SOME EFFECTS OF RESPONSE-DEPENDENT CLOCK STIMULI IN A FIXED-INTERVAL SCHEDULE[1]

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Two experiments studied the effects of brief response-dependent clock stimuli in fixed-interval schedules of reinforcement. In the first experiment, two pigeons were exposed to a fixed-interval schedule. Two conditions were compared. In both conditions each peck on the key produced a brief stimulus. In one condition, pecks produced a different stimulus in successive sixths of the interval. This was the clock condition. In the other condition, the same stimulus was produced throughout the interval. Response rates were lower and the pause after reinforcement was longer in the clock condition. In the second experiment, a two-key optional clock procedure was used. Responding on the clock key produced one of three stimuli correlated with the three successive minutes of a fixed-interval schedule. A response on the other key produced grain at the end of the 3 min. When the final stimulus was removed from the situation and pecking produced nothing during the third minute, responding to the clock key declined to a very low rate. When the first two stimuli were removed and the third one replaced, responding to the clock key was resumed.

In a fixed-interval schedule, reinforcement is dependent on the first response after a fixed amount of time has elapsed from some reference point, usually the preceding reinforcement. An exteroceptive stimulus, which changes in some systematic way with the passage of time, may be added to a fixed-interval schedule. Such a stimulus change is called a "clock" (Ferster and Skinner, 1957). Frequently, a discontinuous clock is used where stimulus changes divide the interval into equal portions, for instance, equal quarters or thirds (Segal, 1962; Hendry and Dillow, 1966). An example of a discontinuous clock would be a fixed-interval schedule where a red light was displayed to the subject during the first minute, a yellow light during the second minute and a green light in the third minute of a 3-min interval. Ordinarily, the final stimulus in the clock would remain present until the response that produced the reinforcing stimulus occurred.

In the example given above, the clock stimuli were not dependent on responses. They may be made response-dependent by briefly displaying a stimulus appropriate to the particular portion of the interval whenever the subject emits a response. The clock stimuli may also be made response-dependent on some schedule of intermittent reinforcement (Hendry and Dillow, 1966). Further, if the clock stimuli are dependent on responses they may be dependent on the same response that produces reinforcement (Segal, 1962), or on a separate response, called an "observing response" (Hendry and Dillow, 1966). This latter situation may be referred to as an "optional clock", following Hendry and Dillow, (1966) because the reinforcer may be obtained even though no clock stimuli have been displayed.

Segal studied the effects of a four-stage discontinuous clock in fixed-interval schedules. The clock stimuli were either independent of or dependent on responses to the key. In the independent clock condition, there were fewer responses in the first three-quarters of the interval than there were when there was no clock. In the response-dependent condition, there were fewer responses in the first three-quarters of the interval in the clock condition than when only one stimulus was dependent on responses throughout the interval. There was usually more responding in the first three quarters of the interval with the response-dependent clock than with the response-

independent clock. Thus, the clock depressed responding in the first three quarters of the interval but the response-independent clock depressed responding more than the response-dependent clock. Segal suggested that clock stimuli early in the interval had two effects in the response-dependent condition. One effect was that the early clock stimuli acted as negative discriminative stimuli for further responding. The second effect was that early stimuli in the clock sequence were punishing, as a result of their remoteness from reinforcement. Only one of these two hypotheses is necessary to account for the data, however.

Hendry and Dillow (1966) performed an experiment with an optional clock. In their experiment, clock stimuli were dependent on responses to a second key. They studied behavior on the clock key under conditions where each clock stimulus was correlated with a separate component of a chain schedule and under ordinary fixed-interval conditions. In the first condition, a response to the food key was necessary to initiate a new component of the schedule when the previous one had timed out. This response was not necessary in the fixed-interval condition. Thus, optional clock responding converted a tandem schedule to a chain schedule in the first condition. They concluded that the optional clock stimuli became conditioned reinforcers in their experiment. This assertion is at variance with Segal's suggestion that early clock stimuli are punishing, since Hendry and Dillow's (1966) conclusion was that all of the clock stimuli became conditioned reinforcers.

The following experiments attempted to clarify the role of response-dependent timing stimuli in a fixed-interval schedule.

