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OBSERVING BEHAVIOR DURING INTERVAL SCHEDULES[1]

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Experiment 1 showed that the three stimuli associated with three chained fixed-interval links could be used to maintain observing behavior. Experiment 2 showed that three stimuli correlated with the passage of time since the last reinforcement in a fixed-interval schedule could be used to maintain observing behavior. In both experiments most observing responses occurred midway between reinforcements. Few occurred just before or just after reinforcement. Experiment 3 showed that the decline in the rate of observing behavior just before reinforcement was reduced when more stimuli could be observed. The relatively high terminal rate of observing behavior that resulted was maintained even when at least 4 sec intervened between the reinforcement and the last observed stimulus.

The stimuli of multiple schedules may be effective reinforcers. (Kelleher, 1958; Kelleher, Riddle, and Cook, 1962; Kendall, 1965b; Wyckoff, 1952). Performance maintained by such stimuli is usually referred to as "observing behavior". The present investigation sought to determine whether observing behavior could be sustained by, first, the stimuli of a chain schedule, and second, by stimuli correlated with passage of time in interval schedules.

GENERAL METHOD

A Grason-Stadler two-key pigeon box was used. Behind each key was a device for projecting colors or symbols on the key. General illumination was provided by a 6 w lamp with three quarters of the bulb painted black. The observation window was blacked out, but a small opening, normally covered, could be used to observe the birds. Conventional switching and timing equipment was used for programming and data were collected on counters and cumulative recorders.

A different, naive, adult, male homing pigeon, reduced to 75-80% of free-feeding weight, served in each experiment. The birds were trained to peck one key for food, first on continuous reinforcement (CRF), then on an interval schedule. Reinforcements were 3-sec access to grain. Water was continuously available. Stimuli which differed according to time since the last reinforcement could be projected on either key. When such a set of stimuli is used in conjunction with a fixed-interval (FI) schedule, the procedure is called "added clock" (Ferster and Skinner, 1957). In the present experiments, stimuli presentations were contingent on responses on the second key. The procedure is therefore called "optional clock". For the sake of brevity the second key is referred to as the "clock key" or simply the "clock". Responses on the clock key are observing responses.

In Exp. 1 the schedule on the food key was first Chain FI 1 FI 1 FI 1. The schedule was then changed to Tandem FI 1 FI 1 FI 1, and, at the same time, the chain stimuli could be produced by observing responses. The chain stimuli were numbered in the reverse of their temporal order of appearance in the chain. Thus, S1 was the stimulus available just before reinforcement, S2 was the preceding stimulus, and so on.

In Exp. 2 the schedule on the food key was FI 6 and resolution of the clock was 2 min. The schedule on the food key was later changed to FI 3 and resolution of the clock to 1 min.

In Exp. 3 the schedule on the food key was FI 6 and clock resolution was 1 min.

In Exp. 2 and 3 reading of the clock depended only on the passage of time between

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reinforcements. In Exp. 1 what the clock registered depended both on passage of time and performance of the bird.

EXPERIMENT 1

Procedure

The initial procedure was designed to establish control of responding by S3, S2, and S1 before using them to reinforce observing responses. After CRF the bird was trained on Chain FI 1 FI 1 FI 1. Components of the chain were indicated by the color of the food key (S3 was green, S2 red, and S1 white). During reinforcement the food key was dark.

Optional clock (VI 3). After 11 sessions of Chain FI 1 FI 1 FI 1 the schedule on the food key was changed to Tandem FI 1 FI 1 FI 1. (The stimuli no longer appeared on the food key and it remained dark, but the response requirements for reinforcement were unchanged). The clock key, which had been dark, was now yellow. Pecking the clock key, which previously had had no consequences, now intermittently (VI 3) darkened the clock key and illuminated the food key with the appropriate chain stimulus. (Responding on the clock key was shaped by turning on the chain stimuli after every response on the clock). The stimulus was timed to last 15 sec, but it went off if it ceased to be appropriate—that is, if the next link of the tandem schedule was entered. The procedure gave the bird the opportunity, by pecking the clock key, partially to convert the tandem schedule on the food key into the original chain schedule. Only partial conversion to the original chain was possible, since the chain stimuli could be obtained on the average for no more than 15 sec in 3 min, or about once per reinforcement. Responses were recorded on different counters according to whether the chain stimuli were on or off.

Optional Clock (CRF). The schedule of stimulus production on the clock key was changed after 14 sessions of VI 3 to strengthen responses on the clock by allowing them to have a consistent and immediate effect. Both keys were now dark. The tandem schedule was still in effect on the food key. Every observing response now produced the appropriate chain stimulus on the clock key, not the food key, for 0.1 sec (0.075 sec in one session). This procedure was in effect for six sessions. It allowed the bird to "observe its progress" through the tandem schedule without affecting either the color or the response requirements on the food key.

Results

Chain FI 1 FI 1 FI 1. Performance typical of this schedule was established in a few sessions. Eventually, there was a low rate in S3 (< 1 R/min), an intermediate rate in S2 (40-60 R/min), and a high rate in S1 (100-120 R/min), as illustrated in Fig. 1.

Optional Clock (VI 3). Observing behavior with this procedure was easily established and Table 1 shows the final effects. Rates on both keys in the presence and absence of the chain stimuli are separately tabulated. Table 1 shows that the rate on the food key went down when S3 was on, stayed much the same when S2 was on, and went up when S1 was on. Thus, the presence of the stimuli changed the food key rates in the direction of the corresponding rates in the various components of the original chain schedule. Table 1 also shows that rate on the clock key was lower when the chain stimuli were on, except during S3, when it was higher.

The high rate of responding on the clock key during S3 is unexpected since responses on the clock key could not change a stimulus while any chain stimulus was on. Examination of the cumulative records showed that the tabulated figure, obtained from counters, was misleading. The most frequent result of presenting S3 was a zero rate of responding on the clock key with one or two responses being made on the food key. Occasionally, however, responses on the clock key occurred at a high rate, up to about 120 per min (with a zero rate

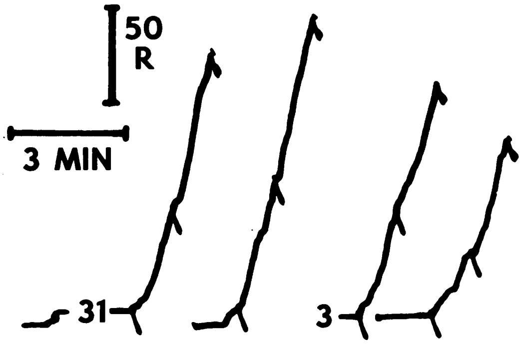

Fig. 1. Typical performance on Chain FI 1 FI 1 FI 1. Numbers are durations (in minutes) of periods of no responding which have been omitted from the record. Pips indicate changes from one link to the next.

