FIXED-INTERVAL BEHAVIOR: EFFECTS OF PERCENTAGE REINFORCEMENT¹

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The percentage of fixed intervals terminating with food presentation was varied parametrically. Intervals that did not end with food were terminated by a stimulus uncorrelated with food presentation (a timeout stimulus). In Experiment I, the pigeons' response rates were an inverted U-shaped function of the percentage of food presentations: decreasing the percentage from 100% to 90%, 70%, or 50% produced an increase in response rates; lower percentages decreased the rates. The patterns of responding in the 100% condition differed from those of the other conditions. In Experiment II, the chamber was darkened after food presentations and timeouts. Response rate was directly related to the percentage of food presentations: decreasing the percentage decreased the response rate. Characteristic fixed-interval patterns of responding were maintained as long as there were occasional food presentations; pausing followed by positively-accelerated responding occurred in percentage conditions ranging from 7% to 100%. The ability to maintain fixed-interval performance with percentage reinforcement suggested that the behavioral sequences occurring in each interval may operate as unitary responses.

A simple fixed-interval (FI) schedule specifies that reinforcement follows the first response occurring a constant time period after the preceding reinforcement. It is also possible to reinforce fixed-interval behavior intermittently instead of every time an interval is completed. In a second-order schedule involving fixed-interval components, only occasionally does the completion of a fixed interval terminate in food presentation. For example, Kelleher (1966) presented food after every thirtieth fixed interval; this is a second-order schedule having fixed-interval components reinforced according to a fixed-ratio (FR 30) schedule.

A consistent finding with second-order schedules has been that if each fixed interval ends with a brief stimulus paired with food presentation, responding is similar to that occurring when food follows every interval (Byrd and Marr, 1969; de Lorge, 1967; Kelleher, 1966; Marr, 1969; Stubbs, 1969). Namely, a pause at the outset of each interval is followed by a positively accelerated rate of responding. If, however, the brief stimulus is not paired

with food presentation, this pattern may not prevail. For example, Byrd and Marr (1969) found that pigeons paused after food presentation but did not do so after the presentation of a brief nonpaired stimulus. Neuringer and Chung (1967) and Stubbs (1971), however, found that a stimulus did not have to be paired with food presentation to maintain pausing and positive acceleration. A stimulus uncorrelated with food presentation had effects identical to that of food in controlling the rate and pattern of responding.

The discrepancy between Neuringer and Chung's and Stubbs' and the other data indicates the importance of obtaining further information about the effects of stimuli not paired with food presentation. The present experiments studied such a procedure by varying the relative number of fixed intervals ending with food and with a stimulus not paired with food. In Ferster and Skinner's (1957) terminology, these were percentage reinforcement experiments; in second-order schedule terminology, they involved the reinforcement of fixed-interval behavior according to variable-ratio schedules. Previous research has studied fixed-ratio and variable-interval behavior under a range of percentage reinforcement conditions (Crossman, 1968; Ferster and Skinner, 1957; McMillan, 1971), but there are few comparable data with fixed-interval sched-

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ules. Staddon and Innis (1969) investigated percentage reinforcement with fixed-interval schedules but used only a condition in which 75% of the intervals ended with food presentation, while Neuringer (1968) studied a range of percentages but used a very short fixed-interval schedule (FI 5-sec) and did not report data on the patterning of responses.

EXPERIMENT I: TERMINATING
FIXED INTERVALS WITH
FOOD OR WITH A STIMULUS NOT
PAIRED WITH FOOD

By varying the proportion of intervals ending with food presentation, it was possible to determine the behavior maintained by a stimulus uncorrelated with food over a range of percentage reinforcement values. Intervals that did not end with a 4-sec food presentation were terminated by a 4-sec change in the stimulus present on the response key. Thus, the stimulus was never directly correlated with food presentation, and every interval was ended and preceded by an event of equal duration.

METHOD

Subjects

Three White Carneaux pigeons were maintained at 80% of their free-feeding weights. All had extensive experimental histories with a variety of reinforcement schedules, and Bird 16 had been exposed to differential reinforcement with respect to three stimuli differing in color.

Apparatus

The experimental chamber was a standard single-key unit (Ferster and Skinner, 1957).

