CONDITIONED REINFORCEMENT IN SECOND-ORDER SCHEDULES¹

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Pigeons responded under a schedule in which food was presented only after a fixed number of fixed-interval components were completed. Two such second-order schedules were studied: under one, 30 consecutive 2-min fixed-interval components were required; under the other, 15 consecutive 4-min fixed-interval components were required. Under both schedules, when a 0.7-sec stimulus light was presented at completion of each fixed interval, positively accelerated responding developed in each component. When no stimulus change occurred at completion of each fixed interval, relatively low and constant rates of responding prevailed in each component; a similar result was obtained when a 0.7-sec stimulus change occurred at completion of each fixed interval except the one which terminated with primary reinforcement. The 0.7-sec stimulus correlated with food delivery was an effective conditioned reinforcer in maintaining patterns of responding in fixed-interval components despite low average frequencies of food reinforcement.

Long and orderly sequences of responses and stimuli uninterrupted by primary reinforcement endow behavior with much of its apparent purposefulness. A powerful technique for analyzing sequences of behavior is to make primary reinforcement contingent upon completion of two or more consecutive schedule components. With such sequences of schedule components, it is possible to investigate ways in which scheduled stimulus presentations affect responding in a sequence without changing the contingencies of primary reinforcement (see review by Kelleher and Gollub, 1962). The present paper reports the first of a series of studies of behavior in extended sequences of schedule components.

Chained schedules of reinforcement have been used frequently to study sequences of behavior. In a chained schedule, responding in the presence of one stimulus produces a second stimulus; responding in the presence of the second stimulus produces a third stimulus; and so forth, until responding in the

presence of the last stimulus in the sequence produces food (Ferster and Skinner, 1957). Studies of behavior in extended chained schedules have shown that as the number of components is increased it becomes increasingly difficult to maintain any behavior in the initial components (Kelleher and Gollub, 1962). The results consistently indicate that the discriminative stimuli in the initial components do not become conditioned reinforcing stimuli. For example, under a chained schedule comprising five 1-min fixed-interval components, pigeons develop prolonged pauses in the first component (Gollub, 1958). Token reinforcement studies in which a chimpanzee must obtain several tokens before food is available are functionally similar to chained schedules; chimpanzees develop prolonged pauses under fixed-interval schedules of token reinforcement (Kelleher, 1957).

Several studies have indicated that the length of a chained schedule under which responding will be maintained is limited because a conditioned reinforcer is less effective than the reinforcer used to establish it (see Kelleher and Gollub, 1962). This limitation can be partially overcome by presenting the component stimuli in a variable sequence so that each component stimulus is intermittently paired with food presentation (Kelleher and Fry, 1962). Also, studies using extinction procedures have shown that a

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briefly-presented stimulus that is intermittently paired with food presentation can become a conditioned reinforcing stimulus (for example, Zimmerman, 1957; Kelleher, 1961). Finally, Zimmerman (1963) reported that stimuli correlated with food presentation (under a variable-interval schedule) on one response key would act as a conditioned reinforcer that could maintain schedule performance on a second response key. These results suggest that a response-produced stimulus that is temporally contiguous with a reinforcer becomes a conditioned reinforcer whose effectiveness is directly related to the frequency of reinforcement in its presence (see Kelleher and Gollub, 1962).

A briefly-presented stimulus that is occasionally associated with food presentation should be an effective conditioned reinforcer that could maintain responding in the components of an extended sequence of schedules. Two studies using this type of procedure have been reported. Findley (1962) found that performance in the pigeon was better maintained when food presentation was contingent upon the completion of eight successive chained FR 10 FR 10 FR 10 schedules, with a briefly-presented stimulus occurring at the termination of each chain, than under a chained FR 80 FR 80 FR 80 schedule of reinforcement. Findley and Brady (1965) reported that performance in the chimpanzee under an FR 4000 schedule of reinforcement was better maintained when a briefly-presented stimulus followed every 400th response than when no stimulus was presented during the ratio. These experiments indicate that a briefly-presented stimulus that is occasionally paired with food reinforcement can facilitate responding in sequences in which reinforcement is contingent upon completion of a fixed number of responses.

