*THE EFFECT OF MULTIPLE S^A PERIODS ON
RESPONDING ON A FIXED-INTERVAL SCHEDULE:
III. EFFECT OF CHANGES IN PATTERN OF
INTERRUPTIONS, PARAMETERS AND STIMULI¹*

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Pigeons responding under fixed-interval schedules of reinforcement were interrupted by S^A periods during the course of the intervals. Whether intervals were interrupted by 1, 2, or 5 S^A periods, the general scalloped pattern of FI responding persisted. Parameter values up to 27¾ hr for the FI and 2¾ hr for the individual S^A interruptions were studied. The results further weaken the hypothesis that the FI pattern of responding depends crucially on control of responding by continuously chained mediating behavior.

Previous papers in this series have shown that the pattern of increasing frequency of responding in individual intervals under FI schedules of reinforcement is not disrupted by insertion of several S^A periods during each interval (Dews, 1962, 1965). In the first experiments, on pigeons, S^D and S^A segments of equal length alternated regularly through the interval. In subsequent observations on a squirrel monkey an identical alternation of S^D and S^A segments and a similar duration of FI were used. The results suggest it is no longer permissible to assume an indispensable role for chained responding as mediating behavior in the organization of behavior patterns over periods of several minutes.

The present experiments sought to determine whether less regular and longer interruptions of FI by S^A periods would disrupt overall patterns of responding. Since the FI pattern of responding is relatively invariant over wide ranges of parameter value (Ferster and Skinner, 1957; Dews, 1958) it was possible to study interruptions by S^A periods of as long as 2¾ hr during FI's slightly longer than one day. The general scalloped pattern of cumulative responding under FI survives all these forms of interruption, despite gross local perturbations of responding by the S^A presentations and cessations.

MATERIALS AND METHODS

The subjects were five male White Carneaux pigeons designated 40, 44, 62, 152, and 158. Their weights on unrestricted feeding were about 530, 565, 480, 530, and 480 g. During the experiments they were maintained at close to

424, 400, 420, 480, and 375 g respectively, *i.e.*, from 70% to 90% of their free feeding weights. The apparatus, response, and food reinforcer were standard (Ferster and Skinner, 1957), food being presented for 3.5 sec as the reinforcing stimulus. As in previous experiments, the single key was transilluminated by white lights and the houselight (HL) was a white light projected from the upper rear of the pigeon compartment (Dews, 1962). Water was constantly available.

EXPERIMENT 1: CHANGE IN PATTERN OF INTERRUPTIONS BY S^A

Schedules

See Fig. 1. Food was never presented when the houselight, designated as S^A, was present.

(1) *TO 50 sec FI 500 sec with single S^A segment.* For the first 50 sec after the start of the session no lights were in the chamber. Then the key was transilluminated. The first response emitted when the key light had been on for 500 sec was reinforced (FI 500 sec). The houselight was present only in the 50-sec segment from 200 sec to 250 sec from the start of the interval. Following the reinforcing stimuli, no lights were present in the chamber for 50 sec (TO 50 sec), starting a new schedule cycle.

(2) *TO 540 sec FI 900 sec with two S^A segments.* This schedule was similar except (i) the FI was 900 sec and the houselight was present in two 180-sec segments, the first from

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Fig. 1. Diagrams of schedules. The shaded portions show when the stimulus or condition obtains. KL—key light. HL—housetlight.

180 sec to 360 sec and the second from 540 sec to 720 sec from the start of the interval, and (ii) the periods with no lights present were 540 sec.

(3) *TO 300 sec FI 3000 sec with single S^A segment.* This schedule was FI 3000 sec with the houselight present only in the 600-sec segment from 1200 sec to 1800 sec from the start of the interval.

Procedure

Only Pigeon 152 was studied under FI 500 sec. Pigeons 62 and 152 were studied under FI 900 sec and 152 and 158 under FI 3000 sec. The performance in FI with houselight was compared with that under the identical schedule with no houselight. This was done successively in FI 500 sec and FI 3000 sec. The birds were subjected to a series of consecutive sessions in which every schedule cycle was identical—either every interval involved houselight presentation or none did. A consistent series of sessions on the complementary procedure followed. In the case of FI 900 sec, however, each session consisted of seven schedule cycles, four with houselight presentations and three without. Houselight was presented during the second, third and seventh schedule cycles.

The initial schedule cycle was always omitted in tabulation of figures. Results were not collected until the birds had been exposed to at least 10 schedule cycles (usually many more) and mean rates were calculated from 10 or more schedule cycles.