The 0.75-in. (2-cm) diameter response key (R. Gerbrands Co.), operated by a minimum force of 0.12 N was transilluminated by either two green or two red 7-w lamps. A 2-in. (5-cm) square aperture centered 3.25 in. (8 cm) below the key provided occasional access to Purina Pigeon Checkers, the birds' standard diet. During the 4-sec feeder cycles, a 1.1-w white lamp illuminated the aperture. A lamp (GE 25T10/1F) in series with a 300-ohm resistor served as a houselight and provided continuous dim general illumination. White noise masked most extraneous sounds.

Procedure

Throughout the experiment, Bird 4 had an FI 8-min schedule, Bird 16 an FI 4-min schedule, and Bird 40 an FI 2-min schedule. The schedules were different for each bird in order to obtain some estimate of the generality of effects over a range of interval values without the large increase in the number of sessions that would be required to study each bird under each interval. Each of the five experimental sessions conducted each week terminated when 30 intervals were completed.

The key was transilluminated by the green lamps when a fixed interval was in effect and during food presentations. Intervals not ending with a food presentation terminated with a change in the key color from green to red for 4 sec. Responses while the key was red had no scheduled effect and were not recorded. The periods of red key presentation are referred to as timeouts. Food or the timeout were always produced by the first response occurring at the end of the interval.

The percentage of the 30 intervals that were followed by food presentation was varied according to the sequence shown in Table 1. Exposure to the 100% condition (all intervals

Table 1
Sequence of Conditions: Experiment I

Bird 4 FI 8-min			Bird 16 FI 4-min			Bird 40 FI 2-min		
Condition	Sessions		Condition	Sessions		Condition	Sessions	
1. 100%	40		1. 100%	40		1. 100%	40	
2. 90%	17		2. 50%	17		2. 30%	18	
3. 100%	22		3. 100%	12		3. 100%	12	
4. 10%	25		4. 90%	18		4. 70%	18	
5. 100%	45		5. 100%	14		5. 100%	12	
6. 50%	17		6. 30%	34		6. 10%	35	
7. 100%	12		7. 100%	14		7. 100%	12	

ending with food presentation) preceded and followed each lower percentage condition. Taking the 30 intervals in three blocks of 10, the same percentage of intervals ended with food presentation in each block. The first interval of every session ended with food. A stepping switch scheduled food presentations and timeouts; the sequence was constant throughout each condition. A condition was maintained for a minimum of 12 sessions, and until behavior appeared stable as judged from cumulative records, and until the quarter-life (Herrnstein and Morse, 1957)—the percentage of the interval that elapsed before the first 25% of the total responses were emitted—for each of five successive sessions was within 5% of the median value for the sessions. Quarter-life was computed for responses cumulated over each entire session on the basis of Gollub's (1964) report that such a procedure yields results corresponding closely to the mean quarter-life for individual intervals.

RESULTS

Response rates increased immediately when timeouts were substituted for food presentations: the rate in the first session was from 0.10 to 0.31 responses per second higher than that occurring in any of the five preceding sessions

Fig. 1. Response rate for each bird.

of the 100% condition. These increases occurred because of curtailed pauses at the outset of intervals preceded by timeouts. The single exception (Bird 40, 70% condition) revealed no immediate rate change with the transition from 100% to 70% food presentations.

Fig. 2. Quarter-life for each bird.

With maintained exposure to each condition, the rates often changed. Figure 1 shows the median rate of responding for the last five sessions of each condition, and Figure 2 shows the median quarter-life. Response rates for the individual sessions usually were within 10% of the medians. The rate and quarter-life shown for the 100% condition is a median of medians: the median for the last five sessions of each of the four exposures was within 10% of the overall median. Reading from right to left in Figure 1, response rate first rose and then declined as the percentage of food presentations decreased. Figure 2 shows that quarter-life decreased monotonically for Birds 4 and 40, and was constant and then decreased for Bird 16. The source of the rate and quarter-life changes can be seen from the cumulative records.

