*THE EFFECT OF MULTIPLE S^A PERIODS ON
RESPONDING ON A FIXED-INTERVAL SCHEDULE:
IV. EFFECT OF CONTINUOUS S^A WITH
ONLY SHORT S^D PROBES¹*

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Pigeons were studied under FI 500 sec in which an S^A was present throughout the interval except during the terminal 50-sec segment and one earlier 50-sec segment. Very little responding occurred during the presence of S^A. The rate of responding in the earlier 50-sec S^D segments was lower than in the terminal S^D segment. There was a clear trend for the rate of responding in the earlier S^D segment to be progressively higher the later it occurred in the course of the FI 500 sec. This trend was shown roughly to parallel the increasing rate of responding in a conventional FI 500 sec with no interruption by S^A. Since the changing tendency to respond through the FI survives massive disruption by S^A, it is concluded that the control of responding through the FI does not require continuous mediating behavior. It is suggested that it is the decaying retroactive influence of the reinforcer on responses that occurred longer and longer before the reinforcer occurred which produces the familiar scalloped pattern of responding under FI schedules.

Previous papers in this series have shown (Dews, 1962, 1965) that a general scalloped pattern of cumulated responding under a fixed-interval schedule of reinforcement (FI) survives interruption of the individual intervals by S^A periods. It was concluded that the rate of responding in any particular short period during the course of the interval is determined by the temporal relation of the short period to the beginning and end of the interval, rather than by the behavioral activities before and after the short period. An extreme case of interference with responding is the imposition of an almost continuous effective S^A condition throughout the "fixed interval". Short S^D probes can then be inserted in individual intervals at different times after the start of the interval to examine the tendency to respond at that time. If the relative tendency to respond during these probes, as a function of position in the interval, recapitulates the relative rates of responding at corresponding periods of uninterrupted fixed intervals, then the previous conclusion that the pattern of fixed interval responding does not necessarily require continuous responding is further strengthened.

S^D probes of duration equal to one-tenth the length of the fixed interval have been inserted as the second, third, fourth, fifth, sixth, seventh, or eighth decimal part of the interval. The tenth segment, concluding with a response followed by food, was of necessity always S^D. The rate of responding in the isolated decimal S^D parts resembled closely the rate of responding in the corresponding parts of uninterrupted fixed intervals.

Materials

Three male White Carneaux pigeons, numbered 44, 152, and 157, were maintained near 400, 480, and 475 g respectively throughout the experiments. Their respective weights on free feeding were about 550, 525, and 590 g. The apparatus, response, and food reinforcer were standard and the stimuli were the same as those used in the previous experiment (Dews, 1962).

Schedules

The basic schedule was FI 500 sec TO 50 sec. During the TO period, no lights were present. The key light was present throughout the FI 500 sec and thereafter until a response occurred. The 500-sec interval was subdivided into 10 consecutive segments each of 50 sec. During the tenth segment (450 sec to 500 sec from the beginning of the interval), and thereafter until a response occurred (followed by

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the reinforcer), no houselight was present. The presence of the key light but not the houselight was thus S^D and the houselight was an S^A . In standard sessions the houselight was present during segments 1, 3, 5, 7, and 9; S^D segments were 2, 4, 6, 8, and 10. In probe sessions the houselight was present continuously throughout the interval except during the tenth and one earlier segment, *viz.* 2, 3, 4, 5, 6, 7, or 8.