As increasingly complex sequences of schedules and stimuli are studied, it becomes unwieldy to refer to all of them as chained schedules. For example, using a terminology in which behavior under any schedule is considered as an operant, Findley (1962) has described some extremely complex sequences of schedules. The present paper considers such sequences as schedules of schedules or second-order schedules. A *second-order schedule* treats a pattern of behavior engendered by a schedule contingency as a unitary response

that is itself reinforced according to some schedule of reinforcement. In one of the chimpanzee token-reinforcement studies, for example, tokens were delivered according to a 5-min fixed-interval schedule (FI 5); tokens could be exchanged for food when six successive FI 5 components had been completed (Kelleher, 1957). Behavior under the FI 5 schedule can be considered as a unitary response that is reinforced according to a six-response fixed-ratio schedule (FR 6). This second-order schedule, in which reinforcement is contingent upon an FR 6 of FI 5's, can be designated FR 6 (FI 5). Similarly, the schedule in the study by Gollub (1958), in which primary reinforcement was contingent upon completion of five successive FI 1 schedules, can be designated FR 5 (FI 1). The schedule studied by Findley and Brady (1965) can be designated FR 10 (FR 400). The stimulus conditions in these second-order schedules can be specified by additional terms, using current terminology (for example, Ferster and Skinner, 1957) where possible. For example, the chained schedule in the Gollub study would be designated chain FR 5 (FI 1) to indicate that a different discriminative stimulus was correlated with each of the FI components; the tandem schedule used as a control would be designated FR 5 (FI 1) to indicate that no exteroceptive stimulus changes occurred until completion of the fifth FI 1. The schedule used by Findley and Brady would be designated FR 10 (FR 400:S) to indicate that a stimulus was briefly presented at completion of each FR 400 component.

The present study sought to determine whether a brief stimulus that was occasionally contiguous with food delivery would maintain responding in fixed-interval components of an extended FR (FI:S) second-order schedule of reinforcement. It was found that this procedure would maintain long and orderly sequences of fixed-interval responding. Several experiments were then conducted to analyze how the reinforcing effectiveness of the brief stimulus was controlling responding.

METHOD

Subjects

Three adult male White Carneaux pigeons were maintained at about 75% of their free-feeding body weights. All birds had long ex-

perimental histories on various schedules of food reinforcement.

Apparatus

An experimental chamber, similar to that used by Ferster and Skinner (1957), was connected to control and recording equipment in another room. A standard response key (R. Gerbrands Co.) mounted on one wall of the chamber could be transilluminated by blue, white, or red lights (One Plane Digital Display Unit, Model No. 10256-Q, Industrial Electronics Engineers). A peck with a minimum force of 10 g was required to operate the response key. Each such response produced an audible click of a relay in the experimental chamber. Approximately 3 in. below the response key was a 2-in. square opening which provided occasional access to grain (food). During food presentation, the opening was illuminated by two 6-w lamps. The response key was not transilluminated during food presentation but white light from the food opening did reflect on the key. Continuously presented white noise masked most extraneous sounds.

Procedure

Experimental sessions were conducted daily from Monday through Friday. Each session ended when three food presentations had occurred. Except as noted, each food presentation comprised 10 successive 3-sec presentations of grain.

The two basic second-order schedules used were FR 30 (FI 2) and FR 15 (FI 4). Under FR 30 (FI 2), food reinforcement was contingent upon completion of 30 consecutive FI 2 components; under FR 15 (FI 4), food reinforcement was contingent upon completion of 15 consecutive FI 4 components. Thus, the maximum frequency of food reinforcement was one per hour. During preliminary training, the first response occurring after 2 min in the presence of a blue key-light produced a 0.7-sec presentation of a white (W) key-light (FI 2:W). The number of FI 2 components required for food reinforcement was gradually increased from 5 to 30 over the first 20 experimental sessions; that is, the schedule was changed from FR 5 (FI 2:W) to FR 30 (FI 2:W). When the final component of each sequence was completed, food was presented at

the termination of the 0.7-sec presentation of the white key-light.

The order of procedures and number of sessions under each procedure are shown in Table 1. Three procedures were investigated.

