CHAINED VI PERFORMANCE OF PIGEONS MAINTAINED WITH AN ADDED STIMULUS¹

J. ZIMMERMAN AND C. B. FERSTER²

INDIANA UNIVERSITY MEDICAL CENTER

Pecks at a first (left) key were reinforced by a partial movement (advance) of the voltmeter behind the key toward the maximum position. When the meter reached maximum deflection, pecks at a second key were continuously reinforced with food. The schedule of reinforcement by which pecking the first key produced a deflection, as well as the size of the deflection, were varied in a series of experiments. The rate of responding on the first key was more affected by changes in the number of steps required to move the meter to the maximum position (the size of the deflection) than by the value of the variable-interval schedule by which pecking produced a meter deflection. The rate at which the bird pecked was low when the meter was near the null position, and high as the meter approached the maximum deflection.

Kelleher (1957a, 1957b) demonstrated that behavior of chimpanzees could be maintained by intermittent reinforcement with poker chips, when the chips could be exchanged for food only after a certain number had been obtained. Kelleher's experiments, an extension of the experiments by Wolfe (1936) and Cowles (1937), demonstrated important properties of conditioned reinforcers, such as poker chips, which could be carried about and manipulated. Since the chimpanzees accumulated the poker chips before they could be exchanged for food, the number possessed bore the same relation to the animal's behavior and reinforcement as an added discriminative stimulus (Ferster and Skinner, 1957, ch 4). The number of chips the animal had accumulated bore a one-to-one relation to the number of responses emitted since the last food delivery and the number of responses required before the next. Hence, the poker chips could exert discriminative control over behavior because of the consistent correlation with reinforcement.

Kelleher's data confirmed the control by the number of poker chips in the animal's pos-

session. The rates of responding were very low until at least several chips were obtained. Rates accelerated to a high, steady value as more chips were accumulated. The performances observed by Kelleher are consistent with performances on extended chain schedules, such as those observed by Gollub (1958), Kelleher and Fry (1962) and Ferster and Skinner (1957).

The present study involved an experimental situation similar to Kelleher's, except that instead of delivering a poker chip, a voltmeter was deflected one step toward the maximum reading. Only at the maximum deflection of the voltmeter, was another response reinforced with food. Control over the pigeon's behavior by the deflection and position of the meter was investigated.

METHOD

Subjects

Two adult, male, White Carneaux pigeons were maintained at 80% of free-feeding weights.

Apparatus

A standard, two-key, experimental space for pigeons was modified by mounting a 30-v dc meter directly behind each of two clear plexiglas keys. The angular displacement from zero to maximum deflection was 80°. All markings on each meter, except the grid, were removed.

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²Now at the Institute for Behavioral Research, College Park, Maryland. Reprints may be obtained from J. Zimmerman, Institute for Psychiatric Research, Indiana Univ. School of Medicine, Indianapolis, Indiana.

Procedure

The general plan of the experiment was to set up a chain consisting of pecks at the left key, which intermittently advanced the meters toward maximum. With the meters at maximum deflection, responses on the right key produced access to the feeder for a number of reinforcements equal to the number of conditioned reinforcements required for full scale deflection of the meters.

In the first session, a red light was projected on the right key and the right key meter was at maximum deflection. Pecks on this key were continuously reinforced with food. The subjects (Ss) were then trained to peck both keys in the sequence left key, right key, food reinforcement. At the start of each sequence, both keys were red and both meters were at null position. A response on the left key produced maximum deflection of the meters, a response on the right key produced food and reset the meters to the null position. In the next few sessions the conditions were the same, except that left-key responses deflected the meters toward the maximum position on a VI 3 schedule. Next, left key responses were followed by the advance of the meters to half-scale deflection on the same VI 3 schedule. Therefore, two advances of the meter on the VI 3 schedule were required to produce maximum deflection, and hence, to produce the condition where each of two right-key responses produced food. Finally, the size of each meter deflection was decreased so that a large number of steps was needed to reach the final position. The number of times right-key responses operated the feeder was always equal to the number of steps needed to deflect the meters to maximum. A daily session was ended after 60 reinforcements, or occasionally when low rates of responding extended a session beyond available apparatus time.