Procedure

All subjects had had extensive experience under FI schedules of reinforcement (and others). In the first phase of the present experiments, they were subjected to at least 75 standard sessions each of 20 cycles of FI 500 sec TO 50 sec, in which the houselight (S^A) was present during alternate 50-sec segments. Standard sessions were continued daily, five days per week, except on the days of probe sessions. In any single probe session, there was no houselight in the same segment (S^D segment) of all intervals. Two, and only two, sessions were observed with the first S^D segment in each of the positions two through eight. The various positions of the single S^D segment were studied in the following sequences: for Bird 44—5, 7, 3, 8, 8, 2, 2, 6, 6, 4, 4, 7, 3, and 5; For Bird 152—5, 8, 8, 2, 2, 6, 6, 4, 4, 7, 3, 5, 7, and 3; for Bird 157—5, 3, 7, 8, 8, 2, 2, 6, 6, 4, 4, 7, 3, and 5. For the odd numbered S^D segments (3, 5, 7) the probe was a single session preceded and succeeded by standard sessions. For the even numbered S^D segments (2, 4, 6, 8) two consecutive probe sessions were conducted. The second sessions did not appear to differ systematically from the first, so results from odd and even numbered segments are handled similarly. Results from all such probe sessions are included in the results. Probe sessions in which no houselight was presented were made before, for 44 and 152, and after, for 157, the series of sessions with single S^D segments. Results are presented for two such sessions of uninterrupted FI for each bird. Each had been preceded by a session of uninterrupted FI. The results for standard sessions are the mean of 10 sessions, each preceded on the previous day by a standard session.

The numbers of responses in the first and second halves of each segment were collected cumulatively through each session.

RESULTS

Representative cumulative records of Pigeon 152 with the first S^D segment at various positions in the interval are shown in Fig. 1. It is obvious that the rate of responding in both the TO period (no lights present in apparatus) and in the S^A periods during the interval (both key light and houselight present) can be very low; many schedule cycles show no responses whatever outside of the S^D periods. Responding was characteristically substantial in the terminal S^D segment comprising the 50 sec before the reinforcer was presented. When the first S^D period was late in the interval (upper records of Fig. 1) there was considerable responding in this segment too. When the first S^D segment was early in the interval, however (lower records of Fig. 1 other than bottom record), there was generally much less responding, and many schedule cycles showed no responding in these early S^D segments. The cumulative record of responding during the 50-sec S^D segments shows a characteristic scallop, previously described as a miniature FI (Dews, 1962, 1965).

The same relations can be seen in the averaged rates of all similar sessions for all three birds (Fig. 2). In the upper bar graphs, where the first S^D segment was late in the interval, there was comparatively little difference between the rates in the first and second S^D segments, whereas in the lower graphs the mean rates in the first S^D segments were half or less of those in the terminal segment. Rates are shown separately for the first and second halves of the S^D segment. The miniature FI scallops lead the mean rates in the second halves of the S^D segments to be consistently greater than the mean rates in the first halves.

The mean rates of responding in whole segments of the interval under the three conditions studied (single 50-sec S^D segment in addition to terminal segment, alternating 50-sec S^D and S^A segments, and uninterrupted FI) are shown in Fig. 3. The rates of responding are, in general, very similar for each of the three schedules. That is to say, the rate of responding in the individual 50-sec segments of FI 500 sec is roughly the same whether there is continued responding before and after the individual segment, or whether responding is continuously or intermittently interrupted by S^A .

Fig. 1. Representative cumulative-response records of Pigeon 152 from sessions in which the first S^D segment was, from above downward, in position 8, 7, 6, 5, 4, 3, and 2 of the 10 segments of 50 sec comprising the 500-sec interval. The bottom record shows performance when successive 50-sec segments were alternately S^A and S^D . In all records, the presence of the houselight is shown by downward offsetting of the cumulative recorder pen. This pen returns to the baseline at the end of each interval. The next 50-sec segment is time-out with no lights present in chamber. The key light then appears and continues through the 10 segments of FI until the presentation of reinforcing stimuli. The lower event pen associated with each record shows the occurrence of reinforcing stimuli. A key has been superimposed on the record of the second interval, with solid black polygons indicating the segments without houselight (the S^D periods). Notice how the amount of responding in the first S^D period tends to increase as the period occurs closer to the end of the interval.

