BEHAVIOR UNDER EXTENDED EXPOSURE TO A HIGH-VALUE FIXED INTERVAL REINFORCEMENT SCHEDULE*

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Information in the literature on behavioral effects of fixed interval schedules is limited to only the first several hundred hours of training. In the course of some preliminaries to other experimental work, opportunity was afforded to examine trends in 30-minute fixed interval behavior during exposures of about 2300 hours for individual organisms. A survey of the effects observed is presented here.

METHOD

Three White Carneaux hen pigeons served as subjects. Following an initial period of acclimatization to the laboratory, the birds' weights under about 2 months' *ad libitum* feeding were determined. Thereafter, weights were reduced through restricted feeding to 80% of each bird's *ad lib* value and were maintained at that level throughout the remainder of the experiment.

For each bird, the key-pecking response was conditioned and given 50 regular reinforcements per day for five successive days. Each bird was shifted to the 30-minute fixed interval reinforcement schedule on the day following the 250th regular reinforcement.

The apparatus employed has been described elsewhere (1). In the present experiment, the programming device made one reinforcement available at the end of every 30-minute interval, the thirty minutes being timed from the last onset of reinforcement availability and not from the last occurrence of reinforcement. The initial key-pecking response in each thirty minutes was reinforced and subsequently no reinforcement was available until the beginning of the next 30-minute cycle.

Each experimental session was 960 minutes (16 hours) in duration, beginning at approximately 5:00 P.M. and terminating exactly 16 hours later. At the beginning of each experimental session, the position of the reinforcement timer cam was allowed a random setting, so that each session was begun at a different place in the reinforcement cycle. Each bird was run daily providing its weight at the beginning of the experimental session was within ± 15 grams of its prescribed 80% of *ad lib* weight. In no case was it necessary to skip more than one day between experimental sessions before a bird's weight was back to the requirement.

RESULTS AND DISCUSSION

The behavior of birds 30 and 34 upon their initial exposure to the 30-minute fixed interval schedule is exhibited in the form of cumulative response curves in Figures 1 and 2, where the whole record of the first 16-hour session of each bird is shown. In the case of bird 30 (Figure 1), a reinforcement has set up prior to the beginning of the session. While this meant that 33 reinforcements could have been delivered during the session, the bird "missed" one reinforcement between reinforcements 6 and

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BIRD 30 - day 1

Figure 1. Cumulative response record of the first sixteen-hour session of Bird 30 on the 30-minute fixed interval schedule. Reinforcements are marked by pips, and are numbered consecutively from the beginning to the end of the session. Record segments are arbitrarily spaced in the vertical.

BIRD 34 - day 1

Figure 2. Cumulative response record of the first sixteen-hour session of Bird 34 on the 30-minute fixed interval schedule. Reinforcements are marked by pips, and are numbered consecutively from the beginning to the end of the session. Record segments are arbitrarily spaced in the vertical.

7 through failure to respond within thirty minutes. Thereafter, throughout the experiment, care was taken to assure that no reinforcement had become available at the outset of the session (i.e., that the first response of a session would not be reinforced). As expected from other studies of fixed interval schedules, the early inter-reinforcement intervals are extinction-like, with a burst of responding following, and a low rate preceding, each reinforcement. In addition, there may be some tendency for bursts of responding to occur toward the middle of inter-reinforcement intervals. Such bursts are seen, for example, in the record for bird 30 (Figure 1) between reinforcements 2 and 3, 13 and 14, 18 and 19, and 22 and 23. In the record for bird 34 (Figure 2), similar bursts appear between reinforcements 1 and 2, 17 and 18, and, in striking degree, between reinforcements 26 and 27, and 27 and 28. These bursts have also been observed by Ferster and Skinner (2) during initial exposure to high-value fixed interval schedules and are called by them "break-throughs."