TABLE 1

Response Rates (R/min) on the Food Key and the Clock Key in Each Link of Tandem FI 1 FI 1 FI 1 When Observing Responses Occasionally (VI 3) Produced a Stimulus.
(Averages of final two sessions)

	Food Key Initial Link	Food Key Middle Link	Food Key Final Link	Clock Key Initial Link	Clock Key Middle Link	Clock Key Final Link
Stimuli on keys without obs. R's	dark	dark	dark	yellow	yellow	yellow
Rate in absence of clock stimuli	12.6	47.7	49.3	6.4	12.3	7.5
Stimuli produced by obs. R's	green (S3)	red (S2)	white (S1)	dark	dark	dark
Rate in presence of clock stimuli	6.2	45.0	140.0	19.5	2.1	0.0

TABLE 2

Response Rates (R/min) on the Food Key and the Clock Key in Each Link of Tandem FI 1 FI 1 FI 1 When Every Observing Response Produced a Stimulus.
(Averages of sessions 2 and 3)

	Food Key Initial Link	Food Key Middle Link	Food Key Final Link	Clock Key Initial Link	Clock Key Middle Link	Clock Key Final Link
Stimuli on keys without obs. R's	dark	dark	dark	dark	dark	dark
Stimuli produced by obs. R's	dark	dark	dark	green (S3)	red (S2)	white (S1)
Overall rate	8.1	36.0	77.0	6.9	19.5	9.6

on the food key). The occasional instances of a high rate accounted for the high average rate of responding on the clock key in S3 shown in Table 1.

Some representative records of performance on both keys are shown in Fig. 2. The two pairs of records at left show that typical tandem performance occurs on the food key (upper traces) when no stimuli happen to be obtained on the clock (lower traces). The two pairs of records at right illustrate the effects of S1, S2, and S3. The observing rate is low during S1, S2, and S3 (*i.e.*, between pairs of pips). The effects of the stimuli on the food key rate are difficult to illustrate with cumulative records, but the increased rate during S1 may be detected in the two instances that S1 appears in Fig. 2. The occurrences of S1 are indicated by brackets on the food key records.

Optional Clock (*CRF*). Adjustment to this schedule was almost immediate and performance changed very little over the six sessions it was in effect. Averaged response rates over sessions 2 and 3 are given in Table 2 (counter records of sessions 4-6 were lost). Durations of the optional stimuli were so brief that virtually no responses could occur while the stimuli

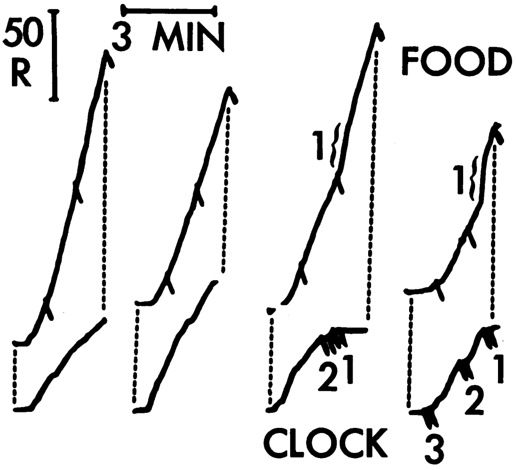

Fig. 2. Representative performance on Tandem FI 1 FI 1 FI 1 with VI 3 optional clock (see text). Dotted lines indicate corresponding times on the food key and clock key records. For the food key (upper traces) pips indicate changes from one link to the next. For the clock key (lower traces) pips appear in pairs and indicate the duration (15 sec) of the chain stimuli appearing on the clock. Which chain stimulus, S1, S2, or S3, actually appeared is indicated by the number below the pips. The brackets on the food key record show where S1 occurred.

were on. Therefore, overall rates are given in Table 2, whereas in Table 1 different rates are given according to whether the chain stimuli were on or off. Typical performance on each key is shown in Fig. 3. Both Table 2 and Fig. 3 show that observing behavior was well maintained. Moreover, performance on the food key appeared more characteristic of the original chain schedule than the tandem schedule actually programmed. A direct comparison with performance on a simple tandem schedule is not possible since the tandem schedule was never in effect without an optional clock. However, compared with the rates on the food key in the absence of the chain stimuli shown in Table 1, the food key rate in Table 2 is lower in the first two links and higher in the final link. The difference in the middle link is of equivocal significance, but the higher rate in the final link and the lower rate in the initial link is in accordance with the stimulus control established in the original chain. In addition, the food key performance in Fig. 3 is more similar to that shown in Fig. 1 (chain) than to that in Fig. 2 (tandem). Evidently, the maintained observing behavior was sufficient to bring performance on the food key largely under the control of the original chain stimuli. By exposing itself to the chain stimuli the bird effectively converted the tandem schedule into the corresponding chain schedule. It is important to remember that during this phase no stimuli were produced on the food key. Moreover, presentations of stimuli on the clock were so brief that both keys must have been dark at the beginning of every response on the food key.

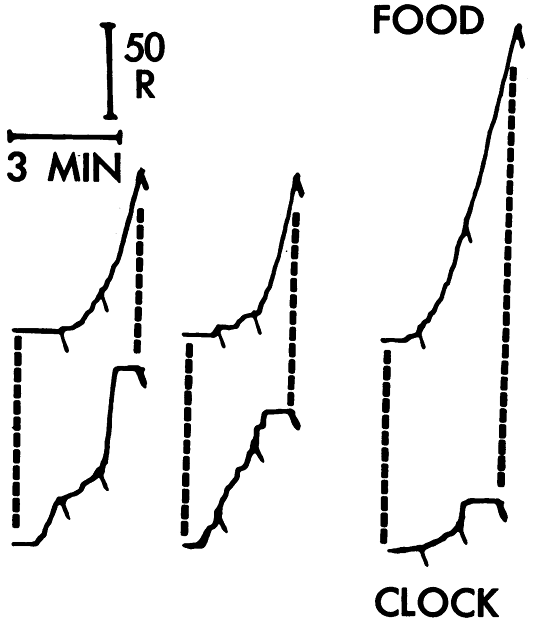

Fig. 3. Typical performance on Tandem FI 1 FI 1 FI 1 with CRF optional clock. Dotted lines indicate corresponding times on the food key and clock key records. Responses on the clock key transilluminated it for 0.1 sec with the stimuli of the chain schedule on which the bird had originally been trained. Pips indicate transitions from one link of the tandem schedule to the next. Heavy pips indicate primary reinforcement.

