PREFERENCE AND SWITCHING UNDER CONCURRENT SCHEDULING[1]

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Recent work by Ferster and Skinner (2) includes several experiments with a type of procedure described as concurrent scheduling. In one variation of this procedure, two operants are separately maintained by primary reinforcement. Reinforcement of these operants is programmed by independent schedules such that the reinforcement of one operant is not directly contingent upon the emission of the other.

The specific behavior resulting from such concurrent scheduling depends upon the nature of the schedules imposed, but is largely characterized by the observed prepotency of first one operant and then the other. This alternation in prepotency, here defined as switching, may be further accompanied by a second characteristic, namely preference. Thus, if a sample of the behavior shows the organism to be emitting one operant to the partial exclusion of the other, then a relative preference is defined for that operant.

The present paper reports a series of experiments concerned with the maintenance of preference and switching under concurrent-type procedures. These experiments originated with the scheduling of primary reinforcement for two operants in a manner similar to that described by Ferster and Skinner (2). Consideration of this experiment resulted in the development and exploration of a modified procedure in which switching was made more explicit, and in which the behavior receiving primary reinforcement was subject to greater stimulus control.

GENERAL PROCEDURES AND TECHNIQUE

The general technique, common to all of the following experiments, was the training of Utility King pigeons to peck one or more illuminated keys for grain. Delivery of such grain together with the special conditions of a given experiment were programmed by automatic equipment. The birds were typically trained for a given period each day, 7 days a week.

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[1] Opinions or conclusions contained in this report are those of the author. They are not to be construed as necessarily reflecting the view or the endorsement of the Navy Department.

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The technical considerations relevant to operant-conditioning experiments with pigeons have been extensively described by Ferster and Skinner (2), and by Ferster (1). Since the general procedures and apparatus used in the present experiments follow closely that used by the above investigators, only sufficient detail will be presented with each experiment to clarify the special procedures under consideration. Some departures in general technique, however, are mentioned below.

The grain used as reinforcement of the pecking response was that portion of commercial Purina Pigeon Chow which would pass freely through 3/16-inch-diameter holes, but not through 1/8-inch wire mesh. The remainder of this chow was used in nonexperimental feeding, if needed to maintain desired body weights. Vitamins, grit, and mineral supplement were made available to all birds to insure good health.

The experiments were begun with a single experimental unit to which a second and third were subsequently added. Recording of behavior and stimulus conditions from these units was by means of counters, Telechron clocks, and two cumulative recorders.

Partly as a consequence of limitations in recording devices, the general program received an emphasis upon final performance under a given procedure. This emphasis, unfortunately, resulted in the loss of much systematic data on acquisition and transitional effects. In the experiments to follow, therefore, discussion of such effects are minimized.

TWO - KEY CONCURRENT SCHEDULING

The first procedure investigated consisted of training pigeons to peck two illuminated keys for grain. These keys were separated by 6 inches in the front of a conventional pigeon apparatus, and reinforcements were programmed for each key by two continuously moving variable-interval (VI) tapes.[4] The mean interval of these schedules was 4 minutes. A special feature of the programming circuit was a delay contingency such that a reinforcement on one key could not follow a response on the other by less than 5 seconds.

After approximately 30 experimental hours, the behavior had become reasonably stable and the birds were observed to work first at one key and then the other, switching keys on the order of 9 times per minute. These switches characteristically followed either the delivery of grain, or a brief period of responding at each key.

The behavior was recorded with separate cumulative recorders, and it was apparent that the responding at each key was a high and sustained rate. However, since the time axis of both recorders ran continuously, the record from one key also included the time devoted to responding on the other. Figure 1 shows the resulting stepwise-type recordings for two birds. In this type of record, switches from one key to another were not difficult to infer, since the birds worked a fairly definite period of time at each key as a consequence of the delay contingency. But when the delay contingency was subsequently removed, the switching rates approximately doubled and consequently removed much of the stepwise character from each record.

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[4] All programming of interval contingencies reported in this paper were timed from the end of a previous interval, not from a previous reinforcement.

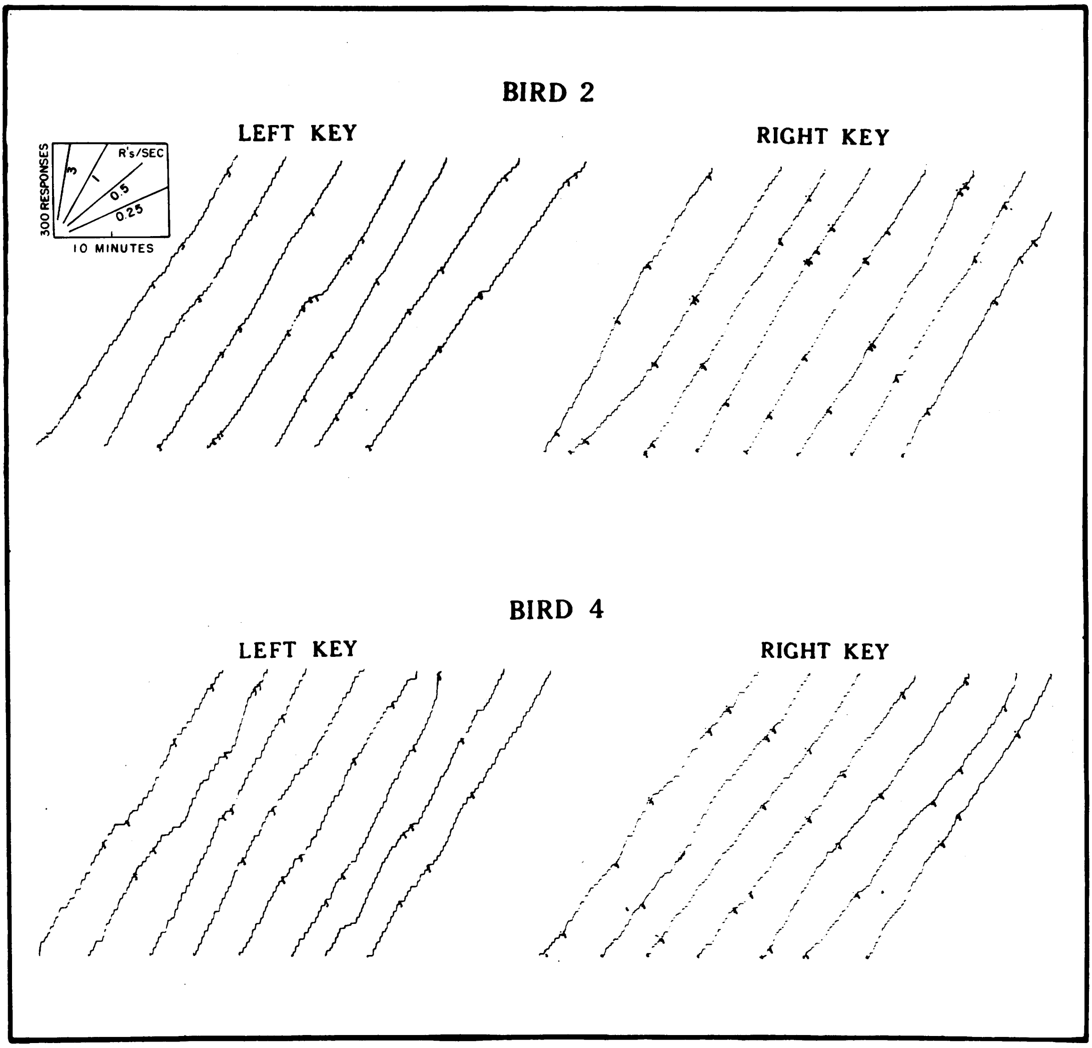

Fig. 1. Performance under two-key concurrent scheduling with a 5-second delay contingency.

In general, the results of these brief experiments were similar to those of Ferster and Skinner (2) in indicating that concurrent scheduling may be expected to maintain two operants and generate substantial switching. In the above experiments, however, the exact conditions providing the basis for switching were not clear, and much of the total behavior sequence appeared to be omitted. Two types of procedural modifications were indicated. First, the switching behavior needed to be made explicit; and secondly, the stimulus occasion for each operant reinforced with grain needed to be clearly specified and more subject to the experimenter's control. A procedure was then developed to meet these general demands.

THE SWITCHING - KEY PROCEDURE

In this procedure, pigeons were trained to peck a key which could be illuminated either red or green, and provision was made for associating a given grain schedule with each color. A second key, illuminated white, was located 3 inches to the left and permitted the birds, by a single peck, to switch the color appearing on the first key. This procedure, then, made explicit a switching operant and allowed the behavior reinforced with grain to come under the control of the two colors. Each change in color was defined as a switch.

PREFERENCE AND SWITCHING UNDER VARIABLE - INTERVAL

In the first experiments performed with the newly adopted procedure, VI schedules were also used, programmed as before, but without a delay contingency. They were designed to determine to what extent the rates of response and the percentage time spent in the two colors could be influenced by the mean values of the schedules imposed.

