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INTERRESPONSE-TIME SHAPING BY VARIABLE-INTERVAL-LIKE INTERRESPONSE-TIME REINFORCEMENT CONTINGENCIES[1]

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The interresponse-time reinforcement contingencies and distributions of interreinforcement intervals characteristic of certain variable-interval schedules were mimicked by reinforcing each key peck with a probability equal to the duration of the interresponse time it terminated, divided by the scheduled mean interreinforcement interval. The interresponse-time reinforcement contingency was then eliminated by basing the probability of reinforcement on the fifth interresponse time preceding the key peck. Even though distributions of interreinforcement intervals were unaffected by this manipulation, response rates consistently increased. A second experiment replicated this effect and showed it to combine additively with that of mean reinforcement rate. These results provide strong support for the contention that current analyses of variable-interval response rates that ignore the inherent interresponse-time reinforcement contingency may be seriously in error.

Key words: IRT reinforcement, reinforcement rate, shaping, VI schedules, key peck, pigeons

Many current analyses of operant behavior are based on mean rates of responding maintained by various mean rates of reinforcement on variable-interval (VI) schedules and compounds of such schedules (Baum, 1973; Herrnstein, 1970; Rachlin, 1973). Shimp (1974) pointed out that mean rate of responding is the reciprocal of the mean of a distribution of interresponse times (IRTs), so that an analysis of mean response rates may be in error if it ignores variables that influence this distribution. One candidate for such a variable is the distribution of reinforced IRTs. Morse (1966) showed that VI schedules preferentially reinforce longer IRTs, in the sense that the conditional probability of an IRT being followed by the reinforcer, given the occurrence of that IRT, is an increasing function of IRT duration. The exact shape of this conditional probability function depends on the distribution of interreinforcement intervals comprising the VI schedule, but typical functions begin at the origin and increase with constant or negative acceleration to a value of unity for IRT durations in excess of the maximum scheduled interval.

The relationship between conditional reinforcement probability and IRT duration on VI schedules defines a reinforcement contingency on IRT duration. As a result of this contingency, the relative frequency distribution of reinforced IRTs should always tend to be displaced positively from the relative frequency distribution of all IRTs. Such conditions might be expected to shape longer IRTs by a process of successive approximations. If this expectation were to prove true, accounts of response rates on VI schedules would have to include consideration of the IRT-reinforcement contingency.

Unfortunately, possible effects of the relative frequency distribution of reinforced IRTs on the relative frequency distribution of all IRTs cannot be established simply by showing orderly relationships between these two distributions on traditional VI schedules, because such relationships are mathematically forced in that context (Reynolds and McLeod, 1970). It has been amply demonstrated with differential-reinforcement-of-low-rates (DRL) (Richardson, 1973) and percentile (Alleman and Platt, 1973; Kuch and Platt, 1976) reinforcement schedules that IRT contingencies can affect IRT distributions, and hence, re-

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sponse rates. However, these schedules arrange a sharp transition from zero to unity conditional reinforcement probability as IRT duration increases. Such conditional probability functions define a much stronger IRT contingency than is present in VI schedules (Reynolds and McLeod, 1970).

The best evidence that the distribution of reinforced IRTs is a determinant of IRT distributions on traditional VI schedules is provided by synthetic VI schedules that experimentally control the relative frequency distribution of reinforced IRTs, while mimicking many features of a VI schedule (Anger, 1956, 1973; Shimp, 1973, 1974). Resulting orderly relationships between IRT and reinforced-IRT distributions establish the effectiveness of the latter variable and provide a *prima facie* case for its involvement in traditional VI schedules.

Despite the usefulness of synthetic VI schedules for isolating relationships between IRT and reinforced-IRT distributions, they cannot be used to evaluate the effectiveness of the IRT-reinforcement contingencies inherent in traditional VI schedules. A relatively minor problem in this respect is that synthetic VI schedules confound overall reinforcement rate with the relative frequency of IRT classes selected for reinforcement. A more critical problem is that synthetic VI schedules gain control of the relative frequency distribution of reinforced IRTs at the expense of losing control over the IRT-reinforcement contingency defined by the conditional reinforcement probability function on IRT duration. Thus, in a traditional VI schedule, the fixed IRT-reinforcement contingency ensures that the reinforced IRT distribution will always tend to be positively displaced from the distribution of all IRTs. On a synthetic VI schedule, the IRT-reinforcement contingency, and hence the relationship between IRT and reinforced-IRT distributions, depends on the IRT distribution.

The only direct attack to date on the effect of IRT-reinforcement contingencies inherent in traditional VI schedules has sought to eliminate the contingency by appending short limited holds (*e.g.*, Ferster and Skinner, 1957; Schoenfeld, Cumming, and Hearst, 1956). Under these circumstances, conditional reinforcement probabilities for all IRT durations in excess of the limited-hold duration are equivalent. Morse (1966) reviewed a number of such studies showing several-fold increases in mean response rate when the availability of reinforcement on a VI schedule was limited to brief durations. Although Morse interpreted these results as strong evidence for the effectiveness of IRT-reinforcement contingencies inherent in VI schedules, this interpretation can be seriously questioned. Appending a brief limited hold to a VI schedule not only eliminates the IRT-reinforcement contingency, but also introduces a strong positive correlation between mean response rate and mean reinforcement rate, as in ratio schedules. Since ratio schedules are known to produce high response rates for reasons having nothing to do with an IRT-reinforcement contingency (Reynolds and McLeod, 1970), it is unclear whether the enhanced response rates produced by limited holds on VI schedules result from elimination of the IRT-reinforcement contingency, or from some aspect of the added correlation between response and reinforcement rates.