The effects on the food key performance of the CRF optional clock are consistent with the effects of VI 3 optional clock. The differences in rate which can be attributed to the presentation of a particular chain stimulus are in the same direction for the two procedures.

EXPERIMENT 2

Experiment 1 showed that the stimuli associated with the components of Chain FI 1 FI 1 FI 1 became conditioned reinforcers. The effect could have been due to the fact that in the original chain at least one response was required in the presence of each chain stimulus. On the other hand, it may be that the chain stimuli simply indicated the passage of time and the information "so-many minutes to reinforcement" is reinforcing whether or not any intermediate, unreinforced responses are required by the schedule of food reinforcement. Experiment 2 was designed to test this conjecture by eliminating the formal chaining requirement of the food-reinforced response. A fixed-interval schedule of reinforcement was in effect on one of the keys and stimuli which indicated the time to reinforcement were available on the other. The response-produced stimuli on the second key constituted a discontinuous optional clock. The main question to be answered was whether observing behavior could be established. Observing behavior with the optional clock procedure proved easy to establish, and various test procedures were adopted to assess the importance of the clock stimuli in maintaining the observing behavior.

Procedure

After performance was established on the food key (one session of CRF), responses on it always produced food on a 6-min fixed-interval schedule (FI 6). This key was always dark. Responses on the other key (the clock key) transilluminated it with a 0.5-sec stimulus. If another observing response occurred during the stimulus, it blinked (current off for 40 msec) and stayed on for a further 0.5 sec.

Three different clock stimuli were available. In the first 2 min after reinforcement an observing response produced a red light (S3) on the clock key. In the next 2 min the available clock stimulus was a blue light (S2). The final stimulus, a green light (S1), remained available until reinforcement occurred (*i.e.*, usually for 2 min). The position of the food key and the clock key were switched after every reinforcement. The clock key was identified by projecting on it a white plus sign.

The bird was given two kinds of test sessions. In the first, clock stimuli were available for a complete session, or most of a session, on a variable-ratio schedule rather than CRF. These tests are called VR clock tests. With a VR 2 clock test, for example, the clock stimuli would be obtained, on the average, with every second observing response. In the second test, only one stimulus (S1, S2, or S3) was available for a complete session, or part of a session, for all observing responses. These tests are called stopped clock tests. Test sessions were interspersed among sessions with the regular procedure described in the previous paragraph. Normal performance was usually, but not always, restored in one or two sessions after a test session.

The bird was given 30 daily 4-hr sessions, by which time performance on both keys had stabilized. Then the VR clock tests and the stopped clock test were given (one per session). These lasted 42 sessions including intervening control sessions. The reinforcement schedule of the food key was changed to FI 3, and the clock stimuli changed every 1 min instead of every 2 min. After 12, 2-hr sessions, when performance had stabilized, VR clock tests and stopped clock tests were given again.

Results

FI 6. The traces marked "A" in Fig. 4 show typical performance on both keys. The performance on the food key is, not surprisingly, like that produced by a fixed-interval schedule, with perhaps an unusually sharp transition from the low rate after reinforcement to the high rate before the next reinforcement. It should be noted, however, that the interval-like performance was being maintained at the same time as a considerable rate of observing behavior. The pattern of observing behavior was easily distinguished from that on the food key, mainly because the rate of observing behavior usually declined shortly before reinforcement became available on the food key.

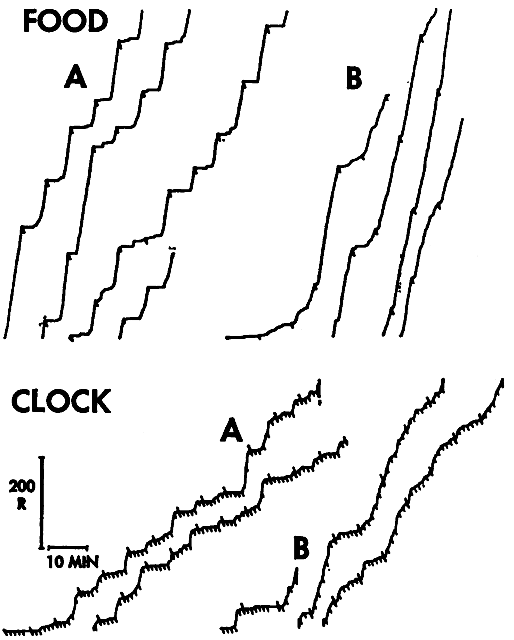

Fig. 4. Concurrent performance on FI 6 and the optional clock (see text). A and B are continuous. In A, every response on the clock key produced the appropriate stimulus. In B, on the average, every other response on the clock key produced the appropriate stimulus (VR 2). Minutes since reinforcement are marked by pips on the record of performance on the clock key; elongated pips indicate reinforcement (on the other key).

The traces marked "B" in Fig. 4 show a VR clock test, and are explained below.

The results of the VR clock tests are shown in Fig. 5. Relative frequencies of responding are shown because the absolute rates differed during the tests. The bars represent the average relative frequencies of responding in a given minute of the fixed-interval. Thus, each set of six bars sums to 1.00, and there are eight sets in Fig. 5. The open bars represent three different test sessions and the solid bars represent averages of control performance in the three pre-test sessions. The control data (solid bars) for the food key show that response rate increased up to the end of the interval. Thus, about 40% of all responses on the food key were emitted in the 1 min before reinforcement.

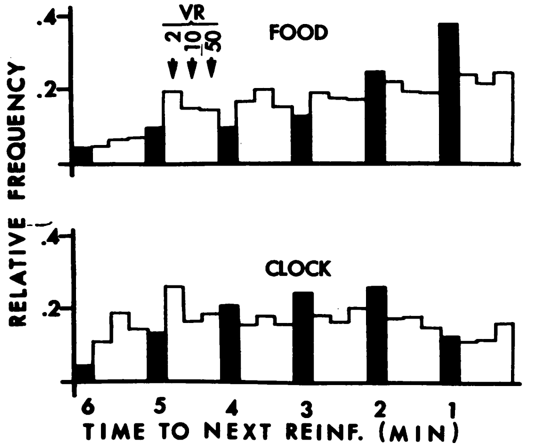

Fig. 5. Relative frequency of responding in successive minutes of FI 6, with the food key and the clock key treated separately. Solid bars represent control sessions in which every response on the clock key produced the appropriate clock stimulus. Open bars represent test sessions in which responses on the clock key intermittently obtained the appropriate clock stimulus. The schedules of stimulus-production on the clock key were variable-ratios whose values are indicated opposite the second set of open bars.