The birds used in the previous experiments were now exposed to the switching-key procedure. The transition was quite rapid and required no special training. Following adaptation, a program was pursued in which the four birds were trained for 4 hours a day for 7 days under a given pair of schedules, and then successively shifted to other pairs of schedules. The means of the schedules were 2, 4, 6, 12, and 20 minutes.[5] From the last 150 minutes of each 4-hour session the following data were obtained: time spent in each color, the rate of response in each color, and the switching rate.

Birds 5 and 6

The procedure followed for Birds 5 and 6 consisted of pairing successively a VI 6-minute schedule in the red with a 2-, 4-, 6-, 12-, and 20-minute VI schedule in the green. (See Table 1.) Figure 2 shows a typical pair of recordings from Bird 6

Table 1

Mean VI Schedules Paired in Red and Green
Expressed in Minutes

Birds 5 and 6		Bird 2		Bird 4	
Red	Green	Red	Green	Red	Green
6	2	2	20	2	2
6	4	4	12	4	4
6	6	6	6	6	6
6	12	12	4	12	12
6	20	20	2	20	20

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[5] All VI schedules were based upon arithmetical progressions from the expressions: $S = N/2(A + L)$ (1), and $D = (L - A)/(N - 1)$ (2), where S = the sum, 60 minutes; N = the number of intervals or reinforcements; A = the minimum interval, 0.2 minute; L = the longest interval; and D = the progression constant. Since, for a given mean schedule, S, N, and A were known, solution of (1) gave L. Having obtained L, solution of (2) gave D. Knowing D, the series of intervals were determined and then randomized.

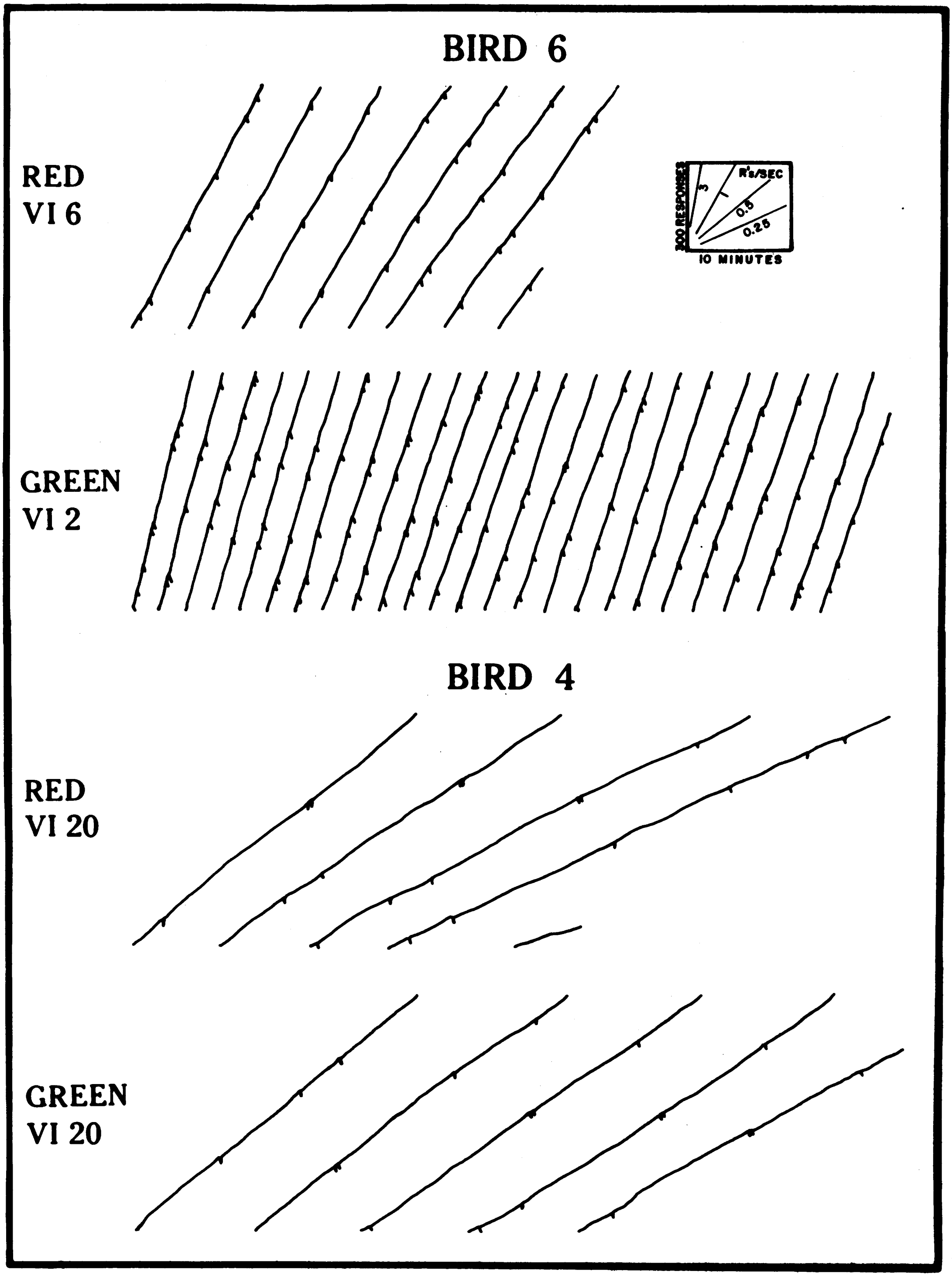

Fig. 2. Typical behavior under switching-key procedure with variable-interval schedules associated with each color.

covering a complete 4-hour session. Each cumulative record sums the responses and time only under a particular color. This pair of records indicates that the rate of response under a given color and the division of time between colors depended upon the mean value of each schedule. These two types of effects were also found in the data obtained from the last two and a half hours under all combinations of schedules. These data are summarized for Birds 5 and 6 in Fig. 3. As the mean reinforcement interval in the green was increased, both birds responded at a slower rate in the green, and worked for shorter periods of time in this color. The response rates while in the red showed little change for Bird 5, but showed an increase for Bird 6.

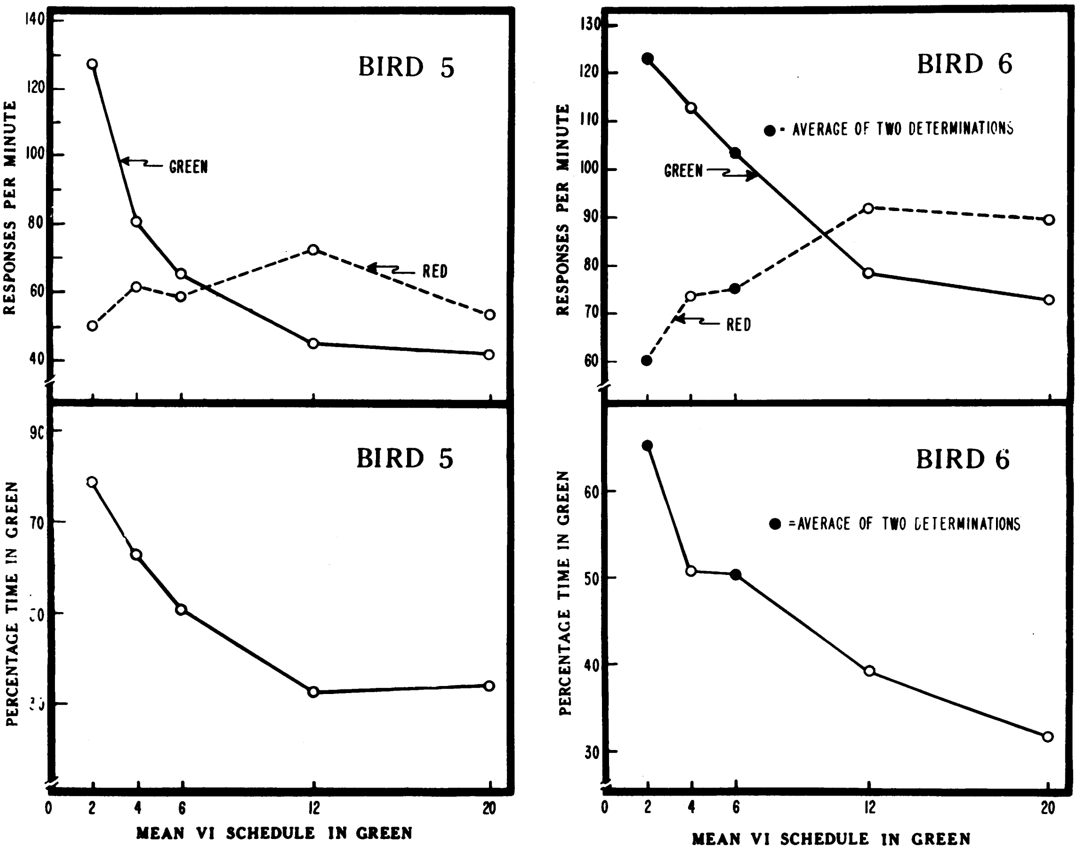

Fig. 3. Rates of response and percentage time in green as a function of mean variable-interval in green.