Figure 3 shows the cumulative records for Bird 16 (FI 4-min) for the last session of each condition. When all intervals ended with food (Segment A), there was a period without responding at the start of each interval. After this pause, the rate of responding was either uniformly positively accelerated, or first positively accelerated and then steady or somewhat negatively accelerated. When 90% of the in-

Fig. 3. Cumulative records for Bird 16 for the 100% condition (A), the 90% condition (B), the 50% condition (C), and the 30% condition (D). The response marker reset at the completion of each interval. The event marker at the bottom of each record offset during a timeout. Neither responses nor time were recorded during food presentations or timeouts.

Intervals terminated with food (Segment B), the behavior was similar to that of the 100% condition. However, there were intervals containing more responses than were evidenced under the 100% condition. These intervals, marked "a" on the record, occurred in all of the last five sessions and always appeared after successive intervals ending with food presentation. The 50% condition (Segment C) produced more negative acceleration after the initial positive acceleration than was observed in the 100% and 90% conditions, but again the patterns of responding did not differ in intervals following food presentation or timeout. Intervals with more responses than occurred in the 100% condition occasionally followed both food presentations (see intervals marked "a") and timeouts (intervals marked "b"). When 30% of the intervals ended with food (Segment D), periods without responses occurred at various parts of individual intervals, and some intervals were not completed on time. In addition, responding was different following food and following timeouts. After a food presentation, there was usually a pause followed by a low response rate, but after a timeout

many intervals began with key pecks without a preceding pause. The absence of positively accelerated responding preceded by a pause in the post-timeout resulted in the decreased quarter-life for the session. Intervals with a large number of responses (as at "b") occurred only after timeouts.

Figure 4 shows the behavior of Bird 40 (FI 2-min). The 100% condition (Segment A) produced pausing followed by positively accelerated responding. Under the 70% condition (Segment B), this pattern followed food presentation. After a timeout, responding was maintained from the beginning to the end of most intervals. Bird 40 differed from Bird 16 in that intervals containing the most responses always followed timeouts. Differential pausing after food and timeout was maintained in the 30% condition (Segment C), and intervals with few responses became more prevalent than under the 100% and 70% conditions. Under the 10% condition (Segment D), responding was maintained similarly to the 30% condition. Since there were fewer food presentations, there were correspondingly fewer intervals with pauses followed by posi-

Fig. 4. Cumulative records for Bird 40 for the 100% condition (A), the 70% condition (B), the 30% condition (C), and the 10% condition (D). Recording as in Figure 3.

tive acceleration. Responding after timeouts typically occurred at a stable or negatively accelerated rate, although sometimes positive acceleration did occur. Quarter-life declined as the number of intervals that began without a pause increased.

Figure 5 shows the behavior of Bird 4 (FI 8-min). The 100% condition produced behavior like that observed with the other birds (Segment A). The rate increase with the 90% condition (Segment B) was the outcome of the factors that operated separately in Birds 16 and 40. There were high response intervals temporally remote from timeouts (intervals marked "a") as had occurred with Bird 16, as well as responding at a steady rate after a timeout, as had occurred with Bird 40. With the 50% condition (Segment C), pauses or pauses following a brief period of responding appeared after about half of the timeouts. The rate increase over the entire session from the 90% to the 50% condition occurred because additional timeouts maintain increased numbers of intervals beginning without a pause. The occasional rate enhancements seen after intervals ending with food presentation in the 90% condition did not occur in the 50%

condition. Decreasing the percentage of food presentations to 10% (Segment D) frequently produced intervals with few responses and pauses that extended beyond the interval parameter value.

Since rate increases after timeouts occurred with the birds given the FI 2-min and FI 8-min schedules, but not with the bird given the FI 4-min schedule, there did not appear to be an orderly relation that exists between interval value and post-timeout responding. A rate increase following food presentation occurred only with the FI 4-min and FI 8-min schedules. As a result, interval duration may have influenced the latter effect. Staddon and Innis (1969) also observed the first but not the second effect under an FI 2-min schedule.

