SEQUENTIAL PATTERNS IN POST-REINFORCEMENT PAUSES ON FIXED-INTERVAL SCHEDULES OF FOOD¹

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Responding by one pigeon was reinforced with food on fixed-interval schedules of 30, 60, and 300 sec duration. A second pigeon was studied under fixed-interval durations of 60 and 300 sec. For both birds, the average post-reinforcement pause was one-half the duration of the fixed interval. Autocorrelation coefficients revealed first-order sequential dependencies in series of post-reinforcement pauses. On the 300-sec fixed-interval schedule, successive post-reinforcement tended to alternate between long and short durations. At the shorter fixed-interval durations there was less evidence of alternation sequences. A second experiment was conducted to determine if the time intervals between the first response after reinforcement and the next reinforcement (the work periods) were responsible for the alternation patterns in the series of post-reinforcement pauses. To evaluate the role of the work period, several procedures were used to modify the work period from that obtained on the fixed-interval 300-sec schedule. Adding a schedule to the fixed-interval schedule that set the minimum amount of time that could elapse between the first response after reinforcement and the next reinforcement eliminated the alternation pattern. Control schedules indicated that the elimination of alternation patterns resulted from constraints on the work period *per se* and not from confounded changes in the interreinforcement intervals.

On fixed-interval (FI) schedules of food, animals pause after each reinforcement and then respond at a moderate rate until the next reinforcement. When the FI duration remains constant, the durations of post-reinforcement pauses vary considerably from one interreinforcement interval to the next. However, the average post-reinforcement pause computed over a number of intervals increases systematically with the FI value (Sherman, 1959; Harzem, 1969; Schneider, 1969; Staddon, 1969; Shull, 1970b). The interreinforcement interval seems to be a major factor controlling average post-reinforcement pause durations (Neuringer and Schneider, 1968; Killeen, 1969; Shull, 1970b). However, when the FI is held constant,

fluctuations in post-reinforcement pause duration cannot be attributed to changes in the interreinforcement interval. There have been few systematic analyses of the factors determining the duration of post-reinforcement pauses from one interreinforcement interval to the next with the FI held constant. Some investigators may have assumed that the variability around the mean value is random, reflecting the effects of uncontrolled factors. Were it not for the "noise", each post-reinforcement pause would equal the mean value, according to this assumption.

Some observations by Ferster and Skinner (1957) suggest an intriguing alternative view of the variability in post-reinforcement pause duration. The variability might reflect a control process that is an inherent feature of FI schedules. With pigeons on FI 4-min and FI 8-min schedules of food, Ferster and Skinner (1957, p. 159-168) noted that successive post-reinforcement pauses tended to alternate between long and short durations. This alternation pattern implicates behavior in one interval as a determiner of post-reinforcement pause duration in the subsequent interval. To account for the alternation of pause length, Ferster and Skinner considered the possible

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effect of the number of responses made per reinforcement in one interval on the strength of responding in the subsequent interval. They suggested that when many responses occur in an interval, the high ratio of responses per reinforcement decreases the response strength so that responding occurs relatively late in the next interval. When few responses occur in an interval, the low ratio of responses per reinforcement increases the response strength so that responding begins relatively soon after reinforcement in the next interval.

Recent data raise the possibility that response number might not play a major role in controlling post-reinforcement pause duration. These studies independently manipulated the interreinforcement interval and responding during the interval and found mean post-reinforcement pause duration to be independent of the response rate and the number of responses in the interval (Farmer and Schoenfeld, 1964; Neuringer and Schneider, 1968; Killeen, 1969; Shull, 1970b). Although these studies looked only at the effects on mean post-reinforcement pause duration, it is possible that the number of responses per reinforcement is unimportant in controlling post-reinforcement pause duration from one interval to the next. The Ferster and Skinner analysis could be made consistent with this possibility, however, by modifying their account slightly. The two-state analysis of FI performance (Sherman, 1959; Schneider, 1969) conceptualizes the FI as composed of two time periods, the post-reinforcement pause and the time interval between the termination of the post-reinforcement pause and the next reinforcement. This latter time interval may be termed the "work period". Perhaps, the latency of initiating responding in one interval is directly related (or the strength of initiating responding inversely related) to the duration of the work period in the preceding interval. A necessary feature of FI schedules is that in any particular interreinforcement interval the duration of the work period depends on the duration of the post-reinforcement pause within the same interval. That is, within any particular interreinforcement interval, the duration of the work period varies inversely with the preceding post-reinforcement pause. This inverse relation that is inherently arranged by FI schedules could generate alternation patterns in the following way. A long

