervals in terminal links, proportion of reinforcements obtained on right key, and responses per minute on left and right keys. Rates are geometric means from the last five days at each value.

Bird	Obtained Interreinforcement Interval		Proportion of Reinforcements Obtained on Right Key	Link 1		Link 2	
	Left	Right		Left	Right	Left	Right
	321	20.8	5.4	0.53	7.2	71.3	28.9
367	20.1	5.4	0.53	6.0	45.5	70.3	50.3
394	20.5	5.6	0.63	2.2	50.5	86.7	177.0
467	20.2	5.2	0.68	1.0	40.9	71.3	163.0
321	20.7	14.2	0.51	20.6	40.2	25.7	33.8
367	20.9	14.1	0.50	19.5	33.8	41.5	47.8
394	20.2	13.6	0.55	5.5	46.0	79.8	117.0
467	20.3	13.7	0.51	12.8	40.5	78.3	118.0
321	20.4	31.1	0.50	36.3	19.9	30.9	31.2
367	20.2	31.0	0.48	27.8	8.8	65.7	63.0
394	20.3	30.9	0.47	41.2	7.0	73.0	74.4
467	20.6	31.0	0.47	29.2	5.5	89.4	59.8
321	20.7	60.9	0.47	57.9	6.3	46.0	48.3
367	20.1	61.6	0.42	38.3	1.97	75.5	58.2
394	19.8	60.7	0.46	29.5	5.5	82.2	66.5
467	20.0	60.7	0.20	34.9	0.32	86.1	63.5

reduction stemmed from the inordinate improbability of response runs, especially on the less-favored key.

## DISCUSSION

The present study confirms Herrnstein's (1964*b*) finding: pigeons prefer the shorter of two FI schedules more than predicted by the matching relation. In an experiment similar to the present one, Davison (1969) studied choice between fixed-interval and mixed-interval schedules, the latter composed of two fixed-intervals. He found matching only when the reciprocals of the interreinforcement intervals of the terminal link schedule were raised to the 3.0 power. The present data also approximate matching if the reciprocal of the FI values are raised to the 2.5 power. Unlike Davison's study, no change-over delay was employed here; had one been used, preferences would probably have been more extreme (Shull and Pliskoff, 1967; Todorov, 1969) and an exponent of 3.0 more fitting.

It is unclear why the immediacies must be cubed to obtain matching in studies of choice between two FI schedules, whereas a simple harmonic mean produces matching when one or both of the terminal links is a VI schedule. It is possible that the discrepancy is due to the range of reinforcement frequencies that have

been employed in the various studies, rather than to some qualitative difference in the nature of VI and FI schedules. The arithmetic rate of reinforcement for a constant probability VI schedule is approximately one-fourth of its harmonic rate of reinforcement. The FIs used in the present study and that of Davison's are therefore equivalent to VIs of 20 to 240 sec. The largest VI used by Herrnstein (1964*a*) was 36 sec and by Killeen (1968) was 80 sec.

In a recent series of experiments, MacEwen (1969) measured preference for two FI schedules whose absolute values varied over a large range. Even though the ratio of the two FIs was always two-to-one, preference for the shorter FI uniformly increased with increases in the absolute value of the FIs. No single exponent could predict preference over the whole range of FIs studied. A similar function was found when VI schedules were used in the terminal links. MacEwen showed that approximate matching occurred for only a limited range of terminal link schedules, just as Fantino (1969) showed that it occurred for only a limited range of initial link schedules.

The sequential data from the present study show a large negative recency effect: pigeons responded less on the key that last provided reinforcement than would be predicted from overall response rates. This is not surprising, since the average delay until the next termi-