The present experiments used a different approach to eliminate IRT-reinforcement contingencies from schedules mimicking various relevant aspects of traditional VI schedules in order to estimate contributions of IRT-reinforcement contingencies and mean reinforcement rate to response rates. The general procedure used was what Weiss (1970) designated "Stochastic Reinforcement of Waiting" (SRW) schedules. An SRW schedule reinforces any response with a probability (P) equal to the duration of the IRT it terminates, divided by a constant (T):

$$P = \frac{\mathrm{IRT}}{\mathrm{T}}. \tag{1}$$

This schedule mimics several significant features of traditional VI schedules. Mean reinforcement rate will be approximately constant for a wide range of response rates. So long as all IRTs are of shorter duration than T, the expected value of the interreinforcement interval is simply T. Provided all IRTs are short relative to T, the relative frequency distribution of interreinforcement intervals will be approximately geometric, as in a random-interval (Farmer, 1963) or constant-probability VI (Catania and Reynolds, 1968) schedule. Furthermore, SRW schedules specify an IRT-reinforcement contingency very similar to those inherent in traditional VI schedules, since conditional probability of reinforcement increases linearly with IRT duration to a maximum of unity at an IRT duration equal to T. This contingency can be easily removed by using an earlier IRT in the behavioral stream to determine the reinforcement probability for the current response. Such a modification has no expected effect on the relative frequency distribution of interreinforcement intervals, and introduces no relationships between mean response rate and mean reinforcement rate.

EXPERIMENT I

METHOD

Subjects

Eight adult, experimentally naive White Carneaux pigeons obtained from Palmetto Pigeon Plant were maintained at 80% of their free-feeding weights.

Apparatus

The experiment was conducted in four identical, three-key Lehigh Valley pigeon chambers. Only the center key was used; it was mounted 19 cm above the floor and transilluminated with an 1820-GE bulb operated at 28 V dc. Experimental control and data acquisition were accomplished with a Digital Equipment Corporation PDP 8/e computer equipped to resolve real time to the nearest 0.02 sec. The computer recorded any closure of the pecking-key microswitch as a response, provided it was separated by at least 0.1 sec from the preceding closure. The keys required a minimum operating force of approximately 0.1 N.

Procedure

Key pecking was initiated by an autoshaping procedure (Brown and Jenkins, 1968). The birds were then randomly assigned to two groups, with the restriction that each group contain exactly four birds. Birds in each group were scheduled to receive the same average interval between the first peck of a session, or the first peck after food presentation, and the next food presentation. For the two groups, these intervals were 10 and 120 sec, respectively. Birds in the 120-sec condition first received one session at each of the following scheduled food presentation intervals: 10, 30, and 60 sec. All food presentations were 3 sec access to mixed grain, and a session always terminated with the thirtieth food presentation. During food presentations, the keylight was turned off and the food-hopper light was on. The houselight was on throughout each session. The first key peck of a session and the first key peck following a food presentation were not eligible for reinforcement, nor were they recorded as terminating IRTs. The first IRT in such instances was recorded as the time between the first two key pecks.

The first phase of the experiment consisted of 26 sessions on an SRW schedule with a T value of either 10 or 120 sec. Two birds at each T value received a Lag 0 schedule and the other two received a Lag 5 schedule. On the Lag 0 schedule, each eligible key peck was followed by food with a probability equal to the duration of the IRT it terminated, divided by the appropriate T value. The actual decision was made by reference to a pseudorandom number generator. In the Lag 5 condition, the procedure was identical, except that the fifth IRT preceding that terminated by the key peck was used to compute the reinforcement probability.

The second phase of the experiment consisted of 26 sessions, during which the assignment of lag conditions to birds was the reverse of that for Phase I. The last phase involved 18 sessions, with each bird treated the same as it had been in Phase I.

RESULTS

The last three sessions of each phase were selected for analysis. Since major changes in response rate between phases were complete within one to 10 sessions, the sessions chosen for analysis reasonably represent steady-state performance as it is commonly gauged on VI schedules. Figure 1 shows each bird's response rate at the end of each phase. Data of birds scheduled for 10- and 120-sec mean reinforcement intervals are represented in the upper and lower panels of the figure, respectively. The three bars for each bird represent the three phases of the experiment, in chronological order, with shaded and unshaded bars representing Lag 0 and Lag 5 conditions, respectively. Response rate was computed as the reciprocal of the mean IRT in minutes, so that reinforcement times and postreinforcement pauses were excluded. The number above each bar indicates the obtained reinforcement rate. It was computed as the number of food presentations, divided by the sum of all IRTs in hours. The quantities thus represent reinforcements per hour, excluding periods between presentation of a reinforcer and the first subsequent key peck.

Since the number of birds per group was relatively small, and some comparisons of interest were between groups, it was desirable to obtain statistical confidence levels for differences displayed in Figure 1. An analysis of variance was performed on response rates from the last two phases. The variables in this analysis were Scheduled Reinforcement Interval (T = 10 *versus* T = 120 sec), Lag (0 *versus* 5) and Order of Lags. In every case, except the third phase for Bird 9, Lag 0 produced lower response rates than Lag 5. The main effect of Lag was statistically significant; $F(1, 4) = 12.04$, $p = 0.025$. Lag 5 response rates were higher in birds that received Lag 5 before Lag 0. This was reflected in a statistically significant Lag by Order interaction; $F(1, 4) = 9.12$, $p = 0.039$. Three of the birds scheduled for a 120-sec mean reinforcement interval displayed lower response rates at each lag value than any of the birds scheduled for a 10-sec interval. The response rates of Bird 15, however, were quite similar to those for the 10-sec group. The main effect of Scheduled Reinforcement Interval only approached statistical significance; $F(1, 4) = 5.74$, $p = 0.075$. Differences between Lag 0 and Lag 5 response rates were larger in the 120-sec group than in the 10-sec group. The respective mean differences were 28 and 10 responses per minute, but the interaction of Lag with Reinforcement Interval fell short of statistical significance; $F(1, 4) = 2.67$, $p = 0.177$. No other main effect or interaction approached statistical significance.

