**SOME FACTORS CONTROLLING PREFERENCE
BETWEEN FIXED-RATIO AND VARIABLE-RATIO
SCHEDULES OF REINFORCEMENT¹**

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A multiple schedule of food reinforcement for key-pecking was arranged which consisted of nine fixed-ratios, each of which operated in the presence of a different stimulus. Pigeons could complete a given fixed-ratio within the multiple schedule or, by pecking a second key, could switch from the fixed-ratio schedule to a variable-ratio schedule consisting of the same nine ratios. Stable switching behavior was established which did not maximize simple probability or rate of reinforcement. Instead, the subjects showed a stable preference for the variable-ratio schedule of food reinforcement. Increasing the number of responses required to switch, and removing the occasions on which reinforcement was delivered after a single response in the variable schedule, decreased the number of switches to the variable schedule. Periods of delay interposed between a completed switch and the availability of reinforcement after one response in the variable schedule also decreased switching to the variable schedule, particularly at long delay intervals.

CONTENTS

Method

Experiment I: *Effects of switching requirement on switching behavior*

Experiment II: *Effects of one-response ratio and delay interval before one-response ratio on switching behavior*

Discussion

Preference among schedules of positive reinforcement has been investigated in several ways (Catania, 1966). One procedure arranges that a subject's responses on one operandum change or switch the schedule of reinforcement in effect on a second operandum (Findley, 1958, 1962; Weiner, 1966). With this procedure, preference for a particular reinforcement schedule may be defined by the relative frequency with which subjects switch to the schedule. Another procedure allows a subject to respond concurrently on either of two operanda, each associated with a different primary-reinforcement schedule (Catania, 1963;

Findley, 1958; Herrnstein, 1961) or associated with the opportunity to engage in further behavior reinforced by different (but non-concurrent) schedules of primary reinforcement (Autor, 1960; Fantino, 1967, 1968; Fantino and Herrnstein, 1968; Herrnstein, 1964a, 1964b). In the concurrent procedure, preference may be defined by the relative rate of responding on each operandum during the period that the concurrent schedules are available.

Two studies which have used concurrent schedules to investigate preference (Fantino, 1967; Herrnstein, 1964b) have shown that subjects preferred schedules in which reinforcement was delivered on a variable rather than on a fixed basis. Herrnstein investigated the behavior of pigeons with a two-key, concurrent, chained schedule. In this procedure, responses on one key produced the opportunity to respond on a fixed-interval schedule of food reinforcement; responses on the other key produced the opportunity to respond on a variable-interval schedule of food reinforcement. Preference was defined by the relative rate of responding on each key during the initial concurrent components of each chain schedule. Herrnstein found that subjects emitted a higher rate of responding on the key which produced the variable-interval schedule of food reinforcement when the mean interval of this schedule was equal to the interval of the fixed schedule. Fantino,

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using a procedure similar to Herrnstein's, compared pigeons' preferences for mixed fixed-ratio schedules of food reinforcement (a limited form of a variable-ratio schedule) with a given fixed-ratio schedule. He found that pigeons showed a higher response rate on the key which produced the mixed fixed-ratio schedule of food reinforcement when the mean response requirement of this schedule was equal to the response requirement of the fixed-ratio schedule. These studies indicate a preference for variable rather than fixed schedules of reinforcement for both interval and ratio schedules. In contrast, Weiner (1966) employed a switching procedure in which human subjects could change the reinforcement schedule from a fixed-ratio to a variable-ratio schedule with an equal mean response requirement, or *vice versa*, and found no preference between these schedules.

The purpose of the present study was to explore further preference among fixed-ratio and variable-ratio schedules of positive reinforcement. A switching procedure was employed in which subjects could engage in behavior reinforced on one of a series of fixed-ratio schedules of food reinforcement (multiple fixed-ratio schedule) or could switch the particular fixed-ratio schedule to a limited variable-ratio schedule (mixed fixed-ratio schedule). In the first experiment, preference, as defined by switching behavior, was examined as a function of the number of responses required to switch. In the second experiment, preference was examined as a function of the distribution of ratios in the variable-ratio schedule and delays imposed between switching behavior and the opportunity to emit responses reinforced on the variable-ratio schedule.