EXPERIMENT I

Experiment I was basically a replication of part of the Segal (1962) experiment. Segal found less responding in the first three quarters of the interval under the response-dependent clock condition than under a control condition in which only one stimulus was response-dependent throughout the interval. In the present experiment, the pause following reinforcement was measured in addition to response rates and distributions.

METHOD

Subjects

Two female White Carneaux pigeons, which had originally been trained by the auto-shaping procedure described by Brown and Jenkins (1968), had also received training on a variable-interval schedule in the apparatus used in the present experiment. During this training, the key had been transilluminated with a green light. They were maintained at about 80% of free-feeding weight during the present experiment.

Apparatus

The experimental chamber was a demonstration model (Ralph Gerbrands) made of clear plastic. The plastic was covered with contact paper so that the birds could not see out. A second key was added to the work panel 2.5 in. (6.25 cm) to the right side of the center key. This was the only key used in Experiment I. Both keys required a force of about 15 g (0.15N) to operate. A multiple stimulus projector was added behind the side key. A 25-w light bulb was placed in the lamp housing on the top of the pigeon chamber and served as a houselight. A small area on the top of the plastic box was not covered with contact paper so that the light from the houselight would illuminate the inside of the box. This area was covered with cumulative recorder paper to make the light dimmer. A white masking noise was continuously present in the room in which the pigeon chamber was placed. Electromechanical scheduling and recording equipment were placed in an adjacent room.

Procedure

The subjects were transferred from the variable-interval schedule mentioned above, to a fixed-interval schedule of two minutes (FI 2-min). For scheduling and recording purposes, this interval was divided into six 20-sec segments. Two conditions were compared in the present experiment. In the first condition, a peck on the key produced a different stimulus during each of the successive 20-sec segments of the interval. These stimuli were dependent on responses on the same key that produced reinforcement. When the bird pecked the key, the stimulus flashed on the key for 0.2 sec. The stimuli were, in succes-

sive sixths of the interval; (1) a white light, (2) three white horizontal stripes on a dark background, (3) a yellow light, (4) three white vertical dots on a dark background, (5) a blue light, and (6) a white triangle on a dark background. It was hoped that this kind of sequence would make a change from one stimulus to another more noticeable than a sequence composed of all colors or all figures on dark backgrounds. The final response of the interval did not produce any of these stimuli; it produced 3-sec access to mixed grain. This condition will be called the "clock" condition.

In the other procedure, each response produced a red light on the key for 0.2 sec throughout the interval. This condition will be called the "single stimulus" condition.

Each bird was given 36 sessions on the clock condition followed by 23 sessions on the single stimulus condition. Behavior stabilized faster in the single stimulus condition, so that fewer sessions were needed. The duration of experimental sessions varied both between and within subjects from 30 to 60 reinforcements. The length of a session depended on the amount of food necessary to maintain the bird and its weight on a given day. The weights were kept at about 80% of the free-feeding value throughout the experiment.

RESULTS

Figure 1 presents the results in two ways. In the upper half of the figure, the response rate in successive sixths of the interval is plotted for each subject. In the lower half of the figure, the percentage of the total responses in successive sixths is presented. The data are averages from the last five sessions under each condition.

The upper half of Figure 1 reveals that, for both subjects, the overall rate and the rate in each of the first five-sixths of the interval was lower for the clock condition than for the single stimulus condition. The response rates for Bird 2 were about equal in the final sixth. Since the single stimulus condition was similar to an ordinary fixed interval, it would appear that the clock engendered a lower rate of responding in the first five sixths of the interval.