In summary, response rates usually increased in the first session independent of the percentage of intervals ending with food. The terminal behavior, however, depended on the particular condition. Response rate first increased and then decreased as the percentage of intervals ending in food presentation decreased. The effects on patterning were less uniform across birds: Bird 4 and Bird 40 responded

Fig. 5. Cumulative records for Bird 4 for the 100% condition (A), the 90% condition (B), the 50% condition (C), and the 10% condition (D). Records are of the final part of each session. Recording as in Figure 3.

differently after timeouts and after food presentations, whereas Bird 16 did not display this difference until the percentage of intervals that ended with food was reduced to 30%.

EXPERIMENT II: EFFECTS OF SEPARATING INTERVALS WITH BLACKOUTS

Experiment II developed from the speculation that a stimulus that neither preceded nor was contiguous with food presentation might maintain behavior similarly to food if it clearly demarcated the end of each interval. Casual observations during Experiment I revealed that the birds occasionally continued to respond during the timeout and then responded throughout the next interval. It seemed possible, therefore, that the timeouts could have been ineffective in signalling the end of the interval. The procedure of Experiment II in-

involved the addition of a stimulus change that would tend to stop responding between successive intervals. A period of complete darkness (a blackout) is an event that disrupts responding in pigeons (Ferster and Skinner, 1957), and has maintained positively accelerated responding when it was interpolated during fixed intervals (Dews, 1962, 1965). In this experiment, as in Experiment I, the percentage of intervals ending with food presentation was varied. In addition, a 10-sec blackout followed every food presentation and timeout. Staddon and Innis (1969) found that blackouts longer than 8 sec could function similarly to food when food followed 75% of the fixed intervals. The blackouts in their experiment were presented contiguously with food presentations as well as when food was omitted. The present experiment studied a range of percentage reinforcement conditions without the contiguous presentation of food and blackout.

METHOD

Subjects and Apparatus

The procedure differed from Experiment I in that a 10-sec period with the houselight and keylights turned off (a blackout) followed each interval. Responses during the blackout were recorded but had no scheduled consequences. Again, different conditions involved variations in the percentage of intervals that were followed by food presentation and by timeout. The key remained green during the 4-sec food presentations; other intervals terminated with a 4-sec key-color change from green to red (timeout). The 10-sec blackout followed every food presentation and timeout. As in Experiment I, Bird 4 had an FI 8-min schedule, Bird 16 an FI 4-min schedule, and Bird 40 an FI 2-min schedule.

Table 2 shows the sequence of conditions. Each condition in which all intervals did not end with food presentation was preceded by the 100% condition. In addition, after the range of percentage conditions had been studied, Bird 16 was shifted directly from a 0% condition (no food presentations) to the 7% condition (first and sixteenth intervals ended with food). Finally, the birds were changed to the procedure of Experiment I involving no blackouts, and were given the lowest percentage condition used in Experiment I either immediately or after exposure to the 100% condition. These last conditions investigated whether the behavior of Experiment I would

be recovered after the additional history with fixed-interval schedules and percentage reinforcement involving blackouts.

RESULTS

The transitory rate-enhancing effects of timeouts observed in Experiment I either did not occur at all or were minimal in Experiment II. In 11 of the total of 16 conditions in which a lower percentage value immediately followed the 100% condition, the rate in the first session was within the range observed in the preceding five sessions. Of the five changes that did occur, three were rate increases (Bird 16, 30%; Bird 40, 30% and 10%) and two were decreases (Bird 4, 7%; Bird 16, 10%). In all five, the first session rate was within 0.06 responses per second of the closest rate observed in the preceding five sessions.

Figure 6 shows the final rates of responding under each condition. Again, the behavior with each exposure to the 100% condition was sufficiently similar to permit showing it with a single point. Response rates remained approximately constant at the higher percentage values. Orderly changes did not appear until 30% of the intervals ended in food presentation for Birds 4 and 16 and until the 10% condition for Bird 40. Under those conditions, rates decreased. Rather than the inverted U-shaped function found in Experiment I, decreasing the percentage of intervals ending with food generated curves that were essen-