Bird 2

The procedure for Bird 2 was the same as that for Birds 5 and 6 except that as the mean reinforcement interval in the green was increased at successive stages from 2 to 20 minutes, the mean interval in the red was decreased from 20 to 2 minutes. (See Table 1.)

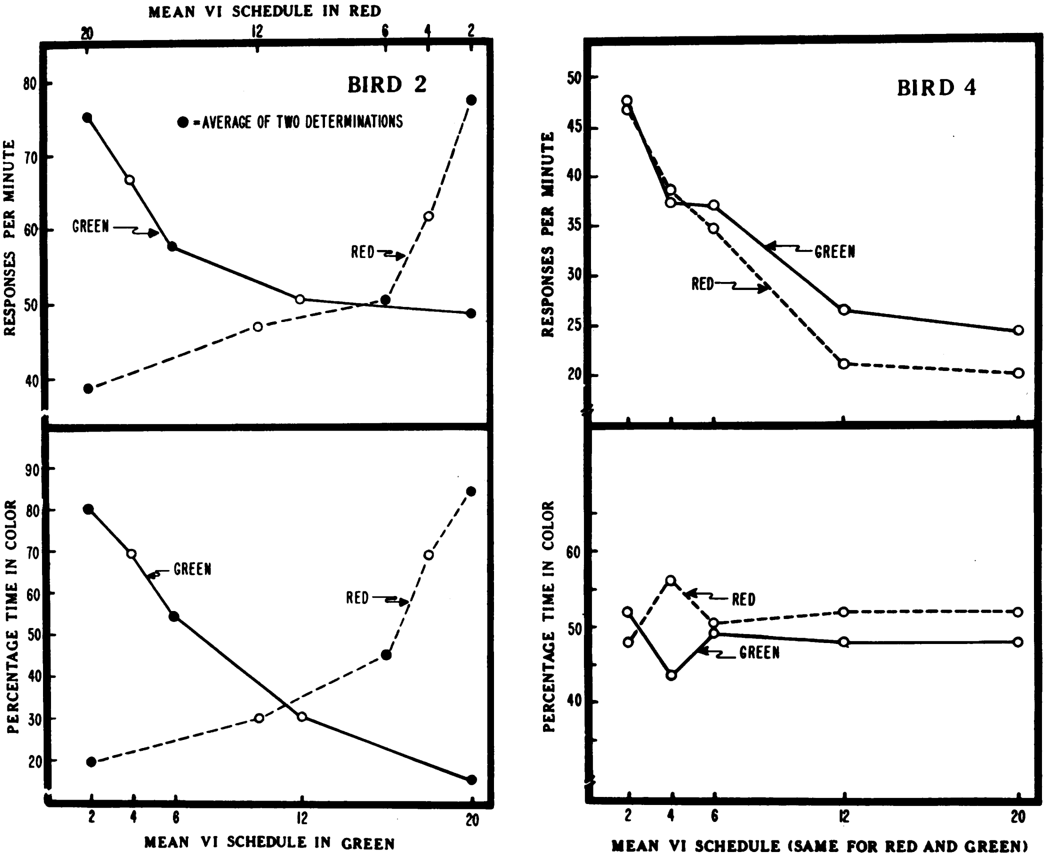

Fig. 4. Response rates and percentage time in each color as a function of mean variable interval schedules.

Under this procedure the rate of response in each color and the percentage time in each color were found to be inversely related to the mean reinforcement interval. Figure 4 summarizes these data under the different schedules.

Bird 4

To serve as a control for the effects of differential schedules, Bird 4 was trained under identical mean schedules in red and green, and the mean of these schedules was varied from 2 to 20 minutes. As the mean reinforcement interval was increased, the rate of response in both colors declined, while the amount of time spent in red and green remained approximately equal. (See Fig. 4 and Fig. 2.)

The results of the above experiments were clear in indicating that the division of time between the two colors was a function of relative reinforcement conditions. Thus, preference, defined by the relative predominance of one color, was easily manipulated by altering the mean value of the schedules. The over-all response rate in each color was generally observed to follow changes in the grain schedules.

Switching Rates

The above data summarizing relative response rates and percentage time in each color were possible, of course, since the birds were switching colors on the order of 12 to 20 times per minute. Changes in the switching rates, however, were generally not found to vary in an orderly fashion with changes in the mean reinforcement schedules. Lack of an orderly relationship between these variables was concluded to result, on the one hand, from the arbitrary length of training under a given pair of schedules, and, on the other hand, from the manner which the schedules provided for the switching. Where two punched tapes are providing the VI schedules, these tapes may run continuously, or they may be set to run only in the presence of each color. If the two tapes run continuously, as in the above procedure, the total reinforcements may be maximized by a given switching rate to an extent determined by the mean values of the schedules. In practice, however, the switching rate may vary considerably without materially affecting the total reinforcements received. This is possible since a reinforcement can accrue on the tape associated with the absent color. Such an accrued reinforcement would then be delivered with the first response following the reappearance of that color.

The delivery of a reinforcement in one color closely following a switch, either as a result of an accrued reinforcement or as a consequence of the varying intervals of the schedules, would presumably not only strengthen responding in a given color, but would also strengthen switching. Thus, in the above procedures, the maintenance of switching was due in part to the maximizing of total reinforcements, and perhaps to a greater extent due to the occasional delivery of reinforcement closely following a switch in colors. Since under a given pair of schedules the factors affording this maintenance were specified only within rather wide limits, little systematic effect on the switching rate was found when the means of the various schedules were varied.

Observation of the switching rates of birds previously trained under the method of continuously moving tapes when the tapes were set to run independently for each color proved that this method was largely responsible for the maintenance of the switching behavior; i.e., the tape for a given color would run only during the presence of that color. Figure 5 shows the decline of the switching rate in two such cases. For Bird 5, a VI 6-minute schedule in the red was paired with a VI 2-minute schedule in the green; and for Bird 2, the schedules were VI 6 minutes in both colors. An examination of the switching rate during the last hour of each daily session showed in both cases a decline to almost zero by the end of the fourth session. Thus, when each tape was run only in the presence of each color, much of the indirect reinforcement for switching was removed. Consequently, this aspect of the behavior was not maintained. Following the decline in switching rates the birds would occasionally remain in one color throughout the entire session. In the case of Bird 5, where the two schedules differed, the color having the shorter mean interval was found to predominate.

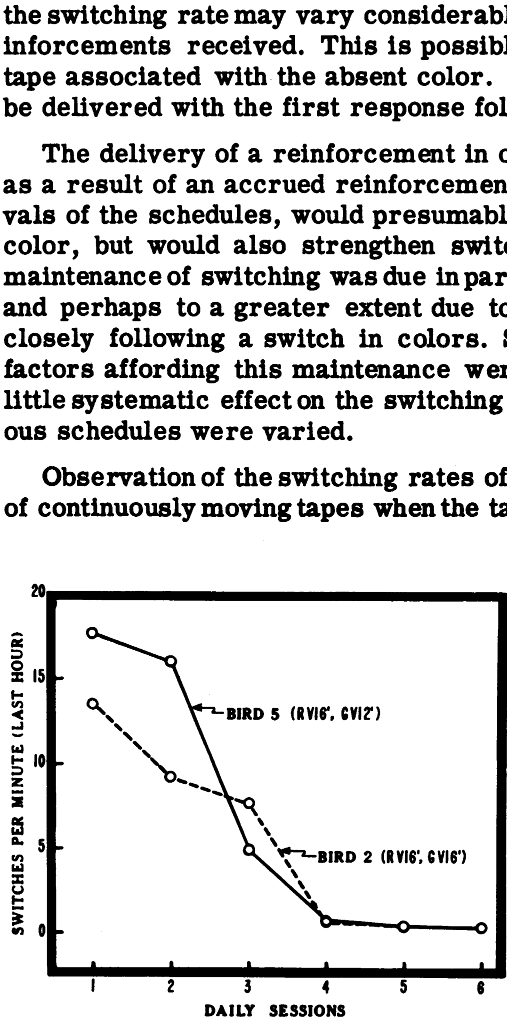

Fig. 5. Showing decline in switching rates when each reinforcement tape ran only in the presence of each color.

SWITCHING UNDER PROGRESSIVE CONTINGENCIES

In order to examine switching behavior further, reinforcement schedules were sought which would not only give rise to switching, but which would also be better specified and free of the undesirable effects found under VI schedules programmed with continuously moving tapes. After a period of experimentation, schedules were developed in which the contingencies for reinforcement in a given color became progressively altered with successive reinforcements and each switch in color would reinstate the original contingencies.