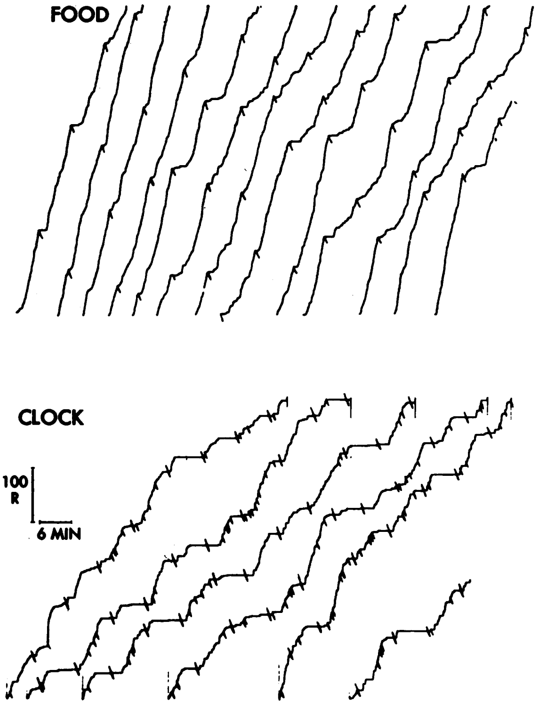

Fig. 6. Performance on both keys when the schedule of stimulus-production on the clock key was VR 25. Elongated pips on the record of performance on the clock key indicate the occurrence of reinforcement on the food key; small pips show where a response on the clock key produced one of the clock stimuli.

The lower panel of Fig. 5 shows a different pattern of control performance on the clock key, where response rate increased up to the fifth minute and declined in the sixth. The terminal decline in rate of observing behavior was such that very few responses (fewer than 1%) ever occurred after reinforcement became available on the food key. This result is also shown in Fig. 4 where the pip indicating the end of the sixth minute cannot be distinguished from the elongated reinforcement pip, since they occurred in quick succession.

The upper panel of Fig. 5 shows that during the VR clock tests responses on the food key were more evenly distributed within the fixed-interval. The result shows that the "temporal" discrimination on the food key was actually being controlled by the clock, since the discrimination was attenuated when the clock stimuli appeared less frequently. The lower panel of Fig. 5 shows that during the VR clock tests the observing behavior itself was affected, responses being more evenly distributed within the fixed-interval. The effects of the VR clock tests on the pattern of responding between reinforcements did not seem to depend strongly on the size of the VR. Figure 5 shows that having even the smallest ratio (VR 2) on the clock virtually eliminated the positive accelerations (scallops) on the food key and the "inverse scallops" on the clock. This effect is also shown in the traces marked "B" in Fig. 4. "A" and "B" are continuous and were taken from a session not represented in Fig. 5. After the last reinforcement appearing in "A" the clock schedule was changed from CRF to VR 2 and the pens were reset to the base line, without disturbing the bird or interrupting the session. Changing the schedule on the clock impaired the differentiation of response rate on both keys: the height of the open bars in Fig. 5 varies less than the height of the solid bars. However, it was to be expected that systematic patterns of responding would gradually be established with a VR schedule on the clock key. Therefore, after the stopped clock tests (see below), the bird was given three sessions with VR 25 on the clock key. Figure 6 shows the performance in the third session. Performance on the food key is irregular, but, on the average, the rate increases up to reinforcement. Performance on the clock key is quite systematic. The percentage of responses on the clock key in successive minutes since reinforcement is 12.5, 19.0, 26.8, 22.8, 12.8, 6.1. Responses on the clock key, but not those on the food key, are emitted in short bursts, as is to be expected if the responses are reinforced on a VR schedule.

Figure 7 shows the result of the stopped clock tests. In all tests, the observing response rate gradually declined. The decline was slowest when the clock was stopped at S1 (the terminal stimulus), and fastest when it was stopped at S3 (the initial stimulus). The overall observing response rates in Fig. 7 partly reflect these differences in resistance to extinction. The rate on the food key increased during every stopped clock test. Figure 7 reveals that the normally low rate at the beginning of the interval increased during the tests. This result confirms that, in a general sense, the "temporal" discrimination on the food key was controlled by the clock. In particular, the normal low rate on the food key after reinforcement was presumably due to occasional observation of S3 or S2 on the clock. However, when every observing response produced S3 or S2, the rate on the food key was *not* depressed, but actually increased. This result was quite unexpected. It perhaps indicates that the stopped clock procedure quickly eliminated the discriminative control of the test stimulus, so performance on the food key reverted to what it would be on early exposure to FI 6, with little pausing after reinforcement.

FI 3. Adjustment to this schedule was almost immediate, as would be expected if performance on both keys were controlled by the clock.

The results of the VR clock tests are shown in Fig. 8, which has the same format as Fig. 5. The tests produced a more even distribution of responses within the fixed-interval. The effect on responding on the food key, though similar to that shown in Fig. 5, is not so marked. Response rate increases somewhat toward the end of the interval, though less than in the control sessions. By contrast, no progressive increase in rate appears in the tests shown in Fig. 5. The result indicates that food key performance on FI 3 was under clock control, but perhaps to a lesser extent than when the schedule was FI 6. Again, the effect of the tests did not seem to depend strongly on the size of the VR. The results of the stopped clock tests are shown in Fig. 9,. which has the same format as Fig. 7. The effects of the tests