METHOD

Subjects

Two adult male pigeons, a White Carneaux (#6) and a homing pigeon (#10), were maintained at approximately 80% of their free-feeding weights. Both birds had extensive experimental histories on various fixed-ratio schedules of reinforcement.

Apparatus

The experimental chamber was a picnic ice chest similar in design to that described by

Ferster and Skinner (1957). One wall of the chamber was the response panel on which were mounted two response keys (a ratio key and a switching key) 4.5-in. apart, 9-in. from the floor, and equidistant from the center of the panel. The ratio key could be illuminated with 10 different colors or geometric forms by a one-plane digital display unit, and the switching key could be illuminated with white light. When either key was illuminated, a response on that key produced a click from a feedback relay mounted on the back of the response panel. Directly below the response keys and equidistant from each was a 2- by 2-in. opening which allowed access to grain reinforcement when the food magazine was operated. During operation of the food magazine the key lights and house light were turned off and the food opening was illuminated. The chamber was illuminated by a 7-w house light located on the top center of the response-key wall. The chamber was ventilated by a blower; masking noise was provided by a white noise generator. Scheduling was accomplished automatically by switching relays and timers. Data were recorded on electrical impulse counters and a cumulative recorder.

EXPERIMENT I: EFFECTS OF SWITCHING REQUIREMENT ON SWITCHING BEHAVIOR

Procedure

Establishing a multiple fixed-ratio baseline. Initially, a nine-component multiple fixed-ratio (FR) schedule of food reinforcement was arranged on the ratio key: reinforcement was delivered after a fixed number of responses had been emitted on the ratio key, but this fixed number could take any one of nine values, each of which was correlated with a separate stimulus projected onto the ratio key. The nine ratios and the stimulus correlated with each were: FR 1 (I), FR 30 (white), FR 60 (×), FR 90 (blue), FR 120 (yellow), FR 150 (—), FR 180 (Δ), FR 210 (green) and FR 240 (+). The sequence of ratio presentation was unsystematic but no ratio occurred twice in succession and each had an approximately equal probability of occurrence over an experimental session. After a subject completed a particular ratio requirement, grain was presented for 3.25 sec and then the stimulus for another ratio was presented on the ratio key.

A blackout, variable in duration, in which all lights in the experimental chamber were out, preceded and followed each experimental session. Sessions lasted until 50 reinforcements were delivered. The procedure was continued for 14 sessions at which time the distribution of pre-ratio pauses and responses rates indicated a discrimination among the ratios for each bird apparent by visual examination of the cumulative records and graphic plotting of the response rates for each ratio.

Introducing the switching option. While the multiple-schedule baseline was established, the switching key was dark and responses on it had no scheduled consequences. The switching key was then illuminated with white light. A response on the switching key turned off its light and changed the ratio key to red. In the presence of red, a variable-ratio schedule of food reinforcement, consisting of nine ratios which were the same as the nine ratios in the multiple schedule, was in operation. The ratios in the variable schedule occurred in an unsystematic sequence in which no ratio occurred twice in succession and in which each had an approximately equal probability of occurrence over an experimental session. The ratio in effect on the variable schedule had no systematic relationship to the ratio from which the subjects switched.

Once the switching option had been introduced, the scheduled sequence of events was as follows: at the beginning of each session and after each reinforcement, the ratio key was illuminated with the stimulus for one of the ratios from the multiple schedule and the switching key was illuminated with white light. If a subject's first response was on the ratio key, the switching key light was turned off, thus eliminating the switching option for that ratio, and the subject was locked into whichever multiple FR was scheduled on the ratio key until that ratio was completed and reinforcement delivered. However, if the first response occurred on the switching key, the switching key light was turned off and the ratio key was illuminated with red light. This locked the subject into the variable-ratio schedule until the ratio in effect for that schedule was completed and reinforcement was delivered. After each reinforcement, the cycle was repeated with a different FR from the multiple schedule in effect with its stimulus illuminating the ratio key, and with white

light illuminating the switching key. As before, sessions were terminated after 50 reinforcements.