post-reinforcement pause will necessarily result in a short work period and may, consequently, increase the strength of initiating the work period in the next interreinforcement interval. In the next interval responding will start sooner after reinforcement, resulting in a longer work period. Consequently, the subsequent post-reinforcement pause will lengthen again, and so on. Since the number of responses in an interval is highly correlated with work time in an FI schedule, this account of the alternation of long and short post-reinforcement pauses is essentially equivalent to Ferster and Skinner's account. The present account differs by shifting the emphasis from response strength to strength of initiating the work period as the controlled factor. The important point of this account is that the inherent feature of FI schedules insuring an inverse relation between post-reinforcement pause and the work time in an interreinforcement interval may be partly responsible for the fluctuations in a series of post reinforcement pauses. Although this analysis emphasizes work time rather than response number as the controlling factor, the present experiments did not determine whether it is the time *per se* or the work during the work time that influences subsequent pausing.

Experiment I attempted to quantify more precisely the tendency of successive post-reinforcement pauses to alternate between long and short durations under several values of FI. Experiment II evaluated the importance of the work period in generating the alternation patterns. According to the analysis presented above, alternation of post-reinforcement pause durations should not occur if the work period was constant, regardless of the post-reinforcement pause in that interreinforcement interval (or if the work period varied unsystematically with the post-reinforcement pause in that interreinforcement interval). A schedule arranging such a constant work period is the tandem fixed-ratio one fixed-interval (*tand* FR 1 FI) schedule in which the first response after reinforcement initiates the FI. Since the response that terminates the post-reinforcement pause starts the FI, work time equals the FI and is constant regardless of the preceding post-reinforcement pause. On *tand* FR 1 FI schedules, the average post-reinforcement pause increases with the FI (Chung and Neuringer, 1967; Shull, 1970a). Experiment II compared the

tendency of long and short post-reinforcement pauses to alternate on an FI schedule and on a *tand* FR 1 FI schedule. In addition, the alternation patterns were studied with a modified FI schedule that made it possible to control the minimum work period.

EXPERIMENT I

METHOD

Subjects

Two adult male Silver King pigeons, obtained from Palmetto Pigeon Plant, were maintained at approximately 80% of their free-feeding weight. Both had previous experience with fixed-interval and variable-interval schedules of food reinforcement (Shull, 1970*b*; Shull and Brownstein, 1970).

Apparatus

The experimental chamber was enclosed in an ice chest. A ventilation fan provided masking noise. A translucent plastic response key was mounted 8.5 in. (22 cm) above the floor behind a 0.75-in. (19-mm) diameter hole through one wall of the chamber. When the key was transilluminated by a blue light, a force exceeding 20 g (0.18 N) applied to the key broke an electrical contact that operated control and recording circuits and also produced a feedback click. The key was disconnected from the control circuit when darkened. The reinforcing event was a 5-sec presentation of mixed grain, which was accessible through an opening below the key. When grain was available, the feeder opening was illuminated and the key darkened. The keylight and the feeder light were the only sources of illumination in the chamber. A transformer isolated from the main power supply provided power for the keylight.

Digital counters and a cumulative recorder were used to record data. During selected sessions, a digital printing counter recorded each post-reinforcement pause in a session. These durations were transferred to IBM cards for computer analysis.

Procedure

Because of their prior training, the birds did not require preliminary key training. The basic schedule in Exp. I was a fixed-interval schedule. That is, the first response after a

fixed interval of time produced food. The first interval in each session was timed from the start of the session; all subsequent intervals were timed from the termination of the preceding reinforcement. Bird P 1 was exposed to the following sequence of FI durations with the numbers in parentheses indicating the number of sessions: FI 60-sec (82), FI 30-sec (37), and FI 300-sec (67). Bird P 2 was exposed to FI 60-sec for 71 sessions and FI 300-sec for 67 sessions. In addition, 11 sessions of the FI 300-sec during Exp. II provided redetermination points.

Sessions were conducted daily. Each session terminated automatically after the sixty-first reinforcement. Data were not recorded during the first interval in each session.

