*SOME BEHAVIORAL EFFECTS OF A TWO-VALUED,
TEMPORALLY DEFINED REINFORCEMENT SCHEDULE¹*

J. R. MILLENSON²

COLUMBIA UNIVERSITY

Attempts to systematize variable-interval (VI) reinforcement schedules for operant behavior encounter two problems. First, in those VI schedules where reinforcements are made available following time intervals, t_x , measured from a previous reinforcement, the specification of the schedule is not complete without reference to the behaving organism. Because of this partial control by the animal, such VI schedules are difficult to specify precisely, and are thereby deprived of defining properties with completely independent status. The second problem is that if the sequence of intervals is random, a VI schedule may be described by its distribution of intervals. However, because an infinite number of distributions is available, many of which are not obviously related to one another, organization of all VI schedules in terms of a finite set of defining variables is difficult. Furthermore, the functions relating behavior to parameters of interval distributions (e.g., the mean interval and the interval variance) do not appear to be invariant for all distributions.

In the present study, an attempt is made to meet these problems by an appeal to a system of schedules specified within an independent, temporally defined framework of variables. Use of these schedules provides a measure of experimental control to be gained over the specification of the reinforcement contingencies. Furthermore, by restricting the present considerations to the limiting case of VI schedules, those containing only *two* randomly alternating intervals, the available interval distributions reduce to values of the relative proportion of the two intervals to each other, a continuous variable with a finite range from zero to 1. Although the effects of classical VI schedules are complex and diverse (Ferster & Skinner, 1957, Chap. 6), extensive exploration of some of the parameters of the simplest VI schedules—beginning with those containing only two intervals—may reveal the as yet unknown necessary and sufficient conditions for generating such behavioral effects.

Reinforcement schedules containing only two programmed intervals (two-valued schedules) have been sampled elsewhere, and are members of a class of schedules called "mixed schedules" (Ferster & Skinner, 1957, Chap. 11). The behavioral effects of the schedules studied by these workers are complex, with multiple inflections and abrupt shifts in the cumulative-response curves appearing frequently during the longer intervals of the schedule. Pauses after reinforcement may also appear, depending on the values and proportions of the two intervals. The shifts and inflections in rate are often quite predictable since they usually bear a specific temporal relationship to a previous reinforcement. However, the mixed schedules studied so far may constitute a small and possibly special group of two-valued schedules, since no attempt has been made as yet to systematically or extensively explore the numerous parameters of two-valued schedules.

The system of temporal parameters in which the present schedules are defined has been described in detail elsewhere (Schoenfeld, Cumming, & Hearst, 1956). Briefly, it defines two

¹This paper is based in part on a dissertation submitted to Columbia University in 1959 in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Thanks are due Profs. W. N. Schoenfeld and W. W. Cumming for suggestions and assistance throughout the present research. This research was supported by National Science Foundation Grants G3408 and G5517.

²Present address: Department of Psychology, Birkbeck College, University of London.

fundamental variables, one of which, t^D , refers to a time period during which a nonzero probability of reinforcement exists for given operant responses. A second time period, t^A , denotes an interval during which a lesser probability (including zero) of such reinforcement exists. In investigations to date, and in the present study, the probability condition in t^D are such that only the first response occurring in this period is reinforced; in t^A the probability of reinforcement is zero. In addition, t^D and t^A are alternated. In the system, two analytic variables have been defined in terms of the fundamental variables, $t^D \neq t^A = \bar{T}$ (termed cycle length) and $t^D/(t^D \neq t^A) = \bar{T}$. These quantities are the ones that have been experimentally manipulated in research to date. In previous studies with temporally defined schedules of this sort (Schoenfeld & Cumming, 1957; Hearst, 1958; Brandauer, 1958; Clark, 1959), only fixed cycle lengths have been used; but if two cycle lengths are incorporated into a single schedule, the necessary and sufficient conditions for a two-valued schedule can be met. Figure 1 illustrates, for a sample case, the relationships between two randomly alternating cycles, T_A and T_B , the organism's response, R , and the reinforcing stimulus, S^R . Note that t^D 's and t^A 's are alternated in such a way that cycle A is made up of a t^D_A period followed by a t^A_A period, and that cycle B is composed of a t^D_B period followed by a t^A_B period. In this example, cycle A = 2.0 minutes and cycle B = 0.5 minute. The quantity $\bar{T}$ is not unique, but may take on two values: $\bar{T}_A = t^D_A/(t^D_A \neq t^A_A)$ and $\bar{T}_B = t^D_B/(t^D_B \neq t^A_B)$. In Fig. 1, however, $\bar{T}_A = \bar{T}_B = 0.40$.