The steady rate of response, which began to appear on the first day's record of bird 30, continued for all birds for about two weeks. Figure 3 shows the cumulative response curve for the 13th day of bird 34's exposure to the schedule. The behavior is characterized by a low and rather steady rate of responding throughout the 16-hour session, and is typical of this second stage in the birds' performances. The average rate for the record shown is 3.7 responses per minute. This steady response rate is gradually replaced by "scallopings" between reinforcements. Figure 4 shows a number of phases in the development of scallops by bird 30. From sessions spaced approximately 24 days apart (discrepancies are due to the fact that cumulative records were not taken on each bird each night), a sample of inter-reinforcement intervals was selected. An effort was made to select intervals from all portions of the session. (Other portions of the records for these days may be found in Figures 9, 11, 12 and 13). In the record for day 24, there is evident a tendency for the rate of responding immediately following reinforcement to be lower than the rate immediately preceding reinforcement. In addition, "breaks" (long periods of no responding) begin to appear in the middle portion of the interval. By day 51, these breaks have become prominent features of the behavior. Only infrequently do such breaks begin immediately after the reinforcement. As exposure to the schedule is prolonged, however, the breaks tend to occur with shorter latency following the reinforcement so that by day 95 they occur almost always immediately after reinforcement.

Close inspection of Figure 4 shows several other effects of extended exposure to this 30-minute fixed interval schedule. The total number of responses emitted during one inter-reinforcement interval does not change greatly from the 24th day to the 144th day. The time spent in not responding, however, increases greatly. Furthermore, while the overall rate is remaining fairly constant, the terminal rate is reached almost immediately after the break and the terminal rate is much higher in the later days of the experiment. Noteworthy, too, is the degree of invariance of response rates on day 144 as compared with earlier stages. The performance on day 144 is of such an all-or-none character that the bird's behavior can be described by two expressions, one indicating the duration of the break and the other indicating the response rate. This type of performance has usually been attributed to ratio schedules, and its appearance even on a high-value fixed interval schedule may have some relevance to recent suggestions bearing on the general categorization of sched-

BIRD 34 - day 13

Figure 3. Cumulative response record of the thirteenth sixteen-hour session of Bird 34 on the 30-minute fixed interval schedule. Reinforcements are marked by pips, and are numbered consecutively from the beginning to the end of the session. Record segments are arbitrarily spaced in the vertical.

BIRD - 30

Figure 4. Stages in the development of behavior of Bird 30 under the 30-minute fixed interval schedule. Selected inter-reinforcement record segments are presented for the indicated days. The numbers at the left of the segments give the ordinal reinforcement number terminating each segment.

ules (1, 3, 4). The slight negative acceleration observed on day 144, and in some intervals on earlier days, may have arisen in part artifactually from a defect in the recorder. From later re-calibrations it appears that these portions of the record should actually have been drawn by the recorder more nearly as straight lines; but from other data (2) and our own findings in the present study, it seems possible that some degree of negative acceleration may actually be present.

In Figure 4, individual inter-reinforcement intervals have been isolated from their context. In order to display more fully the development of scalloping as well as other features of the records, Figures 5, 6, 7 and 8 are presented showing full 16-hour sessions for both birds 30 and 34. In Figure 5 (bird 30, day 43) the acceleration in rate between reinforcements can be seen clearly, as between reinforcements 5 and 6, 8 and 9, 17 and 18, and 30 and 31. A later stage in behavioral development is shown in Figure 6 (bird 34, day 74). The high rate of responding at the beginning of the session is characteristic of this stage. The scallops are quite regular with some breaks appearing in the course of some inter-reinforcement intervals after responding has started, as between reinforcements 4 and 5, 15 and 16, and 23 and 24. The scallops shown here for the middle stages of the experiment are typical of fixed interval schedules (e.g., 2, 5) though they are quicker to appear when intervals shorter than thirty minutes are used. The final stages of 30-minute fixed interval performance are exemplified by Figures 7 (bird 34, day 110) and 8 (bird 30, day 146). Figure 7 shows a relatively advanced stage of the "break and run" behavior that characterized the last developments observed, and this is even more striking in Figure 8. Also appearing is the typical graininess of the last intervals of the 16-hour session; for example, inter-reinforcement intervals 27 through 32 in Figure 7, and 28 through 32 in Figure 8, yield a grainy record owing to alternation between rapid responding and short breaks rather than the smooth records of earlier intervals in the sessions. In addition, late scallops in the days' records show a tendency for negative acceleration before reinforcement.