The behavior on the left key was the dependent variable of the experiment. The independent variables were (A) the number of steps required to produce the maximum deflection of the meters (analogous to the number of components in a chain), (B) the schedule of reinforcement by which responses advanced the meter, and (C) stimulus changes, such as a flash of the house lights, which accompanied and augmented the meter deflection. Other procedures were designed to meas-

ure the reinforcement of left-key responses, independently of the discriminative control by the position of the meter.

Table 1 presents the order of the experimental procedures and the number of sessions spent on each procedure over the course of the study for each S. Many of the procedures were designed to eliminate pecking at the food key before the meters reached maximum deflection. In Procedure 1 of the table, for example, Bird 80R was run for 21 daily sessions in which left key responses were followed by a 1/10th scale advance of the meters on the VI 3 schedule. After the meters reached maximum deflection, each of 10 right-key responses were continuously reinforced with food. Right key responses in the absence of maximum deflection (in the presence of S^A for food) stopped the VI 3 tape for 10 sec. In Procedure 2, 20 steps were required in each chain. Throughout the rest of the experiment, (a) a VI 1 schedule of meter advance was employed, (b) a brief flash of the house lights (H. L.s) accompanied every meter advance (to make such events more discriminable), and, (c) all right-key S^A responses produced a time out (TO). In Procedure 3, 20 steps were required in each chain and a 10-sec TO followed each right-key S^A response. In Procedure 4, only 10 steps were required. In Procedure 5, 20 steps were again required, but in addition, the right key remained dark in every sequence until maximum deflection was reached. The red light was then projected on the right key until all food reinforcements were obtained. The right key was dark in S^A throughout the rest of the experiment. In Procedure 6, only 10 steps were required to maximum deflection and in the first five sessions, the TO duration was rapidly and progressively raised to 15 min. (The 15-min TO virtually eliminated right key S^A responding.) Final performance on Procedure 6 was then used as a baseline against which to evaluate the effect of the meter position, meter advances, and H. L. flashes, on left key behavior. Procedures 6, 8, and 10 were identical. In Procedure 7 the meters were removed from the circuit and remained at null position. In Procedure 9, the meters and the H. L. flashes were removed and Ss were thus on a tandem schedule.

In summary, Bird 80R was run through two procedures in which the schedule of meter advance was held at VI 3, while the number

Table 1
Experimental Conditions

<i>Left Key</i>	<i>BIRD 80R Right Key</i>	<i>Ses- sions</i>	<i>Pro- cedure</i>	<i>Left Key</i>	<i>BIRD 79R Right Key</i>	<i>Ses- sions</i>
VI 3, 1/10th scale	10 S ^D responses reinforced with food. S ^A responses stop tape for 10 sec.	21	1	VI 3, 1/10th scale	10 S ^D responses reinforced with food. S ^A responses stop tape for 10 sec.	18
VI 3, 1/20th scale	20 S ^D responses reinforced with food. S ^A responses stop tape for 10 sec.	14	2	VI 3, 1/20th scale	20 S ^D responses reinforced with food. S ^A responses stop tape for 10 sec.	12
VI 1, 1/20th scale and H. L. flash	20 S ^D responses reinforced with food. S ^A responses produce 10-sec TO.	9	3	VI 1, 1/30th scale and H. L. flash	30 S ^D responses reinforced with food. S ^A responses produce 10-sec TO.	15
VI 1, 1/10th scale and H. L. flash	10 S ^D responses reinforced with food. S ^A responses produce 10-sec TO.	7	4	VI 1, 1/20th scale and H. L. flash	20 S ^D responses reinforced with food. S ^A responses produce 10-sec TO.	6
VI 1, 1/20th scale and H. L. flash	10 S ^D responses reinforced with food. Right key dark in S ^A . S ^A responses pro- duce 10-sec TO.	7	5	VI 1, 1/10th scale and H. L. flash	10 S ^D responses reinforced with food. Right key dark in S ^A . S ^A responses pro- duce TO. TO raised over 7th to 11th sessions from 10 sec to 15 min.	14
VI 1, 1/10th scale and H. L. flash	10 S ^D responses reinforced with food. S ^A responses (dark key) produces TO. TO raised in first five ses- sions from 10 sec to 15 min.	14	6	VI 1, H. L. flash only, 10 steps. (Meters at zero).	10 S ^D responses reinforced with food. S ^A responses (dark key) produce 15-min TO.	6
VI 1, H. L. flash only, 10 steps. (Meters at zero)	10 S ^D responses reinforced with food. S ^A responses (dark key) produce 15-min TO.	6	7	VI 1, 1/10th scale and H. L. flash	Same as above.	6
VI 1, 1/10th scale and H. L. flash	Same as above.	6	8	VI 1, tandem chain, 10 steps.	Same as above.	6
VI 1, tandem chain, 10 steps	Same as above.	7	9	VI 1, 1/10th scale and H. L. flash	Same as above.	7
VI 1, 1/10th scale and H. L. flash	Same as above.	7	10			