Increasing the switching requirement. After the pattern of switching had stabilized with only one response required to switch from the multiple FR schedule to the variable-ratio schedule, the responses required for switching were increased in the following sequence: 5, 15, 30, 60, and 90. Both subjects were given each value of the switching requirement until their performances were stable (no apparent trend for five successive sessions by visual inspection). This required 14 ± 4 sessions at each switching requirement. Whenever the response requirement for switching exceeded one response, the following was scheduled: after each reinforcement the ratio key was illuminated with one of the stimuli from the multiple FR schedule and the switching key was illuminated. If the switching requirement was completed before the ratio key was pecked, red light (indicating the variable-ratio schedule) was substituted for the multiple FR schedule stimulus on the ratio key. If the switching requirement was not yet completed, the first response on the ratio key turned off the switching key light (eliminating the switching option) and locked the subject into the particular FR scheduled on the ratio key. The total number of switches and the number of switches from each FR in the multiple schedule were recorded separately for each switching requirement.

RESULTS

Initial Establishment of Multiple FR Baseline

After 14 sessions of the multiple FR baseline, rate of response generally decreased as ratio size increased for both subjects. Figure 1 shows the average rate of response (responses per minute) for each ratio for each subject during the last session of the multiple FR schedule. The times required to complete each ratio were taken from the cumulative records and were measured from the point at which the ratio key was illuminated with the stimulus for each ratio. Thus, the plot includes time subjects spent not responding. No measure of the rate of response for FR 1 was available. Figure 2 presents sample cumulative records of the performance of both birds dur-

MULTIPLE SCHEDULE FR'S

Fig. 1. Average rate of response on last day of multiple FR baseline.

ing the last session of the multiple FR baseline. The figure shows that, although pauses occurred at the beginning of the larger ratios (FR 150 to 240), during the first half of these ratios bursts of responses often alternated with periods of non-responding until the subjects began to respond at high and steady rates. On the smaller ratios (FR 30 to 90) few pauses occurred during the ratio performance.

Performance with the Switching Option

Figure 3 shows median number of switches initiated and completed to the variable-ratio schedule during the last five sessions at each switching requirement for each bird. The number of switches initiated was the number of times a pigeon pecked the illuminated

SWITCHING REQUIREMENT

Fig. 3. Median number of switches initiated and completed to the variable-ratio schedule at each switching requirement. Note ordinal scale on abscissa.

Fig. 2. Sample cumulative records for Bird 6 and 10 during the last day of the multiple FR baseline. The recording pen reset at the completion of each ratio. During reinforcement the recorder was stopped.

switching key at least once, whether or not the switching requirement was completed before the ratio key was pecked. Each point on this figure represents 50 opportunities to switch. Figure 3 shows that number of switches to the variable-ratio schedule initiated and completed decreased as the switching requirement increased, although, at the higher switching requirements (30 to 90 responses) the number of switches initiated was slightly higher than those completed for both birds.

Figure 4 shows the proportion of switches completed for each bird at each FR over the last five sessions at each switching requirement.

The pattern of switching as a function of the multiple-schedule FRs at each switching requirement showed a consistent characteristic: a very low number of switches completed when the FR was small, and a fairly abrupt increase in switches at some particular FR and all larger ones. In effect, a criterion or threshold for switching can be described for each bird, such that subjects switched on most occasions when the ratio was above this criterion and did not when the ratio was below it. The general effect of successively increasing the switching requirement was to shift upward the point within the multiple FR schedule at which greater proportions of switching occurred. That is to say, as the switching requirement increased, the shift from a low proportion of switches completed to a high proportion of switches completed occurred at larger ratios.