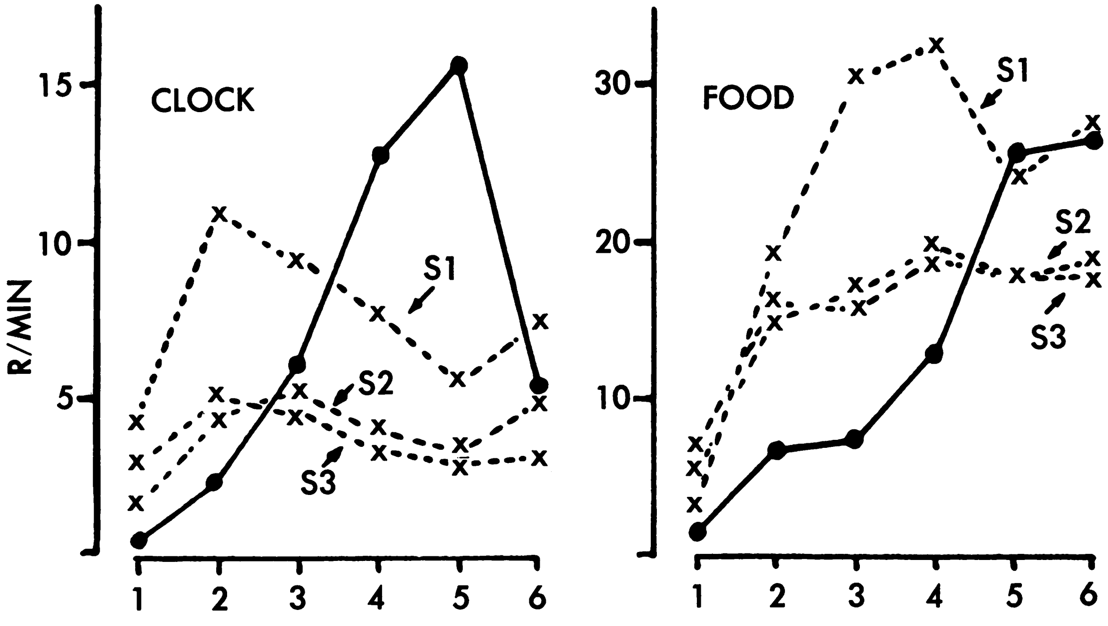

Fig. 7. Effects on both keys of stopped clock tests when the schedule of reinforcement on the food key was FI 6. The solid line represents the rate in three pre-test control sessions in which every response on the clock key produced the appropriate stimulus. The broken lines show the rate in test sessions when every response on the clock key produced the same stimulus—S3, S2, or S1, as indicated.

were very similar to those obtained with FI 6 on the food key.

EXPERIMENT 3

The results of Exp. 1 and 2, taken together, show that stimuli which differ according to passage of time between reinforcements occurring at fairly regular intervals may become conditioned reinforcers. Whether or not unreinforced responses are required in the schedule does not appear to be important. The results strongly suggest that in both cases the birds were using clock stimuli for timing, insofar as the stimuli controlled rates of food key responding appropriate to the schedule of reinforcement on the food key.

The terminal decline in observing response rate in Exp. 1 and 2 was to be expected if observing behavior were maintained by the temporal significance of the stimuli obtained; once the final stimulus (S1) was observed, no further, different, timing stimulus could be obtained. This interpretation was tested in the present experiment. It was predicted that a de-

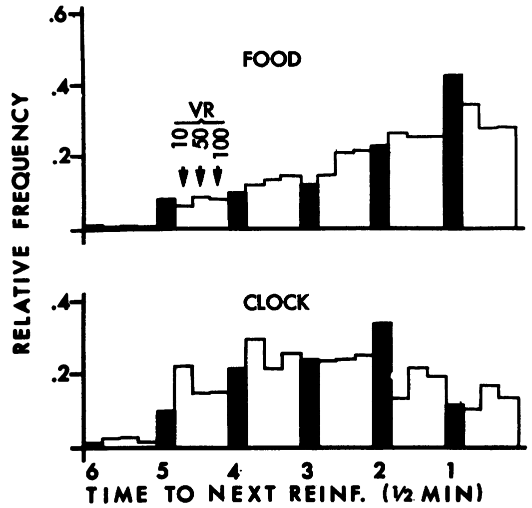

Fig. 8. Relative frequency of responding on each key in successive ½ min of FI 3. See Fig. 5.

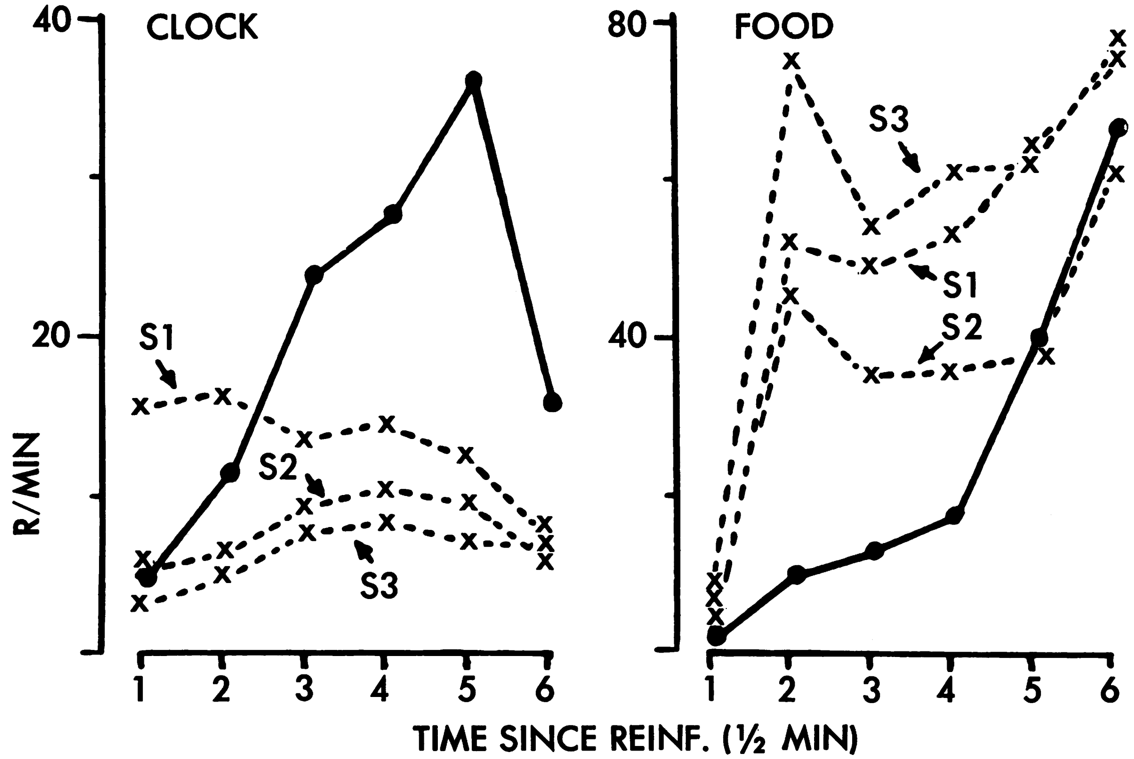

Fig. 9. Effects on both keys of stopped clock tests, when the schedule of reinforcement on the food key was FI 3. See Fig. 7.

cline in the rate of observing responses in the sixth minute of FI 6 would not occur if observing responses in the sixth minute produced a further timing stimulus. In this experiment, therefore, the resolution of the clock was changed one-sixth, rather than one-third of the fixed-interval.