Table 1
Summary of Procedures

Procedure	Number of Sessions
FR 30 (FI 2:W)	37
FR 30 (FI 2)	6
FR 30 (FI 2:W)	22
FR 15 (FI 4:W)	27
FR 15 (FI 4)	5
FR 15 (FI 4:W)	15
FR 15 (FI 4:W) $S^* = 3$ sec	18
FR 15 (FI 4:W)	8
Tandem [FR 14 (FI 4:D)] [FR 1 (FI 4)]	7
FR 15 (FI 4:W)	56
Tandem [FR 14 (FI 4:R)] [FR 1 (FI 4)]	17
FR 15 (FI 4:W)	10

(1) The patterns of behavior when the white key-light was presented at the completion of each FI component were compared with behavior patterns when there was no exteroceptive stimulus change between food presentations (tandem schedules in the terminology of Ferster and Skinner, 1957). Comparisons were made between FR 30 (FI 2:W) and FR 30 (FI 2) and between FR 15 (FI 4:W) and FR 15 (FI 4). These comparisons indicated whether the brief presentations of the white stimulus were modifying the patterns of responding under the basic second-order schedules.

(2) The effects of reducing the duration of food presentation at the end of each sequence from 10 successive 3-sec presentations of grain to a single 3-sec presentation were studied under FR 15 (FI 4:W).

(3) The effects of presenting the white key-light at the completion of each FI component were compared with the effects of briefly presenting a different stimulus at the completion of each FI component except the one that terminated with primary reinforcement; that is, food was presented immediately at the termination of the final component of each sequence. In one study, the stimulus was a completely darkened (D) key; in another it was a red (R) key-light. At no time was either the dark key or the red key-light paired with food presentation. Under tandem [FR 14 (FI 4:D)]

[FR 1 (FI 4)], for example, the key was dark for 0.7 sec at completion of each of the first 14 FI 4 components [FR 14 (FI 4:D)]; at the end of the 15th FI 4 component, food was presented without any preceding stimulus change [FR 1 (FI 4)]; the notation for this entire schedule is tandem [FR 14 (FI 4:D)] [FR 1 (FI 4)]. Performances under FR 15 (FI 4:W) were compared with those under tandem [FR 14 (FI 4:R)] [FR 1 (FI 4)]. These comparisons indicated whether the effects of the briefly-presented white key-light were due to its occasional pairing with food reinforcement.

The number of responses in each successive fixed-interval component of every sequence were recorded on a printing counter. Rates of responding were computed in responses per second from digital counters and elapsed time

meters. The quantitative data are presented as responses per second in quarters of the fixed-interval components averaged over each experimental session. In each session under FR 15 (FI 4), for example, there were 45 fixed-interval components (three sequences of 15), and the response rates from the first minute of each of the 45 components were averaged; the response rates from the second, third, and fourth minute of each component were averaged in the same way.

RESULTS

Under both FR 30 (FI 2:W) and FR 15 (FI 4:W) schedules, responding developed readily and was well-maintained throughout each sequence. Representative performances during

Fig. 1. Representative performances showing positively accelerated responding within fixed-interval components under each second-order schedule (Bird 128). Each panel shows a complete experimental session comprising three sequences (from top to bottom), each terminating in food reinforcement. Left panel, 20th session during second exposure (see Table 1, 1.3) to FR 30 (FI 2:W); right panel, 24th session during first exposure (see Table 1, 1.4) to FR 15 (FI 4:W). In each sequence the recording pen reset to the bottom of the record whenever 1100 responses had cumulated. The recorder stopped during 0.7-sec presentations of the white light, indicated by short diagonal strokes on the cumulative record, and during food presentations.

complete experimental sessions are shown in Fig. 1. Each sequence was usually completed in about 60 min because pauses in the individual fixed-interval components seldom exceeded the duration of the interval. Within each fixed-interval component, initial brief periods of pausing were followed by increased responding until a response produced the white key-light and terminated the component. Responses seldom occurred during the brief presentations of the white key-light. The positively accelerated responding in the fixed-interval components of each sequence was qualitatively similar to that occurring under comparable fixed-interval schedules of food presentation.

The number of responses in consecutive fixed-interval components did not increase continuously during each sequence between food presentations. Figures 2 and 3 show responses from consecutive fixed-interval components from representative sequences under each second-order schedule. Although the number of responses in each fixed-interval component tended to be lower in the early components of each sequence, there were marked variations in numbers of responses in consecutive fixed-interval components, especially under FR 30 (FI 2:W). These variations

are similar to those that prevail between components under fixed-interval schedules of primary reinforcement (Ferster and Skinner, 1957).