Figure 5 shows for both birds those ratios at which the probability of switching was calculated to be 0.50 for each switching requirement. These points were calculated from Fig. 4 for each switching requirement by linearly interpolating between the two FR values which first bracketed 0.50 probability of switching. The points of 0.50 probability of switching, in general, occurred at higher ratios as the switching requirement increased. It is significant that at the lower switching requirements (1 to 30 responses) the point at which the probability of switching was 0.50

Fig. 5. Points on the multiple FR schedule at which the probability of switching to the variable-ratio schedule was calculated to be 0.50 for each switching requirement. Note ordinal scale on abscissa and truncated ordinate.

Fig. 4. Proportions of switches from each ratio of the multiple schedule at each switching requirement.

did not maximize the overall probability of reinforcement (number of reinforcements per response) on the ratio key. Since the mean response requirement on the variable-ratio schedule was approximately 120, if subjects were to maximize the probability of reinforcement on the ratio key, they would remain in the multiple schedule at all ratios below 120 and switch to the variable-ratio schedule at all ratios above 120. Relative to this strategy, both subjects showed a marked preference for the variable-ratio schedule.

The dotted line in Fig. 5 represents the locus of points at which switching maximizes the overall probability of reinforcement, when switching responses are included as part of the response requirement. Thus, at a switching requirement of 30 responses, if subjects were to maximize the overall probability of reinforcement (including the switching requirement) they would switch at all ratios above 150. Figure 5 shows that the points of 0.50 probability of switching more closely approximated this locus of maximum probability of overall reinforcement as the switching requirement increased.

Figure 6 shows the arithmetic mean rate of reinforcement (reinforcements per minute) for each FR in the multiple schedule and for the overall variable-ratio schedule for each bird averaged over all switching requirements. The rates of reinforcement for the multiple schedule during baseline and after the switching option had been introduced are presented separately for comparison purposes. The measures of time for each FR and the overall variable-ratio schedule were taken from the cumulative records: for the multiple FR baseline measure the records from the last five sessions under this condition were used; for the multiple FR measure after the switching option had been introduced, and the overall variable-ratio measure, the records from the last five sessions at each switching requirement were used. For each FR, the time required to complete it was measured from the time that the ratio key was first illuminated with the multiple FR stimulus, unless responses on the illuminated switching key occurred. If a response occurred on the illuminated switching key, but the total switching requirement was not completed, the time required to complete an FR was measured from the last switching key response. If the switching requirement

was completed, no time was recorded for any FR and the time required to complete the variable-ratio component was measured from the time when the switching requirement was met. No measure of the rate of reinforcement for the FR 1 was available.

For both birds the rate of reinforcement on the multiple schedule decreased as the FR size increased. In general, similar rates of reinforcement were obtained for both birds on the multiple schedule during baseline and after the switching option had been introduced. When compared to the rates of reinforcement for each FR after the switching option had been introduced, the rate of reinforcement

Fig. 6. Average rate of reinforcement within the multiple FR schedule and variable-ratio schedule (VR) for multiple FR baseline conditions and after the switching option was introduced, over all switching requirements.

on the variable-ratio schedule for both birds fell between that obtained for the FR 90 and the FR 120, but was closer to the FR 120 in each case. Thus, if subjects were to maximize the arithmetic mean rate of reinforcement on the ratio key, they would switch from the multiple schedule at all ratios above 90 and remain at all ratios below 90. However, at the lower switching requirements of 1 to 30 responses this did not occur (see Fig. 5). Instead, subjects showed more preference for the variable-ratio schedule than would be predicted on the basis of a comparison between mean rates of reinforcement.

Figure 7 shows sample cumulative records for Bird 10 at several switching requirements. Switching responses, in general, tended to occur as a group. Once the subject began to respond on the switching key it usually completed the switching requirement rather than respond on the ratio key before the switch was completed. Also, once the switching requirement was completed, the subject frequently emitted several responses on the red ratio key and then paused before beginning to respond at a high and steady rate. This pattern of behavior also occurred with Bird 6 but to a lesser extent. The occurrence of pauses after

Fig. 7. Sample cumulative records for Bird 10, at five switching requirements. Steps of the recording pen indicate responses on the ratio key; pips indicate responses on the switching key; deflections of the event pen downward indicate completion of a switching requirement, putting the subject into the variable-ratio schedule. The recording pen reset and the recorder was stopped at each reinforcement.

several responses had been emitted in the variable-ratio schedule suggests that, within this schedule, the subjects discriminated between the one-response ratio and the remaining ratios.