RESULTS

A. Analysis of Data

The experiment was concerned with sequential patterns in a series of post-reinforcement pauses. Several techniques are available for such an analysis. For example, the data could be summarized in the form of a transition matrix (Wertheim, 1965). However, presenting a matrix of numbers for each day's data would be cumbersome. What is needed is a single numerical index whose value expresses the extent to which long and short post-reinforcement pauses alternate. The autocorrelation with a lag of 1 seemed most suitable for present purposes. The logic of the autocorrelation in the present context can be illustrated by the treatment of some sample data. Figure 1 plots the post-reinforcement pause for each successive interval in a selected session for P 2 on FI 300-sec. Successive post-

Fig. 1. Post-reinforcement pause duration plotted over the ordinal position of the interval in a session of 60 intervals. The schedule is FI 300-sec. The dashed line indicates the median duration.

reinforcement pauses appear to alternate between long and short durations. Figure 2 presents the same data in the form of a scatter plot with the pause on one interval (Interval N) plotted over the pause of the immediately preceding interval (Interval N-1). The scatter plot can be summarized by a single number—the correlation coefficient. When, as in the present example, the correlation is between adjacent points in an ordered series of observations, the term autocorrelation (lag of 1) is applied. It also is possible to compute autocorrelations with different lags. Thus, lag of 2 refers to the correlation of the pause in Interval N with the pause in Interval N-2. The present study (Exp. I and Exp. II) reports autocorrelation coefficients with lag of 1 only. Autocorrelation coefficients with other lags were not consistently related to the various procedures. Weiss, Laties, Siegel, and Goldstein (1966) discussed properties of the autocorrelation and related sequential analyses and have provided computational formulas.

If successive post-reinforcement pauses were more similar than would be expected by chance (*i.e.*, if long pauses tend to follow long pauses and short pauses tend to follow short pauses), the points in the scatter plot would tend to distribute around the positive diagonal and the autocorrelation would be positive. If

successive post-reinforcement pauses were less similar than would be expected by chance (*i.e.*, if long and short pauses tended to alternate), the points would be distributed around the negative diagonal and the autocorrelation would be negative. If the post-reinforcement pauses in a series vary randomly, the expected value of the autocorrelation coefficient is $-1/(N-1)$, where N refers to the number of observations in the series (Tintner, 1952). Since in this study N was 60, the expected value was -0.017 . Thus, the autocorrelation coefficient can be considered an index ranging from -1.0 to 1.0 that reflects the extent to which successive post-reinforcement pauses alternate (negative values) or group (positive values). In the example shown in Fig. 2, the autocorrelation coefficient is -0.59 , reflecting the alternation pattern clearly visible in Fig. 1. As will be shown below, the alternation pattern in this example is more pronounced than usual.

B. Presentation of Data

Figure 3 shows median post-reinforcement pause plotted over FI duration for both birds. The medians are from the last five sessions of a condition. The data points do not deviate systematically from the line representing a linear increasing function with slope of 0.5 and zero intercept, thus corroborating previous reports of an approximately linear relation between post-reinforcement pause and FI duration with rats (Sherman, 1959;

Fig. 2. The post-reinforcement pause from one interval (Interval N) plotted over the duration of the pause from the preceding interval (Interval N-1). The scatter plot is based on the data in Fig. 1. The autocorrelation coefficient (lag of 1) is -0.59 .

Fig. 3. Median post-reinforcement pause duration plotted over FI duration for P 1 and P 2. The medians are based on the last five sessions (300 intervals) of each FI. The redeterminations (open symbols) are from the last five sessions of Condition D in Exp. II.

Harzem, 1969) and with pigeons (Schneider, 1969; Innis and Staddon, 1970). Redetermined points with the FI 300-sec schedule closely approximated initial determinations.

Figure 4 shows median autocorrelation coefficient (lag of 1) plotted over FI duration. The medians are from the last five sessions of a condition. For both birds and for both determinations, the autocorrelation coefficient was negative at the FI 300-sec schedule. For P 2, the sign of the autocorrelation coefficient was negative at FI 60-sec. For P 1, the coefficients were positive at FI 60-sec and at FI 30-sec. Thus, sequential patterns of alternating long and short pauses occurred at the FI 300-sec schedule, but not at the shorter FI durations for P 1.

The actual values of the five autocorrelation coefficients at each FI duration on which the medians are based are listed below.