The data plotted in the lower half of Figure 1 show that the percentage of responses emitted in the final sixth of the interval was higher in the clock condition for both birds. There was relatively less responding in the
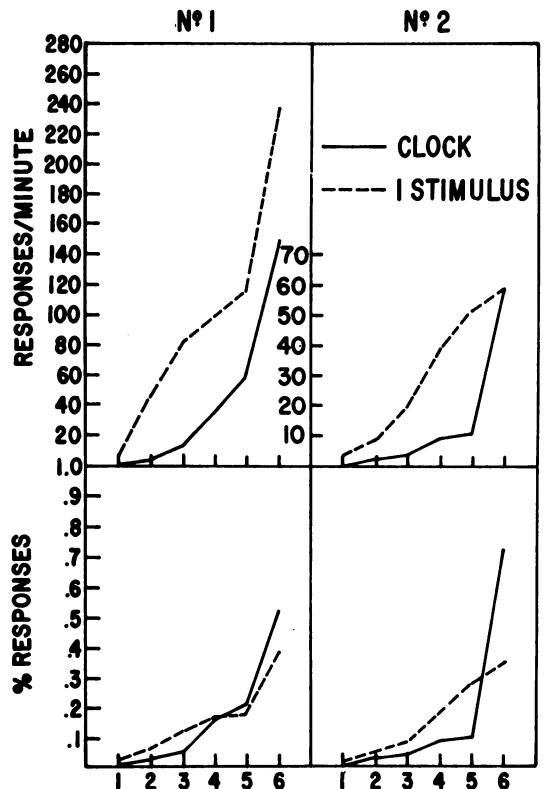

Fig. 1. Response rates (upper half of figure) and percentage of responses (lower half of figure) in successive sixths of the fixed interval for clock and single stimulus conditions.

first half of the interval for Bird 1 in the clock condition and in the first five sixths of the interval for Bird 2. There was relatively less responding in the early part of the interval for both birds.

Figure 2 presents the average time per interval from the termination of reinforcement until the first response in the next interval (pause after reinforcement). It can be seen that for each subject the pause was greater in the clock condition than in the single stimulus condition. The difference for each bird was about 10 sec.

EXPERIMENT II

Experiment I replicated previous findings by Segal (1962). In addition, it demonstrated that the pause after reinforcement was longer in the clock condition than in the single stimulus condition. This latter finding does not suggest that the first clock stimulus was a conditioned reinforcer as Hendry and Dillow
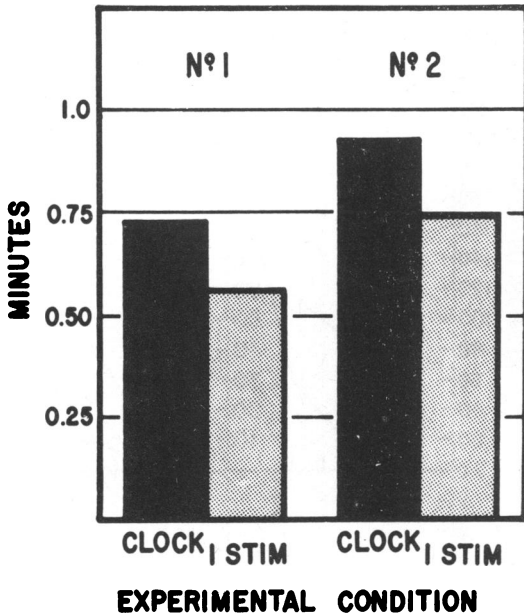
Fig. 2. Mean pause after reinforcement per interval under clock and single stimulus conditions.

(1966) claimed. However, Experiment I did not provide a direct attack on the question of which of the stimuli in the clock sequence are conditioned reinforcers. Hendry and Dillow's procedure, using an optional clock, is better suited to answer this question because the clock stimuli are dependent on a response that is separate from the food-producing response.

METHOD

Subjects

Three female White Carneaux pigeons, designated number 4, 5, and 6, had previously been exposed to a multiple schedule involving the differential reinforcement of not responding and a variable-interval schedule, each of 1 min. Another apparatus was used.

Apparatus

The apparatus was the same in in Experiment I.

Procedure

The birds were exposed to three conditions. Under all conditions, a fixed-interval 3-min schedule was in effect on the center key and clock stimuli were produced by pecks to the side key. In the first condition, the interval

schedule was in effect on the center key and a three-stage optional clock was in effect on the side key. The center key remained dark at all times. A peck on the side key produced a 0.2-sec flash of white during the first minute of the interval. During the second minute, a flash of green was produced and a flash of red during the third. The side key remained dark when one of these three colors was not being displayed. A changeover delay was in effect during the third minute, which ensured that a peck on the center key could not be reinforced until at least 3 sec had elapsed since the last peck to the side key. Pecks on the side key will be called observing responses.