The inclusion of a second value of cycle length into a temporally defined reinforcement schedule introduces a number of variables whose behavioral import remains to be seen. A partial list of these follows.

1. The mean cycle length can assume any positive value. (The mean of a two-valued schedule is determined by the absolute values of the two cycles and the relative frequency of one cycle to the other.)
2. The cycles in a pair may differ in varying degree, a dimension that can be represented numerically by both the absolute and relative difference between the two cycle lengths.
3. Any pattern of alternating or random succession of cycles is possible.
4. When a schedule contains two or more nonidentical cycles, the temporal position of the t^D within each particular cycle enters into the specification of the reinforcement contingencies.

Figure 1. Schematic representation of the temporal contingencies of a two-valued reinforcement schedule. For details see text.

5. Changes in the value of the respective t^D 's are possible; furthermore, variables representing the relationship of the magnitude of the two t^D 's to each other, and to their respective cycle lengths, are definable.

Even from this incomplete catalog of parameters, it is apparent that the addition of a second cycle-length value to a reinforcement schedule increases its complexity manifold. In the research to be described below, two of these parameters were singled out for study: $\bar{T}$, the relative portion of each cycle occupied by the t^D period; and a variable, $\bar{P}$, expressing the relative proportion of the longer cycles. The present report deals in particular with the effects of experimental changes in these two variables on the "stabilized" key-pecking response rates of birds exposed to temporally defined, randomly alternating, two-cycle reinforcement schedules.

SUBJECTS, INITIAL PREPARATION, AND APPARATUS

The subjects were 18 White Carneaux hen pigeons, all lacking previous experimental history. During the last week of an initial 2-to-3-week period of acclimatization to the laboratory, the birds' weights were determined under free feeding. Thereafter, weights were gradually reduced through restricted feeding to 80% of each bird's free-feeding value. During the latter days of this period, the response of magazine approach was conditioned, and the key-pecking response was subsequently shaped. Following key-peck conditioning, the birds were maintained daily on regular reinforcement for about 1 month.

The experimental space in which each bird was first trained and then exposed to various reinforcement schedules has been described in detail elsewhere (Hearst, 1956). The controlling and recording equipment was located in a separate room, where the temporal contingencies were generated by a quartet of reset timers in conjunction with a circuit of multivibrators and relays. A random-number table was used to determine the actual sequence of cycles. The accuracy of the temporal contingencies was as follows: reinforcement duration was fixed at 3 seconds ± 0.1 second, cycle lengths were maintained within $\pm 1\%$, and t^D length varied within a ± 0.01 -second range.

PROCEDURE

The general design of the experiment involved exposure of birds to related two-valued schedules containing randomly alternated cycles of 2.0 and 0.5 minutes of the general type shown in Fig. 1 above. Following the preliminary conditioning described above, the birds were divided into six groups of three animals each, and a fixed value of the schedule parameter $\bar{P}$ was assigned to each group. In this way, six values of $\bar{P}$ (0.95, 0.90, 0.60, 0.40, 0.10, and 0.05), chosen to fill out the range of the variable from zero to 1, were studied across groups. [The limiting cases, $\bar{P}$ equal to zero and 1 (not investigated here), degenerate into single, fixed-cycle-length schedules, in this case, 30 seconds and 2 minutes, respectively. These two extreme limits of $\bar{P}$ have been investigated previously (Hearst, 1958; Clark, 1959) and form points of contact tying the present study, involving variable schedules, to a body of research using single cycle lengths.]

Birds in every $\bar{P}$ group were exposed to progressive changes in $\bar{T}$, beginning with $\bar{T} = 1.0$. [At this value of $\bar{T}$, $t^A_A = t^A_B = 0$; hence, these schedules are identical to "mixed FI FI" (Ferster & Skinner, 1957) in which the intervals are timed from the termination of the previous interval.] In succeeding schedules, $\bar{T}$ took on values of 0.25, 0.10, 0.05,

0.025, 0.0125, 0.00625, and 0.003125. These $\bar{T}$'s represent t_A^D 's of 120, 30, 12, 6, 3, 1.5, 0.75, and 0.375 seconds, respectively; and t_B^D 's of 30, 15, 3, 1.5, 0.75, 0.375, 0.1875, and 0.09375 seconds, respectively. Such a series of $\bar{T}$'s spans the regions found by Hearst (1958) and Clark (1959) in single-cycle-length schedules to give "interval-like" and "ratio-like" behavioral effects.