Results

The general FI scallop survived single or double interruptions as well as the regular interruptions previously reported (Fig. 2). The S^A segments showed much lower rates of responding than occurred in corresponding parts of the interval in absence of S^A (Fig. 3). The individual S^D segments showed miniature FI patterns (Dews, 1962). Compared with performance in the same subjects on the same FI with no S^A periods, there was a net deficit of responding in the S^D segments as well as in the S^A segments. The rates and pattern of responding shown under FI 900 sec seem generally intermediate between those under FI 500 sec and FI 3000 sec. This indicates that mixing of S^A interrupted and uninterrupted cycles within the same session, as was done in the FI 900 sec series, gives results similar to those obtained in sessions of homogeneous cycles, as in the FI 500 sec and the FI 3000 sec series.

EXPERIMENT 2: PROLONGATION OF FI AND OF S^A INTERRUPTIONS

Schedules

See Fig. 1. The houselight was again S^A.

(1) *TO 1000 sec FI 10,000 sec with alternate S^A segments.* For the first 1000 sec, no lights were in the chamber. Then the key was transilluminated. The first response emitted when the key light had been on for 10,000 sec was reinforced. When the magazine cycle had been completed, the next response produced another magazine cycle, and so on until, at the conclusion of the 10th magazine cycle, all lights were extinguished and a new schedule cycle started. There was thus an overall average frequency in time of one magazine cycle per 1000 sec. The basic schedule could be designated as: mult (TO 1000 sec) (tandem FI 10,000 sec FR₁1, FR₂1 . . . FR₉1).

The houselight came on when the TO ended, remained on 1000 sec, was extinguished for 1000 sec, came on for 1000 sec and continued to alternate in this manner until at

Fig. 2. Cumulative records of responding under various schedules of Exp 1. Two intervals are shown in continuity across the lower half of the figure (A) and in each of the upper quadrants (B and C). Records from different birds or different days on same schedule are stacked in phase, one above the other. A: FI 3000 sec with single S^A segment. Upper records of Pigeon 152, lower of Pigeon 158. B: FI 9000 sec with two S^A segments. Upper records of Pigeon 62, lower of Pigeon 152. C: FI 500 sec with single S^A segment. Both records of Pigeon 152, but upper and lower drawn from different sessions. The key to the stimulus changes is shown below the respective cumulative records. Drawn ordinates show stimulus change and the thickened black segment of the abscissa shows the houselight S^A segment. The key is drawn for only one of the four intervals in each part of the figure, but in all intervals the houselight S^A period is indicated on the original cumulative record by downward offsetting of the pen.

the conclusion of 10,000 sec (at which time the houselight was not present) the houselight remained off until 10 magazine cycles and the 1000-sec TO concluded. The key light was continuously present except during the TO.

(2) *TO 3000 sec FI 30,000 sec with alternate S^A segments.* This schedule was identical in all respects to that just described except for a threefold increase in all parameter values. The houselight alternated on and off with a period of 3000 sec. At the conclusion of 30,000 sec the schedule was FR 1 until 30 responses had been reinforced, keeping the average frequency of reinforced responses at one per 1000 sec.

(3) *TO 10,000 sec FI 100,000 sec with alternate S^A segments.* This schedule was also iden-

tical to those described except for parameter values. One hundred responses were reinforced under FR 1 at the conclusion of each 100,000-sec interval during which the houselight had been present during alternate 10,000-sec segments.

Procedure

Two birds, 44 and 152, were studied under these schedules. At all parameter values, the birds were exposed to at least 10 schedule cycles before the numbers shown in the figures and tables were collected. The mean rates shown were calculated from 10 to 15 schedule cycles. The birds were also subjected to FI 100,000 sec TO 10,000 sec with no houselight at any time.

Fig. 3. Mean rates of responding in successive segments of key light periods in Exp 1. Top: FI 500 sec (Bird 152). Middle: FI 900 sec (Birds 62, 152). Bottom: FI 3000 sec (Birds 152, 158). Open bars: mean rates of responding in S^D segments of intervals with S^A segments. Solid bars: mean rates of responding in S^A segments. Bars topped by dashed lines: mean rates of responding in the segments under the FI schedule with no S^A segments. Cross slant areas show deficit in responding due to imposition of S^A segments.

Results

At all parameter values, responses increased in successive S^D segments of individual intervals, giving the cumulative records, despite interruption by S^A segments, a generally scalloped appearance (Fig. 4 and 5).

Under FI 10,000 sec and FI 30,000 sec, responding in S^D segments showed miniature²

²The S^D segments under FI 30,000 sec are each 50 min long, so the FI engendered in these individual segments are hardly "miniature" by ordinary standards.

FI patterns (Dews, 1962). Responding in S^A segments was much more uniform (Fig. 4 and 5). These tendencies are, however, less obvious in the cumulative records for FI 100,000 sec (Fig. 5).