EXPERIMENT II: EFFECTS OF ONE-RESPONSE RATIO AND DELAY INTERVAL BEFORE ONE-RESPONSE RATIO ON SWITCHING BEHAVIOR

The results of Exp. I showed that the subjects switched to the variable-ratio schedule at points which maximized neither the probability nor the rate of reinforcement. Further, the patterns of responding on the variable-ratio schedule suggested that the subjects discriminated the one-response ratio from all other ratios in the variable schedule. The purpose of Exp. II was to examine the effect upon switching behavior of two manipulations: removal of the one-response ratio from the variable-ratio schedule; and, imposition of periods of delay between a completed switch and the opportunity to respond to the one-response ratio during the variable-ratio schedule.

Procedure

Removal of the one-response ratio from the variable-ratio schedule. During this condition only eight ratios were possible in the variable-ratio schedule (ratios of 30, 60, 90, 120, 150, 180, 210, and 240). This condition was in effect at switching requirements of both 5 and 30 responses for Bird 6 and at switching requirements of both 1 and 30 responses for Bird 10. In all other respects the switching situation remained the same as described in Exp. I. Subjects were given the one-response

ratio in the variable-ratio schedule at each switching requirement for several sessions before and after sessions in which it was removed. The sequence and number of sessions under each procedure for the two subjects is shown in Table 1.

Delay periods before the one-response ratio in the variable-ratio schedule. This manipulation was performed with the one-response ratio available in the variable-ratio schedule. However, a delay period was imposed between the time when a switch was completed and the ratio key was illuminated with red light if reinforcement was to be presented after one response. That is, the delay period was instituted only on the occasions when the one-response ratio was to be presented next in the variable-ratio schedule. Several lengths of delay were used: 5 sec, 15 sec, 30 sec, 60 sec, 120 sec, and 240 sec. The delay began immediately after the switching requirement was completed. During the delay period, both the house light and the key lights were turned off. Any responses which occurred on the keys during the delay had no scheduled consequences. Immediately after the delay period, the house light came on, the ratio key was illuminated with red light, and a single response on the ratio key produced reinforcement. After reinforcement the subjects again had the option of responding to a new multiple FR stimulus on the ratio key or to switch out of it into the variable-ratio schedule. Delay periods were instituted at switching requirements of 1 and 30 responses for both subjects. The order and number of sessions at each delay value are presented in Table 2. Under the delay procedure, other than when the delay period was imposed, the switching procedure remained the same as described in Exp. I.

Table 1

Sequence and number of sessions with the one-response ratio present and absent from the variable-ratio schedule.

One-Response Ratio Present or Absent in Variable Schedule	Bird 6		Bird 10	
	Switching Requirement	Sessions	Switching Requirement	Sessions
Present	5	3	1	3
absent	5	26	1	30
present	5	13	1	12
present	30	16	30	6
absent	30	22	30	13
present	30	13	30	9

Table 2

Sequence and Number of Sessions at Each Delay Value

Switching Requirement	Delay (Sec)	Sessions	
		Bird 6	Bird 10
30	0	13	9
30	5	9	8
30	15	6	6
30	30	9	8
30	60	9	9
30	120	6	8
1	0	8	6
1	60	11	13
1	120	8	8
1	30	13	13
1	240	15	14
1	0	34	36

RESULTS

Removal of the One-Response Ratio from the Variable-Ratio Schedule

Figure 8 shows the proportion of switches from different ratios of the multiple schedule for both birds with and without the one-response ratio in the variable schedule at both switching requirements. Since the one-response ratio was used only three days in the variable schedule at the switching requirements of 1 and 5 before it was removed, the data are plotted for only these three days. The remainder of the points represent the proportion of switches over the last five days under each con-

Fig. 8. Proportions of switches from each ratio of the multiple schedule with and without the one-response ratio in the variable-ratio schedule at two switching requirements.

dition. The two curves for the condition with the one-response ratio in the variable schedule at each switching requirement represent the performance of each subject before (curve A) and after (curve B) its removal.