Table 1 summarizes the effect of Lag on reinforced IRTs. The mean and standard deviation of all IRTs and of reinforced IRTs is shown for each bird over the last three sessions with each lag value. At Lag 0, the mean reinforced IRT was always longer than the mean IRT, and the difference between these means was larger in the 120-sec group than in the 10-sec group. There were no consistent differences between mean IRT and mean reinforced IRT at Lag 5.

Figure 2 further details the effect of Lag on reinforced IRTs by showing distributions of all IRTs and of reinforced IRTs at each lag for one bird from each reinforcement interval group. Birds 11 and 16 were chosen because they showed substantial effects of Lag and had overall response rates typical of their group. At Lag 5, distributions of reinforced IRTs were essentially identical to distributions of all IRTs. At Lag 0, distributions of reinforced IRTs were displaced to the right of distributions of all IRTs, and the magnitude of displacement was larger in the 120-sec group than in the 10-sec group. The major effect of this displacement on distributions of all IRTs appeared to be an increase in positive skew.

Obtained reinforcement rates are displayed for each bird in Figure 1. These rates varied

Table 1

Mean and standard deviation in seconds of all IRTs and of reinforced IRTs for each bird over the last three sessions at each lag.

		Lag 0		*Lag 5*	
T	*Bird*	*All*	*Reinforced*	*All*	*Reinforced*
10	9	0.57(0.26)	0.69(0.32)	0.67(0.42)	0.63(0.30)
	10	0.72(0.39)	0.90(0.53)	0.66(0.33)	0.67(0.30)
	11	0.94(0.57)	1.31(0.73)	0.57(0.67)	0.60(0.44)
	12	0.75(0.47)	1.03(0.54)	0.69(0.67)	0.67(0.40)
	Mean	0.75(0.42)	0.98(0.53)	0.65(0.52)	0.64(0.36)
120	13	1.26(0.75)	1.43(0.59)	1.20(2.20)	1.12(0.72)
	14	1.37(1.51)	2.38(2.38)	1.01(1.68)	0.94(1.18)
	15	0.85(0.95)	2.06(5.06)	0.52(0.91)	0.44(0.36)
	16	1.95(1.99)	3.58(2.29)	0.75(1.08)	0.77(1.10)
Mean		1.36(1.30)	2.36(2.58)	0.87(1.47)	0.82(0.84)