Table 2
Sequence of Conditions: Experiment II

Bird 4 FI 8-min		Bird 16 FI 4-min		Bird 40 FI 2-min	
Condition	Sessions	Condition	Sessions	Condition	Sessions
1. 100%	24	1. 100%	38	1. 100%	16
2. 70%	18	2. 70%	21	2. 50%	16
3. 100%	17	3. 100%	12	3. 100%	18
4. 30%	31	4. 10%	31	4. 90%	16
5. 100%	16	5. 100%	18	5. 100%	20
6. 50%	19	6. 30%	17	6. 70%	20
7. 100%	17	7. 100%	14	7. 100%	16
8. 7%	20	8. 7%	17	8. 30%	17
9. 100%	16	9. 100%	12	9. 100%	12
10. 10%	17	10. 0%	3	10. 7%	16
11. 100%	16	11. 7%	12	11. 100%	14
No blackout					
12. 10%	17	12. 30%	15	12. 10%	12
No blackout		No blackout			
				13. 10%	14
				No blackout

Fig. 6. Response rate for each bird.

tially flat initially and then decreased. There were no responses during the blackouts in any condition.

Cumulative records from the final sessions of four conditions for Bird 40 appear in Figure 7. In Experiment I, when 70% of the intervals ended with food, this bird had responded at a high rate at the outset of every interval preceded by a timeout. Now, however, the behavior was essentially the same in the 100% condition (Segment A) and in the 70% condition (Segment B) whether intervals were preceded by timeouts or by food presentations. Records for the 90% and 50% conditions were indistinguishable from those of the 100% and 70% conditions. Under the 30% condition (Segment C), a number of intervals contained few responses. However, the pattern of responding remained stable. Even when 7% of the intervals ended with food (Segment D), and in the 10% condition as well, the rates and patterns were similar in each interval and not unlike those occurring in the other conditions. Long pauses appeared under the 10% and 7% conditions, and there were intervals with few responses; these were the bases of the rate decreases depicted in Figure 6.

The similarity in behavior in the individual intervals meant that quarter-life, a summary statistic that measures patterning, was representative of each interval. In Experiment I,

quarter-life revealed overall effects but did not represent patterning in individual intervals when patterns differed depending on whether an interval was preceded by a food presentation or by a timeout. The median quarter-life for the last five sessions of each condition is shown in Figure 8. The data for Bird 40 confirm the cumulative records of Figure 7 in showing that the pattern of responding was not affected markedly by the percentage of food presentations. Since the behavior in individual intervals was equally stable for Birds 4 and 16, Figure 8 summarizes their patterns adequately as well. All of the conditions produced a pause at the onset of each interval followed by positively accelerated responding. The quarter-life was greater than 0.50, except in the 7% condition for Bird 4. Values of this magnitude mean that over half of the interval elapsed before the first 25% of the total responses were emitted; they were the outcome of maintained pausing followed by positively accelerated responding. Even when the decreased frequency of food presentation lowered the rates (Figure 6), the patterns were maintained. The decreases in quarter-life to between 0.48 and 0.54 with the lowest percentage of food presentations were the outcome of the lowered response rates, but even then the basic fixed-interval pattern was maintained.

Figure 8 also shows the quarter-life for the 100% condition of Experiment I, the only condition of that experiment in which quarter-life was representative of the behavior in individual intervals for all birds. The blackout increased the quarter-life under the 100% condition by prolonging the pause at the beginning of each interval, thereby accentuating the rate differences in the early and late sections. The quarter-life for the 100% condition without blackouts was comparable to that of the 30%, 10%, and 7% conditions with blackouts.

When blackouts were omitted as the final conditions of Experiment II, the behavior was like that in Experiment I. For Bird 16, responding was related to whether the preceding interval ended with food or with a timeout. Birds 4 and 40 had the variety of patterns observed in Experiment I. These data indicated that the differences observed in Experiment I and II could not be attributed to the additional period of exposure to fixed-interval schedules.

Fig. 7. Cumulative records for Bird 40 for the 100% condition (A), the 70% condition (B), the 30% condition (C), and the 7% condition (D). Recording as in Figure 3. Neither responses nor time were recorded during blackouts.

To determine how well the timeout-blackout combination would maintain responding in the absence of food presentations, Bird 16 was studied under a 0% condition. Segment B of Figure 9 shows the behavior in the third session. Few intervals were completed during the session, and responding was minimal throughout. Maintained responding, therefore, did depend on food presentations. With the change from the 0% condition to the 7% condition, responding resumed and pausing followed by positively accelerated responding prevailed (Segment C). Thus, few food presentations were necessary for the timeout and blackout to control patterns similar to those observed when each interval ended with food (Segment A), but it was essential that there be some.