To obtain response-rate stability, 60 running days were devoted to exposure at the first $\bar{T}$ point ($\bar{T} = 1.0$). [Data reported by Cumming and Schoenfeld (in preparation) show that by 60 days, the over-all response rates of birds exposed to a 30-second, fixed-cycle-length schedule have reached asymptotes.] It seemed likely that fewer running hours would be necessary to achieve rate stability in shifting from one value of a schedule to another than would be required at the initiation of an experimental history of exposure to reinforcement schedules. Therefore, 25 days' exposure was selected as a somewhat arbitrary figure for subsequent $\bar{T}$ points. However, at $\bar{T} = 0.25, 0.10$, and 0.05 , the disparities between observed reinforcement frequencies and scheduled reinforcement opportunities (t^D frequency) turned out to be negligible for most of the birds. At these $\bar{T}$ values, therefore, exposure was limited to 15 days and the data collected then can be taken as supplementing those at $\bar{T} = 1.0$.

Sessions were 30 minutes (occasionally, 25 minutes); but in order to obtain data free from warm-up effects, responses were recorded only during the last 20 minutes of a session. Each bird was run daily providing its weight was within ± 15 grams of its 80% free-feeding value.

RESULTS³

Sample Individual Session by Session Rates

Over-all session response rates on each of the 205 consecutive daily exposures for a sample of 4 of the 18 birds representing $\bar{P}$ groups 0.95, 0.60, 0.40, and 0.05 appear in Fig. 2. The rates plotted have been corrected for eating time by subtracting the total time the grain magazine was available (3 seconds $\times$ number of reinforcements) from the 20-minute test session. Data collected from birds in $\bar{P}$ groups 0.95 and 0.05, respectively, and are therefore not reproduced here. The prevailing values of $\bar{T}$ appear approximately centered over the plotted points associated with them. Although $\bar{T}$ values are shown only for the topmost graph, they apply to the three lower plots as well. The solid vertical arrows indicate a change in $\bar{T}$.

Two general trends characterize the four records of Fig. 1, and are seen in the data for nearly all of the 18 birds. The first is a fairly gradual rise in response rate during the first 60 days of schedule exposure, up to the point where the first change in $\bar{T}$ occurs (the left-most arrow). As noted above, reinforcement frequency deviated only negligibly during $\bar{T} = 0.25, 0.10$, and 0.05 (the region between arrows 1-4, reading from left to right). Hence, the continued rise in rate through these values seen in Fig. 2 for the lowermost three birds likely represents an extension of the effects seen at $\bar{T} = 1.0$. A leveling off in rate eventually occurs, but, for many birds, not until nearly the 100-session mark. This finding may be compared with data of Cumming and Schoenfeld (in preparation), indicating that with a 30-second, fixed-cycle schedule such a leveling off in rate comes before the 60th session. Thus, the reinforcement schedule may be an important parameter of the rate-stability function.

³A more complete analysis of the data, including tables with individual results, is available in the original dissertation which can be obtained on Inter-library loan from the Columbia University Library. A microfilm copy can be purchased from University Microfilms, 313 N. First St., Ann Arbor, Michigan. Order number MIC 59-4081.

Figure 2. Individual session-by-session corrected response rates for the entire experiment for a sample of four birds in $\bar{P}$ groups 0.95, 0.60, 0.40, and 0.05. Each plotted point represents a 20-minute session rate.

The second general trend apparent in Fig. 2 is the increase in response rate as $\bar{T}$ is decreased beyond 0.05. The increase is correlated in all cases with a decrease in reinforcement frequency. For birds in high $\bar{P}$ groups (containing predominantly 2-minute cycles), this rate increase is delayed until $\bar{T} \leq 0.006$. (Bird 76 in Fig. 2 illustrates this phenomenon.) Birds in $\bar{P}$ groups 0.05, 0.10, and 0.40, whose schedules contain predominately 30-second cycles, react to larger $\bar{T}$'s, as records of Birds 94 and 86 in Fig. 2 show. The record for Bird 82 exhibits the low rates and small rate increases with decreasing $\bar{T}$'s characteristic of group $\bar{P} = 0.60$. The smallest value of $\bar{T}$ often resulted in a decline in rate, giving an appearance of a maximum in the function. Although this was found with Birds 82 and 94 in Fig. 2, it was not seen with all birds. Associated with these declines were reinforcement frequencies of less than one-third of the reinforcement opportunities.