of steps was changed. In the next four procedures, the experiment was repeated with a VI 1 schedule under somewhat different conditions. In the last four procedures, the stimulus events occurring on the VI 1 schedule were manipulated.

Bird 79R was run through a similar series of procedures as outlined in Table 1.

RESULTS

Number of Steps Required to Full Scale Deflection. Figure 1 presents cumulative rec-

ords of left-key responses for bird 80R, which show the effect of the number of steps to full-scale meter deflection when the schedules of reinforcement were VI 1 and VI 3. Each response chain was characterized by a low initial rate of responding which increased gradually to a terminal rate of the order of one response per second. The pips on the records indicate the meter advances (steps) programmed on the variable-interval schedule. The overall rate of responding was closely correlated with position of the meters, as can be seen by counting the number of advances.

In every case, increasing the number of steps required for maximum deflection produced a large magnitude increase in the initial period of very low rates of responding and therefore a decrease in the overall rate of responding. Each record contains representative chains from the final two sessions on the procedures, and each chain corresponds closely with the neighboring performances. These results occurred regardless of the presentation order of different numbers of steps in the VI 1 series (Procedures 3, 4, 5 and 6). The comparison between the VI 3 and VI 1 performances is discussed below.

Changing the number of meter steps from 10 to 20 produced similar results for bird 79R, for which VI 3 cumulative records are presented in Fig. 2. The 10-step response chains in the top portion show the extremes of the range of pauses at the start of the chain. Pauses of the magnitude of the bottom two segments occurred rarely. The period of low rate of responding at the start of a chain increased by a factor of 2-5 (bottom records) when the number of steps required to bring the meter to the payoff position was increased to 20. The same results occurred with the VI 1 schedule (records not shown).

S^A Responding on the Right Key. The amount of S^A responding on the right key in-

creased when the left-key responses advanced the meter on a variable-interval schedule. Eventually, the rate of responding on the right key correlated closely with responding on the left key. The tendency to respond on the food key concurrently with the left-key responses was more marked for 80R than for 79R in the VI 3 series (Procedures 1 and 2). When the schedule of reinforcement by the meter was changed to VI 1 (Procedure 3), 79R's rate of S^A responding on the food key increased. Figure 3 presents cumulative records of left key (meter) and right key (S^A) responding of 80R from a representative response chain from each of four experimental procedures, as indicated. Responding, in every case, increases in food-key responding when the meter key responding increases. Figure 4 presents similar records for 79R from a stage in the experiment (Procedures 3 and 4) where there was also a close correlation between responding on the two keys. These records illustrate the strong correlation between behavior on the two keys, but did not occur typically with this bird. Response rates on the two keys were correlated wherever any responses occurred on the left key. The graphs in Fig. 4 show food key behavior during the early parts of the chain, when the rate of responding on the left key was high.

Fig. 1. Cumulative records of left key responding of Bird 80R for four representative chains from the final two sessions on each of four experimental procedures: VI 1, 10 steps (Procedure 4), VI 1, 20 steps (Procedure 3), VI 3, 10 steps (Procedure 1), VI 3, 20 steps (Procedure 2). Pips indicate steps on the VI schedules.