Removal of the one-response ratio from the variable schedule decreased the total switches and shifted the criterion for switching to the larger ratios of the multiple schedule. For Bird 6, the effects of the removal of the one-response ratio from the variable schedule were greater when the switching requirement was smaller. For Bird 10, this was not apparent.

At switching requirements of 1 or 5 responses, if subjects were to maximize the probability of reinforcement (reinforcements per responses) with the one-response ratio in the variable schedule, they would switch from the multiple schedule at all ratios above 120 and remain at all ratios below 120. Both birds, instead, showed a marked preference for the variable-ratio schedule: both remained at the majority of ratios only at FR 1 and 30. With the one-response ratio removed from the variable schedule the mean response requirement of that schedule became 135. Under this condition, at a switching requirement of 1 or 5 responses, if subjects were to maximize the probability of reinforcement, they would switch from the multiple schedule at all ratios above 150 and remain at all ratios below 150. The switching behavior of Bird 6 approached this pattern. The switching behavior of Bird 10, although not matching this pattern, more closely approximated the switching pattern of maximum probability of reinforcement when the one-response ratio was not in the variable schedule than when it was. At 30 responses to switch, if the ratio requirement to switch is included as part of the response requirement for the variable schedule, the behavior of both birds more closely approximated the pattern resulting in the maximum probability of reinforcement when the one-response ratio was not in the variable schedule than when it was.

Figure 9 shows the arithmetic mean rate of reinforcement on the multiple FR schedule and the variable-ratio schedule with and without the one-response ratio in the variable schedule for both subjects. The data for this figure were taken from the cumulative records as described in the Results section of Exp. I. Only the records for the last five (or three) days under each condition were employed and

the rates were averaged over the two switching requirements. No point is plotted for the FR 210 for Bird 6 with the one-response ratio in the variable-ratio schedule because, under these conditions, this subject switched from all of these ratios.

Removal of the one-response ratio from the variable schedule had no apparent effect upon the mean rate of reinforcement in any of the components of the multiple FR schedule for either bird when averaged across the two switching requirements. Further, these rates were quite similar to those obtained during Exp. I after the switching option had been introduced (see Fig. 6). Removal of the one-response ratio from the variable schedule also had no apparent effect upon the mean rate

Fig. 9. Rate of reinforcement on multiple FR schedule and variable-ratio (VR) schedule with and without the one-response ratio in the variable-ratio schedule, averaged over two switching requirements.

of reinforcement in that schedule for either bird averaged across the two switching requirements. For Bird 6, the mean rate of reinforcement on the variable schedule was 0.74 when the one-response ratio was in the variable schedule, and 0.77 when the one-response ratio was removed from the variable schedule. For Bird 10, the corresponding rates were 0.52 and 0.57. This result is somewhat surprising as it might be expected that removal of the one-response ratio from the variable schedule would decrease the mean rate of reinforcement. However, this did not occur because response rate increased for both birds in the variable schedule when the one-response ratio was removed. This increase in response rate resulted, in part, from the reduction of periods of non-response early in the variable schedule. That is, when the one-response ratio was in the variable schedule, the pigeons invariably pecked the red key immediately after completing the switching requirement. If reinforcement was not presented at that time, both birds frequently paused briefly before beginning to respond at a high and steady rate. When the one-response ratio was removed,

both subjects typically began to respond at a high and steady rate with little pausing immediately after a switching requirement had been completed. Thus, although mean rate of reinforcement in the multiple and variable schedule showed little change when the one-response ratio was removed from the variable schedule, the pattern of switching and of responding on the variable-ratio schedule did change for both subjects.