Thus, as before, birds were reinforced with grain for pecking a key which was illuminated either red or green. Pecking in a given color, however, became less favorable, grain-wise, the longer that color and the associated schedules were in effect. At any time following the first reinforcement in a given color, a peck on the switching key changed the color and reset the schedules to zero. Pecks on the switching key before the first reinforcement were ineffective.

During this period of experimentation, a rather wide variety of schedules were explored and use was made of both ratio and interval contingencies. For a given bird, however, the same set of contingencies prevailed in red and green. Examination of Fig. 6 reveals, in general, the type of schedules imposed and the method of recording.

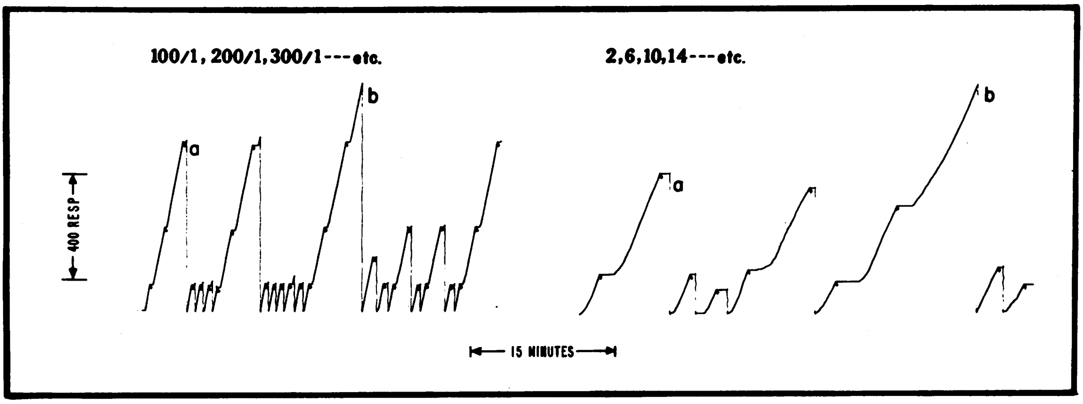

Fig. 6. Example of behavior under progressive contingencies showing method of recording.

In Fig. 6 the left record was obtained with schedules based upon the following ratio contingencies. The first reinforcement in each color required 100 responses; the second, 200 responses; the third, 300 responses; etc. Thus, the number of responses required for reinforcement increased by 100 responses with each successive reinforcement. The first switch in colors occurs at point a, which is indicated by the recorder returning to the base line and by the delivery of reinforcement following only 100 responses in the new color. The recorder also resets to the base line at point b, after traveling the maximum excursion, but does not indicate a switch in color.

The second record shown in Fig. 6 was obtained under interval contingencies. Beginning in a given color, the first interval was 2 minutes; the second, 6 minutes; the third, 10 minutes; etc. Thus, the minimum interval in both colors was 2 minutes and increased by 4 minutes with each successive reinforcement. The reset of the pen at point a again indicates a switch in colors, while that at point b does not. In practice, these two cases may be easily distinguished by a knowledge of the schedules and by an examination of the record following a reset of the pen.

The type of behavior illustrated in Fig. 6 often requires considerable training to establish, and its development varies widely, depending upon the past history of the organism and the values of the schedules. In general, however, the acquisition of such behavior is observed to follow certain stages. Early behavior under such schedules is characterized by extended periods of responding in one color, extinction-like performance, and few pauses following reinforcement. With continued training, the switching response increases in strength and the effect of either ratio or interval contingencies is seen in the over-all response rate and in the development of pauses following reinforcement. A final performance is often indicated by the occurrence of switches primarily following the pause after reinforcement, and by a reasonably stable day-to-day switching rate.

From a period of exploratory treatment of progressive contingencies, it became clear that stable switching behavior could be maintained under certain conditions. Further experiments were then pursued to examine behavior under these schedules in greater detail, and to determine to what extent the maintenance of the switching behavior depended upon the progressive schedules.

Four of the birds used in the previous experiments were given extensive training in which successive comparisons were made between the behavior under fixed- and under progressive-reinforcement contingencies. Figure 7 shows typical records from these comparisons after approximately 500 reinforcements under a given condition. In Fig. 7 the schedules were based upon interval contingencies for Bird 10, and upon ratio contingencies for Birds 8 and 5. For a given bird and condition, identical schedules were again used in red and green.

Following a past history of various progressive schedules, Bird 10 was trained under fixed-interval (FI) schedules of 1 minute in both colors. Within 25 experimental sessions the switching rate had declined to almost zero. An example of behavior during the latter days of this condition is that shown in Fig. 7. On day 26, the fixed schedules were altered to progressive schedules 1, 9, 7, 25, etc. Under these schedules, the switching behavior reappeared and stabilized at a relatively high rate within 9 additional sessions. Part of a record from the last day under this schedule is that shown in the top record of Fig. 7.

In Fig. 7 the records for Birds 8 and 5 show comparisons between stable behavior obtained under progressive-ratio and under fixed-ratio schedules. High switching rates were found under the progressive-ratio schedules, but could not be maintained under the fixed-ratio schedules. This effect was found independent of the order of transition, although, as was found with the interval comparisons, considerably more training was required for the decline of the switching rates than for their establishment.

In general, the results of these comparisons outlined in Fig. 7 not only showed that switching behavior could be maintained under progressive contingencies, but also revealed its absence under fixed schedules. This latter finding was consistent

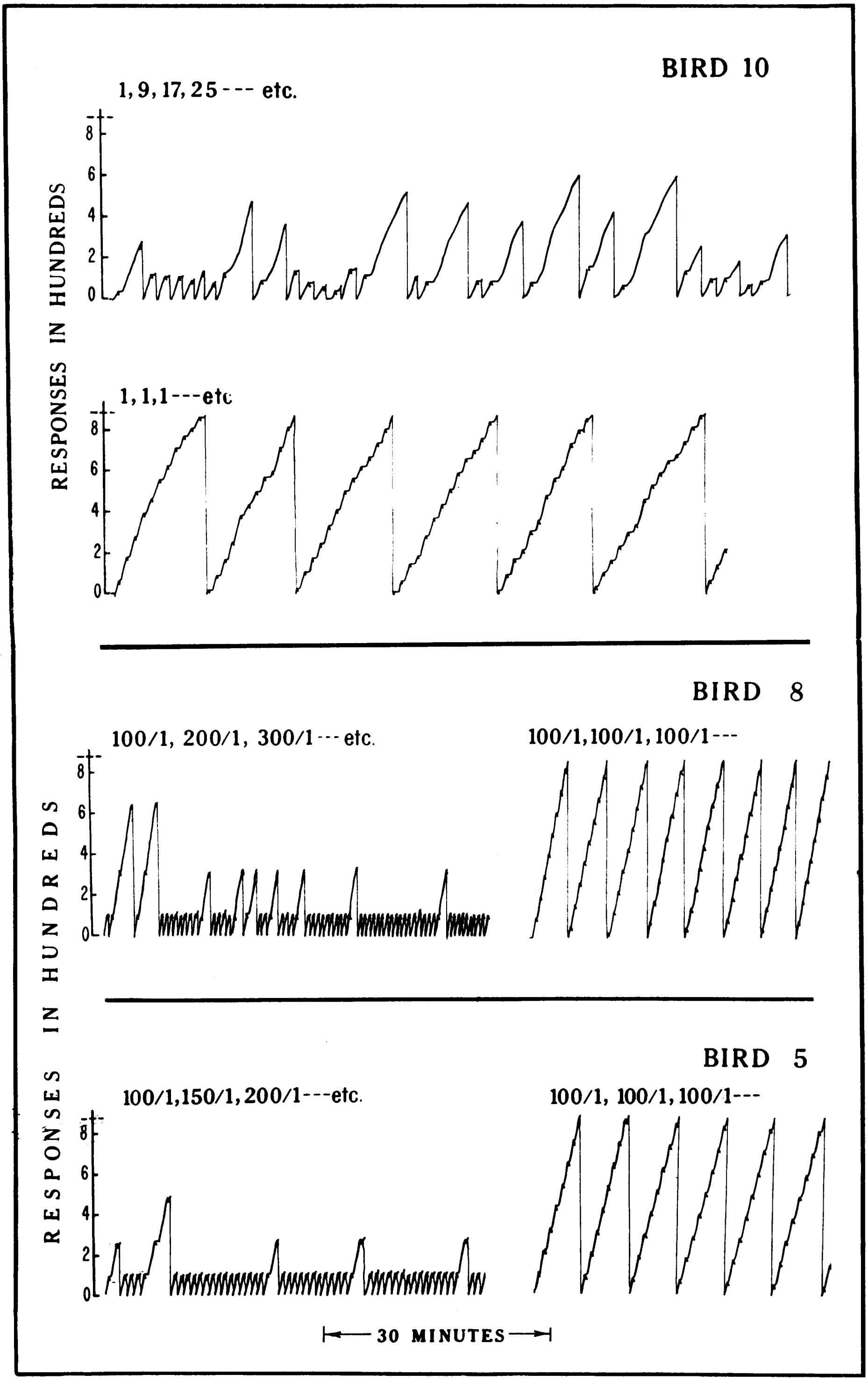

Fig. 7. Sample records comparing behavior under fixed and under progressive contingencies.

with the lack of switching found under VI schedules programmed to run only in the presence of each color, and again suggested that a procedure was being used which gave rise to little spontaneous switching.