Fig. 2. Cumulative records of left key responding of Bird 79R for four representative chains from the final two sessions on each of the two experimental procedures: VI 3, 10 steps (Procedure 1) and VI 3, 20 steps (Procedure 2). Pips indicate steps on the VI 3 schedule.

Fig. 3. Cumulative records of left key responding (top record in each group of three) and of right key responding (middle record in each group of three) of bird 80R for a representative chain from each of four experimental procedures; VI 1, 10 steps (Procedure 4), VI 1, 20 steps (Procedure 3), VI 3, 10 steps (Procedure 1), and VI 3, 20 steps (Procedure 2). Pips on the left key records indicate steps on the VI schedules.

Neither the application of a 10-sec TO for S^A responses nor the use of a color on the food key as a discriminative stimulus reduced the tendency to peck at the food key before the

Fig. 4. Cumulative records of left key responding and right key responding of Bird 79R for a chain from each of two experimental procedures; VI 1, 20 steps (Procedure 4) and VI 1, 30 steps (Procedure 3). Pips on the left key records indicate steps on the VI 1 schedule.

meter reached its maximum deflection. S^A responses were finally eliminated when the TO duration was increased to 15 min.

Removal of the Meters and the House Light Flashes. Control over left key responding by the position of the meter and by the stimulus events on the VI 1 schedule was evaluated by keeping the meters at the null position, and by removing the other stimuli (H. L. flashes) that had been paired with the meter deflection. Figure 5 presents cumulative records of left key performance for 80R for representative response chains from the final two sessions during each procedure in which the consequences of left key responding was manipulated (Procedures 6, 7, 8, and 9). The first column presents chains in which left-key responses advanced the meters and produced a H. L. flash. The performances show varying degrees of acceleration of rate. Records in the second column show that keeping the meter in the null position alters the shape of most chains. Some were scalloped (top and bottom chains, for example) as before, but most indicated a partial loss of correlation between response rate and number of steps completed. Negative acceleration of response rate often occurred in the middle or even towards the end of a chain. In some (middle chain for example), high rates of responding occurred early in the chain. Reinstating the movement of the meters (third column) again produces orderly scallops which are well correlated with the number of steps completed, and

Fig. 5. Cumulative records of left key responding of Bird 80R for four or five representative chains from the final two sessions on each of four experimental procedures. Each procedure involved the VI 1, 10 step condition. First and third columns: Meters and H. L. flashes were programmed. Second column: Only the H. L. flashes were programmed. Fourth column: Tandem Schedule. Pips indicate steps on the VI 1 schedule.

therefore, with the position of the meter. Removing both the meters and the H. L. flashes (fourth column) leads to almost constant response rates. This is a tandem VI 1 schedule. Reinstating the meters and H. L. flashes in other experiments produced records similar to those shown in columns 1 and 3. The same procedures led to similar results with Bird 79R (Fig. 6).

DISCUSSION

The number of steps required to move the meters to maximum deflection had a large influence upon how well the S's behavior was maintained. When the VI schedule was held constant, an increase in the number of steps from 10 to 20, resulted in an extreme weakening of behavior (Fig. 1 and 2). The number of steps appeared to be a more significant variable than the VI schedule value. Although the potential frequency of food reinforcement was higher for the VI 1, 20-step procedure than for the VI 3 10-step procedure, the former generated weaker behavior (Bird 80R, Fig. 1). The comparison between VI 1 and VI 3 behavior is confounded, however, by the addition of the H. L. flashes and the 10-sec TO in the VI 1 series. However, the comparison may still be legitimate because the tape-stop "punishment" procedure used in the VI 3 series actually attenuated the VI 3 schedule and, therefore, in effect, made the VI 1 schedule even more favorable. Bird 79's performance confirms 80R's, with respect to the num-

ber of steps. In presenting the VI 1, 30-step procedure after the VI 3, 20-step procedure, the potential frequency of food reinforcement was increased. Yet, the pausing was so severe that the actual frequency of reinforcement fell drastically. The rate of responding did not increase even when the number of steps was lowered to 20.