Mean Rates and Group Curves

The functions of Fig. 3 result when the last five session rates prior to a change in $\bar{T}$ (at the arrows in Fig. 2) are averaged and plotted against the log of $\bar{T}$ prevailing at the time they were recorded. These functions have the disadvantage that the points they contain (based on only five values) are rather sensitive to local fluctuations that could distort the general trends in Fig. 2. Also, they fail to show the transitory effects that may occur between successive $\bar{T}$ shifts. On the other hand, they do permit perhaps a clearer picture of the rate versus the $\bar{T}$ function than do the individual session plots, and they can be directly compared with results of previous studies. The nature of nearly all of the curves in Fig. 3 is a rate increase with a $\bar{T}$ decrease. This confirms the general effect of $\bar{T}$ seen elsewhere (Hearst, 1958; Clark, 1959); here it is extended to schedules where more than a single cycle is present. Although this inverse function between response rate and $\bar{T}$ appears genuine, the functions of Fig. 3 show more variability within subjects than do analogous individual curves presented by Clark and Hearst.

The functions of $\bar{P} = 0.60$ in Fig. 3 are interesting in that they reveal the resistance of the low rates generated by all members of this group to changes in $\bar{T}$. This is true although at low values of $\bar{T}$ these birds obtain less than half the available reinforcements per session.

The most pronounced response to $\bar{T}$ decreases occurs in $\bar{P}$ group 0.40, where changes in $\bar{T}$ are associated with a two to one change in response rate.

The three-dimensional surface in Fig. 4 shows the response-rate changes as functions of $\bar{P}$ and log $\bar{T}$ as group data, in which the points plotted are means of the three birds in each $\bar{P}$ group. Figure 4 irons out some of the intraindividual variation seen in the individual functions of Fig. 3, and indicates more clearly the nature of the inverse function between $\bar{T}$ and response rate. It also gives a clue to the slopes of these functions, with clearer indications that at high $\bar{P}$ values the effects of $\bar{T}$ are not felt until somewhere below 0.01, while at low $\bar{P}$'s, $\bar{T}$'s of perhaps five times that value are correlated with rate increases. The shape of the three-dimensional surface is complex; and since, in the $\bar{P}$ plane, the shape is based on group differences with $N = 3$, its actual form in that direction cannot be estimated with much confidence from the present data. In the $\bar{T}$ plane, however, the shape may be accepted with more security, since individual birds serve as their own controls in that direction. There, the shape is probably concave upward, with the slope passing through a maximum at $\bar{P} = 0.40$ and possibly a minimum at $\bar{P} = 0.60$. Smaller $\bar{T}$'s than shown in Fig. 4 might reveal an additional "warping" of the surface, with continuing increases in rate and change of rate occurring at high $\bar{P}$'s, and maxima followed by decreases in rate at lower $\bar{P}$'s. The area around $\bar{P} = 0.60$ remains somewhat anomalous; and

Figure 3. Corrected over-all rate in responses per minute as a function of $\bar{T}$ for each of the 18 birds. Each set of coordinates presents means of the last 5 days at each schedule from the three birds in a particular $\bar{P}$ group.

as later evidence will show, qualitative as well as quantitative differences appear in the behavior of birds at this $\bar{P}$ value.

If the surface in Fig. 4 is sliced parallel to the $\bar{P}$ axis at points $\bar{T} = 0.05, 0.025, 0.0125, 0.006$, and 0.003^4 , and the heights of the five slices at each of the six fixed $\bar{P}$ values are referred to a bi-coordinate system, Fig. 5 is obtained. This figure emphasizes the group differences based on N 's = 3 along the $\bar{P}$ dimension, and for that reason must be interpreted cautiously. The $\bar{T}$'s above 0.05 have been omitted, because, as has been pointed out above, the data collected there seem to supplement those obtained at $\bar{T} = 1.0$ rather than provide information about changes in $\bar{T}$. In Fig. 5, then, the open circles of 0.05 pro-

⁴ $\bar{T}$ values 0.00625 and 0.003125 are abbreviated here and in the sequel as 0.006 and 0.003, respectively.

Figure 4. Three-dimensional surface showing group mean corrected response rate as a function of $\bar{T}$ and $\bar{P}$. Each plotted point represents the combined mean rates of three birds, computed over the last 5 days at each schedule. Note that the scale of $\bar{T}$ is logarithmic, that of $\bar{P}$, arithmetic.

vide a base line from which to judge the relative effects of decreases in $\bar{T}$ on the $\bar{P}$ groups. This figure shows clearly the concave nature of the rate versus the $\bar{P}$ function at higher $\bar{T}$ values. As successive $\bar{T}$'s are applied, however, the rate differences between groups tend to be reduced (with the notable exception of $\bar{P}$ group 0.60).

