INTRACTABLE PROPERTIES OF RESPONDING UNDER A FIXED-INTERVAL SCHEDULE

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The behavior engendered by the fixed-interval schedule is characterized by its variability within and across intervals. The present experiment was designed to assess further the magnitude of interval-to-interval dynamics and to explore conditions which might enhance control by response number for subsequent output. Pigeons were exposed to three experimental manipulations after responding had stabilized under a fixed-interval five-minute schedule. First, a discrete five-stimulus counter was added so that the key color changed after a fixed number of responses. Then additional grain presentations were made at the end of the interval so that high response output was differentially reinforced in the presence of the counter stimuli. Finally, the counter stimuli were presented as an irregular clock (i.e., independently of responding), but the durations were yoked to performance under the counter condition. The data show that response number can exert influence from one interval to the next, but this source of control is weak and not influenced by the experimental manipulations. Results from the clock arrangement indicate that behavior is controlled largely by the stimulus conditions prevailing at the time of interval onset.

Key words: fixed-interval schedule of reinforcement, counter, irregular clock, amount of reinforcement, yoked procedure, autocorrelation, key peck, pigeon

Fixed-interval (FI) schedules of reinforcement program a reinforcer delivery to follow the first response after a fixed time since the previous reinforcer delivery. Although only a single response is required after the interval has elapsed, generally, many responses are emitted during the interval. The response number shows considerable interval-to-interval variability, and the relative lack of constraint placed upon response number has been hypothesized as a significant factor in the maintenance of a large but variable output (Herr-

stein & Morse, 1958). However, just what specific variables account for the obtained interval-to-interval variability in output remains an issue (Zeiler, 1979).

Interval-to-interval fluctuations in response output (second-order deviations as defined by Skinner, 1938) have been described in a number of studies as the tendency for intervals containing few responses to be followed by intervals containing many responses (Skinner, 1938) or, alternatively, as the tendency for more intervals with fewer responses than the preceding and following intervals than would be expected by chance (Dews, 1970).

The variable "responses per reinforcer" has been suggested as the controlling factor for these interval-to-interval dynamics (Herrnstein & Morse, 1958; Zeiler, 1977). When an interval terminates with few responses, the value of responses per reinforcer is small, resulting in increased response output in the next interval; when an interval terminates with many responses, the value of responses per reinforcer is large, resulting in decreased output in the next interval. That is, momentary response strength is altered by the number of responses per reinforcer, and the change becomes evident in the next interval.

Wearden (1979) studied the dynamics of re-

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sponse number and post-reinforcement pauses in rats under FI values of one, two, and three minutes. He found no evidence for a negative lag-1 autocorrelation in either variable. A response-prevention manipulation had no effect on the output in the next interval. However, he did find evidence for directional periodicity in that the direction of change did shift more often than expected, a result consistent with the data from Dews (1970) who used FI 3-min. However, the results are not consistent with the data from Shull (1971) who found a stronger periodicity in negative lag-1 autocorrelations for pauses using pigeons under FI 5-min, but not under FI 30 and 60 seconds. There have not been many attempts to alter this dynamic pattern of responding; also, there is some question as to whether or not the lag-1 autocorrelation does show evidence for dynamics (Lowe & Wearden, 1981). The present experiment was designed to assess further interval-to-interval dynamics in response number and to explore possible controlling variables.

Ferster and Skinner (1957) used a continuous counter under several FI schedules with pigeons and found changes in behavior. They concluded that the production of count was reinforcing, which led to earlier responding at a higher rate, resulting in an overall increase in responses per interval. Another effect of the counter was to deepen the scallop. Although they still found second-order effects, Ferster and Skinner (1957) thought that having the counter stimulus the same at the beginning of each interval would eliminate second-order effects. The present experiment employed a discrete counter rather than the continuous counter as used by Ferster and Skinner (1957). With the discrete counter the stimulus conditions change after a fixed number of responses rather than after each response as under a continuous counter. Thus, this experiment contains a replication and extension of the original FI-counter work by Ferster and Skinner (1957).