Two qualifications must be made. First, the curve for the probe sessions with a single S^D segment in addition to the terminal segment is more irregular than the other two curves, showing even a reversal when the S^D segment was number eight. It must be remembered, however, that each point (except for that for the tenth segment) of the curve for single S^D segments was necessarily taken from different sessions, while all points of the other curves were taken from the same sessions. Variability from session to session, which can be seen in Fig. 2, contributes to the variability of the curve for single S^D segments.

Second, taking a mean rate for an entire single 50-sec segment involves averaging the rate over a miniature scallop. The rates in the first halves of S^D segments were much less than they would have been at the corresponding times

in uninterrupted FI. The relationship of Fig. 3 shows there must be compensation for the deficit in responding, and indeed, the lowest frame of Fig. 2 shows that the rates in the second halves of the S^D segments were higher than those in corresponding 25-sec periods of the uninterrupted interval. The compensation is not quite complete, since the lines for the interrupted FI tend to be slightly below the lines for the uninterrupted FI (Fig. 3), except for the sessions when the single S^D period was in the earlier part of the interval. For these segments the rate was unexpectedly high.

DISCUSSION

The mean rate of responding during a segment of an interval under FI depends predominantly on the time during the interval at

Fig. 2. Mean rates of responding in successive fractions of the FI. Numbers of responses were cumulated throughout the session for each successive 25-sec period of the interval, averaged across the three birds and the duplicated sessions, and converted to a mean rate in each 25-sec period. The periods without houselight are shown as solid black rectangles. The bottom graph shows both mean rates in FI with 50-sec S^A and S^D segments alternating (solid lines) and also mean rates in uninterrupted FI (dotted lines).

which the segment occurs, and is relatively unaffected by whether responding occurs or does not occur, or occurs intermittently during the rest of the interval.

In the sessions with single probes, every second S^D period was concluded with food; in those with alternating S^D and S^A segments every fifth S^D period concluded with food. In the uninterrupted FI sessions, every (long) S^D period was concluded by food. In spite of these variations, the relative mean rate of responding in a particular segment of the interval was similar in all sessions. The serial number of the S^D period concluded by food thus had little control over responding. While percentage reinforcement of responding in S^D periods (Ferster and Skinner, 1957, p. 67) is likely to be a factor in maintaining responding, it cannot account for the dependency of rate on position of S^D segment in the interval.

It is not known how the retroactive enhancing effect of the reinforcer can extend back to influence responding that occurred during the interval some hundreds of seconds before, so that responding during these earlier segments of the interval will continue to occur in future schedule cycles at a rate dependent on the time of the segment before the reinforcer. But two points may be made. First, postulation of mediating chains of behavior, in the absence of

Fig. 3. Mean rates of responding in consecutive segments of uninterrupted FI 500 sec (open circles), FI 500 sec with alternate 50-sec S^A and S^D segments (solid circles) and in intervals with only a single 50-sec S^D segment before the terminal 50-sec segment of interval (open triangles).

experimental evidence of such mediation, will conceal the problem rather than solve it and may tend to inhibit experimental analysis by providing facile "explanations". Second, since the fundamental paradigm of operant conditioning is that a succeeding reinforcing stimulus reinforces a preceding response, the effect of the reinforcer must always be retroactive, so the problem of retroactive effects is inherent in all operant conditioning situations. There is no difference in principle whether the reinforcer be considered to influence responses that occurred a few milliseconds or a few hundred seconds before. Since the tendency to respond at various times during the interval, as revealed by brief probes, recapitulates the rates that would have been occurring at corresponding times in the fixed interval, it is suggested that it is the decaying retroactive influence of the reinforcer on responses that occurred longer and longer before the reinforcer occurred that is responsible for the familiar scalloped pattern of responding under FI.

This mechanism continues to operate even when subjects have had long exposure to FI, as in the present experiments. Secondary influences on the number of responses and the pattern of responding, such as rate of responding at the moment of reinforcement, number of responses emitted per interval, mediating chains of behavior and S^A -like properties of beginning of FI (Ferster and Skinner, 1957, p. 134), can operate, but to an extent that remains to be determined.

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