P 1: FI 30-sec (0.076, -0.143, 0.051, 0.133, 0.122); FI 60-sec (0.199, 0.101, -0.100, 0.189, 0.264); FI 300-sec (0.165, -0.018, -0.190, -0.116, -0.296); FI 300-sec (-0.213, -0.371, -0.016, -0.250, -0.078). P 2: FI 60-sec (-0.158, -0.117, -0.086, -0.211, -0.028); FI 300-sec (-0.174, -0.272, -0.147, -0.402, -0.389); FI 300-sec (-0.083, -0.322, -0.372, -0.301, -0.313).

A median test showed a significant ($p < 0.05$) effect of FI duration on autocorrelation coefficient for both birds.

EXPERIMENT II

Experiment II was designed to see if the time between the first response after reinforcement and the next reinforcement—the work period—was responsible for the alternation patterns on FI 300-sec schedules.

METHOD

The subjects and apparatus were the same as in Exp. I.

Procedure

Experiment II used several different schedules. Each is described below.

Fixed-interval 300-sec schedule. The last five sessions of the FI 300-sec schedule in Exp. I served as the baseline schedule in Exp. II. The FI 300-sec schedule was reinstated at various times during Exp. II.

Fig. 4. Median autocorrelation coefficient (lag of 1) plotted over FI duration for P 1 and P 2. The medians are based on the last five sessions (300 intervals) of each FI. The redeterminations (open symbols) are from the last five sessions of Condition D in Exp. II.

Conj (FI 300-sec tand FR 1 FI_x) schedules. To control the minimum work period, a response was reinforced only if the FI 300-sec had elapsed and a specified time interval had elapsed since the first response after reinforcement. This latter interval is a tandem schedule (*tand* FR 1 FI_x). Since both intervals had to elapse for reinforcement, the schedule is a conjunctive schedule (*conj* [FI 300-sec *tand* FR 1 FI_x]) (Ferster and Skinner, 1957; Herrnstein and Morse, 1958). Three different values of the *tand* FR 1 FI_x were used in this study: 60, 120, and 180 sec. If the first response after reinforcement occurred soon enough for the *tand* FR 1 FI_x interval to have timed out before the FI 300-sec interval, the FI 300-sec schedule would govern reinforcement. However, if the first response occurred later after reinforcement so that the FI 300-sec interval had timed out before the *tand* FR 1 FI_x interval, the *tand* FR 1 FI_x schedule would govern reinforcement and the interreinforcement interval would exceed the minimum possible of 300 sec.

Thus, the time interval initiated by the first response after reinforcement set the minimum amount of time that could intervene between the first response after reinforcement and the next reinforcement. According to the formula-

tion presented above, the *conj* (FI 300-sec *tand* FR 1 FI_x) schedule should minimize the alternation of long and short post-reinforcement pauses, to the extent that the bird paused long enough for the *tand* FR 1 FI_x schedule to assign reinforcement. Too few post-reinforcement pauses were long enough for the *conj* (FI 300-sec *tand* FR 1 FI 60-sec) schedule to have any measurable effect on the birds' behavior. Consequently, the data from this condition are not presented.

Variable-interval control schedule. Besides restricting the work period, the *conj* (FI 300-sec *tand* FR 1 FI_x) schedules also changed the distribution of interreinforcement intervals from that obtained with the FI 300-sec schedule. To separate the effects of restricting the work period *per se* from the effects of the accompanying changes in the distribution of interreinforcement intervals, the variable-interval Control schedule arranged a distribution of interreinforcement intervals that approximated the distribution that each bird obtained on the *conj* (FI 300-sec *tand* FR 1 FI 180-sec) schedule. This schedule produced the largest increase in interreinforcement intervals relative to the standard FI 300-sec schedule. The VI Control schedule reinforced the first response after a variable time interval had elapsed since the termination of the preceding reinforcement. Thus, the VI Control schedule did not explicitly restrict the minimum work period. It allowed the work period to vary inversely with the preceding post-reinforcement pause.

The VI Control schedule consisted of a series of 20 intervals that corresponded to consecutive five-percentile points of the distribution of interreinforcement intervals obtained during the last five sessions of the first exposure to the *conj* (FI 300-sec *tand* FR 1 FI 180-sec) schedule. For P 1, the intervals were: 300, 300, 300, 300, 307, 323, 333, 340, 348, 365, 373, 380, 391, 399, 410, 422, 441, 456, 487, and 544 sec arranged unsystematically with respect to duration in a continuous loop. For P 2, the intervals were: 300, 300, 300, 300, 300, 300, 300, 313, 329, 338, 353, 366, 381, 392, 404, 420, 440, 464, 491, and 612 sec, similarly arranged.