Another manipulation that follows from the theoretical analysis of responses per reinforcer is to alter the reinforcer as a function of the number of responses emitted. Zeiler (1979) has discussed the issue of dynamics under FI schedules and concluded that the theoretical accounts are based on a given reinforcing stimulus maintaining a given amount of behavior. Any disturbance in the system leads toward re-

establishing this mean value or oscillating around it. By altering the reinforcing stimulus in proportion to the number of responses emitted, the oscillations should be minimized. Thus, responses-per-reinforcer was held approximately constant by increasing reinforcer magnitude in proportion to the number of responses emitted. This reinforcer manipulation was used in conjunction with the counter. This combination should lead to increased output and enhanced reinforcing properties of the counter, since high output was differentially reinforced in the presence of the counter, a putative conditioned reinforcer.

There have been several studies of the effects of reinforcer magnitude on FI responding, but different procedures have produced equivocal results. Staddon (1970) found that postreinforcement pause under FI 1-min was increased by longer access to grain in the preceding interval; furthermore, the overall and running rates were decreased by the larger magnitudes of the preceding reinforcers. These results were obtained by varying reinforcer magnitude within-session with pigeons.

Stebbins, Mead, and Martin (1959) varied sucrose concentration as the reinforcer across conditions for rats under FI 2-min. They found an increase in overall rate with increasing concentration along with more early responding in the interval.

Meltzer and Brahlek varied number of food pellets (one or three) under FI 3-min with rats both between-groups (1968) and within-subjects (1970). The between-groups experiment produced an interaction between reinforcer magnitude and response rate in successive quarters of the interval, resulting primarily from a higher terminal rate for the three-pellet group. The within-subject design produced similar results: a higher terminal rate for three-pellet sessions and no difference in pattern of acceleration. It appears safe to conclude that response rate can be enhanced by increasing the magnitude of the reinforcer, at least up to some limit, and that patterning under FI schedules is not affected very much, if at all. However, within-session variation might produce different effects.

Zeiler (1979) summarized a number of studies that were conducted in his laboratory in which attempts to differentially reinforce response number, pause duration, and quarter life were unsuccessful. The procedure was to

omit the reinforcer if the criterion was not met (either maximum or minimum). Results with control procedures suggested that percentage reinforcement accounted for the changes that were observed. The present procedure differs in that the nature of the FI schedule is not altered by omitting reinforcers.

Finally, the counter stimuli were presented independently of behavior but for durations that were yoked to counter performance, i.e., an irregular clock. This procedure should yield information on how responses that have been emitted can function as a timing device under FI schedules.

METHOD

Subjects

The subjects were four male White Carneau pigeons (P8, P9, P70, and P289) maintained at approximately 80% of their free-feeding weights. Each of the subjects had previous experience in various operant conditioning experiments; all four subjects were recently used in a second-order schedule experiment involving ratios and intervals. P289 had a more extensive history under second-order schedules. Just prior to the first baseline each of the subjects worked under a fixed interval (FI) 5-min schedule arrangement for over 90 sessions.

Apparatus

The Grason-Stadler operant conditioning chamber (Model E3125AA-3) contained one response key requiring a minimum force of .12 N to operate, and, when operated, provided auditory feedback. A feeder that allowed 2.5-sec access to mixed grain was located below the key. The chamber was illuminated by a 6-W white houselight except during blackouts. The response key could be transilluminated by different colors and stimulus patterns by 28-V dc lamps (GE 1829). Masking noise was present throughout each session. The programming and recording of events was controlled by electromechanical devices in an adjacent room.