Amount of Change with Successive Reinforcements

Early work with progressive contingencies had suggested that the switching rate under a given pair of schedules would in part be determined by the amount of change introduced with successive reinforcements. Such a function seemed even more likely since switching was maintained under progressive schedules, but not under fixed schedules. Thus, a schedule in which the minimum reinforcement contingency increased rapidly with successive reinforcements should result in a high switching rate compared with a schedule whose contingencies increase more slowly. This was found to be the case, both in several instances of shifting schedules to obtain a desired base line, and also from more direct evidence obtained from Bird 7.

Bird 7, which had a substantial past history under interval schedules, was given further training under several progressive-interval schedules, each with different amounts of change. The variable under investigation was the constant with which the minimum interval increased with successive reinforcements. This minimum interval was always 1 minute and the schedules used were based upon a constant increment of 8, 6, 4, 2, or 0 minutes, and presented in that order. The bird was run for at least 500 reinforcements under a given set of schedules and until the switching rate had become reasonably stable.

Sample records from the latter days under each condition are presented in Fig. 8. Under the 1, 9, 17, 25, etc. schedules, where each successive interval increases by 8 minutes, a relatively high switching rate was observed of the order of 0.5 per minute. It should be observed that the maximum switching rate would be one per minute, since no peck on the switching key was effective until after the first reinforcement in each color.

Under the schedules with less change, 1, 5, 9, 13, etc., and 1, 3, 5, 7, etc., the pauses following reinforcement grew longer and the bird typically remained in both colors for greater periods of time before switching. These effects resulted in a lower and somewhat more variable switching rate. The introduction of the FI 1-minute schedule was again observed to reduce the switching rate to near zero.

A plot of the data from the last two days under each of the above conditions revealed the switching rate to be an increasing monotonic function of the constant with which successive intervals were increased.

Fixed-ratio Contingencies for Switching

In the experiments discussed thus far, one peck of the switching key was sufficient to reverse the color on the key providing the delivery of grain. This was considered as the simplest contingency that could be imposed. Implied in this contingency, however, is a class of various requirements which might have been used, e.g., higher ratios, higher intervals, and perhaps delayed responding. One such contingency which was treated in some detail was the ratio required to switch colors. This variable, like amount of change with successive reinforcements, was found to have a pronounced effect upon switching rate. The direction of this effect, however, was opposite.

A given fixed ratio required to accomplish a switch in colors (FR to SW) was introduced into the general procedure in the following manner. If, for example,

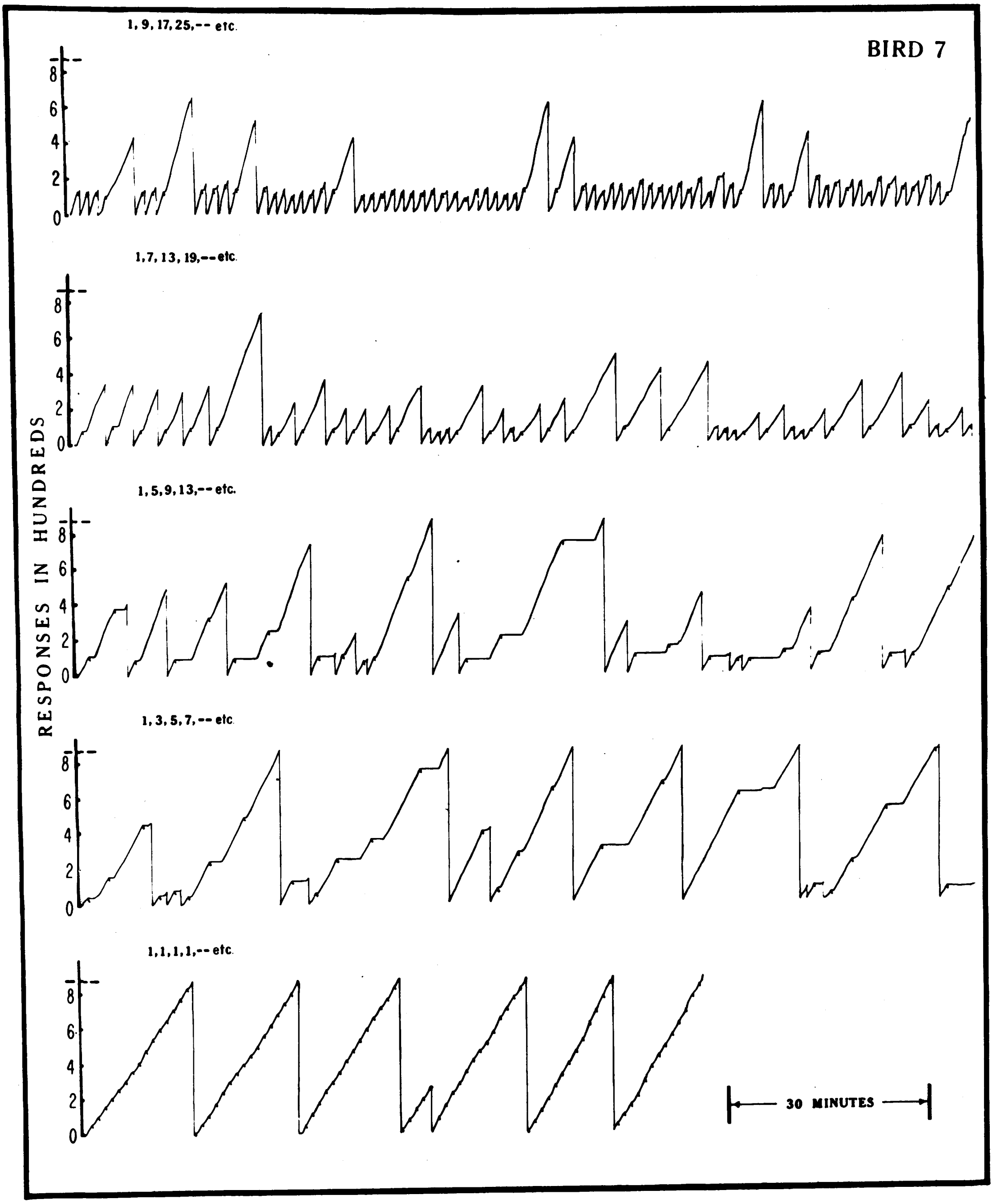

Fig. 8. Sample records showing switching rate as a function of the amount of change with successive intervals.

an FR of 10 was required, the first peck on the switching key would remove the prevailing color from the grain-reinforced key. The tenth peck on the switching key would then re-illuminate the grain-reinforced key with the new color and reset the schedules. The response and time components of the recorder were disconnected during the switching of colors, but indicated the occurrence of a switch, as before, by a reset of the pen to the base line.

The effects of higher FR's required to switch colors were first examined with Bird 8, which had previously been stabilized on identical progressive-ratio schedules in each color. These schedules were 100/1, 200/1, 300/1, 400/1, etc., and one peck had been required to switch colors and reset the schedules. When, at this point, an FR of 10 was introduced, some disruption of the behavior resulted; but within approximately 6 hours of further training, ratio performance was established on the switching key and a switch of colors would be completed within seconds. The bird was now observed, however, to work for a longer period in each color before switching.

Following this preliminary training, Bird 8 was given further training under each of five different FR's required to switch colors. These ratios were 1, 20, 40, 80, and 100 responses. The bird was run for at least 500 reinforcements and until the behavior had stabilized under each FR. Figure 9 shows sample records from the latter days under each condition.

An examination of data from these conditions reveals most of the general characteristics which were previously outlined for behavior under progressive schedules. The effect of increasing the FR required to switch colors was primarily to drive the organism to higher ratios before the occurrence of a switch. This effect was obtained without any loss in the over-all response rate, and the responding which switched the colors was typical ratio performance and revealed no "breaks."

The average switching rate, obtained from the last 3 days under each condition, was found to be a decreasing monotonic function of the ratio required for a switch.

PREFERENCE UNDER PROGRESSIVE CONTINGENCIES

In the previous experiments with progressive schedules, use had been made of identical schedules in red and green. Under these conditions, no consistent preferences developed for either color. The introduction, then, of two different schedules seemed likely to result in a preference for the schedule in which the contingencies changed more slowly. Such was found to be the case.

Several exploratory experiments were conducted with Birds 8 and 12 in which various combinations of schedules and FR's required to switch were examined. It immediately became apparent that the behavior was subject to the extremes of high switching rates with no obvious preference on the one hand, and low switching rates with extreme preferences on the other. A combination of conditions was then selected for each bird in which the behavior fell between these extremes.