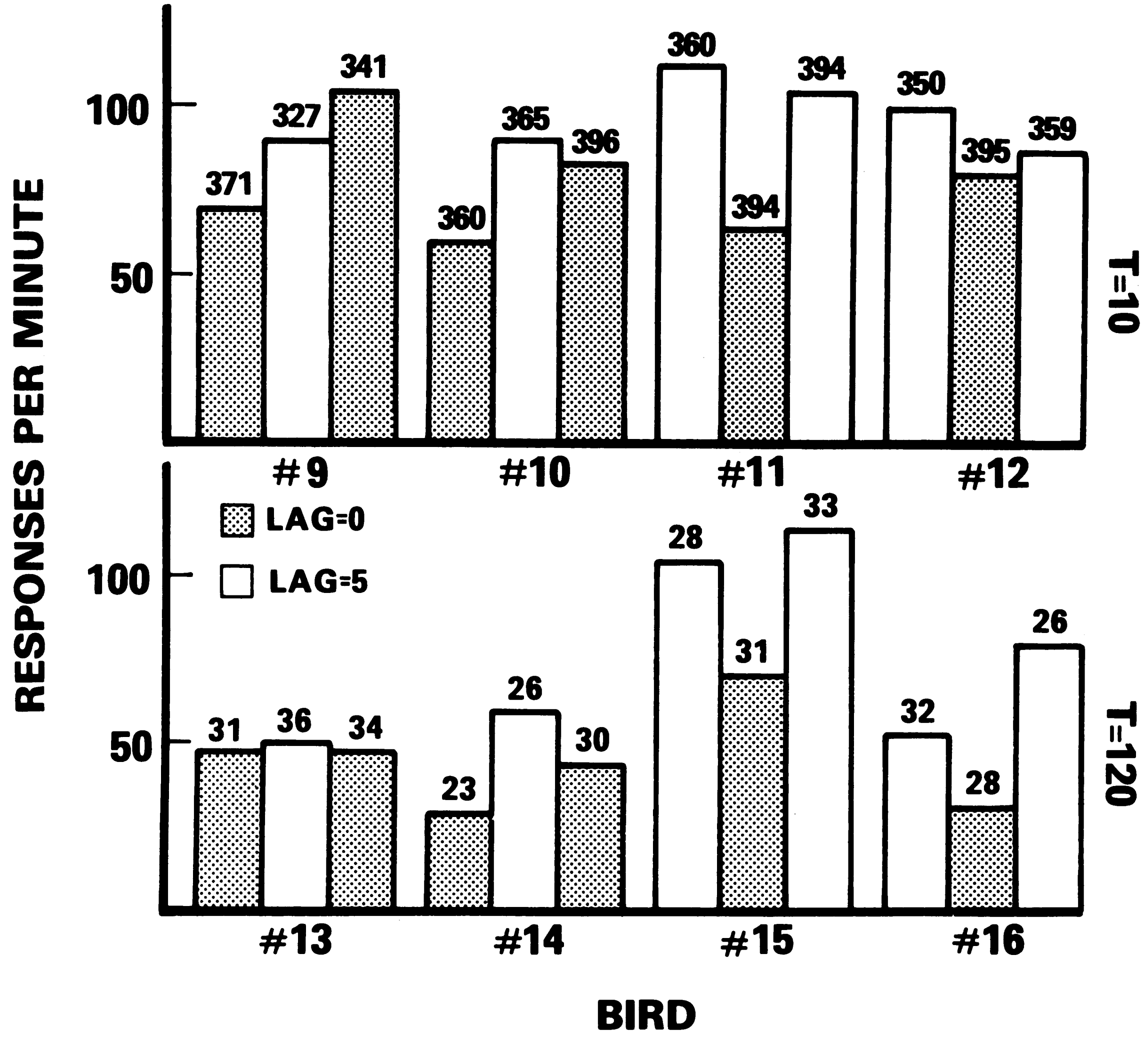

Fig. 1. Response rates for each bird in the last three sessions of each experimental phase. Numbers on top of each bar represent the reinforcements per hour actually obtained during those three sessions.

about their expected values of 360 and 30 reinforcements per hour for T = 10 and 120 sec, respectively. There was no apparent tendency for variations in response rates across phases to be correlated with fluctuations in reinforcement rate. This, of course, does not guarantee that the distributions of reinforcement intervals were independent of Lag, or that they were in any way typical of those generated by VI schedules. Therefore, a distribution of obtained reinforcement intervals was compiled for each bird over the last three sessions at each lag value. Since there was negligible between-bird variability in these distributions, they were combined over birds within a condition, and the resulting distributions are shown in Figure 3. The means of these distributions were close to their expected values of 10 and 120 sec. The means were slightly higher at Lag 5 than at Lag 0, but even this small difference was in a direction opposite to that required to explain obtained effects of Lag on response rates. In addition, the standard deviations of these distributions were very similar to their means, which is characteristic of a geometric distribution. An exponential approximation to the geometric was thus fitted to each distribution, using the reciprocal of the observed mean as the rate parameter. These fits are shown in Figure 3 and were generally quite good, given the nonsystematic variance in the data points. The worst dis-

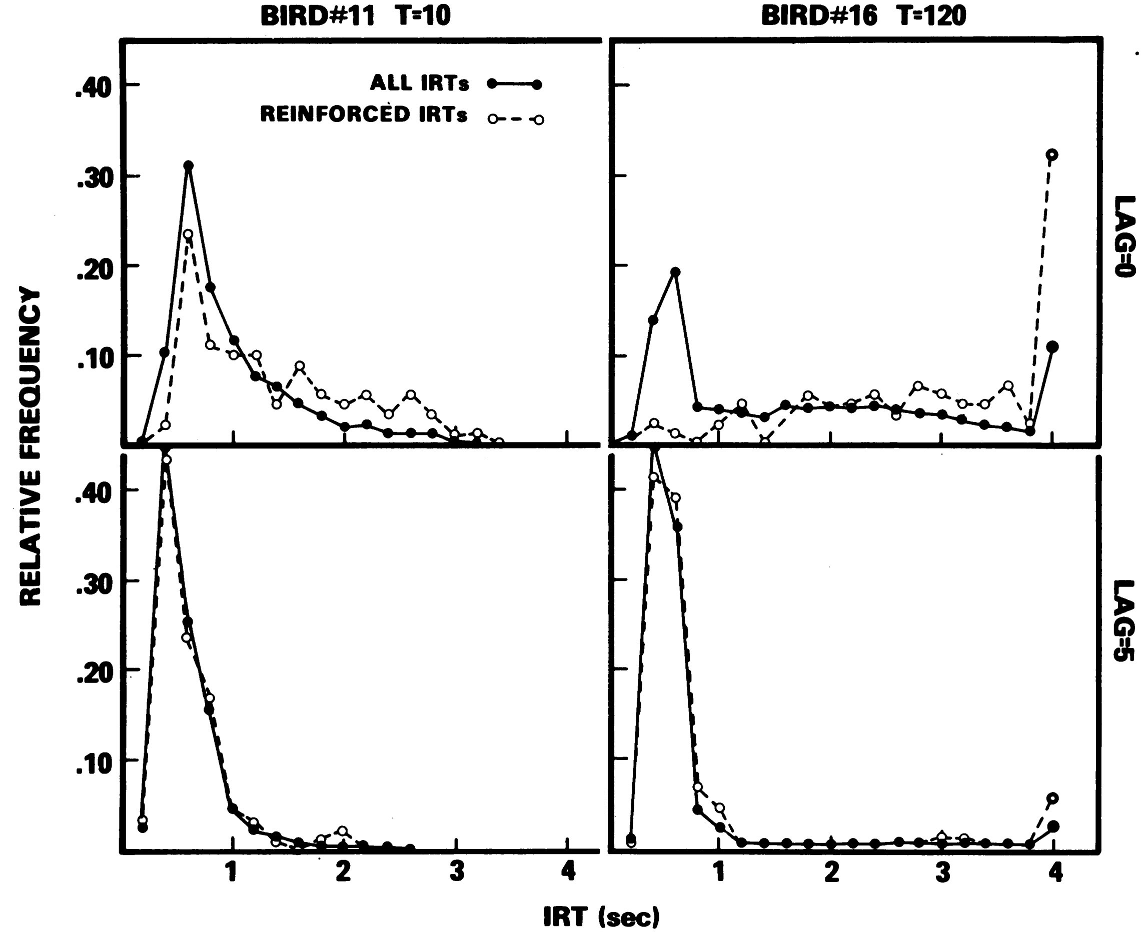

Fig. 2. Distributions of all IRTs and of reinforced IRTs over the last three sessions at each lag for one bird at each value of T.

crepancy was obtained in the T = 120, Lag 5 condition, where the data points show a marked discontinuity near the mean reinforcement interval.