Procedure

Baseline performance under an FI 5-min schedule was established first. The first response on an amber-lit key after 5 min initiated the reinforcement sequence. The reinforcement sequence began with the immediate offset of the keylight. The feeder magazine was

lit .5 sec later and grain presented simultaneously. After 2.5-sec access to grain the chamber was darkened for 1 min, after which the cycle restarted with the onset of the amber keylight and the houselight. Responding during the blackout had no scheduled consequences. According to Ferster and Skinner (1957), a 1-min blackout should not alter second-order effects. Each session ended after the twentieth interval. This baseline (Condition I) remained in effect until quarter life and response rates showed no trend.

Condition II had added stimuli that changed as a function of the number of responses emitted in the interval. Four different key colors and one symbol comprised this counter: (in order) amber, green, white, red, and square (white on black). The counter changed after a constant number of responses based on the performance under the baseline condition so that if the mean number of responses (based on the last five sessions of Condition I) were emitted, the reinforcer would be presented during the fifth (and last) stimulus of the counter. This constant number of responses per stimulus was 25 for P8, P70, and P289 and 50 for P9. This condition remained in effect until quarter life, overall response rate, and response rate in the presence of each stimulus had stabilized.

Condition III was a return to baseline with the procedure being identical to Condition I.

Condition IV used the counter again as under Condition II. In addition, the reinforcement sequence at the end of the interval was altered so that multiple reinforcer presentations could occur. When more than one 2.5-sec grain presentation was arranged, each successive grain presentation followed the previous one by .5 sec. The number of grain presentations at the end of the interval was determined by the number of responses emitted during the interval so that responses per reinforcer were held approximately constant. Thus, if the interval terminated in the first stimulus, there was one grain presentation; if in the second stimulus, two grain presentations were made; etc. Since there were only five stimuli in the counter, the maximum number of grain presentations was five. This condition remained in effect until quarter life, overall response rate, and response rate in the presence of each of the counter stimuli showed no detectable trend.

Condition V was a reinstatement of the counter and single reinforcer as in Condition II. The data obtained in the last four sessions of this condition were used to generate yoked-control sessions for each bird for the final condition (VI). The durations of the stimuli were recorded under the counter dependency and then used as durations of the same stimuli under a "clock" arrangement. Thus, under Condition VI the same five stimuli were presented to the pigeons independently of their responding but for durations which they had generated under the preceding counter condition (V) on an interval-by-interval basis. The four yoked-control sessions were presented to the subjects in a random order an equal number of times until responding had stabilized. Table 1 summarizes the sequence of conditions and the number of sessions in each condition.

RESULTS

The results described below indicate that the effects of the counter (Condition II) and the counter with correlated reinforcer frequency (Condition IV) were virtually nonexistent. However, the yoked-control procedure (Condition VI) shows that the added stimuli were effective in maintaining control over responding.

Responding Rate and Quarter Life

The overall response rate (number of responses in a session divided by session duration, excluding blackouts) means and ranges across the six conditions are plotted in Figure 1 for each of the subjects. The only apparent changes were from the counter to the clock conditions (V to VI) for two pigeons: P289 showed a decrease and P9 showed an increase in overall rates. P8 and P70 showed no effect of the transition from counter to clock. Thus the effects of the experimental manipulations were minimal and inconsistent for the overall response rate.

Quarter life is the percentage of the interval that has elapsed when on the average one fourth of the total responses for an interval have been emitted. Quarter life data did show more consistent effects than rates. Figure 2 shows quarter life means and ranges for each of the conditions. Over the duration of the experiment (approximately one year), there was

Table 1

Experimental conditions and number of sessions per condition.

I	FI 5-minutes: baseline	
	P8	17
	P9	16
	P70	17
	P289	17
II	FI 5-minutes: counter	
	P8	39
	P9	37
	P70	39
	P289	41
III	FI 5-minutes: no counter	
	P8	21
	P9	20
	P70	20
	P289	23
IV	FI 5-minutes: correlated reinforcement amount and counter	
	P8	52
	P9	57
	P70	60
	P289	60
V	FI 5-minutes: counter	
	P8	13
	P9	14
	P70	13
	P289	12
VI	FI 5-minutes: clock yoked to counter in V	
	P8	19
	P9	17
	P70	18
	P289	22

a gradual increase in quarter life. There was an increase in quarter life for three of the subjects (P8, P9, and P289) in the transition from counter to clock (V to VI); the increase was not as marked for P70.

