FIXED-INTERVAL BEHAVIOR MAINTAINED BY CONDITIONED REINFORCEMENT¹

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The key-pecking of a pigeon was reinforced with grain on an 18-min second-order schedule. During the 18 min, a key peck which completed a 3-min fixed interval produced a stimulus of 0.5-sec duration. The first 3-min fixed interval completed after 18 min resulted in primary reinforcement. Behavior characteristic of fixed-interval schedules was produced on both the 3-min components and the 18-min schedule. This performance was shown to be enhanced whenever the 0.5-sec stimulus was also presented before the presentation of grain.

Kelleher and Gollub (1962) suggested that a stimulus presented briefly after each component in a sequence of behavior should become a conditioned reinforcer that would maintain behavior in each component when the sequence results in primary reinforcement. Following this suggestion, several studies have shown that behavior could be maintained and controlled with a conditioned reinforcer in much the same way that behavior is controlled with a primary reinforcer (Zimmerman, 1963; de Lorge, 1964; Findley and Brady, 1965; Marr, 1965; Kelleher, 1966b).

These scheduled sequences of behavior have been designated by Kelleher (1966a) as second-order schedules. In a second-order schedule, a pattern of behavior generated by one schedule contingency is treated as a unitary response that is reinforced by some schedule of reinforcement. Studies by Findley and Brady (1965) and others, have shown that patterns of responding in the units of a second-order schedule can be better maintained by presenting a conditioned reinforcer of brief duration at the completion of each unit than by presenting nothing when the unit has been completed. Most of the studies showing this effect indicate that it depends upon the con-

tinguity between the conditioned reinforcing stimulus and primary reinforcement. None of the studies, however, has had adequate controls with which to show this dependence except for some recent work by Kelleher (1966b). A control for the possibility that any neutral stimulus may have an "enhancing" effect would be to present the to-be-conditioned reinforcer at the end of a unit and later pair it with primary reinforcement, or, after having paired it with primary reinforcement, to present primary reinforcement without pairing it with the conditioned reinforcer. Another technique might be to present a "neutral" stimulus at the termination of the unit and compare its effects with the conditioned reinforcing stimulus.

The purpose of the present study was threefold: (1) to determine whether briefly presented stimuli enhance or maintain behavior as a result of their correlation with primary reinforcement; *i.e.*, to determine whether or not they are conditioned reinforcers; (2) to discover the effects of presenting a stimulus that was not paired with primary reinforcement; and, (3) to see if the conditioned reinforcer would lose its effect by no longer pairing it with primary reinforcement. An extended fixed-interval second-order schedule (FI:S) of reinforcement was used.

METHOD

Subjects

One male White Carneaux pigeon, approximately 3-yr old, was maintained at about 80% of free-feeding weight. The bird had pre-

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viously been studied on a red-green discrimination reversal experiment for 130 days, in which responding was reinforced with grain on a variable-interval schedule of 90 sec.

Apparatus

The bird was studied in an experimental chamber similar to that described by Ferster and Skinner (1957). The response mechanism was a plastic key that could be transilluminated by red, yellow, or green lights. Each key peck operated a relay located within the experimental chamber, producing an audible signal. Primary reinforcers initially consisted of 5-sec exposures of grain in an illuminated hopper. Throughout the experiment the food hopper was illuminated during each exposure to grain. This reinforcement cycle was later extended to 6.5 sec to insure that the bird would maintain a stable weight. The only access to food was during the experimental session. Water and grit were continuously available through apertures in the rear of the experimental chamber. Low-level illumination and white noise were present during the sessions. Conventional relay and timing circuitry was located in an adjoining room. Responses were recorded on a Gerbrands cumulative recorder.

Procedure

Since the bird had previously been trained to peck a key, no magazine or key training was necessary. During conditioning the key was always illuminated with a red light except for the 0.5-sec presentation of the green key-light or the 0.5-sec presentation of the yellow key-light. For 0.5 sec before grain presentation, the yellow light illuminated the key and remained on until the reinforcement cycle terminated. The yellow key-light always accompanied primary reinforcement (S^R) except during a later phase of the experiment. The subject was started on a schedule which presented a response-contingent 0.5-sec yellow key-light at the end of 1 min (FI 1-min:Y). The first 1-min interval to be completed after 10 min had elapsed resulted in the presentation of the 0.5-sec yellow key-light followed by primary reinforcement. The 10-min interval was timed from the withdrawal of primary reinforcement. This schedule is designated as FI 10-min (FI 1-min:Y), following Kelleher (1966).

Sessions initially lasted for 50 food reinforcements. Following exposure to various other values of fixed intervals, the final schedule was FI 18-min (FI 3-min:Y) with a 6.5-sec primary reinforcement cycle. On this schedule, the yellow key-light was presented when a response occurred after 3 min had elapsed. The first 3-min interval to be finished after 18 min was followed immediately by the presentation of the yellow key-light for 0.5 sec, then both the yellow key-light and primary reinforcement occurred together. Each session consisted of 25 primary-reinforcement presentations and therefore lasted for approximately 8 hr. In most sessions, the subject completed 4, 5, or 6 3-min fixed intervals before primary reinforcement; occasionally, it had as many as seven 3-min intervals. The completion of seven 3-min intervals could occur when the subject was responding at a high enough rate near the end of 18 min that the sixth 3-min interval occurred a fraction of a second before the 18-min clock timed out, thereby calling for the emission of one more FI 3-min component before primary reinforcement.