Tand FR 1 VI schedule. Under the FI 300-sec schedule, the work period necessarily varied inversely with the duration of the preceding post-reinforcement pause in the same interreinforcement interval. The *conj* (FI 300-sec

tand FR 1 FI_x) schedule reduced this inverse relation by controlling the work period, but it also changed the variability of work intervals from that obtained under the FI 300-sec schedule. The *tand* FR 1 FI schedule arranged a distribution of work intervals that approximated the distribution obtained under the FI 300-sec schedule. However, the *tand* FR 1 VI schedule arranged the work intervals unsystematically with respect to the duration of the preceding post-reinforcement pause.

With the *tand* FR 1 VI schedule, a response was reinforced only after a variable time interval had elapsed since the first response after reinforcement. The *tand* FR 1 VI schedule consisted of a series of 20 intervals that corresponded to consecutive five-percentile points of the distribution of intervals between the first response after reinforcement and the next reinforcement that each bird obtained during the last five sessions of the initial exposure to the FI 300-sec schedule. For P 1, the intervals were: 28, 66, 93, 108, 122, 131, 137, 145, 151, 158, 166, 170, 175, 178, 184, 189, 196, 205, 216, and 249 sec, arranged unsystematically with respect to order in a continuous loop. For P 2, the intervals were: 44, 60, 72, 82, 91, 101, 109, 115, 120, 130, 140, 147, 155, 164, 179, 195, 205, 222, 239, and 254 sec similarly arranged.

Tand FR 1 FI schedule. The *tand* FR 1 FI schedule was implemented to evaluate the effects of arranging a constant *vs* a variable work period. With the *tand* FR 1 FI schedule, a response was reinforced only after a fixed time interval had elapsed since the first response after reinforcement. Thus, the *tand* FR 1 FI arranged a constant work period. The duration of the FI of the *tand* FR 1 FI schedule for each bird was the arithmetic mean of the series of intervals used in the *tand* FR 1 VI schedule. For P 1, the duration was 153 sec; for P 2, 141 sec.

Table 1 outlines the sequence of experimental conditions, notes the number of sessions devoted to each condition, and indicates the sessions for which data are reported.

As in Exp. I, sessions were conducted daily. Each session terminated automatically after the sixty-first reinforcement. Data were not recorded during the first interval in each session.

RESULTS

The top panels of Fig. 5 show for P 1 and P 2 the median and interquartile range of

Table 1

The sequence of experimental conditions, the number of sessions devoted to each and the sessions for which data are reported.

Experimental Condition	Number of Sessions	
	Conducted	Reported
A—FI 300-sec <i>Conj</i> (FI 300-sec <i>tand</i> FR 1 FI 60-sec)	68	Last 5
B— <i>Conj</i> (FI 300-sec <i>tand</i> FR 1 FI 120-sec)	10	None
C— <i>Conj</i> (FI 300-sec <i>tand</i> FR 1 FI 180-sec)	22	Last 5
D—FI 300-sec	20	Last 5
E— <i>Conj</i> (FI 300-sec <i>tand</i> FR 1 FI 180-sec)	11	All
F—VI Control. Scheduled intervals based on interreinforcement intervals obtained during last five sessions of Condition C	5	All
G— <i>tand</i> FR 1 VI. Scheduled intervals based on intervals between first response after reinforcement and next reinforcement obtained during last five sessions of Condition A	10	All
H— <i>Tand</i> FR 1 FI. FI duration was mean of VI intervals of Condition G	15	Last 5
I—FI 300-sec	12	Last 5
	5	All

post-reinforcement pauses plotted over successive sessions of Exp. II. The lower panels of Fig. 5 show the autocorrelation coefficients for corresponding sessions. The data are either from the last five sessions of a condition or from all sessions of a condition (see the third column in Table 1). Sessions omitted from Fig. 5 are indicated by the breaks in the horizontal axis.