Computations of reinforcement rates excluded postreinforcement pauses because these times were excluded from the reinforcement dependencies. Since traditional computations of reinforcement rates include these times, Table 2 shows the mean and standard deviation of postreinforcement pauses for each bird over the last three sessions at each lag. Mean pause duration was consistently longer in the 120-sec condition than in the 10-sec condition, but there was no effect of lag value. Thus, traditional rates of reinforcement were approximately 298 and 28.5 reinforcements per hour for the 10- and 120-sec groups, respectively. If reinforcement durations are also included in the computation, these values become 238.7 and 27.8 reinforcements per hour.

EXPERIMENT II

Experiment I showed consistently higher response rates in the absence of a VI-like IRT-reinforcement contingency (Lag 5) than in its presence (Lag 0). Response rates tended to be higher, and Lag effects to be smaller at the higher reinforcement rate (T = 10 sec); however, neither of these latter effects was statistically significant. Since all comparisons involving reinforcement rate were between subjects, and only two values of T were employed, a systematic replication of Experiment I was performed in which each subject was exposed to four values of T under both Lag 0 and Lag 5 conditions.

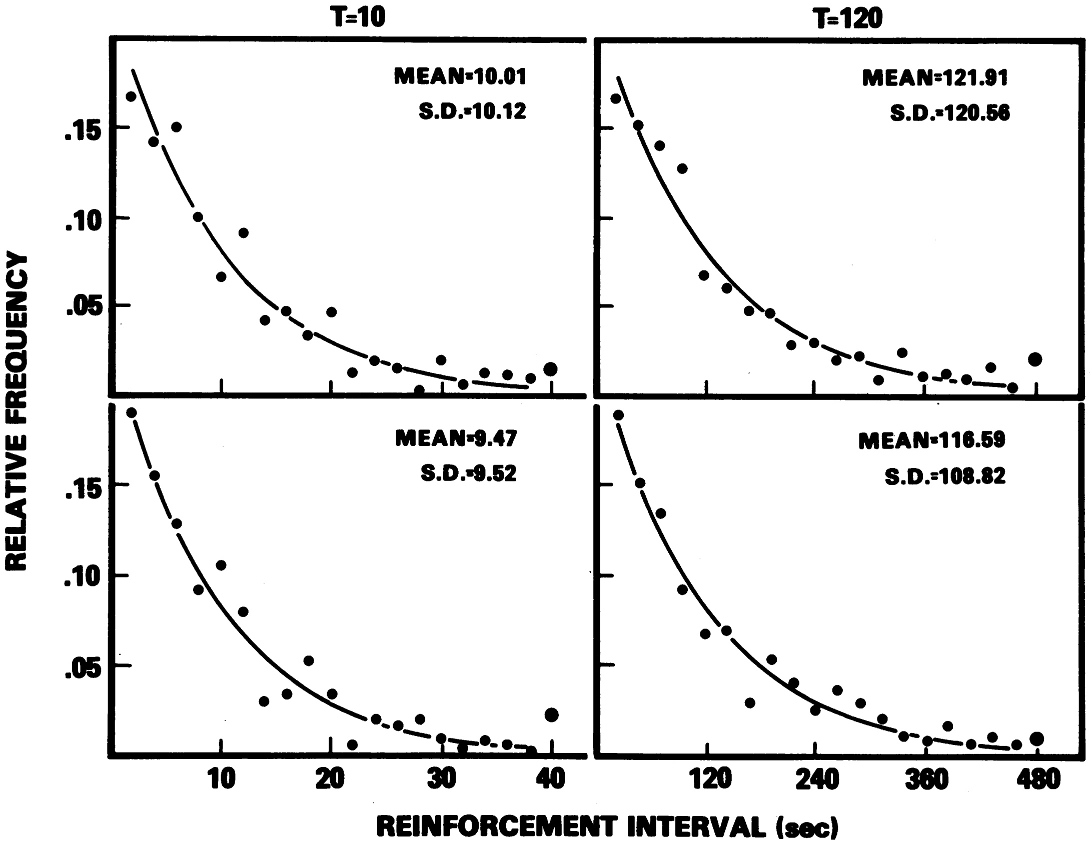

Fig. 3. Distributions of obtained reinforcement intervals over the last three sessions at each lag for each T group. Solid lines represent exponential functions with a rate parameter equal to the reciprocal of the obtained mean. The last class-interval in these distributions includes all reinforcement intervals in excess of 4T.

Method

Subjects

Four adult, experimentally naive White Carneaux pigeons obtained from Palmetto Pigeon Plant were maintained at 80% of their free-feeding weights. One of these birds repeatedly failed to show effects of changes in reinforcement rate or lag value and was discontinued.

Table 2

Mean and standard deviation in seconds of postreinforcement pauses for each bird over the last three sessions at each lag.

T	*Bird*	*Lag 0*	*Lag 5*
10	9	1.69 (0.45)	1.56 (0.41)
	10	2.60 (0.99)	2.36 (0.66)
	11	1.57 (0.46)	3.39 (1.50)
	12	1.84 (0.41)	1.57 (0.48)
	Mean	1.93 (0.58)	2.22 (0.76)
120	13	3.12 (1.46)	5.45(10.80)
	14	10.78 (7.01)	9.63 (5.82)
	15	4.72(11.56)	3.14 (5.11)
	16	8.91 (8.08)	8.08 (3.59)
	Mean	6.88 (7.03)	6.58 (6.33)

Apparatus

The apparatus was the same as employed in Experiment I.