Introduction of the Delay Intervals

Figures 10 and 11 are plots of the proportion of switches for each ratio at each delay interval for each bird at both switching requirements. Each point represents data from the last five sessions of each condition. Increasing the delay intervals decreased the number of switches to the variable-ratio schedule. At a switching requirement of one response for both subjects, all delay intervals increased the ratio at which switching began to occur more often than not, relative to the condition with no delay. In addition, for both subjects the proportion of switches at the larger ratios was reduced at the longest delay interval (240 sec). When 30 re-

Fig. 10. Proportions of switches from each ratio of the multiple schedule for Bird 6, when delay intervals were imposed between a completed switch and the one-response ratio in the variable-ratio schedule.

Fig. 11. Proportions of switches from each ratio of the multiple schedule for Bird 10, when delay intervals were imposed between a completed switch and the one-response ratio in the variable-ratio schedule.

sponses were required to switch, the delay interval had little effect upon the point on the multiple schedule at which subjects began to switch out of the majority of ratios. However, at the longer delay intervals (60 and 120 sec for Bird 6, and 120 sec for Bird 10) subjects switched out of a lower proportion of the larger ratios.

Figure 12 is a plot of the ratio size within the multiple schedule for both birds at each switching requirement and delay interval at which the probability of switching was 0.50. These points were calculated from Fig. 10 and 11 by linearly interpolating between the two FR values which first bracketed 0.50 probability of switching. Figure 12 shows that when one response was required to switch, the points of 0.50 probability of switching were at larger multiple schedule ratio values at the longer delay intervals. However, the greatest increase in the 0.50 switching point occurred between 0- and 30-sec delay periods. When 30 responses were required to switch, Bird 6 showed a slight increase in the 0.50 point of switching as the delay intervals increased. No such effect was noted for Bird 10.

Figure 13 shows the arithmetic mean rate of reinforcement on the multiple FR schedule and the variable-ratio schedule for both birds averaged over the two switching requirements and all delay intervals. The data for this figure were taken from the cumulative records as described in the results section of Exp. I. Only the records for the last five days under each

delay interval were employed, and rates were calculated not including the delay interval. The mean rates of reinforcement on the components of the multiple FR schedule for both birds were similar to those obtained in Exp. I after the switching option had been introduced and to those obtained for the prior conditions of Exp. II. However, rates of reinforcement on the variable-ratio schedule were somewhat lower for both birds when compared to those rates in Exp. I and the prior conditions of Exp. II. The lower rates of reinforcement on the variable schedule during delay conditions were due, in part, to a greater amount of pausing early in the variable schedule. However, there was no systematic relationship between rate of reinforcement on the variable schedule and the magnitude of the delay interval.

Fig. 12. Points on the multiple FR schedule at which the probability of switching to the variable-ratio schedule was calculated to be 0.50 at two switching requirements over the various delay intervals.

Fig. 13. Rate of reinforcement, multiple FR schedule and variable-ratio (VR) schedule, averaged over all delay intervals.

DISCUSSION

The results show that at relatively low switching requirements, pigeons will switch from a fixed-ratio schedule to a variable-ratio schedule at points where the mean response requirement of the variable-ratio schedule is considerably higher than the fixed-ratio response requirement. These results are consistent with the results of Fantino (1967) who found that subjects preferred a variable-ratio (mixed FR) schedule of reinforcement to a fixed-ratio (FR) schedule, when the fixed-ratio requirement was equal to the mean response

requirement of the variable schedule. The results of the present study are also consistent with the results obtained by Herrnstein (1964*b*) who found that subjects preferred a variable-interval schedule of reinforcement to a fixed-interval schedule when the interval of the fixed schedule was equal to the mean of all the intervals in the variable schedule.

In the present study, the degree of the subjects' preference for the variable schedule over fixed schedules was found to be a function of three conditions: (a) the number of responses required for switching; (b) the presence or absence of the one-response ratio within the variable-ratio schedule; (c) the duration of the delay imposed between switching and the opportunity to complete the one-response ratio within the variable-ratio schedule.

The finding that the degree of the subjects' preference for one schedule over another can be manipulated by the number of responses required on the switching key is consistent with the findings of Findley (1958, 1962). He found that initial preferences for one schedule over another could be reduced by systematically increasing the responses required to switch to the preferred schedule.