In the second condition of the experiment, all conditions were exactly as in the first except that observing responses during the final minute of the interval did not produce any stimulus. White and green were still produced by observing responses during the first and second minutes of the interval. In the third condition, observing responses during the first and second minutes did not produce any stimulus, but observing responses during the third minute produced the red light.

Experimental sessions lasted until there were 30 reinforcements. Bird 4 was given for 20 sessions in Condition 1, 15 sessions in Condition 2, and 15 sessions in Condition 3. The number of sessions for Bird 5 was 32, 15, and 10; the number for Bird 6 was 20, 10, and 20. All of the birds went through the conditions in the order described above. No special training was given to the birds in transferring them to this experiment or in shifting from one condition to another.

RESULTS

The results of Experiment II can be seen in Figure 3. There are two panels for each bird. Each graph shows response rates in the three successive minutes of the interval. All response rates are averaged over the last four sessions of a given condition. It can be seen that observing responses were maintained in the first and third conditions of the experiment. In both phases, the red light was dependent on observing responses during the final minute of the interval. Observing response rates fell to an extremely low value during the second phase of the experiment where the red light was not available but white and green were response dependent
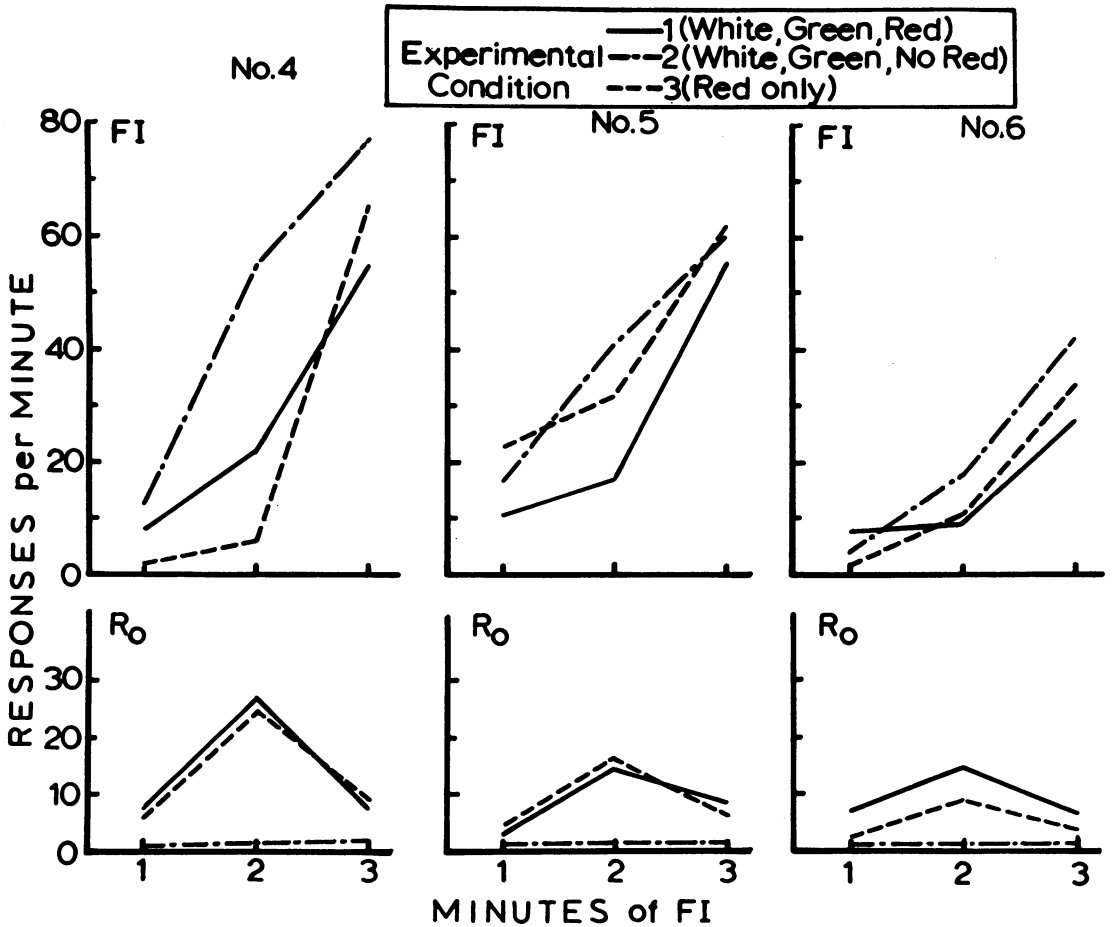
Fig. 3. Fixed-interval and observing response rates for each of the three birds in each of the three conditions. Fixed-interval rates are plotted in the upper panel and observing response rates in the lower panel for each bird.