Autocorrelations

Autocorrelation functions with lags of 1, 2, 3, 4, and 5 were calculated on response number for each subject for the last five sessions under each condition (four sessions for Conditions V and VI). Lag-1 autocorrelations are plotted in Figure 3 for each subject under each condition with 90% confidence intervals (the variance of the lag-1 autocorrelation is approximately, and conservatively, $1/N$). As was the case with overall response rates, there was no effect for any condition that was consistent for all four pigeons. P8 and P9 showed an increase in magnitude of the correlation in the transition

Fig. 1. Mean overall response rate over the six conditions for each subject. The overall rate is based on the number of responses in a session divided by session duration, excluding blackouts. The ranges are for the last five sessions of Conditions I to IV and four sessions for V and VI.

Fig. 2. Mean quarter life over the six conditions for each subject. The ranges are for the last five sessions of Conditions I to IV and four sessions for V and VI.

from baseline to counter with correlated reinforcer frequencies (III to IV); however, P70 and P289 showed no effect.

The data in Figure 3 are not only quite consistent across the six conditions, but also the confidence intervals indicate that the lag-1 autocorrelations are typically less than zero. Of the 24 lag-1 autocorrelations shown, none was positive and only eight included zero in the 90% confidence interval. Although these data indicate a consistent negative lag-1 autocorrelation, the magnitude is quite small. The proportion of variability (the square of the correlation) in response number in one interval accounted for by response number in the preceding interval is between 0 and 15%.

The autocorrelations with higher lags (2 through 5) showed no consistency in sign nor were they reliably different from zero.

Response Rates with Added Stimuli

Response rates in the presence of each of the five stimuli which comprised the counter and clock for Conditions II, IV, V, and VI are plotted in Figure 4 for each of the subjects. In addition, response rates for baseline condition III

were calculated as if the counter stimuli were present (i.e., rate for the first n , second n , etc., responses). P289 and P70 showed a decrease in response rates for the second and third stimulus of the clock condition (VI). P9 had an in-

Fig. 3. Lag-1 autocorrelations over the six conditions for each subject. The 90% confidence intervals are based on the last five sessions of Conditions I to IV and four sessions for V and VI.

Fig. 4. Response rate in the presence of each of the stimuli which comprised the explicit counter and clock.

crease in response rate in the fourth and fifth stimulus of the clock. P8 showed no effect of the changing conditions.

Clock Performance

Since the clock stimuli of Condition VI were yoked to the performance under the preceding condition with a counter, it was possible to look for sources of control for FI responding by directly comparing the behavior maintained by two conditions. It was found that the response numbers in the corresponding intervals of the two yoked sessions were highly correlated, ranging as high as +.98. Since under the counter condition (V) a high response interval was associated with a short completion time for the first 25 (or 50) responses, and vice versa, perhaps the control in the clock arrangement derived from the duration of the first stimulus.

The high negative correlation between response number in an interval and the duration of the first stimulus of the clock demonstrated that the clock stimuli exerted powerful control over behavior. That is, when the change from the first to the second stimulus occurred early in the interval, there was a higher response count in that interval. The data are shown in Figure 5 for P9 for each of the four

Fig. 5. Responses emitted in an interval as a function of the duration of the first stimulus of the clock under Condition VI for P9. Each panel is the fourth exposure to one of the four yoked-control sessions. The correlations and regression constants are shown in each panel.

yoked-control sessions (A4, B4, C4, and D4). A least-squares regression line was fitted for the response number and the first stimulus duration for the four sessions for each pigeon. The data for all four pigeons are presented in Table 2.