In these records of complete sessions some additional characteristics are apparent. One feature is the double scallop in which the pre-reinforcement response rate is largely uninterrupted by the reinforcement and continues until a second reinforcement has been obtained. In Figure 5, for example, the scallop following reinforcement 9 is not markedly broken by reinforcement 10, but carries through until the delivery of reinforcement 11. The same effect in Figure 7 is seen to emerge between reinforcements 18-20, and 24-26, while in Figure 8 such a double scallop may appear between reinforcements 14-16. Another type of double scallop is seen in Figure 5, reinforcements 20-22, 26-28; Figure 7, reinforcements 8-10, 10-12, 22-24; Figure 8, reinforcements 4-6, 20-22, 25-27. Perhaps an intermediate case is represented in Figure 6, reinforcements 19-21.

Double scallops, as we have seen from foregoing examples, may be of two varieties. In one, the effective pause following reinforcement may exceed 30 minutes with a final terminal rate developing only toward the end of a 60-minute period (late in the second inter-reinforcement interval). Other instances of this sort of double scallop are shown in the top portion of Figure 9 where four examples are given for each bird. The second variety of double scallop occurs when the terminal rate develops in normal fashion but is not interrupted by the reinforcement, persisting instead through the next inter-reinforcement interval. Other instances of

BIRD 30 - DAY 43

Figure 5. Cumulative response record for the forty-third sixteen-hour session of Bird 30 on the 30-minute fixed interval schedule. Reinforcements are marked by pips, and numbered consecutively. Recorder pen was reset only after reaching the limit of its excursion on the recorder.

BIRD 34 - DAY 74

Figure 6. Cumulative response record for the seventy-fourth sixteen-hour session of Bird 34 on the 30-minute fixed interval schedule. Reinforcements are numbered consecutively, with the recorder pen being reset at each reinforcement as well as at the limit of the pen excursion if reached.

Figure 7. Entire cumulative response record for the 110th sixteen-hour session of Bird 34 on the 30-minute fixed interval schedule. Record segments, arbitrarily spaced in the horizontal, show consecutive reinforcements as numbered.

Figure 8. Entire cumulative response record for the 146th sixteen-hour session of Bird 30 on the 30-minute fixed interval schedule. Record segments, arbitrarily spaced in the horizontal, show consecutive reinforcements as numbered. This is the last session with Bird 30, and represents the last sixteen of a total of 2336 hours of training on this schedule.

Figure 9. Selected segments of cumulative response curves of Birds 30 and 34 showing double scallops. Numbers at the left of segments indicate ordinal session number; circled numbers above the records indicate ordinal reinforcement numbers within the session. On days 71 and 87 for Bird 34, the recorder pen was reset both at reinforcement and at the limit of pen excursion; all other records are presented as continuous.

this variety of double scallop are shown at the bottom of Figure 9 where again four cases are shown for the two birds. In order to show the double scallop in detail and in context, two instances of the first variety have been selected for reproduction in Figure 10. The upper record, for bird 30, day 125, shows two successive double scallops running from reinforcement 4 to reinforcement 8. The lower record for bird 34, day 89, reinforcements 20 to 25, shows two double scallops separated by a single scallop. It will be noted that the double scallops for bird 30's 125th day show behavior of the "break and run" variety characteristic of the final stages seen in Figure 4, while the data for bird 34's day 89 show the more gradual acceleration characteristic of single scallops at this earlier stage. The slight negative acceleration preceding bird 30's reinforcements 6 and 8 may have resulted from the recorder defect mentioned earlier. Apparently, these double scallops reflect the same effects observed by Ferster and Skinner (2) and called by them "second-order effects" (i.e., "A relation between the numbers of responses emitted in two or more successive intervals on FI in which an over-all acceleration may be observed throughout all segments," p. 733).

Occasional examples are available of scallops persisting through three 30-minute intervals. Figure 11 shows three instances of this for both birds 30 and 34. A triple scallop, as shown in Figure 11, and in Figure 5, reinforcements 13-16, often consists of an initial break lasting beyond the first reinforcement, succeeded by the terminal rate which is not broken, or is only briefly halted, by the second reinforcement. Thus, a triple scallop consists of a combination of the two kinds of double scallops. Figure 11 shows two instances, for bird 34, in which the triple scallop is bounded on both ends by a normal single scallop. The slight negative acceleration preceding reinforcements which end the multiple scallops is again dubious, but that preceding bird 30's reinforcement 10 on day 141 is not altogether attributable to recorder deficiency.