during the first 2 min of the interval. Observing responses occurred at the highest rate in the second minute of the interval in the first and third conditions. In the third condition, however, there was no stimulus being produced during the second minute.

The fixed-interval rates were higher in the second condition (white and green only) than in Condition 1 (three stimuli). The second condition was the one in which observing response rates declined substantially. Considering the fixed-interval rates, there seemed to be no systematic relationship between Conditions 1 and 3, except that the rate in the last minute of the interval was higher for all three birds in Condition 3 than in Condition 1. The fixed-interval gradient appeared to be steeper for Birds 4 and 6 in Condition 3 than in Condition 1.

DISCUSSION

The results of Experiment I replicated reasonably well the previous findings of Segal (1962). Segal reported there was less responding in the first three quarters of a fixed-interval schedule when there were response-dependent clock stimuli than when there was only one response-dependent stimulus throughout the interval. The present experiment demonstrated this finding with six stimuli instead of four. Segal offered two explanations that might account for this effect. The first was that all clock stimuli except the final one are negative discriminative stimuli. This has been demonstrated when response-independent clock stimuli are presented (Segal, 1962; Ferster and Skinner, 1957). Any response occurring before the final segment

of the interval produces a stimulus in which responding has never been reinforced. The second explanation was that stimuli remote from reinforcement become punishers. It was mentioned previously that only one of these explanations is sufficient to account for Segal's findings.

Since response-independent clock stimuli lead to less responding in the presence of all stimuli except the final one, the suggestion that response-dependent clock stimuli act as negative discriminative stimuli to suppress responding is quite reasonable. It is somewhat difficult to see how this could account for the longer pause after reinforcement found in the clock condition in Experiment I, however. One possibility is that early clock stimuli are punishing, as Segal suggested. Another suggestion is that the clock stimuli are less reinforcing than the stimulus in the single stimulus condition. This latter suggestion would imply that a response-dependent stimulus in a fixed-interval schedule is, to some extent, reinforcing. There is no reason to suspect that this is the case, however. The peck that produced food did not produce a stimulus in either the clock or single stimulus condition so that these stimuli were not directly associated with primary reinforcement. This reduces the likelihood that the stimulus in the single stimulus condition was a conditioned reinforcer. Another possibility is that a non-aversive response-dependent stimulus change might have some slight reinforcing effect (Kish, 1966). This latter possibility cannot be ruled out in the present experiment. If neither of the two factors mentioned above (conditioned reinforcement or reinforcement by stimulus change) were operating in the present experiment, then Segal's suggestion that early clock stimuli are punishing is plausible.

The results of Experiment II are relevant to the issue of which stimuli in a clock sequence are reinforcers. Hendry and Dillow (1966) claimed that all stimuli in a clock sequence become conditioned reinforcers by providing the subject with reliable time-correlated cues. Although the information hypothesis of conditioned reinforcement (Hendry, 1969) was not specifically mentioned in their paper, presumably the suggestion that all clock stimuli are reinforcing is consistent with this hypothesis.

The results of the first condition in Experiment II where three clock stimuli were available replicated the findings of Hendry and Dillow (1966) in showing that observing responses on a separate key could be maintained when they produced clock stimuli. The results also agree with theirs in showing that the rate of responding in a three-component clock situation was highest for the observing key in the middle third of the interval.