There were 24 sessions on FI 18-min (FI 3-min:Y) to assure the stability of performance. For the next 11 sessions, the subject was studied on a schedule utilized to assess the effects of a stimulus not contiguous with primary reinforcement. This schedule, FI 18-min (FI 3-min:G), was the same as the earlier schedule except that the completion of FI 3-min resulted in the presentation of a green key-light; however, the yellow key-light still occurred before and during primary reinforcement. During the next seven sessions the subject was returned to the FI 18-min (FI 3-min:Y). Following this recovery period, the subject was placed on FI 18-min (FI 3-min) for seven sessions. In this schedule, no key-light change occurred at the completion of FI 3-min except before and during primary reinforcement. The next four sessions were again recovery sessions on the FI 18-min (FI 3-min:Y) schedule. The following 14 sessions were conducted to see if the behavior associated with the yellow key-light would extinguish when the yellow key-light was no longer contiguous with primary reinforcement. This schedule, FI 18-min (FI 3-min:Y), was identical to the preceding one except that no key-light change occurred before and during primary reinforcement; instead, the red key-light remained

on. The next and last five sessions were recovery sessions for the FI 18-min (FI 3-min:Y) schedule in which the yellow key-light was again associated with primary reinforcement. Table 1 contains a summary of the above procedures.

Table 1
Summary of Procedures

No. of Sessions	Schedule (FI in minutes)	Stimulus Paired with S^R
24	FI 18 (FI 3:Y)	Y
11	FI 18 (FI 3:G)	Y
7	FI 18 (FI 3:Y)	Y
7	FI 18 (FI 3)	Y
4	FI 18 (FI 3:Y)	Y
14	FI 18 (FI 3:Y)	—
5	FI 18 (FI 3:Y)	Y

G = green key-light

Y = yellow key-light

RESULTS

Representative cumulative records of the pigeon's responding are shown in Fig. 1. Each row of records contains the first two, middle three, and last two reinforcement components of the 25 components occurring each session. The top and every other row of records illustrate performance on the FI 18-min (FI 3-min:Y) schedule. Although the number of responses per S^R varied, the general pattern of responding was about the same throughout a session. Responding accelerated during the FI 3-min periods, and in most cases accelerated gradually throughout the period from one S^R to another. As the number of sessions increased on FI 18-min (FI 3-min:Y), including recovery sessions, the acceleration from one S^R to another increased, the length and frequency of pauses after an FI 3 stimulus decreased, and the length and frequency of pauses after S^R increased. This development can be seen by comparing the top and bottom row of records in Fig. 1.

The second row of records in Fig. 1 shows behavior under the FI 18-min (FI 3-min:G) schedule. The postreinforcement (S^R) pause has increased substantially, leading to a decrease in the number of responses per S^R . The pattern of responding, with the exception of the longer postreinforcement pauses, is somewhat similar to the pattern on FI 18-min (FI

Fig. 1. Representative cumulative response records of responding in the various conditions of the experiment. Seven reinforcement segments, indicated by the dots below the cumulative records, taken from one of the three days before changing schedules are shown for each experimental condition. The recording pen reset to the bottom of the record when 550 responses had cumulated or when primary reinforcement occurred. Hash marks indicate the end of an FI 3-min period. Y = FI 18-min (FI 3-min:Y); G = FI 18-min (FI 3-min:G); N = FI 18-min (FI 3-min); -Y = FI 18-min (FI 3-min:Y) where the yellow key-light did not occur before and during primary reinforcement.

3-min:Y). When the schedule was changed back to FI 18-min (FI 3-min:Y) the major differences were the decreases in frequency and length of the postreinforcement pause and the more frequent FI 3-min scallops.

Placing the animal on the FI 18-min (FI 3-min) schedule also produced more and longer postreinforcement pauses and subsequently an overall decrease in responses per S^R . Once responding began it generally continued at gradually increasing rates until S^R occurred. Shifting the schedule back to the yellow key-light condition increased the number of responses per reinforcement and produced the pattern of responding typical of

earlier sessions on the FI 18-min (FI 3-min:Y) schedule.

When the yellow key-light was no longer presented before and during S^R , response rates decreased substantially. This is seen in the row of records designated by -Y in Fig. 1. The decrease occurred gradually over about three sessions. The records shown are from the fourteenth session on this schedule. The yellow key-light still had some effect, however, as indicated in the frequent but short pauses after the light. There was very little increased acceleration from one S^R to another. Note that in the next to the last reinforcement segment of this row of records, the subject apparently waited much longer than 18 min before responding.

Following the yellow-light extinction sessions, only two sessions on the original schedule were needed to produce earlier behavior patterns typical of FI 18-min (FI 3-min:Y), although the original pattern of responding was not completely regained during the last five sessions.