The frequency of right-key responses did not fall when they stopped the VI tape for 10 sec. Nor did a 10-sec TO following food-key S^A responses, or a clear discriminative stimulus on the food key, reduce the S^A level of responding. A 15-min TO, however, virtually eliminated right-key S^A responses, suggesting that such responses were too strongly maintained by other variables to permit moderate manipulations to affect them. This interpretation is supported by other data obtained in this laboratory which indicates that strong behavior is difficult to eliminate by "punishment" with TOs of moderate durations. It also indicates that TOs of moderate duration may actually exert a conditioned reinforcing effect because of induction from the house and key lights which are also turned off during the magazine cycle.

The data from the final phase of the study (last four procedures) indicated that all positions of the meters controlled S's behavior by low rates near the null position, and high rates near the deflected position. The control is similar to that of an added stimulus as an external counter in a fixed ratio and an added clock in a fixed interval. Whenever the meter was correlated with S's position in the chain, the rate of responding accelerated more or less smoothly from low to high rates of responding. Without the correlated meter, the relation between response rate and progress through the chain disappeared (Fig. 5 and 6, second columns). The data further indicated that the H. L. flashes (programmed in combination with meter advances) also exerted control over S's behavior; when both the added stimulus and the H. L. flashes were removed, the rate of response over the entire chain became almost constant (Fig. 5 and 6, last columns).

Although the effect of removing H. L. flashes while retaining the added stimulus was not examined, the data from the VI 3 series (first two procedures) and more recent results show that the behavior in the presence of the added stimulus alone is more similar to behavior in

Fig. 6. Cumulative records of left key responding of Bird 79R for four or five representative chains from the final two sessions on each of four experimental procedures. Each procedure involved the VI 1, 10 step procedure. First and third columns: Meters and H. L. flashes were programmed. Second column: Only the H. L. flashes were programmed. Fourth column: Tandem Schedule. Pips indicate steps on the VI 1 schedule.

the presence of both the added stimulus and H. L. flashes than to behavior in the absence of the added stimulus. A synthesis of all these observations suggests that the added stimulus has both S^A and S^D characteristics depending on the position of the meters. Behavior is weakened when the meter is at or near zero and strengthened when the meter approaches full-scale deflection. The loss in behavior while the meter is near the null position appears to be greater when the meter deflection is augmented by the flash of the houselight.

There are two possible interpretations of the strain produced by the controlling stimuli. If the basic maintenance conditions of the overall schedule of reinforcement are such that the behavior would be weakened under most conditions, then the addition of stimulus events, such as the flash of the house light, is tantamount to a shift from a tandem to a chained schedule. The latter is more likely to produce a weakening of behavior since the general effect of chaining the responses is to weaken the earlier members. In a similar fashion, the position of the meters would be a discriminative stimulus for the basic condition of the chain. If the chain has many components, it has the essential properties of a fixed-ratio schedule rather than an interval schedule, even though the schedule of reinforcement within components is variable-interval. While the probability of reinforcement increases with time within each component of the chain, the occurrence of successive components depends on the emission response analogous to FR schedules. Presumably, the better the stimulus control of the performances relative to the specific part of the chain, the more severe will be the strain during the earlier members. Ferster and Skinner (1957) observed that the superimposition of a visual added clock on fixed-interval schedules resulted in suppression of behavior to the point where no responding occurred in the initial 90 to 95% of the interval. Ferster and Skinner also observed that behavior in three and four-member fixed-ratio chains was characterized by low rates of responding in the first component of the chains compared to respond-

ing observed early in simple fixed-ratio schedules where ratio value was equal to the sum of all the fixed-ratio values in the extended chains. Gollub (1958) and Kelleher and Fry (1962) similarly observed that responding in the first component of extended fixed-interval chain schedules was extremely weak compared to responding in analogous tandem schedules. All these observations demonstrated that under some conditions, the use of discriminative stimuli which are closely correlated with the contingencies of the chain markedly weaken the behavior.

Our data strongly suggests that the meter functions as a discriminative stimulus, as with the example of chains and fixed ratios with added stimuli that were cited above. Little evidence was obtained in this study, however, which conclusively demonstrated a conditioned reinforcement function, *per se*, of the combination of meter advance and H. L. flash. Work now in progress is directed at this problem.

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