The finding that preference for the variable-ratio schedule over the FR schedule is partially a function of the presence or absence of the availability of the one-response ratio in the variable schedule is somewhat consistent with results reported by Fantino (1967). Fantino compared subjects' preferences for a fixed-ratio schedule and a mixed schedule which consisted of two fixed-ratio components. He found that preference for the mixed schedule increased as the disparity in response requirements between the two components of the schedule increased, even though the mean response requirement of the mixed schedule remained constant. Thus, he found a greater preference for the mixed FR schedule when its components were FR 1 and FR 99 than when the two components were FR 25 and FR 75. It is possible to regard the increased preference for the mixed schedule when the disparity of two components of the schedule increased as a function, in part, of the increased approximation of the lower ratio to an FR 1. The results of the present study with and without the one-response ratio in the variable schedule are consistent with such an analysis. On the basis of this analysis it would seem ap-

propriate to weigh the effects of the lower ratios differentially in a variable schedule when comparing preference between a variable- or mixed-ratio schedule and a fixed-ratio schedule. However, from the present results it is not clear how this weighting would be done. At low switching requirements (1 to 5 responses for Bird 6, and 1 to 30 responses for Bird 10) with the one-response ratio in the variable schedule, preference was not predicted accurately by comparisons of the arithmetic mean of either probability or rate of reinforcement between the fixed and variable schedules.

Fantino proposed in his study that choice was most reasonably predicted on the basis of a comparison between the geometric mean rate of reinforcement on the mixed schedule *versus* that of the fixed schedule. For the present data, the geometric mean rate of reinforcement of the variable schedule was calculated and compared to the mean rates of reinforcement of each component of the multiple schedule for all conditions where the switching requirement was 1 or 5 responses and no delay conditions were in effect. Although comparison of the geometric mean rates of reinforcement generally provided a better prediction than did comparisons of the arithmetic mean rates of reinforcement, preference was not accurately predicted for either subject in the majority of cases. However, there was a large number of procedural differences between Fantino's study and the present one, and there is, of course, no need for both types of procedure to predict preference in exactly the same manner.

A question related to the previous discussion is to what degree schedule variability controls preference between ratio schedules. It is possible to regard the present results in terms other than preference between particular ratios of the multiple schedule and the overall variable schedule. This may be done if one considers switching behavior as mainly controlled by the presentation of the one-response ratio in the variable schedule (appearing on some intermittent basis). For the purpose of this analysis, what is being compared with the procedures of the present study is the opportunity to engage in either FR behavior or switching behavior, with switching behavior being immediately, but intermittently, reinforced with the one-response opportunity

in the variable schedule. Thus, for this analysis the variability of the variable schedule (e.g., the number of different ratios within it or, possibly, the upper range of these ratios) is not as important in controlling preference as is the intermittent presence or simple absence of the one-response ratio. This analysis is supported by the results obtained when the one-response ratio was removed from the variable schedule. However, if this analysis is appropriate, the results obtained when delay periods were interposed between a switching response and the one-response opportunity in the variable schedule indicate that the immediate availability of this ratio is not crucial in controlling switching. Since removal of the one-response opportunity from the variable schedule produced a marked change in the pattern of switching for both birds, it is somewhat surprising that the shorter delay intervals did not produce a greater effect upon the pattern of switching. At the lower switching requirements (1 and 5 responses) the pattern of switching displayed by both subjects when the one-response ratio was removed from the variable schedule was closely approximated only at the delay interval of 240 sec. When 30 responses were required to switch, the pattern of switching displayed by both subjects when the one-response ratio was removed from the variable schedule was not closely approximated at any of the delay intervals. Since the delay interval was imposed only preceding a one-response ratio in the variable schedule, it is possible that the stimulus conditions which accompanied the delay interval acquired conditioned reinforcing properties which served to reinforce immediately those switching responses which produced the delay. This would serve to reduce the effect of the delay intervals in general.

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