Figure 5. Group mean corrected rate as a function of $\bar{P}$. Five values of the parameter, $\bar{T}$, are shown, from 0.003 to 0.05. Each plotted point is a combined mean rate of three birds, computed over the last 5 days at each schedule.

Local Rates and Qualitative Effects

Figure 6 exhibits samples of cumulative records for two birds in $\bar{P}$ groups 0.60 and 0.40, taken from the last 5 days at $\bar{T} = 0.25$ and $\bar{T} = 0.006$. Records for birds in $\bar{P}$ groups 0.95 and 0.90, and 0.10 and 0.05 are not shown, since their local rates closely resemble those generated by fixed-cycle schedules of 2.0 minutes and 30 seconds, respectively. [See Clark

Figure 6. Representative cumulative-response curves for two birds in $\bar{P}$ groups 0.60 and 0.40. The curves are displaced to the base line after approximately 500 responses have accumulated. The value of $\bar{T}$ is shown for each curve, and reinforcements are indicated by short diagonal lines. The records were taken from the last 5 days at each schedule.

(1959) and Hearst (1958) for details of these effects.] To conserve space, only two $\bar{T}$ points are shown in Fig. 6. Because of a defect in the cumulative recorder at $\bar{T} = 1.0$, $\bar{T}$ is shown at the value 0.25. At $\bar{T} = 0.25$, however, reinforcement frequency was never observed to depart from $\bar{r}^D$ frequency, so that the first $\bar{T}$ change had no behavioral effect different from the previous $\bar{T}$ value of 1.0.

The record of Bird 82 in $\bar{P}$ group 0.60 at $\bar{T} = 0.25$ shows the characteristic linear performance generated by the birds of this group at high $\bar{T}$'s. Except for a consistent pause after reinforcement of about 8-10 seconds, the curve is practically free from deviations in local rate. The low and relatively constant rates seen in this bird's record closely resemble curves obtained by Findley (1958) from birds exposed to 15-minute arithmetic series VI.

The range of $\bar{P}$'s that will produce such effects is apparently narrow, since by 0.40 an entirely different performance is seen (typified by Bird 86 in Fig. 6). Here, at the high $\bar{T}$ value, a moderate allover rate is sustained, with some scalloping during 30-second cycles. During long cycles, either abrupt shifts to a lower rate are seen, or a pause followed by a positive acceleration to a second maximal rate. The rate shift occurs a little over one-fourth of the way into the cycle. The effects observed here at $\bar{P} = 0.40$ are similar to effects characterizing the mixed FI FI schedules reported by Ferster and Skinner (1957, Chap. 11).

The local rates of these birds observed at high $\bar{T}$'s undergo progressive modification as $\bar{T}$ is reduced beyond 0.05. By $\bar{T} = 0.006$, $\bar{P}$ group 0.60 shows longer pauses and more positive acceleration after reinforcement, greater over-all rate, and a more "grainy" record, as the right-hand record of Bird 82 in Fig. 6 illustrates. The record for Bird 86 at $\bar{T} = 0.006$ shows the typical effect of reduced $\bar{T}$ in this group. The abrupt rate shifts and multiple inflections have been lost; in their place is a high constant rate alternating with periods of zero rate that may be seen after reinforcement or midcycle.

DISCUSSION

It was argued above that investigation of the limiting case of variable schedules might prove of value in understanding the behavioral effects seen in the more complex schedules of this type. In the present research, since the behavioral effects at $\bar{P}$'s of 0.05, 0.10, 0.90, and 0.95 appear to be closely related to fixed component schedules, the results at $\bar{P} = 0.40$ and 0.60 are most relevant to this argument. At $\bar{P} = 0.40$, the chief effects of Ferster and Skinner's mixed FI FI schedules (1957, pp. 597-605) were observed. When 0.40 of the cycles are 2 minutes long and the remainder are 30 seconds long, birds show consistent pauses after reinforcement and temporal discriminations during the longer intervals. The usual opinion has been that when effects of this sort are present, birds are discriminating their own nonreinforced responses (Ferster & Skinner, 1957). On the other hand, at $\bar{P} = 0.60$, these temporal discriminations are not observed; and, except for the pause after reinforcement, the curves resemble arithmetic series VI curves, with a high mean interval. It is not clear why these birds do not discriminate their unreinforced responses. The present data at $\bar{P} = 0.60$, incidentally, cast doubt on the notion that the mean interval is the principal determining factor in VI response rates. At $\bar{P} = 0.60$ the mean interval is 1.4 minutes, yet the rates generated look as though the birds were on arithmetic VI schedules of about 10 times that value (Findley, 1958, p. 127).