The correlation between response number and first stimulus duration ranged from -.475

Table 2

Data for the four clock sessions (A4, B4, C4, and D4). Shown below are the correlations between response number and first stimulus duration and the regression constants for response number as a function of first stimulus duration (Responses = C(1) Duration + C(2)).

Subject	Session	Correlation	C(1)	C(2)
8	A	-.658	-.729	246
	B	-.475	-.366	155
	C	-.697	-.677	236
	D	-.578	-.375	165
9	A	-.736	-1.349	540
	B	-.868	-1.540	574
	C	-.917	-1.540	583
	D	-.522	-1.122	499
70	A	-.923	-1.843	539
	B	-.916	-1.770	488
	C	-.894	-1.240	444
	D	-.925	-1.430	445
289	A	-.552	-.483	166
	B	-.674	-.396	162
	C	-.760	-.407	165
	D	-.723	-.526	192

Fig. 6. The relative reinforcement frequency in the presence of each of the stimuli for the four yoked-control sessions of Conditions V and VI.

to $-.925$. Thus, between 20 and 85% of the variability in response number under the clock arrangement was accounted for by the first stimulus duration. Some small portion of this variance may be due to the lag-1 autocorrelation resulting from the yoking procedure. P8 had the lowest correlation magnitude consistently and also had the highest frequency of reinforcement in the first stimulus. The data in Figure 6 show that responding was maintained in the presence of each of the clock stimuli by low reinforcement frequencies.

DISCUSSION

The results of this experiment largely reflect no change in baseline FI behavior as a result of the first two experimental manipulations. However, these results in conjunction with the clock data do shed some light on the controlling aspects of FI schedules.

Previous work (e.g., Herrnstein & Morse, 1958) attributed control of interval-to-interval dynamics in responding to responses per reinforcer (see also Zeiler, 1977 and 1979). The lag-1 autocorrelations in the present study showed that the direct manipulation of the responses per reinforcer by holding it approximately constant (Condition IV) did not influ-

ence interval-to-interval dynamics. If this technique of multiple grain presentations does not manipulate responses per reinforcer via "frequency" or "magnitude," it is not clear what can be done to the reinforcer that would change responses per reinforcer without altering the character of the FI schedule. Since the multiple grain presentations did not have the effect of increasing output, we are faced with the question of whether the procedure functioned as an increased reinforcer should. There is considerable evidence in the literature to indicate that if tested in an appropriate choice procedure, pigeons would select multiple grain presentations over a single grain presentation (Catania, 1963; Neuringer, 1967). Thus, it would seem that there is something about control of FI responding that makes this present procedure ineffective as a means of differential reinforcement. These results are consistent with the results of Meltzer and Brahlek (1968, 1970) who found no effect on FI pattern with nondifferential presentations of different reinforcer magnitudes. Since there was a consistent negative lag-1 autocorrelation and the manipulations of responses per reinforcer were ineffective, perhaps the variable of importance is simply response number. Under the standard FI procedure, response number and responses per reinforcer are identical since there is only one reinforcer per interval. Since the introduction of higher reinforcer frequencies did not alter the dynamics of FI responding as shown by the lag-1 autocorrelations, then response number is a more likely candidate for a controlling indirect variable under FI schedules.

Thus, as a direct variable (i.e., specified by the schedule) responses per reinforcer may be very effective, as with FR schedules (Zeiler, 1977) or with conjunctive FI FR schedules (Herrnstein & Morse, 1958). But under FI schedules when operating as an indirect variable, responses per reinforcer as a controlling factor is more likely ineffective and response number only slightly effective across intervals as the consistently negative, small lag-1 autocorrelations demonstrate. As discussed below, the within-interval control by response number may be more powerful.

Some researchers have reported very small or zero lag-1 autocorrelations for responses or pauses (Dews, 1970; Lowe & Wearden, 1981; Wearden, 1979), whereas the present data and

data from Shull (1971) have found evidence for a consistent, negative lag-1 autocorrelation. It is possible that the discrepancy lies in the value of the FI being studied: the shorter FIs produce little evidence for dynamics beyond directional changes and the FI 5-min used here and by Shull (1971) produced the consistent, negative lag-1 autocorrelation for response number (present data) and pause (Shull, 1971). This hypothesis is supported by Shull's (1971) data on the shorter FIs with the same subjects.