DISCUSSION

In Experiment I, when successive intervals were not separated by a blackout, response rate first increased and then decreased as the

percentage of intervals ending with food presentation decreased. The rate increases occurring when between 50% and 90% of the intervals ended with food presentation replicated Staddon and Innis' (1969) and Zimmerman's (1971) reports that terminating 75% or 83% of the intervals with food produced higher rates than did a 100% condition, and extended these findings to both higher and lower percentages. The complete inverted U-shaped function has been observed previously in studies manipulating the percentage of reinforcements in runways under discrete trial conditions (Coughlin, 1970; Weinstock, 1958), with running speed and reciprocal latency as the dependent variable.

Based on experiments finding that rate increases occurred because intervals following food omission showed a maintained high rate from beginning to end, Staddon and Innis (1969) suggested that temporal control over behavior was weakened when some other stimulus was substituted for food. The present study observed the same effect. This phenom-

Fig. 8. Quarter-life for each bird. Filled points are from Experiment II, unfilled points are from Experiment I.

enon also fits Amsel's (1967) view that nonreinforcement enhances ongoing responding via a motivational mechanism. It seems, however, that both accounts lead to the expectation

that rate increases would be restricted to immediate effects of timeouts. They do not appear to explain the occasional rate increases that were not tied to the nature of the preceding stimulus event but occurred after a series of intervals ending with food.

In Experiment II, the addition of a blackout at the end of each interval eliminated both transient and long-term increases. The overall rate of responding was related to the frequency of food presentation; however, rates did not decrease markedly until food presentation terminated 30% or fewer of the intervals. There was neither diminished pausing at the outset of intervals preceded by timeouts nor increased responding during some other intervals. In this respect, the blackouts had effects like those of the longest durations used by Staddon and Innis (1969) who found substantial rate changes only with blackouts of 4 sec or shorter. The present 10-sec blackout (or 14-sec total of timeout plus blackout) seemed to operate similarly to their 16-sec and 32-sec durations.

The major finding of Experiment II was that characteristic fixed-interval patterns were maintained by a timeout followed by a blackout as long as a few intervals ended with food presentation. Whether the effectiveness of the blackout resulted from backwards pairing with food (blackouts always followed food presentations as well as timeouts) cannot be ascertained from the present data. In any event, the timeout-blackout combination and food presentation both resulted in a pause followed by positively accelerated responding even when

Fig. 9. Cumulative records for Bird 16 for the 100% condition (A), the 0% condition (B), and the 7% condition (C). Recording as in Figures 3 and 7.

the overall rate decreased under the lower percentage conditions. Discontinuing all food presentations eventually eliminated responding. Crossman (1968) observed a similar relationship with fixed-ratio schedules: few food presentations were necessary to maintain characteristic fixed-ratio behavior.

The stable sequences of behavior observed in the successive intervals of Experiment II fit an interpretation based on a unitary character of responses produced by fixed-interval schedules. Reinforcing fixed-interval performance according to a variable-ratio schedule generated stable behavior in successive intervals, just as reinforcing individual key pecks on a variable-ratio schedule generates stable response rates. The unitary nature of the behavior is implied by its similarity to an individual response in its ability to be maintained by intermittent reinforcement, and is implied even more strongly when it shows schedule effects like those displayed by individual responses. The present experiments suggest that what is necessary for fixed-interval behavior to operate as a unitary response is that the completion of each sequence be demarcated by an event that effectively terminates the sequence.