Procedure

The procedures were the same as for Experiment I, except that each bird was exposed successively to T values of 10, 30, 60, and 120 sec in the orders shown in Table 3. Each T value was presented under the Lag 5 condition for 14 sessions, then under the Lag 0 condition for 14 sessions, and finally under Lag 5 for an additional 14 sessions.

RESULTS

The last three sessions under each combination of Lag and T value were selected for analysis, and summary statistics were computed in the same manner described for Experiment I. Figure 4 shows mean response rates for each bird at each combination of Lag and T value, as well as means for all three birds. Lag 5 produced consistently higher response rates than did Lag 0; $F(1,2) = 41.67$, $p = 0.023$; and response rates generally decreased with T value; $F(3,6) = 13.86$, $p = 0.004$. There was no consistent tendency for the effect of Lag value on response rate to change with T value, and the interaction of these variables was not statistically significant; $F(3,6) = 1.12$, $p = 0.41$.

Since mean IRT and response rate are reciprocally related, the additive effects of Lag and T value on response rate do not necessarily imply additive effects on mean IRT. Table 4 shows mean IRTs across the three subjects over the last three sessions under each condition. Mean IRTs increased with T and were longer under Lag 0 than Lag 5. The Lag effect on mean IRTs was smaller at $T = 10$ sec than at larger T values, but the interaction of these two variables did not approach statistical significance; $F(3,6) = 1.33$, $p = 0.35$.

Table 4 also compares the mean of all IRTs with the mean reinforced IRT at the end of each condition. Although the present birds had slightly shorter mean IRTs, the relationships are the same as in Experiment I. Mean IRT and mean reinforced IRT were virtually identical in the Lag 5 conditions. With Lag 0, mean reinforced IRT was longer than mean IRT, and the magnitude of this difference increased with T value. Distributions of all IRTs and of reinforced IRTs are not shown, but were similar to those reported for Experiment I. The present results also replicated Experiment I, in that distributions of reinforcement intervals were approximately geometric, with means and standard deviations virtually identical to T value under both lag conditions.

Table 3

Order of presentation of T values for birds in Experiment II.

Bird 1	120	60	10	30
Bird 2	10	120	30	60
Bird 3	30	10	60	120

Table 4

Mean in seconds of all IRTs and of reinforced IRTs over the last three sessions of each condition.

	Lag 0		*Lag 5*	
T	*All*	*Reinforced*	*All*	*Reinforced*
10	0.58	0.82	0.48	0.48
30	0.77	1.19	0.54	0.57
60	0.92	1.63	0.72	0.80
120	1.09	1.94	0.89	0.90

DISCUSSION

The major purpose of these experiments was to mimic the reinforcement intervals and IRT-reinforcement contingencies of traditional VI schedules in a context that allowed experimental manipulation of both variables. The SRW schedules used for this purpose consistently produced approximately geometric distributions of reinforcement intervals characteristic of such common VI schedules as random-interval (Farmer, 1963) and constant-probability VI (Catania and Reynolds, 1968). The Lag 0 SRW schedules necessarily produced linearly increasing conditional probabilities of reinforcement across the range of IRT durations actually obtained. This was empirically reflected in the positive displacement of reinforced IRT distributions from distributions of all IRTs, so that mean reinforced IRT was longer than mean IRT. Figure 5 compares the IRT reinforcement contingencies arranged by constant-probability VI schedules and Lag 0 SRW schedules with the same mean reinforcement interval (T). The two conditional probability functions differ, in that the SRW function increases linearly to a value of unity at an IRT duration equal to T, while the constant-probability VI function increases with negative acceleration to a value of unity at an IRT duration equal to the longest scheduled reinforcement interval. This apparent discrepancy would be expected to have little or no consequence, since IRT durations actually occurring on either schedule are short relative to T, so that only the initial portion of the conditional-probability functions are relevant. The two functions are essentially identical for IRT durations shorter than 0.4 T.