*FI 300-sec schedule and conj (FI 300-sec *tand* FR 1 FI_x) schedules—Initial determinations.* For both birds, the FI 300-sec schedule (Condition A in Fig. 5) produced median post-reinforcement pauses of about half of the FI duration. The *conj* (FI 300-sec *tand* FR 1 FI 120-sec) (Condition B) and *conj* (FI 300-sec *tand* FR 1 FI 180-sec) (Condition C) schedules produced somewhat longer post-reinforcement pauses for P 1 but did not reliably affect pause durations for P 2.

The autocorrelation coefficients, generally negative under the FI 300-sec schedule, became positive in sign under the *conj* (FI 300-sec *tand* FR 1 FI_x) schedules.

*Reinstatement of the FI 300-sec and conj (FI 300-sec *tand* FR 1 FI 180-sec) schedules.*

When the schedule was changed from the *conj* (FI 300-sec *tand* FR 1 FI 180-sec) schedule (Condition C) to the FI 300-sec schedule (Condition D), pause durations shortened and the autocorrelation coefficients shifted from positive to negative values for both birds. These adjustments to the changed conditions occurred within the first session of the FI 300-sec schedule. In general, post-reinforcement pause durations and autocorrelation coefficients obtained during the redetermination approximated values observed during the first exposure to the FI 300-sec schedule. However, post-reinforcement pauses were shorter during the first few sessions after the change than during the last five sessions of the initial exposure to the FI 300-sec schedule.

When the *conj* (FI 300-sec *tand* FR 1 FI 180-sec) schedule was reinstated (Condition E), the autocorrelation coefficients returned to the positive values noted during the first exposure to that procedure (Condition C).

VI Control for interreinforcement interval changes. The VI Control schedule arranged the same distribution of interreinforcement intervals that was obtained during the *conj* (FI 300-sec *tand* FR 1 FI 180-sec) schedule. However, the change from the conjunctive schedule (Condition E) to the VI Control schedule (Condition F) produced an abrupt shift in the autocorrelation coefficients from positive to negative values. These negative values were generally maintained while the VI Control schedule was in effect. For P 1, the VI Control schedule maintained shorter post-reinforcement pauses than did the *conj* (FI 300-sec *tand* FR 1 FI 180-sec) schedule.

*Tand FR 1 VI and *tand* FR 1 FI schedules.* The *tand* FR 1 VI schedule arranged the same distribution of times between the termination of the post-reinforcement pause and reinforcement that was obtained under the FI 300-sec schedule. The *tand* FR 1 VI schedule (Condition G) maintained positive autocorrelation coefficients. Post-reinforcement pause durations were much shorter under the *tand* FR 1 VI schedule than under the FI 300-sec schedule.

The mean interval between the first response after reinforcement and the next reinforcement—i.e., the work period—was the same for the *tand* FR 1 VI schedule and for the *tand* FR 1 FI schedule. However, the *tand* FR 1 FI schedule (Condition H) maintained post-reinforcement pauses that approximated those

Fig. 5. Post-reinforcement pause durations and autocorrelation coefficients for P 1 and P 2. The top panel shows the median and interquartile range post-reinforcement pause durations for the several experimental conditions. Each point represents a single session. The bottom panel shows the autocorrelation coefficients (lag=1) obtained from corresponding sessions. The dashed line indicates the expected autocorrelation coefficient for a random series of 60 observations (-0.017). Omitted data are indicated by the breaks in the horizontal axis. *Condition Code:* A—FI 300-sec; B—*Conj* (FI 300-sec *tand* FR 1 FI 120-sec); C—*Conj* (FI 300-sec *tand* FR 1 FI 180-sec); D—FI 300-sec; E—*Conj* (FI 300-sec *tand* FR 1 FI 180-sec); F—VI Control for changed interreinforcement intervals; G—*Tand* FR 1 VI; H—*Tand* FR 1 FI; I—FI 300-sec.

observed with the FI 300-sec schedule. Autocorrelation coefficients were positive under the *tand* FR 1 FI schedule.

Reinstatement of the FI 300-sec schedule. When the FI 300-sec schedule was reinstated (Condition I) following the exposure to the *tand* FR 1 FI schedule, autocorrelation coefficients abruptly returned to negative values. Post-reinforcement pause durations were not much changed by the schedule change.

Cumulative records. Sample cumulative records from each of the different conditions of the experiment for P 1 are displayed in Fig. 6. The records are from the sessions indicated in the legend of Fig. 6. The records reveal a pattern of pausing after reinforcement followed

by responding at a high rate until the next reinforcement under each procedure. Thus, the various procedures did not produce a general disruption of the response pattern but appeared to act specifically on post-reinforcement pauses.