The fixed interval scallop, whether single, double or triple, is usually bounded at both ends by reinforcements. Instances can be found, however, in which scallops appear to be unrelated to the occurrence of reinforcement. Examples are shown in Figure 12. Following reinforcement 13 on day 51, bird 30 begins a double scallop which comes to an abrupt end before the occurrence of reinforcement 15. Another scallop appears to begin where the first terminated, and this one proceeds through reinforcements 15 and 16 but ends again before reinforcement 17. As another example, bird 34 on day 89 begins a scallop after reinforcement 7 which persists until about three-quarters of the way through the interval between reinforcements 8 and 9, while another scallop begins midway between reinforcements 9 and 10. That this phenomenon occurs occasionally, argues for a control over behavior which can act independently of the reinforcements being provided.

That there is a real tendency for the rate of responding to fall off immediately prior to reinforcement, beyond the reservations cited earlier as to recorder defects, is shown by a number of extreme examples at the top of Figure 13. The scallop appears to begin normally but falls off drastically before reinforcement, resulting in an S-shaped cumulative curve. As has already been mentioned, this effect is most pronounced during the final inter-reinforcement intervals of an experimental session. In no case shown here is the negative acceleration attributable to recorder inadequacy.

Figure 10. Details of double scallops. Two examples are given for each bird, those of Bird 34 having a single scallop interpolated between the two doubles. For each bird, the record shown is a continuous segment extracted from the indicated day's performance, with the ordinal reinforcement numbers encircled above the curve.

Figure 11. Details of triple scallops. Three examples are given for each bird, those of days 83 and 71 for Bird 34 being bounded on both ends by single scallops. For each bird, the record shown is a continuous segment extracted from the indicated day's performance, with the ordinal reinforcement numbers encircled above the curve.

Figure 12. Records demonstrating the occasional low correspondence between response rate and occurrence of reinforcement. For the indicated days (numbers at left of segments), and the indicated ordinal reinforcement numbers (circled), continuous extracts are shown from four records of Bird 30 and one of Bird 34.

Figure 13. The upper portion details some extreme examples of negative acceleration prior to reinforcement. Below each segment is given the number of the session from which the record is taken; circled numbers show ordinal reinforcement within the session. Five examples are reproduced for Bird 30, and seven for Bird 34. The lower portion of the figure details some miscellaneous aspects of responding which seem unclassifiable at present.

Figure 14. Cumulative response record of the 84th sixteen-hour session of Bird 29. Recorder pen was reset at reinforcements which are numbered consecutively. The vertical arrow indicates the last response (reinforcement 22), no further responding being recorded during the final 4 hours and 55 minutes of the session. When the experimental cage was opened, the bird was dead (see text).

Rarely, cumulative response curves appear in shapes which are unclassifiable under the types mentioned heretofore. Infrequency of occurrence prevents description of these curves with inductive certainty although they may well be composed of combinations of the effects already described. They are presented in Figure 13 without comment for the reader's examination (bird 30, day 67; bird 34, days 57, 62, 91).

The data presented thus far have been drawn from 2 of the 3 subjects in this experiment. A third bird, 29, was used for 84 days. When the experimental chamber was opened at the end of the 84th session, the bird was dead. Although the data obtained from this bird prior to the 84th session are comparable in all respects to the data of birds 30 and 34, these data are not presented here since they cannot be followed through to the final stages which the other birds reached. The cause of bird 29's death is uncertain, although it probably resulted from the failure of the air blower system on the experimental cage on that day. On removal from the cage, the bird's body was noticeably warmer than usual, and this may have been contributed to by the cage lights as well as the failure of body cooling normally provided by the air blower of the cage. The complete record of the 84th session for bird 29 is presented in Figure 14. An unusual early graininess is seen in the record, with progressive deterioration in performance up to the 22nd reinforcement, after which no response was made for the last 4 hours and 55 minutes of the session. While the record begins with the scallops expected at this stage of training, it can be seen that after the third hour of running the scallops are greatly fragmented, and after the sixth hour are no longer recognizable. It may be of interest in the future to cross-check with Figure 14 the effects of experimentally controlled oxygen deprivation and environmental temperature upon behavior at various stages of development under high-value fixed interval schedules.

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