Response rate did not increase when higher response rates were differentially reinforced in Condition IV. Correlation between responding and reinforcement amount apparently was not sufficient to increase rates as suggested by Baum (1973) and Rachlin (1976). These results are in accord with Zeiler's (1979) conclusions from the reinforcement-omission procedures that under FI schedules output can function as a discriminative stimulus but even though it does, it is not a directly reinforceable property of behavior.

If response number is a controlling indirect variable under FI schedules, then the addition of a counter would make the control explicit. The counter was used in Conditions II and V and in Condition IV with the increased reinforcer amount. Since response number in one interval controls (to a small degree) response number in the next interval, it was anticipated that making the explicit stimuli associated with response number available would enhance the effect of the variable, i.e., increase the magnitude of the negative lag-1 autocorrelation. This did not occur.

Since response number is weakly effective in controlling behavior, either the counter was totally ineffective (i.e., did not control behavior) or the external counter was no more effective than control already available from behavior itself (and may have gained control of behavior). The response rates in the presence of each stimulus under Conditions II, IV, and V showed that there was no difference from standard FI responding when rates were calculated as if the stimuli were present (Condition III). Therefore, either of the above explanations is plausible. However, the sharp stimulus control demonstrated under the clock arrangement of Condition VI argues strongly for the stimuli having gained control over behavior under the other conditions.

Since the response rates did not differ when

comparing Conditions II, IV, and V with Condition III (conditions with counter added to a no-counter condition), it is not possible to ascribe conditioned reinforcing properties to the counter stimuli or to the production of count (Ferster & Skinner, 1957) beyond that found in standard FI arrangements. The difference between the present results and those of Ferster and Skinner (1957) may reflect the difference in discrete vs. continuous counters. The role of counter stimuli, continuous and discrete, deserves further study (cf., Skinner, 1980, p. 245). Ferster and Peele (1980) recently reported a similar negative finding on the production of explicit count with FR schedules, although they argued for a mixed function of counters since low count is never paired with the primary reinforcer. However, this account cannot be extended to counters under FI schedules because low count can be reinforced.

If time can be measured by the amount of behavior that has occurred since the beginning of the interval (cf. Dews, 1978; Ferster & Skinner, 1957; Laties, Weiss, Clark, & Reynolds, 1965; Laties, Weiss, & Weiss, 1969; Rilling, 1967; Segal, 1962), then, by providing the subject with a response-independent, explicit-stimulus version of its own behavior, control over behavior might be maintained. This was studied by yoking Condition VI to Condition V. Response number under the clock arrangement (Condition VI) was controlled to a large degree by the duration of the first stimulus, which was determined by the time it took to complete the first 25 responses for P8, P70, and P289 and 50 responses for P9 under Condition V. Thus, it is plausible that the indirect variable "amount of behavior" can control momentary response rates under FI schedules, and if response number can exert even weak control from one interval to the next, then more powerful control could be exerted by the same variable within an interval. However, within-interval effectiveness of this indirect variable cannot be verified with the present data for two reasons: behavior other than key pecking was not measured and within-interval changes in response rates were not measured.

Zeiler (1979) deemphasized control by response number because of the moderate-to-low correlations that have been found. However, if a number of variables can be isolated, and it can be demonstrated that each makes an independent contribution to the control of re-

sponding under FI schedules, then perhaps a larger portion of variability in responding could be accounted for. For example, if the lag-1 autocorrelations were independent of the control exerted by the duration of the first stimulus of the clock under Condition VI, then over 90% of the variability in response number could be accounted for in certain sessions of Condition VI. These data as well as data from other studies of pause time (Shull, 1971, 1979), accelerated response rates (Dews, 1978), exteroceptive stimulus control (Ferster & Skinner, 1957; Segal, 1962), etc., would seem to indicate that the interval-to-interval dynamics and within-interval pattern of responding under FI schedules is under very complex control of exteroceptive and proprioceptive-interoceptive stimuli. Thus, an understanding of the FI pattern of responding will derive from an analysis of multiple sources of control, each of which may make a small (independent or interactive) contribution to the total. And, complicating matters further, these multiple sources will probably vary as a function of the FI duration itself (e.g., Shull, 1971; Wearden, 1979).