For Bird 8 the conditions decided upon were as follows. In the red the schedule was 100/1, 200/1, 300/1, etc.; and in the green the schedule was 100/1, 600/1, 1100/1, etc. The FR required to switch was 40 responses. Training was continued for approximately 1000 reinforcements until the preference and over-all behavior had stabilized. The schedules and the colors were then reversed such that in the red the schedule was 100/1, 600/1, 1100/1, etc., and in the green, 100/1, 200/1, 300/1, etc. Figure 10 shows resulting 2/1 preferences of Bird 8 first for the red and then for the green. The reversal of the preference was obtained within three experimental sessions, although better than 1000 reinforcements were necessary for stable performance.

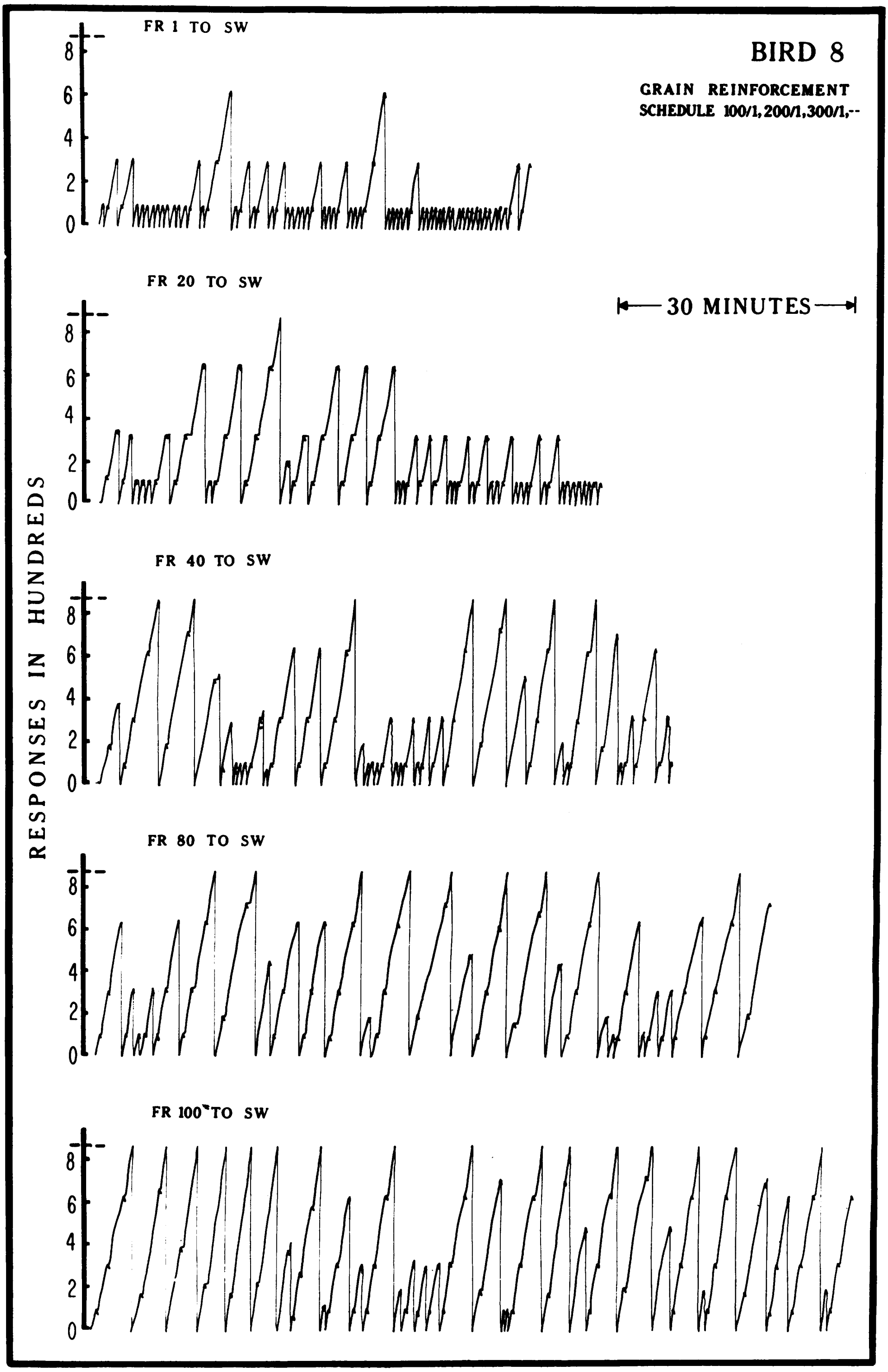

Fig. 9. Sample records showing decline of switching rates with higher fixed ratios required for switching.

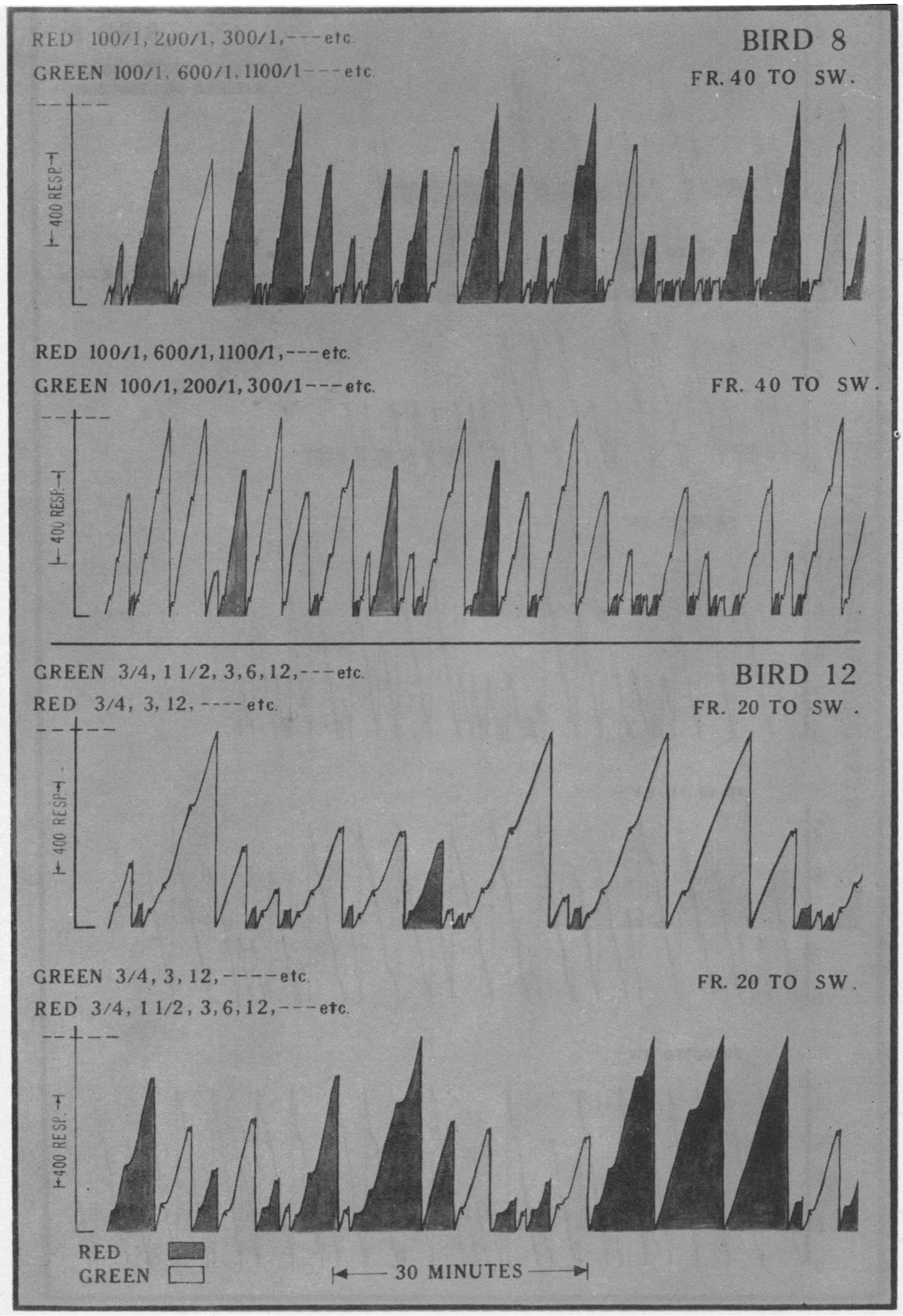

Fig. 10. Preference based upon two different schedules.

The same general procedures were followed with Bird 12, except that preferences were obtained under progressive-interval schedules. Bird 12 was trained under the following schedules: 3/4, 1 1/2, 3, 6, 12, etc., in the green; and 3/4, 3, 12, etc., in the red. Thus, in one case the minimum interval of 3/4 minute increased by a factor of 2, and, in the other, by a factor of 4. A stable preference on the order of 3/1 in favor of the green was obtained after approximately 60 experimental hours. The schedules were then reversed and training continued. Reversal of preference was again found to occur within a few experimental sessions. With continued training, however, the behavior stabilized at a somewhat higher switching rate and the final preference was found to be of the order of 2 to 1 in favor of the red. Figure 10 shows portions of cumulative records from the last few days before and after reversal.