DISCUSSION

Experiment I determined the generality of the alternation patterns in a series of post-reinforcement pauses such as described by Ferster and Skinner (1957). There was clear evidence of patterns of alternating long and short post-reinforcement pauses only with the FI 300-sec schedule. For P 1, the autocorrela-

Fig. 6. Cumulative records for P 1. Pen reset to baseline at 500 responses and after each reinforcement. Each record strip represents approximately 1.5 hr. Condition Code: A—FI 300-sec, last session of second exposure; B—*Conj* (FI 300-sec *tand* FR 1 FI 180-sec), first session of second exposure; C—VI Control, first session; D—*Tand* FR 1 VI, last session; E—*Tand* FR 1 VI, last session.

tion coefficients were positive under the FI 30-sec and FI 60-sec schedules, indicating grouping instead of alternating pause durations. It is not clear why sequential patterns of post-reinforcement pauses are different with different FI durations.

Experiment II tried to identify the source of the alternations under the FI 300-sec schedule. With FI schedules, the interreinforcement interval is essentially constant from one reinforcement to the next. Thus, the interreinforcement interval could not be the source of the systematic variability. Since the post-reinforcement pause in an interval determines the duration of the work period in that interval, the work period could provide the source of systematic variability necessary for generating alternation patterns. The question was, does the work period in one interval control the post-reinforcement pause in the next interval.

The following is a brief synthesis of the general trends observed in Exp. II. (1) The sign (positive or negative) of the autocorrelation coefficients depended on the restrictions imposed on the interval between the first response after reinforcement and the next rein-

forcement. The sign was independent of the distribution of interreinforcement intervals and of the distribution of work periods. Each schedule in which the work period depended on the duration of the preceding post-reinforcement pause—i.e., the FI 300-sec schedule and the VI Control schedule—maintained negative autocorrelation coefficients. By contrast, those schedules that explicitly controlled the work interval—i.e., the *conj* (FI 300-sec *tand* FR 1 FI_x) schedules, the *tand* FR 1 VI schedule, and the *tand* FR 1 FI schedule—produced positive autocorrelation coefficients. (2) Altering the schedules produced abrupt changes in the values of the autocorrelation coefficients. Generally, the adjustments occurred within the first session after a schedule change. Reinstatement of previous schedules generally resulted in a return to previous sequential patterns. (3) The magnitude of the autocorrelation coefficient was small, ranging, for the most part, between -0.3 and 0.3 .

The elimination of alternation patterns by restricting the minimum work period implicated the work period in controlling subsequent post-reinforcement pause duration. Because the VI Control schedule produced negative autocorrelation coefficients, the effects of the *conj* (FI 300-sec *tand* FR 1 FI_x) schedules could not be attributed to changes in the interreinforcement intervals. Nor was the decreased variability of the work periods responsible for the elimination of the negative autocorrelation, since the *tand* FR 1 VI schedule produced positive autocorrelations. Thus, a critical factor in generating alternation patterns in a series of post-reinforcement pauses is arranging that the work period vary inversely with the duration of the preceding post-reinforcement pause. With both the FI 300-sec and the VI Control schedules, the work period necessarily varied inversely with the preceding post-reinforcement pause. These schedules produced negative autocorrelation coefficients.

The rapidity with which the autocorrelation coefficients changed after a schedule change also indicates that the duration of the preceding work period exerts a potent effect. However, the small magnitude of the autocorrelation coefficients reveals a great deal of variability unaccounted for.

Eliminating the negative autocorrelation by controlling the work period is consistent with the present emphasis on the effect of the pre-