The procedure was also designed to show whether the contiguity of S1 and reinforcement was essential to maintain observing behavior. It is possible to reject the conclusion that S3 and S2 were observed in the first two experiments because of their timing function, and to offer alternative explanations by appealing to occasional instances when the bird pecked the clock key just before it was reinforced for pecking the food key. Then observing behavior might be interpreted as a complex superstitious chain, or as being intermittently reinforced by S1, a conditioned reinforcer by virtue of its close relation to a food-reinforced response. Therefore, during most of this experiment, coincidence of S1 and reinforcement was made impossible.

Procedure

The schedule on the food key was FI 6. Sessions usually lasted 4 hr. The clock key was distinguished by being illuminated red, except during reinforcement. The sequence of stimuli, available in successive minutes of FI 6, was a vertical line, a plus sign, an inverted isosceles triangle, a diamond, a square, and a circle, identified as S6, S5, S4, S3, S2, and S1, respectively. Each stimulus was projected in white light on the red key. To the experimenter, the stimuli appeared as white on red, and were very distinct. The sizes of the stimuli were such that they were all just contained within the circular aperture of the key. The positions of food key and clock key switched after every reinforcement.

After 30 sessions the schedule on the food key was changed. Now a response on the food key was reinforced provided 6 min had elapsed since the last reinforcement, and provided that an observing response had not occurred in the previous 4 sec. That is, a minimum delay of reinforcement of 4 sec was imposed after changing over from the clock key to the food key. Therefore, food could not be obtained in the presence of S1. The added contingency will be called 4-sec change-over delay (COD), following the terminology of Herrnstein (1961). The 4-sec COD remained in effect during the VR clock tests and the stopped clock tests. The tests, similar to those described in Exp. 2, lasted 20 sessions including intervening spaced control sessions. The 4-sec COD contingency was eliminated for eight sessions at the end of the experiment.

Results

Observing behavior was readily established. Observing response rate in successive minutes usually varied from zero up to about 20 per min. The rate over an entire session was usually of the order of 5-10 per min. In some sessions more observing responses than food key responses were made. Figure 10 shows cumulative records of performance on both keys.

The rate of observing responses increased in each minute of the fixed-interval. Figure 11 shows the ratio of observing responses in the sixth minute to observing responses in the fifth. Each point represents results from one session. Results from the first 10 sessions are not shown. The control sessions during which a 4-sec COD was in effect are indicated. The VR test sessions and stopped clock test sessions are not included in Fig. 11. Therefore, all sessions in Fig. 11 are consecutive except those where the COD was in effect. It can be seen in Fig. 11 that in nearly all cases the rate in the sixth minute was greater than the rate in the fifth, even when the COD was in effect. In contrast, all the corresponding measures for Exp. 2 were less than one and would appear below the line in Fig. 11. The COD contingency perhaps reduced the relative rate in the sixth minute to some extent, but even with no COD the bird usually stopped responding on the clock key some time before reinforcement was available.

Figure 12, which has the same format as Fig. 5, shows the effect of the VR clock tests. The results show that, during tests, responding on both keys was more evenly distributed within the interval. During the tests response rate on the food key was still positively accelerated up to reinforcement (though less so than in control sessions), probably because the stimuli occasionally obtained from the clock continued to exert some control.

The stopped clock tests were made in a single session since it was found that observing behavior rapidly extinguished when the clock was stopped at a particular reading. The results are shown in Fig. 13. The effects of stop-

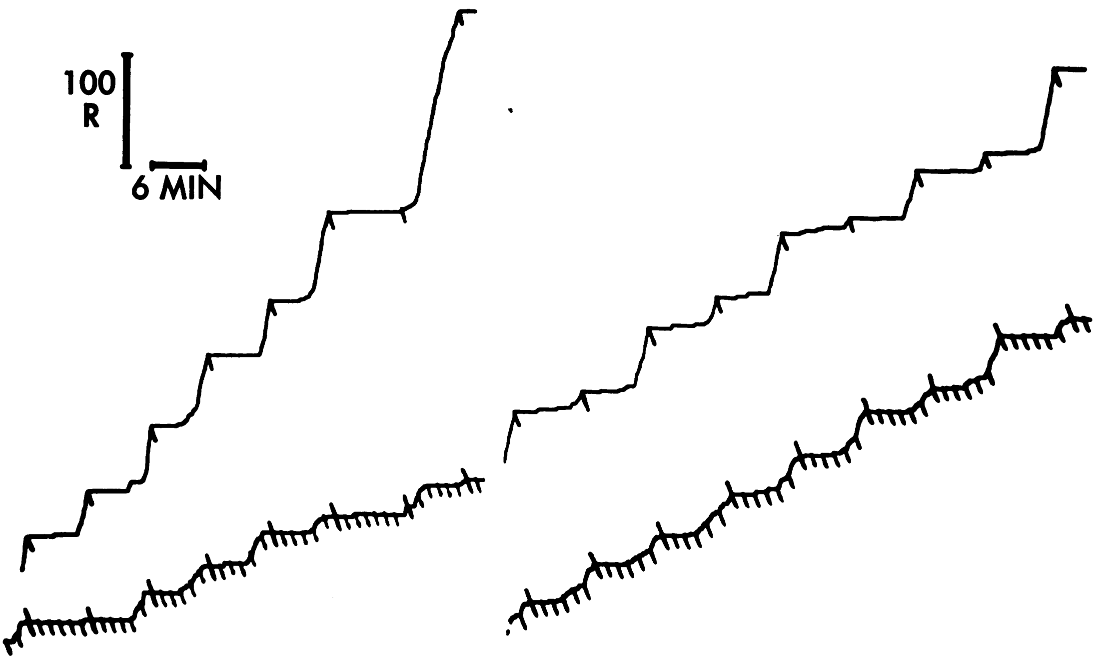

Fig. 10. Concurrent performance on FI 6 and the optional clock. The pair of records on the left was taken from a session in which the COD was in effect, and the pair on the right from a session in which there was no COD (see text). Minutes since reinforcement are marked by pips on the records of clock performance (lower traces). The elongated pips indicate reinforcement.