The generality of the effects at $\bar{P} = 0.60$ for other cycle lengths cannot of course be ascertained from the present data. Investigations of cycle lengths both shorter and longer than those used here will be necessary to establish such generality.

One simple way of eliminating the pause after reinforcement in $\bar{P}$ group 0.60, and thus producing behavior indistinguishable from VI, might be to incorporate a third short ($T < 5$ seconds) cycle into the schedule. A provocative speculation is that three cycles may be sufficient to generate most of the complex and diverse effects of classical VI schedules. If so, then schedule description would appear to have been simplified.

SUMMARY AND CONCLUSIONS

An attempt has been made to treat the problems of integration and experimental specification of variable-interval (VI) reinforcement schedules. An approach to these schedules has been outlined in which such schedules are cast into a temporally defined framework of experimental variables. In this framework, two temporal variables, t^D and t^A , associated with differential probabilities of reinforcement for operant responses, enter into the specification of a schedule which may be considered as the simplest and limiting case of VI schedules generally. In this schedule, two intervals alternate in random order. The properties of this schedule seem to justify a more extensive analysis of its experimental parameters and their behavioral effects, for their implications with respect to more complex VI schedules.

An experiment was described in which the rate of key pecking of pigeons exposed to such two-valued schedules containing intervals of 2 minutes and 0.5 minute was measured as a function of two of the possible parameters. In this study, six groups of birds correlated with one of six values of $\bar{P}$, the relative proportion of 2-minute intervals, were exposed to successive schedules in which t^D periods were progressively reduced.

The findings and conclusions of this experiment were:

1. Throughout 60 days' exposure to schedules identical to "mixed FI FI," the over-all response rates in all $\bar{P}$ groups increased. A leveling off in rate was not observed for many birds until nearly the 100-session mark.
2. As t^D periods were progressively reduced, nearly all birds showed an increase in key-pecking rates. The rate of change of response rate, however, appeared to depend on $\bar{P}$, with birds in $\bar{P}$ group 0.40 showing the largest increases in rate and birds in $\bar{P}$ group 0.60 showing the smallest increases.
3. With $\bar{P}$ group 0.60, low rates at all t^D values and small increases in rate with t^D changes prevailed. The local rate picture was one of short pauses after reinforcement, but was otherwise nearly free from further temporal discriminations and other systematic deviations. This linearity of response rate found here with only two cycles closely matches behavioral effects seen hitherto only in more complex schedules with many more programmed intervals.
4. The data indicated that birds at values of $1.0 > \bar{P} \geq 0.90$ and $0.10 \geq \bar{P} > 0$ gave effects similar to birds on fixed-cycle schedules of 2 minutes and 30 seconds, respectively. Birds on $\bar{P} = 0.40$, however, gave abrupt shifts and inflections in rate characteristic of "mixed" schedules, while birds on $\bar{P} = 0.60$ showed over-all and local rates characteristic of birds on high arithmetic VI schedules.

REFERENCES

- Brandauer, C. The effects of uniform probabilities of reinforcement upon the response rate of the pigeon. Unpublished doctoral dissertation, Columbia Univer., 1958.
- Clark, R. The behavioral effects of some time-correlated reinforcement schedules. *J. exp. anal. Behav.*, 1959, **2**, 1-22.

- Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Findley, J. D. Preference and switching under concurrent scheduling. *J. exp. anal. Behav.*, 1958, **1**, 123-144.
- Hearst, E. The behavioral effects of some temporally defined schedules of reinforcement. Unpublished doctoral dissertation, Columbia Univer., 1956. An abbreviated report based on this dissertation appears in *J. exp. anal. Behav.*, 1958, **1**, 45-56.
- Schoenfeld, W. N., Cumming, W. W., and Hearst, E. On the classification of reinforcement schedules. *Proc. Nat. Acad. Sci.*, 1956, **42**, 563-570.
- Schoenfeld, W. N., and Cumming, W. W. Some effects of alternation rate in a time-correlated reinforcement contingency. *Proc. Nat. Acad. Sci.*, 1957, **43**, 349-354.

Received June 22, 1959