The same patterns of responding emerge from the averaged numbers of responses in successive periods of more than 10 sessions for each of the two birds (Table 1). The table shows rates of responding in the first and second halves of each S^D and S^A segment. Rate of responding increased consistently from the first

Fig. 4. Cumulative records of two consecutive FI 10,000 sec of Pigeon 152. The records have been stacked in phase, one above the other, to conserve space. Ordinates are drawn at the times when the stimuli changed, *i.e.*, at the beginning and end of houselight presentations. The periods when the houselight was present are shown by the thickened black line along the abscissa. The initial TO periods when the key light was not present have been omitted: there was no responding during these periods. Note the overall scalloped pattern of the total FI, the "miniature" FI of individual S^D periods and the quite different distribution of responding during S^A periods.

to the second halves of the individual S^D segments. The only departure was in the first S^D segment of the FI 100,000 sec, but the rate of responding was so low (about one response per 3 min) that no significance can be attached to

the exception. In contrast, responding usually decreased in the second halves of individual S^A segments.

The high degree of consistency in the patterns of response distribution within the in-

Fig. 5. Cumulative records of two consecutive FI 30,000 sec (upper left) and two consecutive FI 100,000 sec (lower right). Arrangement and conventions are the same as for Fig. 1.

Table 1
Mean rates in responses per sec $\times 10^3$ in successive periods of interval.

Length*	S ^A		S ^D		S ^A		S ^D		S ^A		S ^D		S ^A		S ^D		S ^A		S ^D		Whole Interval
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
10	2	1	32	50	6	6	89	202	14	6	124	392	68	56	265	666	110	38	282	826	162
30	2	2	13	37	2	2	8	22	4	5	20	61	6	6	65	148	8	6	75	216	35
100	4	1	6	4	1	1	4	8	2	2	11	20	6	6	36	75	12	13	94	142	22

*In thousands of seconds.
Each interval was divided into 10 equal segments which were alternately S^A and S^D. Each segment was further subdivided into first and second halves. Numbers of responses were cumulated in each of these 20 subdivisions of the interval over 10 to 15 intervals for both birds and then converted to rates of responding to give the table entries.

tervals over the 10-fold change in parameter value can be shown by expressing the number of responses in each segment as a fraction of the number in the terminal S^D segment. The effects of change in parameter value on general tendency to respond is thereby eliminated, and normalizing the time base makes it easier to compare patterns. The pattern of increasing responding in S^D periods clearly emerges (Fig. 6) and can be seen to be relatively invariant over the changes in parameter value.

The pattern of responding under uninterrupted FI 100,000 sec (Fig. 7) strongly resembles the pattern under shorter FI such as those illustrated by Ferster and Skinner (1957; e.g., Fig. 299, p. 255). From the results on interrupted and uninterrupted responding on FI 100,000 sec, the effect of the S^A in suppressing responding can be expressed numerically by calculating the average factor by which the rate of responding during S^A segments must be multiplied in order to bring them into the same relationship to the S^D segments that pertains in uninterrupted FI. The so-called "S^A factor" (Dews, 1962) has the value of 6.1 for the S^A periods of FI 100,000 sec in these experiments. That is, the rate of responding is reduced some sixfold by the presence of the S^A. In the previous experiments on FI 500 sec the S^A factor had a value of 3.5.

EXPERIMENT 3: CONTROL
EXPERIMENTS FOR EFFECTS OF
LIGHT AND DARKNESS

Experiments 1 and 2 show that the scalloped FI pattern survives consistent interruptions by S^A periods. Experiment 3 examined whether the pattern is disrupted during the transition phase following interchange of the S^D and S^A stimuli.

Schedule

See Fig. 1.
TO 50 sec FI 500 sec with alternate S^A periods. The schedule was identical with those of Exp 2 except in parameter values. There was a single magazine cycle concluding each FI.

Procedure

In the first part of the experiment, the FI 500 sec was interrupted by S^A segments which consisted of the absence of the houselight. After more than 400 schedule cycles, the arrangement was changed so that the presence of the houselight became S^A. Thus, numbering the successive 50-sec segments of the interval 1 through 10, in the initial arrangement the houselight was present in segments 2, 4, 6, 8, and 10 (and after), and in segments 1, 3, 5, 7, and 9 in the final arrangement (Fig. 8).

Pigeons 40, 44 and 152 were studied. Nearly 24 hr elapsed between the end of the last session, in which absence of the houselight was S^A, and the beginning of the first session, in which the presence of the houselight was S^A. The birds were in their home cages during this period.