REFERENCES

- Baum, W. M. The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 137-153.
- Catania, A. C. Concurrent performances: A baseline for the study of reinforcer magnitude. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 299-300.
- Dews, P. B. The theory of fixed-interval responding. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules*. New York: Appleton-Century-Crofts, 1970.
- Dews, P. B. Studies on responding under fixed-interval schedules of reinforcement: II. The scalloped pattern of the cumulative record. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 67-75.
- Ferster, C. B., & Peele, D. B. The contribution of an added counter to a fixed-ratio schedule. *Journal of the Experimental Analysis of Behavior*, 1980, 34, 93-105.
- Ferster, C. B., & Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Herrnstein, R. J., & Morse, W. H. A conjunctive schedule of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 15-24.
- Laties, V. G., Weiss, B., Clark, R. L., & Reynolds, M. D. Overt "mediating" behavior during temporally spaced responding. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 107-116.
- Laties, V. G., Weiss, B., & Weiss, A. B. Further observations on overt "mediating" behavior and the discrimination of time. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 43-57.
- Lowe, C. F., & Wearden, J. H. A quantitative model of temporal control on fixed-interval schedules: Dynamic properties of behaviour. In C. M. Bradshaw, E. Szabadi, & C. F. Lowe (Eds.), *Quantification of steady-state operant behaviour*. Amsterdam: Elsevier/North-Holland Biomedical Press, 1981.
- Meltzer, D., & Brahlek, J. A. Quantity of reinforcement and fixed-interval performance. *Psychonomic Science*, 1968, 12, 207-208.
- Meltzer, D., & Brahlek, J. A. Quantity of reinforcement and fixed-interval performance: Within-subject effects. *Psychonomic Science*, 1970, 20, 30-31.
- Neuringer, A. J. Effects of reinforcement magnitude on choice and rate of responding. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 417-424.
- Rachlin, H. *Behavior and learning*. San Francisco: Freeman, 1976.
- Rilling, M. Number of responses as a stimulus in fixed interval and fixed ratio schedules. *Journal of Comparative and Physiological Psychology*, 1967, 63, 60-65.
- Segal, E. F. Exteroceptive control of fixed-interval responding. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 49-57.
- Shull, R. L. Sequential patterns in post-reinforcement pauses on fixed-interval schedules of food. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 221-231.
- Shull, R. L. The postreinforcement pause: Some implications for the correlational law of effect. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour* (Vol. 1). *Reinforcement and the organization of behaviour*. New York: Wiley, 1979.
- Skinner, B. F. *The behavior of organisms*. New York: Appleton-Century, 1938.
- Skinner, B. F. *Notebooks*. Englewood Cliffs, N.J.: Prentice-Hall, 1980.
- Staddon, J. E. R. Effect of reinforcement duration on fixed-interval responding. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 9-11.
- Stebbins, W. C., Mead, P. B., & Martin, J. M. The relation of amount of reinforcement to performance under a fixed-interval schedule. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 351-355.
- Wearden, J. H. Periodicities within a fixed-interval session. *Journal of the Experimental Analysis of Behavior*, 1979, 31, 345-350.
- Zeiler, M. D. Schedules of reinforcement: The controlling variables. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. New York: Appleton-Century-Crofts, 1977.
- Zeiler, M. D. Output dynamics. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour* (Vol. 1). *Reinforcement and the organization of behaviour*. New York: Wiley, 1979.

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