ping the clock at each separate reading are not shown. The open bars represent the average effect of stopping the clock at each reading in turn. The solid bars represent control data for the previous session and not, as in the other similar figures (Fig. 5, 7, 8, 9, 12), the average of several sessions. The control session happened to be one in which the observing response rate was higher in the fifth than in the

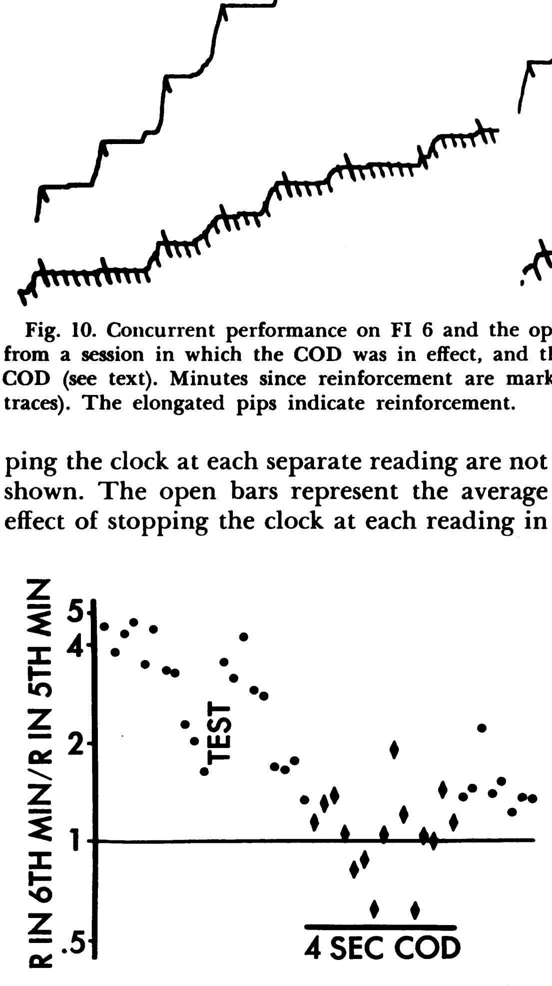

Fig. 11. Ratios of the number of responses on the clock key in the sixth minute of FI 6 to the number in fifth minute of FI 6. Each point represents one session. In the sessions marked "4-sec COD" and represented by lozenges, reinforcement on the food key could not occur sooner than 4 sec after a response on the clock key. The results of test sessions, which occurred when the 4-sec COD was in effect, are not shown. Otherwise, all sessions are successive. A VR test, results of which are not reported in the text, was given in the session marked "test".

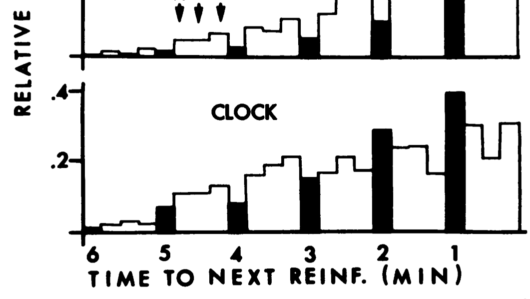

Fig. 12. Relative frequency of responding on each key in successive minutes of FI 6. See Fig. 5.

sixth minute. The results show that stopping the clock produced a virtually complete loss of differentiation of performance on both keys. Very similar results were obtained when the test was repeated. The results indicate that the clock stimuli were exerting very powerful control.

Observation of the bird showed a great deal of unrecorded behavior. Sustained pecking of the cage floor occurred, interrupted by key pecks, for about the first 4 min of the interval. This behavior gave way to erect standing in which the head was pressed against the ceiling, interrupted by pecking the keys and the speaker grille. Repeated tests showed that all these superstitious behaviors were under stimulus control. For example, the bird could be made to peck the floor in the last minute before reinforcement by making the stimulus available on the clock S6 instead of S1. Under normal conditions pecking the floor was virtually never seen in the last minute of the interval.

GENERAL DISCUSSION

In all the experiments a considerable rate of observing behavior was established. The two keys were distinctive, the consequences of responding on them were distinctive, and responding on one of them never produced food. In these respects, the conditions were exactly those that would be used to train a bird to respond on one key and rarely, if ever, on the other key. The present procedure differed from that used for ordinary discrimination (S^D/S^Δ) training only in the systematic nature of the response-produced stimuli for responding to the "negative" stimulus. The maintenance of observing behavior may therefore be attributed to the systematic nature of the response-produced stimuli. That is, these stimuli become conditioned reinforcers.

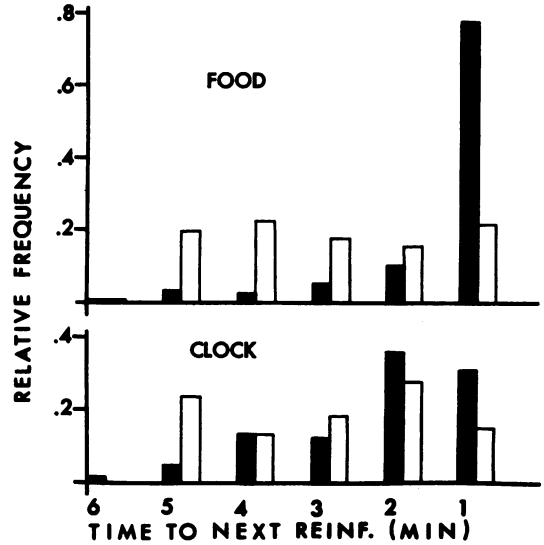

Fig. 13. Relative frequency of responding in successive minutes of FI 6, with the food key and the clock key treated separately. Solid bars represent a control session in which every response on the clock key produced the appropriate stimulus. Open bars represent the results of the following test sessions in which responses on the clock key produced the six clock stimuli in turn, the available stimulus being changed after every reinforcement.

The high rate of switching between two operanda with concurrent schedules of reinforcement can be drastically reduced by adding a COD; that is, a provision that reinforcement never occurs for a short period after a switch (Findley, 1958; Herrnstein, 1961). This result has been interpreted as showing that switching is itself an operant, which the COD weakens simply by delaying reinforcement. It would be unconvincing to interpret the maintenance of observing responses as a consequence of the direct reinforcement of switching behavior, since observing behavior was scarcely diminished by the COD.