ceding work period on post-reinforcement pause duration. However, controlling the minimum work period did more than simply eliminate alternation patterns. It produced positive autocorrelations, indicating that long and short pauses tended to group together. Each of the schedules that controlled the work period arranged a dependency between the interreinforcement interval and post-reinforcement pause duration that might have been responsible for these positive autocorrelations. When reinforcement initiates the FI, the interreinforcement interval is independent of post-reinforcement pause duration, provided the post-reinforcement pause does not exceed the FI duration. However, when the first response after reinforcement initiates the FI, as with the *tand* FR 1 FI (and also with the *tand* FR 1 VI schedule), the interreinforcement interval will covary directly with the post-reinforcement pause in that interval, being shortest when the FI is initiated by a response immediately after reinforcement. As was noted earlier, the duration of a standard FI schedule controls the duration of the average post-reinforcement pause. It is probable, therefore, that preceding interreinforcement intervals influence subsequent post-reinforcement pauses in a series. With standard FI schedules, the preceding interreinforcement interval is virtually constant from one reinforcement to the next. With *tand* FR 1 FI schedules, however, the interreinforcement interval could provide the necessary systematic variability for grouping because it varies with the post-reinforcement pause in that interval. For example, with *tand* FR 1 FI schedule, a long post-reinforcement pause would result in a long interreinforcement interval, which would tend to produce a long pause after the next reinforcement. Likewise, a short post-reinforcement pause would result in a shorter interreinforcement interval, which would tend to produce another short post-reinforcement pause.

Although the correlations presented here have been between consecutive post-reinforcement pauses, the underlying model of FI performance is that the controlling factor is the prior work time. Within an interreinforcement interval on FI schedules, the post-reinforcement pause and the work period are inversely related. Therefore, correlations between consecutive post-reinforcement pauses will differ only in sign from correlations be-

tween post-reinforcement pause and preceding work time. This is not true for the *tand* FR 1 VI schedule because in an interreinforcement interval, the work time is determined by the VI schedule and not by the preceding post-reinforcement pause. It would have been interesting, in view of the present analysis, to determine the correlation between work time in one interreinforcement interval and the post-reinforcement pause in the next interreinforcement interval with the *tand* FR 1 VI schedule. Unfortunately, the data necessary for such an analysis were not obtained.

The preceding analysis identifies two factors that may be involved in the control of post-reinforcement pause duration on FI and *tand* FR 1 FI schedules: the work period and the interreinforcement interval. Determining the relative contribution of each factor is difficult because it is impossible to change one of the factors independently of the other. For example, when the duration of a standard FI schedule is changed, the work period following a given post-reinforcement pause changes in the same direction. If the FI is increased from FI 60-sec to FI 300-sec, the work period following a 30-sec post-reinforcement pause will increase from 30 sec to 270 sec. Studies that have varied the duration of an FI schedule, either between sessions (Sherman, 1959; Schneider, 1969) or with sessions (Staddon, 1969; Harzem, 1969; Innis and Staddon, 1970), have attributed the consequent shifts in post-reinforcement pause duration to the changed interreinforcement interval *per se*. However, it would be just as reasonable to attribute the effects on pausing to the confounded changes in the work period. Although it may be impossible to assess the relative contribution of the two factors when the schedule is changed, it is possible to detect the influence of each by holding one factor constant, permitting the other to fluctuate, and assessing the effect of the fluctuating factor through sequential analysis. This was the present rationale.

The complex sequential dependencies in series of post-reinforcement pauses described here support those who have argued that the performance on FI schedules is controlled by complex dynamic processes (Morse, 1966; Catania and Reynolds, 1968; Kelleher and Morse, 1969). Clearly, it is a gross oversimplification to describe FI performances as "merely a temporal discrimination".

Throughout the present paper, the term work period has been used to identify a variable operating in FI schedules. It might be useful to consider the relevance of the work period variable to other variables studied by psychologists. To the extent that the responses of initiating the work period has different properties from other key pecks, the work period can be considered a delay of reinforcement from the initiating response. The known effects of delays of reinforcement on post-reinforcement pause duration (Azzi, Fix, Keller, and Rocha e Silva, 1964; Keller, 1966) are consistent with the present analysis. Alternatively, the work period may be considered the terminal component of a two-component tandem schedule in which the first response after reinforcement initiates a variable time interval until reinforcement. Thus, the FI schedule could be designated as a *tand* FR 1 VI_(FI-PRP), where the subscript in parentheses indicates that the VI is inversely related to the performance in the initial component of the tandem schedule, the preceding post-reinforcement pause. The duration of the post-reinforcement pause would then reflect the response strength of the initiating response in the initial component of the tandem schedule. A final possibility is that the effects attributed to the work period are actually due to consequences of responding during the work period, such as "fatigue". Since response rate after the post-reinforcement pause was approximately constant for all phases of the study, work time and number of responses covaried. These experiments, therefore, provide no basis for determining whether the effects are purely temporal or response based.

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