Differential Fixed Ratio to Switch

During the above experiments, the importance of the switching requirements for the demonstration of preference suggested a somewhat different means by which preferences might be established. This method was the introduction of differential FR requirements for switching. Thus, under identical progressive schedules in both colors, it was thought possible to establish a preference for red or green by requiring a greater number of pecks to switch colors in one direction than in the other. The effects of such a procedure are outlined below.

Following the termination of the previous experiments with Birds 8 and 12, identical progressive schedules were imposed in both colors. Ratio contingencies were again used with Bird 8 and interval contingencies with Bird 12. As the birds were being stabilized on their respective schedules, it became apparent that under the grain schedules used, rather large differentials were necessary for obvious preferences. Once standard conditions had been adopted, training was continued until the resulting preferences had stabilized, and then the differentials were reversed.

For Bird 8 the reinforcement schedules were 100/1, 200/1, 300/1, etc., in both red and green. To switch from red to green, 79 responses were required on the switching key; and to switch from green to red, only 1 response. Better than 1000 reinforcements were delivered under these conditions, and the resulting preference was on the order of 2 to 1 for the red. The differentials were then reversed for Bird 8 such that only 1 response was required to switch from red to green, and 79 responses from green to red. After about 400 further reinforcements, a preference was obtained now for green, again on the order of 2 to 1. Sample records showing these preferences before and after reversal are found in Fig. 11. With the above preferences, the average switching rate was found to be of the same order as found previously with this bird under the same schedules but with a constant requirement to switch of 40 pecks.

The reinforcement schedules used with Bird 12 were 3/4, 1 1/2, 3, 6, etc., in both red and green. The differentials were, first, 39 responses to switch from red to green, and 1 response to switch from green to red. After reversal, they were 1 response to switch from red to green, and 39 responses from green to red. The preferences obtained before and after reversal were of the order of 5 to 1. Typical records showing these preferences are also found in Fig. 11.

In general, the results of the above experiments with Birds 8 and 12 not only demonstrated that preferences could be readily established and reversed by the

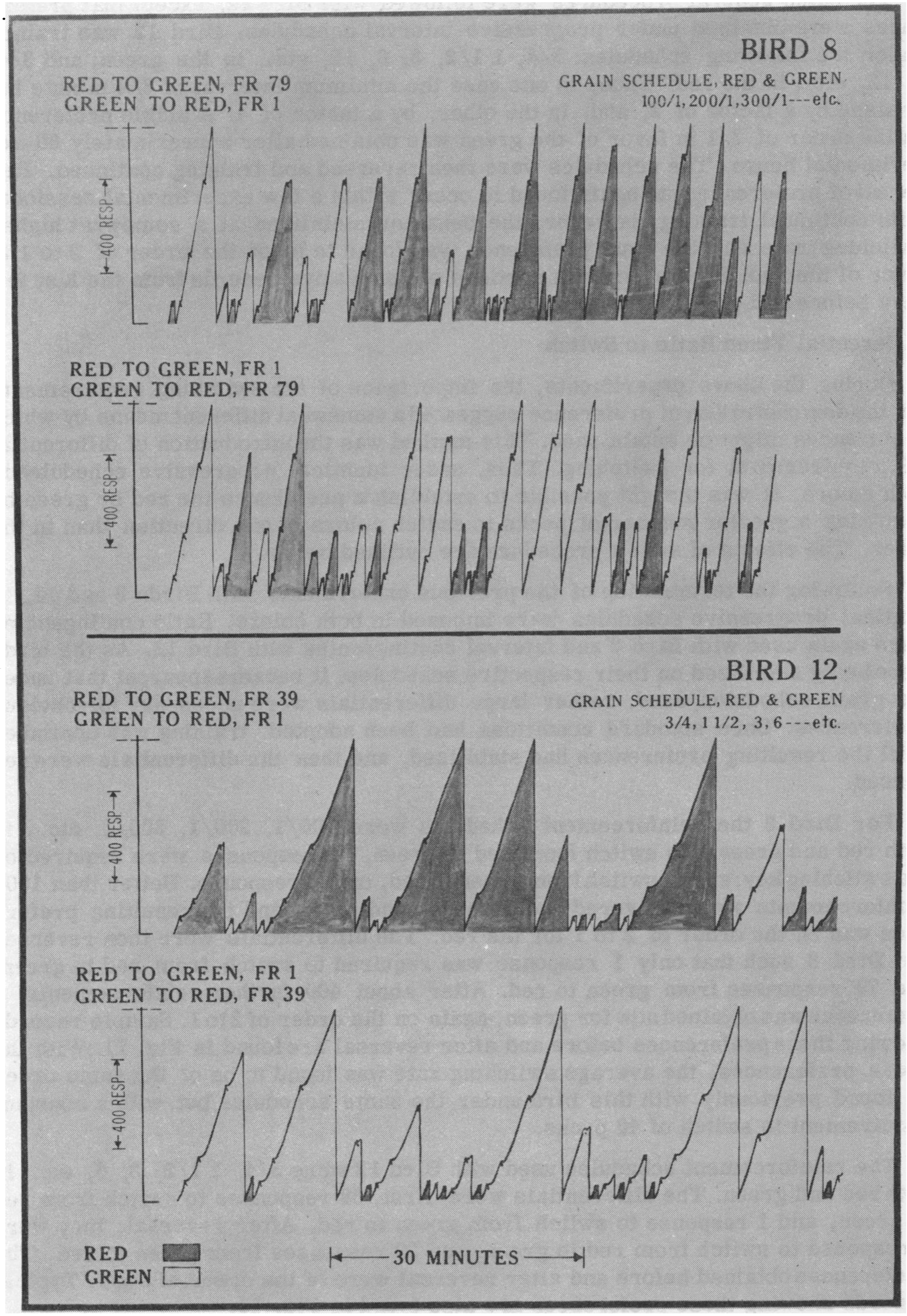

Fig. 11. Preference based upon differential fixed ratios required to switch.

use of two different schedules or by differential FR's required to switch, but also demonstrated how the two variables, amount of change with successive reinforcements, and the FR's required to switch could be played one against the other to obtain a desired effect. This was possible since, as pointed out before, the effects of these two variables were opposite.

SWITCHING BETWEEN RATIO AND INTERVAL CONTINGENCIES

A final complication of the variables outlined thus far was explored briefly by combining both progressive-ratio and progressive-interval contingencies into one experimental procedure. Thus, ratio contingencies were programmed in the red, and interval contingencies in the green. This complication demanded greater stimulus control by each color and provided a further test for the general effects of these schedules.

Bird 17 was given preparatory training under essentially a multiple schedule FR 100 in red and FI 3/4 minute in green. After the behavior had become reasonably appropriate to the two types of contingencies, the switching key was introduced and the schedules altered to progressive ratio and progressive interval. The schedule in the red was now 100/1, 200/1, 600/1, 2400/1, etc.; and in the green, 3/4, 1 1/2, 4 1/2, 18, etc. The FR required to switch colors was at first 2 responses and then raised to 20 responses in a stepwise fashion as the training progressed.

The introduction of the switching key and the progressive schedules disrupted the stimulus control previously obtained and resulted in extinction-like performance. With continued training the switching response gained in strength and the over-all behavior became reasonably stable. Differential effects from the two types of contingencies, however, were observed only after the bird had received more than 2000 reinforcements.

Typical records showing ratio and interval characteristics are found in Fig. 12. In these records the onset of responding in the red is usually quite abrupt, with a high sustained rate terminating in reinforcement. The responding in the green, on the other hand, is characterized by more gradual acceleration to a slightly lower terminal rate. These characteristics are most pronounced in the behavior prior to first reinforcement in each color.

The record shown in Fig. 12A was obtained after long training under the above conditions, and reveals, in addition to ratio and interval characteristics, a decided preference for the green or interval conditions. This preference is suggested not only from the greater time spent in green, but also from the relative infrequency with which this bird worked beyond the first reinforcement in the red.

In an attempt to improve the ratio and interval characteristics, the FR of 20 responses required to switch colors was altered to a differential of 9/1. Thus, 9 responses were now required to switch from red to green, and only 1 response to switch from green to red. The result of this alteration was an increase in the switching rate and the development of a preference now for the red. A record from the seventh experimental session under these new conditions is that shown in Fig. 12B.