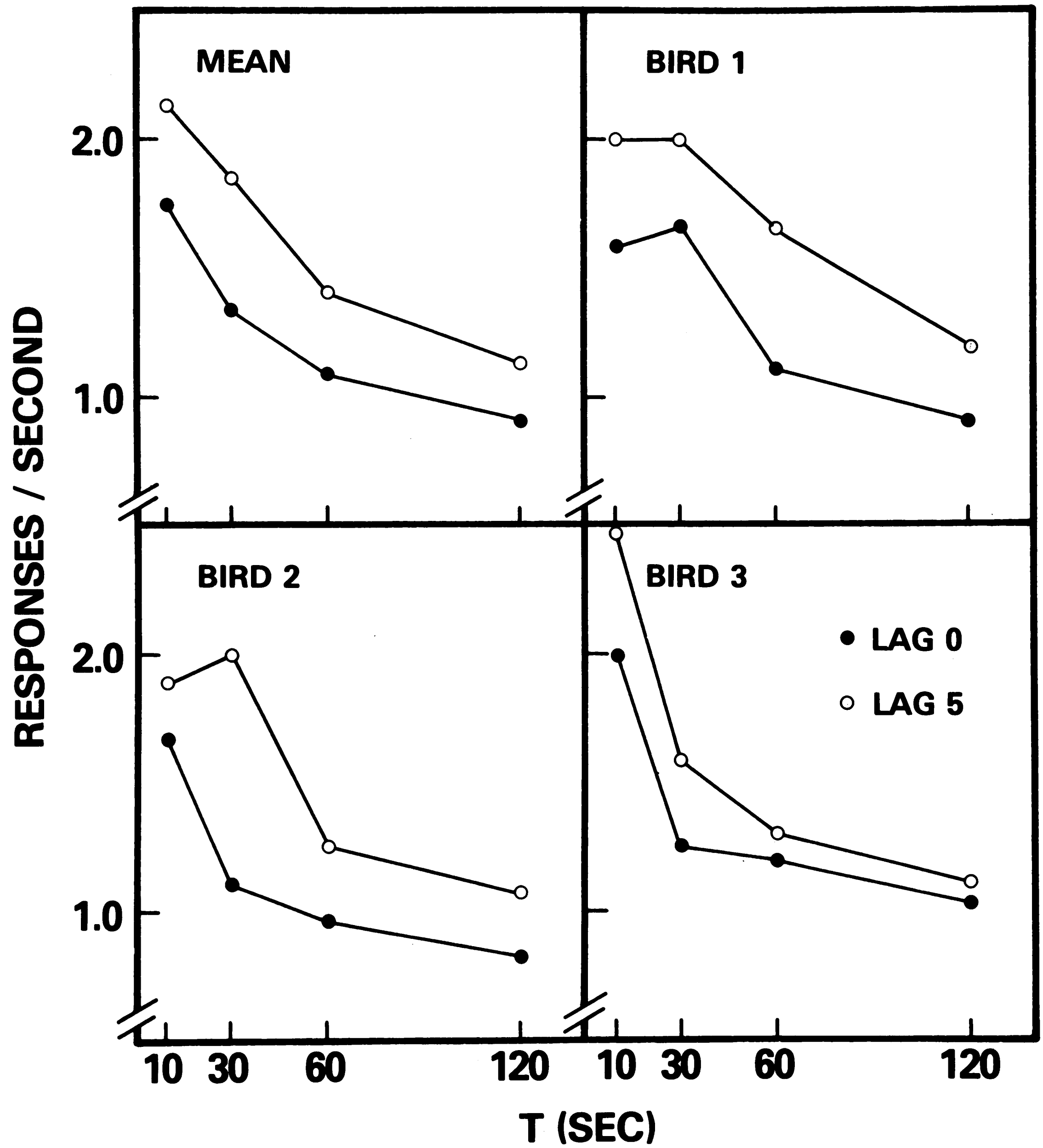

Fig. 4. Response rate during the last three sessions of each condition in Experiment II.

The Lag 5 SRW schedules effectively eliminated the VI-like, IRT-reinforcement contingency, as evidenced by the similarity of relative frequency distributions of reinforced IRTs to those of all IRTs. This elimination was accomplished without noticeable changes in distributions of reinforcement intervals, or introduction of a contingency between reinforcement rate and response rate. The Lag 5 schedules did, of course, contain a contingency between reinforcement and the duration of the fifth preceding IRT. In order for this latter contingency to affect IRT distributions, reinforcement would have to operate over a delay equal to the sum of five IRTs, and the subject would have to detect the relationship in spite of five intervening IRTs whose durations would relate to reinforcement probability only to the extent produced by first-through fifth-order sequential dependencies

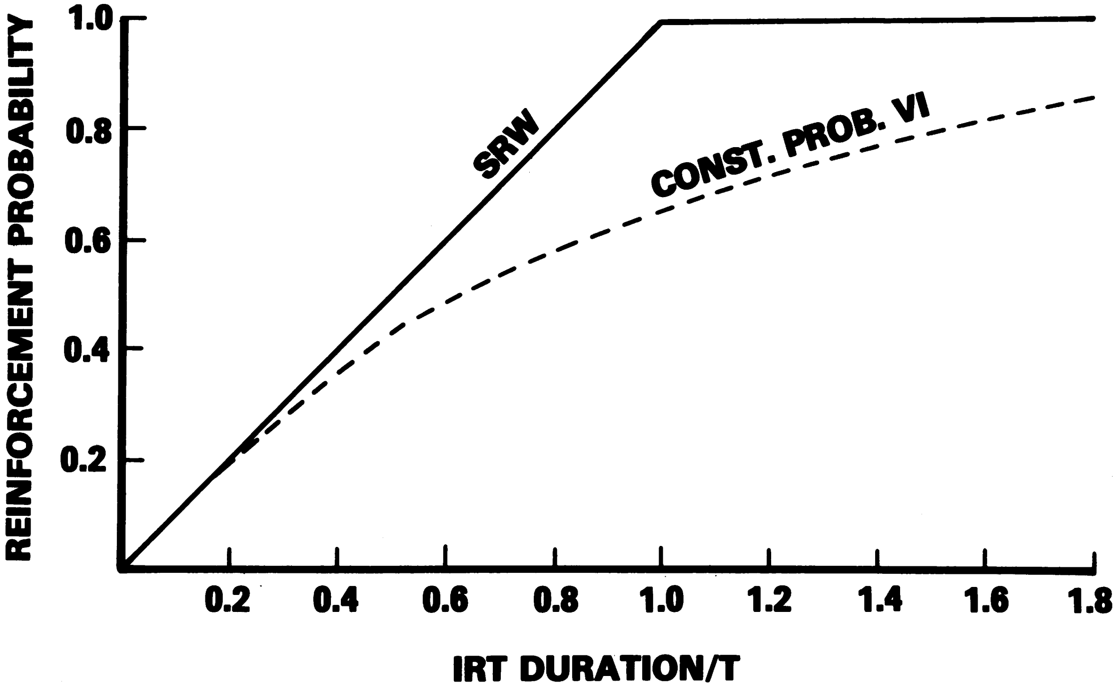

Fig. 5. Conditional probability of reinforcement as a function of IRT duration for constant-probability VI and SRW reinforcement schedules with average scheduled reinforcement intervals of T sec. IRT durations are scaled relative to T.

between IRTs. It thus seems reasonable to view the Lag 5 schedules as void of any effective IRT-reinforcement contingency.