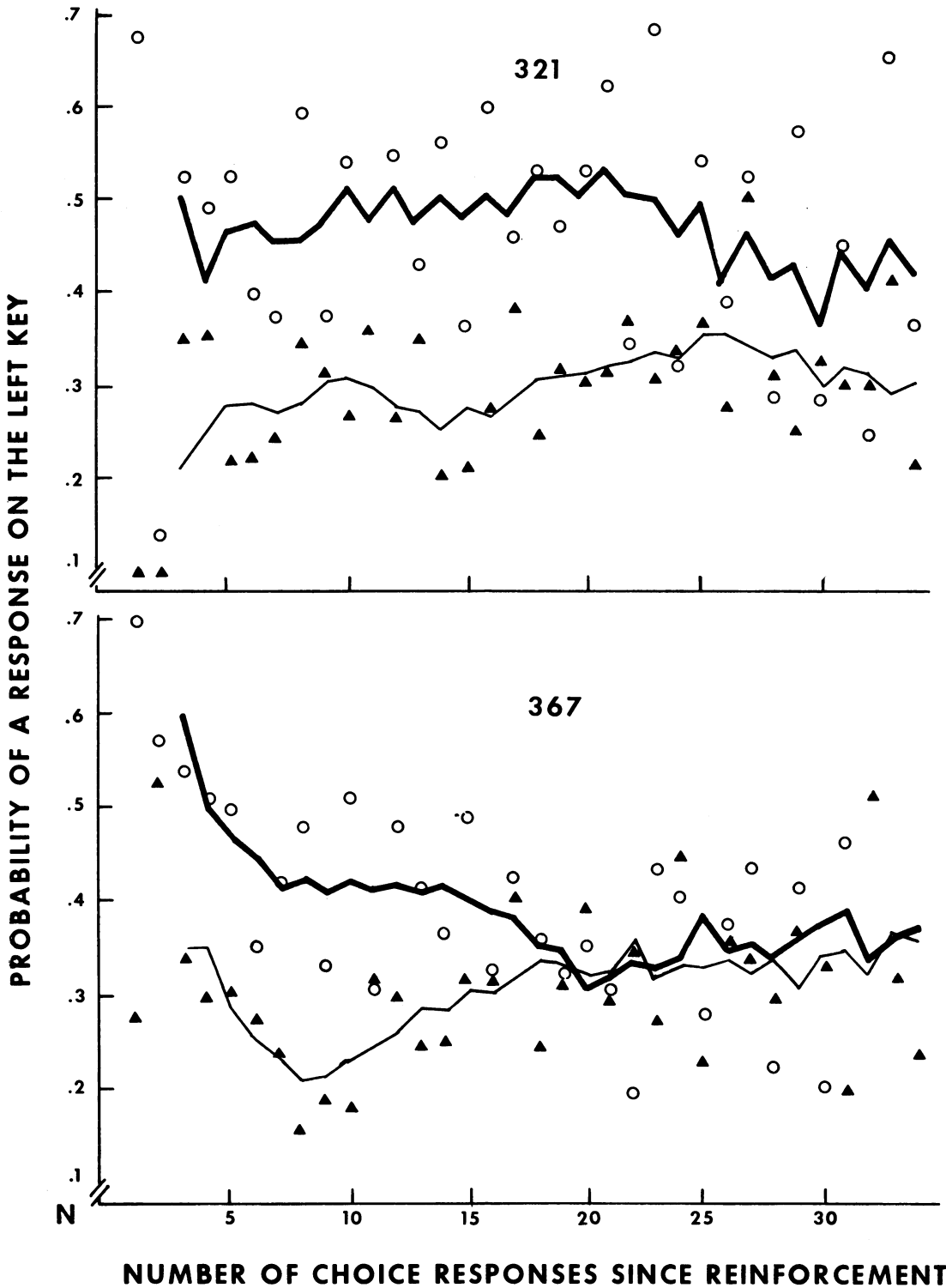


Fig. 1. Relative frequency with which the Nth response in the initial link occurred on the left key, given that the previous reinforcement occurred on the left (triangles) or right (circles) key. The solid lines join running five-point means.

nal link entry is greater on the same key than on the other key. Such negative recency is consistent with the momentary maximizing model of choice behavior proposed by Shimp (1966), although Nevin (1969) found no recency effects in a discrete trial concurrent experiment. There are two possible ways of making behavior less dependent on the locus of the last reinforcement. The initial link VI schedules could be constructed with a larger number of short interreinforcement intervals, so that immediately after a reinforcement, the relative probabilities of reinforcement on the keys are approximately equal. The present schedules were arithmetic progressions that did not have this features. Another possibility that has additional advantages is the use of concurrent percentage-reinforcement schedules (Schwartz, 1969; Stubbs and Pliskoff, 1969). Here, the key on which any particular reinforcement will be obtained is determined by a Gellerman series or some pseudo-random device, while the temporal availability of reinforcement can be arranged by a constant probability VI. Such a schedule can be designed not only to provide an equal number of reinforcements or reinforcement schedules for both keys, but also to make the probability of reinforcement on any key independent of the locus of the last reinforcement.

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