Figure 2 shows the mean rate of responding in each of the FI 3-min components as a function of the schedule. The number in the lower right-hand corner of each curve gives the number of FI 3-min components occurring in that session. One curve from each condition was obtained from the same session as its respective cumulative record in Fig. 1. These data come from the last two or three days on any one schedule. Since the number of FI 3-min components per FI 18-min could, and did, vary, the heights of these curves do not necessarily indicate the amount of responding per session. The initial FI 18-min (FI 3-min:Y) schedule resulted in comparatively equal response rates during FI 3-min components close to S^R , as seen in the figures denoted by Y 23 and Y 24, and the number of FI 3-min components which occurred in these sessions was relatively high. Once the FI 3-min resulted in a different key-light the response rates dropped considerably in the earlier components and increased considerably in the later components, as seen in the ninth through eleventh sessions on FI 18-min (FI 3-min:G); FI 3-min components also decreased in frequency. Returning the animal to the original schedule only produced higher response rates in the earlier components and increased the frequency of FI 3-min components.

The removal of a brief stimulus at the completion of each FI 3-min led to lower rates in the early FI 3-min components and increasing rates in the later components. Again, the overall number of FI 3-min components decreased. Switching back to the original schedule led to an increase in the number of FI 3-min components per session.

Removing the yellow key-light before and during S^R produced substantial decrements in the mean response rate per FI 3-min component and in the number of FI 3-min components per session. Although response rate increased as the end of FI 18-min approached, it never became as great as in the other conditions of the study. Placing the animal back on the original schedule led to mean response rates, after two sessions, similar to those seen in the boxes denoted by Y 3 and Y 4.

Figure 3 illustrates the mean number of responses per food reinforcement (S^R) during the three sessions before changing to another schedule. As seen in this figure, the number of responses during the FI 18-min (FI 3-min:Y) schedules was greatest, and the number of responses during the condition where the yellow key-light was not paired with S^R was least. Each time the schedule was changed from FI 18-min (FI 3-min:Y) to a different schedule, responses decreased, and each time the schedule was changed back to the original, responses increased. Figure 3 shows that as far as the number of responses per S^R is concerned, the non-paired stimulus (G) condition is most similar to the paired (Y) condition, which concurs with Fig. 1 and 2.

One noticeable aspect of Fig. 3 is the general decrease in the number of responses from the earliest to the latest sessions. By the last session, the subject had been given 112 daily sessions on the various FI schedules. Other experimenters have also reported decrements in response rate on FI schedules as the sessions increased (Ferster and Skinner, 1957, pp. 133-325).

DISCUSSION

The main conclusion from the present study is that the response-contingent, brief presentation of a stimulus periodically associated with primary reinforcement increases response output, thereby functioning in much the same way as any other conditioned reinforcer. More-

FI 3 COMPONENTS

Fig. 2. Mean response rate per FI 3 component as a function of the schedule condition. The letters are the same as those shown in Fig. 1 and refer to the same experimental conditions. Numbers after the letters give the session under that particular schedule. Numbers in the lower right-hand corner of each box give the number of FI 3-min components occurring in that session.

over, once that stimulus is no longer accompanied by primary reinforcement, then the response-contingent presentation of the stimulus leads to a decrement in responding, thereby producing suppression effects. This decrement in response strength was seen by comparing behavior under the FI 18-min (FI 3-min) schedule with behavior under the FI 18-min (FI 3-min:Y) schedule in which the yellow key-light and S^R were not paired. These

effects seem analogous to effects obtained in respondent conditioning with conditioned stimuli.

The failure to produce large decrements in response rate on the FI 18-min (FI 3-min:G) schedule was probably due to a failure of the bird to differentiate between the yellow and green key-lights, because the subject had not responded to the key color but only to the change in key colors. In both the yellow and

Fig. 3. The amount of responding per reinforcement as a function of the schedule condition. The symbols are the same as those shown in Fig. 1 and refer to the same experimental conditions.

green key-light conditions there was a change in key color before S^R . Perhaps on a multiple second-order schedule where the briefly presented stimulus is paired with S^R in one component of the multiple, and a stimulus is not paired with S^R in the other component, there would be a chance for discrimination between the two stimuli to occur. It is probable, however, that the history of the present bird influenced its behavior in the presence of the green key-light, for it had been utilized in a red-green discrimination reversal experiment about 1 yr before this study. On the other hand, the present results do show that the temporally contiguous stimulus led to more continuous responding, as indicated by the larger number of FI 3-min components, and more repeatable patterns of responding than did the non-contiguous stimulus.

The control that the conditioned reinforcer

exerted on FI patterns of responding seemed to be as great as that of primary reinforcement. Although rates increased from one S^R to another, the increments were not as accelerated as those from one conditioned reinforcer to another, as indicated by a comparison of the cumulative records. It is probable that under schedules of reinforcement other than fixed-interval schedules, the effects of a briefly presented conditioned reinforcer would not be as discriminable as in the present study. Further experiments utilizing multiple schedules and time-dependent response contingencies are now being conducted to assess the sufficient conditions for establishing a briefly presented stimulus as a conditioned reinforcer.

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