The higher response rates produced by Lag 5 schedules in both experiments indicate the effectiveness of the IRT-reinforcement contingencies of the Lag 0 schedules in shaping longer IRTs. The similarity of the Lag 0 SRW schedules to traditional VI schedules, in respect to both IRT-reinforcement contingencies and reinforcement intervals, provides the clearest evidence to date that a complete account of VI performance must include consideration of the inherent IRT-reinforcement contingencies. Previous attempts to eliminate IRT reinforcement contingencies from VI schedules by appending brief limited holds have produced several-fold increases in response rates (Morse, 1966). In the present study, Lag 5 response rates averaged 1.2 times Lag 0 response rates. This considerably smaller effect supports the contention made earlier in this report that effects of adding limited holds to VI schedules are largely attributable to factors other than elimination of the IRT-reinforcement contingency. One obvious possibility in this respect is the positive correlation between response and reinforcement rates produced by limited holds.

In addition to IRT-reinforcement contingency effects, the present experiments demonstrated consistent effects of mean reinforcement rate similar to those produced by variations in this variable on traditional VI (Catania and Reynolds, 1968) and synthetic VI (Shimp, 1974) schedules. Furthermore, the effects of reinforcement rate and IRT-reinforcement contingency appeared to be additive in Experiment II, regardless of whether response rates or IRT means were employed as the dependent variable. This result is consistent with those of several other studies that have examined both mean reinforcement rate and IRT-reinforcement contingencies. Richardson (1976) compared response rates on various DRL schedules to those for VI schedules yoked to have the same reinforcement intervals. DRL response rates were always lower than yoked-VI rates, but the response-rate functions for the two schedules were parallel over all DRL values in excess of 3 sec. Kuch and Platt (1976) varied mean reinforcement rate and IRT-reinforcement contingencies using percentile schedules and found no evidence of an interaction between these two variables. Finally, Shimp (1974) showed that the function relating response rate to reinforcement rate on synthetic VI schedules can be decomposed into two components, one determined by mean reinforcement rate, and the other by the relative rates of reinforcement for specific IRT classes.

Although the finding of additivity between effects of IRT-reinforcement contingencies and mean reinforcement rates is consistent with the literature, it may seem surprising. When the value (T) of a Lag 0 SRW schedule is changed, the IRT-reinforcement contingency is changed, as well as the mean reinforcement rate. Doubling T halves both reinforcement and the slope of the conditional reinforcement-probability function on IRT duration. This latter effect means that the difference between mean reinforced IRT and the mean of all IRTs will increase with T, as can be seen in Tables 1 and 4. Since Lag 5 SRW schedules do not contain an effective IRT-reinforcement contingency, changing T alters only reinforcement rate. The parallel response-rate functions for the two lag conditions thus might be taken to imply that presence *versus* absence of the IRT-reinforcement contingency is an effective variable, but the nature of the contingency is not. Richardson (1976) reached such a conclusion on similar grounds with respect to variations in DRL schedule value. However, a more parsimonious interpretation is suggested by Shimp's (1973) finding that when all IRT classes were reinforced equally often on a synthetic VI schedule, the relative frequency of an IRT approximately equalled the relative reciprocal of its length. This finding indicates a preference for shorter IRTs when reinforcement for all IRT classes is equated. Platt (*in press*) has reviewed similar evidence from a variety of temporal response dimensions and concluded that the difference between emitted and reinforced response values necessary to shape longer values increases with initial value. In the present context, it would appear that IRT-shaping effects of the increasing difference between relative frequency distributions of all IRTs and of reinforced IRTs, as T increased on Lag 0 schedules, were in direct proportion to those required to shape longer IRTs from the longer initial values produced by the lower reinforcement rate. A similar state of affairs should hold for variations in IRT-reinforcement contingencies produced by changing the schedule value of traditional VI schedules.

The present experiments provide a strong case for the behavioral relevance of VI-like, IRT-reinforcement contingencies, but are silent with respect to the mechanisms by which such contingencies exert their effects. Nevertheless, it is possible to consider how two current approaches might deal with these results. Shimp's (1974) molecular approach viewed mean reinforcement rate as determining time allocated to all reinforced IRT durations, and reinforcement rate for a particular IRT class as determining time allocated to that class. Thus, Shimp's approach has no difficulty dealing with both reinforcement-rate and IRT-reinforcement-contingency effects. However, since both the present schedules and traditional VI schedules control the IRT-reinforcement contingency, rather than rate of reinforcement of particular IRT classes, Shimp's formulation would have to be applied repeatedly, as changes in the IRT distribution change the reinforced IRT distribution, in order to provide a complete quantitative account.

Herrnstein's (1970) molar approach views mean reinforcement rate as determining mean response rate according to the equation

$$P = \frac{kR}{R + R_0}, \qquad (2)$$

where P is response rate, R is reinforcement rate, and k and R_0 are free parameters. The difference between the parallel functions in Figure 4, relating response rate to reinforcement rate in the Lag 0 and Lag 5 conditions, would be reflected in Equation 2 by different values of k. Herrnstein has identified k with asymptotic behavioral output for a particular subject, response topography, and type of reinforcement. The present results thus support Shimp's (1974) contention that "there may be no such thing as an asymptotic mean rate of key pecking that is, as assumed in Herrnstein's theory, independent of reinforced IRTs."

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