Results

The last three cycles under the initial stimulus arrangement and the first 10 cycles following interchange of stimuli are shown in Fig. 8. The initial cycles after the change show suppression in the absence of the houselight, the erstwhile S^A condition, but there was a progressive increase in rate of responding in these segments and a concomitant decrease in responding in the presence of the houselight, the new S^A condition. By the tenth schedule cycle the rate of responding in the

Fig. 6. Mean proportional rates of responding in successive tenth parts of FI. For each of the two birds (44, 152) the numbers of responses in the individual segments were expressed as a fraction of the number in the terminal (tenth) segment of all intervals of a session and these ratios averaged to give the values shown in graph. The solid black bars showing the periods of presentation of the houselight are the S^A segments. The final 10, 30 or 100 responses reinforced on FR 1 are not included in the terminal component.

new S^A conditions had increased above that under the new S^A conditions for Birds 40 and 44, and was fast moving in the same direction for Bird 152. Throughout the process of change, the general scalloped pattern of the cumulative records was not discernibly changed.

DISCUSSION

The results confirm and extend the previously reported survival of the general scalloped pattern of responding under FI when the intervals are interrupted by S^A periods. Neither irregular presentation of the S^A periods, nor 20-fold increase in parameter values, nor the inversion of stimulus control due to interchange of stimuli altered the general scalloped pattern of FI cumulated responding.

Since all food presentations were made in the presence of S^D it might have been anticipated that S^D would become a conditioned reinforcing stimulus and that the change from S^A to S^D would be a reinforcing event. Even though the change from S^A to S^D was programmed by a clock and did not require a response, responding in the S^A segments might nevertheless have been expected to assume the pattern of FI responding, albeit superstitious FI. Conversely, since responding in all S^D segments except the last concluded with a change from S^D to S^A , a punishing effect of such a change might have been expected, as seen by Ferster and Skinner (1957 p. 67 *et seq.*). In fact, the patterns of responding in the S^A and S^D segments were the opposite of those just suggested: responding accelerated through the S^D periods and decelerated through the S^A periods (Table 1). Clearly the observed patterns cannot be explained by the customary notions of the effects of these stimulus changes.

The miniature FI of the S^D periods suggests an analogy to second-order schedules (Kelleher, 1965). Under second-order schedules, whole schedule controlled patterns of responding are taken as new unit responses (macro-responses) which are in turn subjected to a schedule of reinforcement. In a variety of situations, the macroresponse maintains its form under the second-order schedule, and Findley had previously suggested the possibility of using a tree as a unit response (Findley, 1962, p. 165). The pattern of responding in the final S^D period of all the present sched-

Fig. 7. Cumulative record of three consecutive FI 100,000 sec uninterrupted by S^A , stacked as in previous figures.

ules may be considered as a reinforced macro-response. The same macroresponse, a miniature FI, then emerges under similar stimulus conditions earlier in the interval, the temporal

position of the S^D in the interval modulating the strength of the macroresponse, *viz.*, the number of responses in it, and so giving the overall FI scallop.

Fig. 8. Cumulative records of 13 consecutive FI 500 sec for each of three birds. Houselight segments are shown by downward offsetting of pen drawing cumulative record. The first three cycles for each bird are from the end of the last session when responses were reinforced only in presence of houselight, so absence of houselight was S^A . The remainder of the figure shows the beginning of the first session on which stimulus conditions were changed, so that responses were reinforced only in absence of houselight, making presence of houselight S^A . Note that the general scalloped pattern of the FI is continuously preserved despite the large progressive changes in local rates.

The nature of the influence determining the progressive increase in size of the miniature FI as the interval progresses has been suggested to be the progressive decrease in delay of reinforcement of the responding (Dews, 1962). This is a parsimonious hypothesis, and one that has some experimental support (Dews, 1960). The constancy of the FI pattern over large ranges of parameter value, with similar proportions of total responding occurring in successive segments of the intervals (Fig. 6), shows that it cannot be the absolute delay of reinforcement of responding that determines the rate, but may be rather the delay as a fraction of the consistently imposed schedule cycle.

The decelerating pattern of responding in the S^A periods shows that the control by S^A only slowly and progressively attained its full power, even though this power was great as shown by the more than sixfold reduction in mean rate of responding when S^A is present. There was frequently an abrupt reduction in rate at the time of change from S^D to S^A, showing that "attention" was not lacking, but thereafter the rate only slowly fell to zero. No explanation is offered for these phenomena.

All the schedules of this and previous papers in the series have been called FI. Under them all there was, in each schedule cycle, a fixed minimum interval during which the key lights were continuously present and responses were without programmed consequences. The fixed interval was concluded by a response immediately followed by food. These are defining

characteristics of fixed-interval schedules of reinforcement. Some of the schedules studied were modified FI, but the modification did not involve the schedule, only concurrent stimuli, notably the houselight. In keeping with their FI nature, and justifying their classification, all the schedules induced generally scalloped patterns of responding, in spite of gross local perturbations in rate during and after S^A segments when they were present.

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