The use of the COD was designed to test whether observing behavior was maintained because the final stimulus (S1) was a discriminative stimulus in the simple sense of being the occasion for a reinforced response. While the results rule out that interpretation, S1 can still be regarded as a discriminative stimulus in the sense of a stimulus that initiates a reinforced series of responses, without itself being present at or near reinforcement. This might be called a "trace discriminative stimulus". However, there is no evidence as to the reinforcing properties of a trace discriminative stimulus.

The unrecorded behavior observed in Exp 3 suggests that, by providing "labels"[2] for each minute of the fixed-interval, relatively favorable conditions for the establishment of superstitious behavior were created. Superstitious behavior often appears in short FI's but is not often maintained in FI's longer than a few minutes, presumably because the behavior extinguishes (Skinner, 1948). The maintenance of the superstitious behavior in Exp 3 may therefore be interpreted as further evidence that all clock stimuli, not just the stimulus closest to reinforcement, became reinforcing.

The pattern of observing behavior in Exp 1 and 2 was similar in that the rate declined near reinforcement. The decline could be prevented by providing a further timing stimulus, as shown in Exp 3. Evidently, the birds switched their responses predominantly to the food key once the last timing stimulus had been observed.

The pattern of observing responses was similar to that produced by a very different procedure used by Skinner and Morse (1958). In that experiment, rats were reinforced on a fixed-interval schedule for lever-pressing, but also had access to a running wheel. The cumulative record of running in the wheel was S-shaped between reinforcements, just as were the present cumulative records of observing responses. The similarity of these results suggests that they are due to similar features in the two studies. The terminal decline in rate in both cases argues against the interpretation that the wheel-running or the key-pecking was being superstitiously maintained by the reinforcement for the alternative response. Skinner and Morse interpreted their results in terms of competition between running and bar pressing. But the outstanding question is: what was the source of strength for the running response? The present results suggest that the collateral running might have served to provide the rats with timing stimuli. We stress, however, that our results strongly suggest that timing cannot be accomplished by mere activity without systematic sensory consequences. The disruption of timing in the VR and stopped clock tests, which sometimes occurred along with an increase in the amount of observing activity, supports this view.

The "polydipsia" that occurs between regularly-spaced reinforcements also may sometimes occur at highest rates midway between reinforcements (*e.g.* Segal, Oden, and Deadwyler, 1965). Therefore, the polydipsia is probably not superstitiously reinforced either. Deadwyler and Segal (1965) propose, and give some evidence for, the interpretation that the polydipsia acquires a mediating function, helping to mark the passage of time. This interpretation fits well with the conclusions of the present experiments and with our interpretation of the results obtained by Skinner and Morse (1958).

Gollub (1958) and Kelleher and Fry (1962) showed that three-member FI chains produced prolonged pausing during the first stimulus (S3), and scallops during the second stimulus (S2) and the third stimulus (S1). These results might be taken to indicate that stimuli associated with the last two links, but not the first, were conditioned reinforcers. The fact that the stimulus of the first link (S3) actually suppressed the rate of pecking, compared with performance on the corresponding tandem schedule, might indicate that S3 was aversive. On the contrary, results in Exp 1 show that, though S3 controlled a near-zero rate on the food key, it could sustain a relatively high rate of observing behavior when used as a timing stimulus. Instances of repeated observing of S3 accompanying a zero rate on the food key appear in Fig. 2. This result also illustrates the principle that "responding may occur at a fairly high rate when the reinforcement consists of the production of a stimulus controlling a low rate" (Ferster and Skinner, 1957, p. 671). In general, the present results should encourage a cautious attitude about inferring conditioned reinforcing effects of a stimulus from the performance which the stimulus controls. A stimulus in whose presence a reinforced response is suppressed may nevertheless be a conditioned reinforcer.

The conditioned reinforcing value of a timing stimulus may be a consequence of the fact that it controls behavior appropriate to the prevailing schedule of reinforcement. If this were the case the same principle could account for the conditioned reinforcing effects of timing stimuli and the stimuli of multiple schedules. If the components of a mixed schedule are similar, associated stimuli would not control behavior specifically appropriate to each schedule and, therefore, these stimuli should not be conditioned reinforcers. This analysis predicts the trend of the results of a recent experiment (Kendall 1965a). Kendall showed that the stimuli of Mix FR 50 FR 20 reinforced observing behavior, whereas the stimuli of Mix FR 50 FR 30 did not.

REFERENCES

Deadwyler, S. A. and Segal, Evalyn F. Determinants of polydipsia: VII Removing the drinking solution midway through DRL sessions. *Psychon. Sci.*, 1965, 3, 195-196.

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.

Gollub, L. R. The chaining of fixed-interval schedules. Unpublished doctoral dissertation, Harvard University, 1958.

Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. *J. exp. Anal. Behav.*, 1961, **4**, 267-272.

Kelleher, R. T. Stimulus-producing responses in chimpanzees. *J. exp. Anal Behav.*, 1958, **1**, 87-102.

Kelleher, R. T. and Fry, W. Stimulus functions in chained fixed-interval schedules. *J. exp. Anal. Behav.*, 1962, **5**, 167-173.

Kelleher, R. T., Riddle, W. C., and Cook, L. Observing responses in pigeons. *J. exp. Anal. Behav.*, 1962, **5**, 3-13.

Kendall, S. B. An observing response analysis of fixed ratio discrimination, *Psychon. Sci.*, 1965a, **3**, 281-282.

Kendall, S. B. The distribution of observing responses in a mixed FI-FR schedule. *J. exp. Anal. Behav.*, 1965b, **8**, 305-312.

Segal, Evalyn F., Oden, D. L., and Deadwyler, S. A. Determinants of polydipsia: IV Free-reinforcement schedules. *Psychon. Sci.*, 1965, **3**, 11-12.

Skinner, B. F. "Superstition" in the pigeon. *J. exp. Psychol.*, 1948, **38**, 168-172.

Skinner, B. F. and Morse, W. H. Concurrent activity under fixed-interval reinforcement. *J. comp. physiol. Psychol.* 1957, **50**, 279-281.

Wyckoff, L. B. The role of observing responses in discrimination learning. Part 1. *Psychol. Rev.* 1952, **59**, 431-442.

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