The blackout invariably disrupted key-pecking, and the timeout did not do so consistently; the blackout maintained behavior similarly to food, and the timeout usually did not. This correlation suggests that the ability of a stimulus to produce sequences like those occurring with food depends on the power of the stimulus to disrupt behavior. More systematic data both support and indicate the limitations of this hypothesis. Staddon (1972) presented one of six possible 4-sec stimuli at the completion of each interval: food plus a vertical line (F + V), the vertical line alone (V), a bright light (L), an intense sound (S), the light and sound (S + L), or a blackout (B). The rates emitted *during* the stimuli were ordered as follows from lowest to highest (no data are reported for the F + V condition; presumably the birds did not peck the key during food presentation): S + L, S, L, B, V. Since this ordering represents the relative ability of each stimulus to disrupt key pecking, S + L disrupting it the most and V disrupting it the least, the expectation from the "disruption hypothesis" is that S + L would best preserve the integrity of each sequence and V would

do so worst. Yet, as measured by the duration of the pause at the start of the next interval, the pattern was maintained best by V (the stimulus paired with food presentation), and then by S + L, L, S, and B in that order. Staddon notes that he has observed this lack of correlation in other experiments as well. However, there is a positive correlation in the specific data reported if the stimulus paired with food (V) is excluded. It may be, therefore, that the ability to disrupt ongoing responding does determine the effects of a stimulus that is never paired with food.

Neuringer and Chung (1967) and Stubbs (1971) found that a 1-sec or 0.75-sec stimulus functioned similarly to food. However, these are the only experiments showing such effects with a brief unpaired stimulus. Byrd and Marr (1969), de Lorge (1967), Kelleher (1966), Staddon (1972), Staddon and Innis (1969), Stubbs (1969), and the present Experiment I used stimuli ranging from 0.5 sec to 4 sec in duration and failed to obtain the same behavior as when intervals ended with food presentation. Stubbs (1971) used interval values, stimuli, and birds with experimental histories comparable to those of the other experiments; why he obtained different data is puzzling. Neuringer and Chung's effect may be attributable to their 5-sec intervals since other studies used fixed intervals of 30 sec or longer. Very brief fixed intervals could establish behavior that is more like that found with fixed-ratio schedules than with longer fixed-interval schedules. Stimuli like those used by Neuringer and Chung have generated patterns of behavior with fixed-ratio schedules similar to those generated by food. When Kelleher, Fry, and Cook (1964) and Zeiler (1970) followed some ratios with a brief stimulus that was never correlated with food, responding did not differ noticeably depending on whether a ratio ended with these events or with food. Since, in addition, Neuringer and Chung observed identical behavior when they substituted a fixed-ratio for the fixed-interval schedule, it does seem possible that their findings characterize fixed-ratio-like performance.

Puzzling discrepancies among different experiments mean that all of the variables that determine the effectiveness of uncorrelated stimuli in maintaining fixed-interval performance have not yet been isolated. Some have been shown. Stubbs (1971) found that the

amount of stimulus change involved in the stimulus presentation is important: the more radical the change, the better the behavior is maintained. This fits the present data, since the blackout that involved turning off both the keylight and the houselight was more of a change than the timeout, which involved only a change in the color of the keylight. In addition, Stubbs' suggestion that particular stimuli are inherently more effective than others may certainly be true in the case of blackouts and pigeons. Staddon and Innis (1969) found that blackouts maintained responding similarly to food in pigeons but not in rats, a finding consistent with others showing that blackouts have distinctive effects on pigeons (c.f., Ferster and Skinner, 1957, p. 35). Other factors involve an organism's history with respect to a particular stimulus. Kelleher (1966) observed that a stimulus previously but not currently paired with food presentation persistently maintained responding. Another example of an historical effect occurred in Experiment I. Bird 16 previously had a red key as a discriminative stimulus correlated with nonreinforcement. In Experiment I, this bird had similar patterns of responding after food and red-key (timeout) presentations under conditions when the other birds that did not share the history responded differently after the two events.

There is no evidence that stimuli can maintain fixed-interval behavior in the absence of occasional primary reinforcement; even the blackout of Experiment II lost its effectiveness when food was discontinued. Whether, as Neuringer and Chung (1967) suggest, it is necessary for food and the stimuli to appear according to the same schedule, or, whether as Kelleher's (1961) data on stimulus effects under conditions of extinction imply, stimuli can appear according to a different schedule than food, is an open question. An answer to that question would reveal if stimuli preserve the specific sequence that is intermittently reinforced by food, or if food functions to maintain responses that can be organized into certain sequences by behaviorally significant stimulus events.

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