Observing responses declined in Condition 2 where the final stimulus of the sequence (red light) was no longer available. The simplest interpretation is that this decline was due to the removal of the source of reinforcement for the observing response, i.e., the red light. This interpretation is supported by the results of Condition 3, where only the red light was available. In that condition, observing responses increased in strength, with the rate and pattern being substantially the same as in Condition 1, where all three stimuli were available. When the red light was removed, the rate of responding increased on the fixed-interval key. The white and green lights had probably become stimuli for not pecking, since they were not associated with reinforcement. When observing behavior declined in Condition 2, the rate increased because the stimuli controlling not responding were not present. The rate of responding during the final third of the interval increased also in Condition 2 and the above account does not explain this increase, since the stimulus that was removed was presumably a stimulus for pecking. It may be that part of the increase in the fixed-interval response rate was due to a decrease in competition between two incompatible responses, the observing response and the fixed-interval response. When the observing response decreased in strength, competition from the observing response was removed. An account in terms of response competition fits in with the finding that in Condition 3, when the red light was available, but not white or green, the fixed-interval response rate decreased, at least for Birds 4 and 6. This decrease could be due to the reconditioning of the observing response and the increased competition between the two responses.

Response competition might also account for the observing response rate being higher in the middle third of the interval. When the

red light appeared in the final third, the bird switched from the observing response key to the food key, which decreased the amount of responding on the observing key. Another factor that may have lowered the observing response rate in the final third of the interval was the delay imposed between responses on the observing key and reinforcement. No reinforcement could occur until at least 3 sec had elapsed since the last observing response. Whether both competition and the delay were responsible for the pattern of observing behavior or whether only one of the factors is responsible was not decided in the present experiment.

The findings of Experiment II relate to two previously reported experiments in which one stimulus was removed from an observing response situation. Kendall and Gibson (1965) removed either the stimulus associated with a fixed-interval (FI 2-min) or a fixed ratio schedule (FR 50). When the stimulus correlated with the interval schedule was made not available there was no decrement in the probability of an observing response. When the stimulus associated wth FR 50 was removed, observing responses underwent a drastic reduction. Dinsmoor, Flint, Smith, and Viemeister (1969) employed a similar procedure in a situation where one stimulus was associated with a variable-interval schedule and another was associated with the same variable-interval schedule plus fixed-ratio punishment. They found that when the stimulus associated with variable-interval plus punishment was removed, the observing response rate did not decrease. When the stimulus associated with variable interval without punishment was removed, the observing response rate decreased substantially.

The present experiment (Experiment II) and the two mentioned above share one common feature. When one of the stimuli produced by observing responses is removed, the observing response can be maintained. When the other is removed, observing responses decrease to a low rate or probability. In all of these experiments, the stimulus that will maintain observing responses seems to be the most favorable of those available. In the Kendall and Gibson experiment, the delay to reinforcement in FR 50 was quite short compared to the delay in the FI 2-min. In the Dinsmoor *et al.*, experiment, the stim-

ulus that would maintain observing responses was the one associated with variable interval without punishment. In the present experiment, the stimulus that would maintain responding was the one that was closest to reinforcement. These experiments suggest that the main source of reinforcement for observing responses is the stimulus associated with the most favorable of the available reinforcement conditions. This view does not accord with the information hypothesis (Hendry, 1969), which seems to give equal status to all of the stimuli in an observing response situation.

Schaub (1969) concluded that the reinforcing value of stimuli produced by observing responses was a combined function of the "information" value and the "association" value of the stimuli. The need for an "informational" factor may be disputed, however, on the basis that no experiments have shown that the less-favorable stimuli will maintain observing behavior, at least when a separate observing response key is used. If the term "associative" is used to indicate close temporal proximity to positive reinforcement the need for an "associative" factor may be questioned as well. In the present experiment, the final stimulus (red light) was not present at the time food was delivered. In Experiment II, there was a delay period that prevented the final clock stimulus from being present at food delivery. Hendry and Dillow (1966) also noted this and said that the final stimulus might be said to be a "trace discriminative stimulus". Trace discriminative stimuli have been found to be conditioned reinforcers in other observing response experiments (Kendall, 1969).

Experiment II, in addition to the other studies discussed, leads to the tentative interpretation that of the stimuli involved in an observing response situation the one correlated with the most favorable reinforcement condition becomes a conditioned reinforcer. The reinforcing effect of other stimuli in the observing response situation has not been satisfactorily demonstrated.

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