In general, these experiments combining progressive-ratio and progressive-interval schedules demonstrated that where switching rates were relatively high these two types of contingencies might be expected to have their characteristic

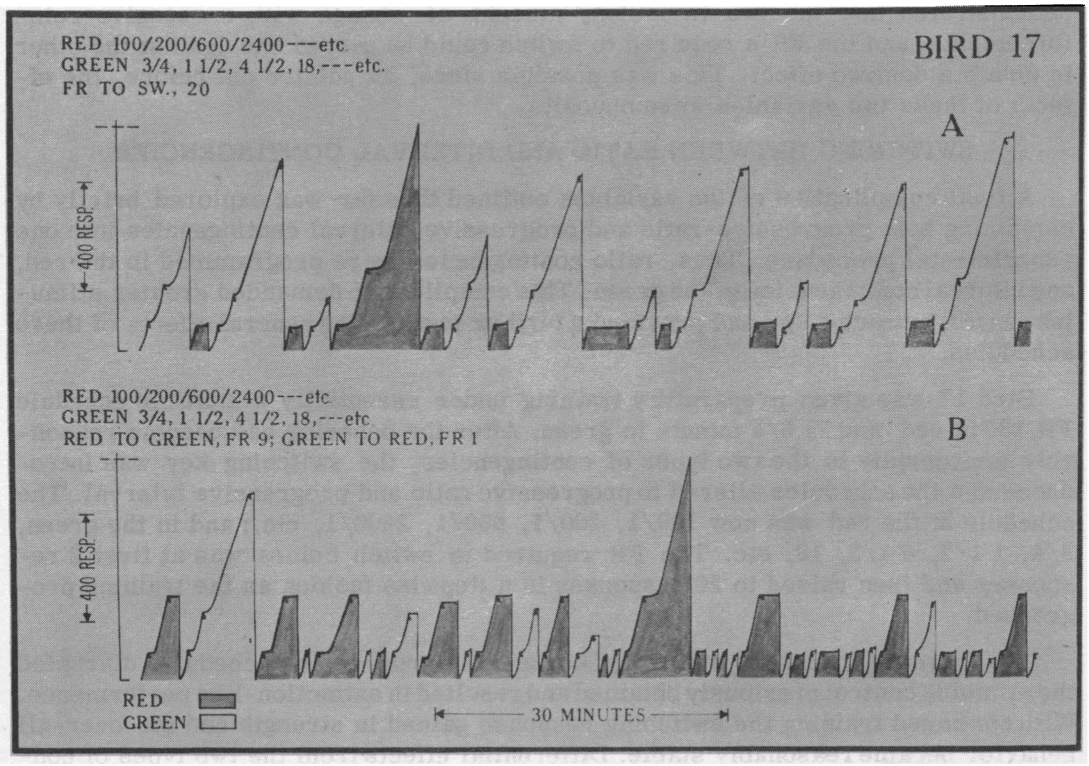

Fig. 12. Switching and preference under progressive-interval and progressive-ratio contingencies.

effects. In other respects, the behavior was similar to that obtained under two progressive-ratio or two progressive-interval schedules.

CHAINING AND PROGRESSIVE CONTINGENCIES

In the above experiments in which progressive-reinforcement contingencies were used, both preference and switching rate were found to be under the control of two opposing variables. These variables were amount of change in a given schedule with successive reinforcements, and the FR, or differential FR, required to accomplish a switch in colors. The effects of these variables and the maintenance of preference and switching follow from the chaining nature of the procedures investigated.

Provided the behavior on the key reinforced with grain has been demonstrated to be under the discriminative control of the two colors, two separate operants can be identified. The behavior on the switching key may then be considered a third operant, which mediates, in a chaining fashion, the alternation from the first to the second. Under such an analysis, the sequence would become as follows: responding under one color, for example, results in certain discriminative stimuli which are the occasion for behavior on the switching key. The consequences of pecking the switching key is the production of the new color which in turn is the discriminative stimulus for again pecking on the key reinforced with grain.

Although this sequence is behaviorally identical with that observed in the above experiments, the procedures do not unequivocally specify the discriminative and reinforcing stimuli for the switching behavior. The exact nature of these stimuli, then, is open to some interpretation.

Since the switching response is never followed directly by primary reinforcement, however, the maintenance of this behavior must depend upon secondary reinforcement. This reinforcement would appear most likely to be the onset of a new color, deriving its reinforcing properties from association with the more optimal grain contingencies. The occasion for switching, on the other hand, would arise as the bird experiences higher contingencies with successive reinforcements.

Assuming that the discriminative and reinforcing stimuli for the switching behavior are derived from responding under both optimal and less than optimal grain conditions, it is further apparent that the basis of these stimuli are removed once changes in the grain schedule cease to occur. This latter condition is provided either by nonprogressive schedules, or, under progressive schedules, by continued switching after the first reinforcement in each color. Under progressive contingencies, therefore, the maintenance of switching, and to some extent its variability, develop from a chaining sequence in which the discriminative and reinforcing stimuli for this behavior are afforded by relative changes in the grain contingencies.

The introduction of either high fixed ratios required to switch colors, or progressive schedules which change value slowly, would tend to make the discriminations between relative conditions more difficult, and consequently drive the bird to higher and higher successive contingencies. A given switching rate or preference for one color results, then, from the ease or difficulty of these discriminations provided by a particular arrangement of conditions.

The chaining nature of behavior under progressive contingencies may be further seen when the procedure is reduced to a simpler chain in which the occasion and reinforcement for switching behavior are better specified. This may be done if the delivery of the first reinforcement in each color produces a nonreinforcement, or blackout condition on the grain key. Under this procedure the blackout becomes the discriminative stimulus for switching, and the reinforcement of this behavior, production of the new color. Figure 13 shows several examples of behavior from such an alteration of procedures.

Since both the stimulus conditions and the contingencies for reinforcement are now specified within narrow limits in contrast with that under progressive schedules without blackout, the results are maximum switching rates and an obvious chain. Also, when the reinforcement contingencies are identical in red and green, as with Birds 8 and 12, the change in color becomes superfluous and the chain reduces to a sequence of only two operants. On the other hand, provision for discriminative behavior based upon the two colors, as with Bird 17, constitutes a chain composed of three operants.

The general pattern of behavior under progressive schedules, then, while apparently a situation in which the organism is free to choose one color or the other, is, in effect, only a complex sequence where the behavior associated with each color is chained in a not-so-obvious fashion to an intermediate operant.

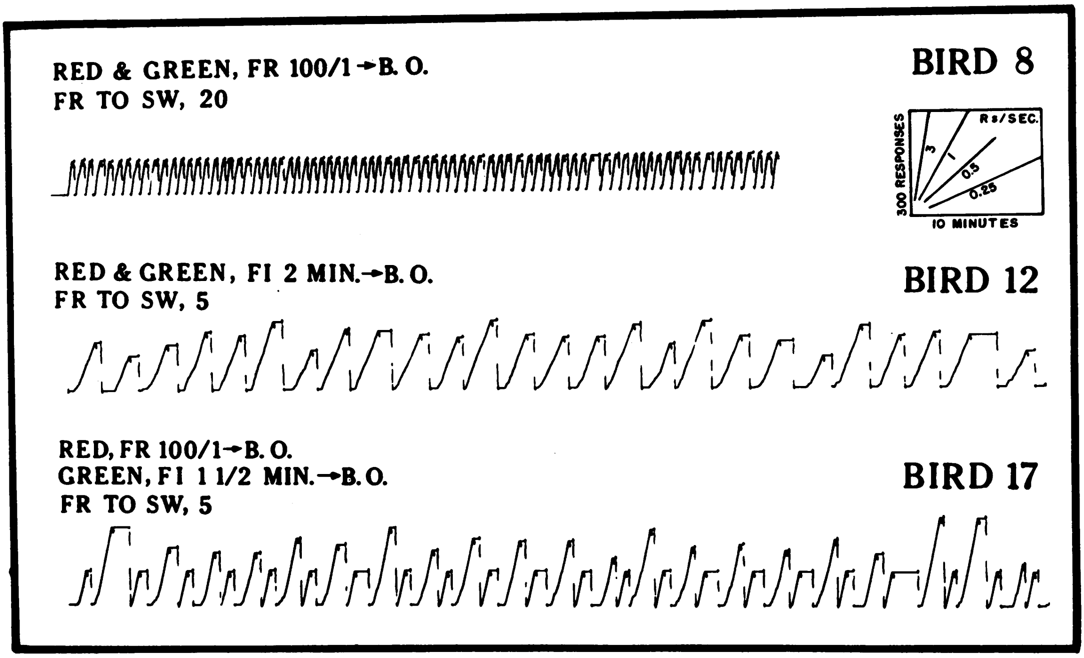

Fig. 13. Maximum switching rates as a result of blackout procedure.

SUMMARY

A series of experiments is reported in which pigeons were trained to peck an illuminated key for grain. The color of this key was either red or green, and associated with each color was a given reinforcement schedule. Pecking on a second key permitted the birds to switch the color appearing on the first key.

The general behavior resulting from this type of procedure suggested an operant chain in which pecking on the second key was maintained by its consequences for reinforcement on the first key. Preferences for a given color and rate of switching colors were found to be a function of the particular schedules and switching contingencies imposed.

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