During those sessions in which no exteroceptive stimulus change occurred at the completion of each fixed-interval component, responding occurred at a fairly steady rate throughout fixed-interval components. A comparison of performances under FR 15 (FI 4:W) and FR 15 (FI 4) is shown in Fig. 4. Under this second-order schedule, omission of the white key-light eliminated positively accelerating responding within the fixed-interval components and decreased the overall rate of responding. When the white key-light was presented again, positively accelerated responding returned within fixed-interval components, and the overall rate of responding increased (Fig. 4, bottom record). Figure 5 presents a quantitative summary of these results for Bird 128 under each second-order schedule.

The results were qualitatively similar with Bird 149 (Fig. 6 and 7). When the white key-light was presented at the completion of each

Fig. 2. Number of responses in each of 30 consecutive fixed-interval components of a representative sequence from the 22nd session of the first exposure (see Table 1, 1.1) to FR 30 (FI 2:W) (Bird 4). The sequence terminated with food reinforcement.

Fig. 3. Number of responses in each of 15 consecutive fixed-interval components of a representative sequence from the 15th session of the second exposure (see Table 1, 1.6) to FR 15 (FI 4:W) (Bird 4). The sequence terminated with food reinforcement.

Fig. 4. Effects of omitting presentations of the white light at the end of each FI 4 component (Bird 128). Each cumulative response record shows a sequence of 15 consecutive FI 4 components; each sequence terminated with food reinforcement. Short diagonal strokes on the records designated FR 15 (FI 4:W) indicate 0.7-sec presentations of white light. Under the FR 15 (FI 4) schedule, there were no exteroceptive stimulus changes during the sequence; short diagonal strokes indicate the end of each FI 4 component.

fixed-interval component, the positively accelerated pattern of responding characteristic of fixed-interval schedules of food reinforcement was maintained throughout each sequence; that is, average rates of responding increased in each successive quarter of the fixed interval. When the white key-light was omitted, average rates of responding were relatively constant in each successive quarter of the fixed interval.

When the FR 30 (FI 2:W) schedule was changed to FR 30 (FI 2) for Bird 4, individual fixed-interval patterns of responding were disrupted and average rates of responding decreased (Fig. 8). When FR 30 (FI 2:W) was again in effect, individual fixed-interval patterns of responding returned, but the overall rate of responding remained relatively low (Fig. 8, bottom record). Figure 9 presents a quantitative summary of the results for Bird 4 under both second-order schedules. In all

Fig. 5. Effects of omitting presentations of the white light on mean rates of responding in each quarter of the fixed-interval components (Bird 128). Each point is the median of the mean rates of responding in the last five sessions under each procedure. Solid circles: white light presented at termination of each fixed-interval component; triangles: no exteroceptive stimulus change at termination of fixed-interval components; open circles: redetermination of effects of presenting white light.

Fig. 6. Effects of omitting presentations of the white light at the end of each FI 4 component (Bird 149). Each cumulative response record shows a sequence of 15 consecutive FI 4 components; each sequence terminated with food reinforcement. Short diagonal strokes on the records designated FR 15 (FI 4:W) indicate 0.7-sec presentations of white light. Under the FR 15 (FI 4) schedule, there were no exteroceptive stimulus changes during the sequence; short diagonal strokes indicate the end of each FI 4 component.

Fig. 7. Effects of omitting presentations of the white light on mean rates of responding in each quarter of the fixed-interval components (Bird 149). Each point is the median of the mean rates of responding in the last five sessions under each procedure. Solid circles: white light presented at termination of each fixed-interval component; triangles: no exteroceptive stimulus change at termination of fixed-interval components; open circles: redetermination of effects of presenting the white light.

Fig. 8. Effects of omitting presentations of the white light at the end of each FI 2 component (Bird 4). Each cumulative response record shows a sequence of 30 consecutive FI 2 components; each sequence terminated with food reinforcement. Short diagonal strokes on the records designated FR 30 (FI 2:W) indicate 0.7-sec presentations of the white light. Under the FR 30 (FI 2) schedule, short diagonal strokes indicate the end of each FI 2 component.

Fig. 9. Effects of omitting presentations of the white light on mean rates of responding in each quarter of the fixed-interval components (Bird 4). Each point is the median of the mean rates of responding in the last five sessions under each procedure. Solid circles: white light presented at termination of each fixed-interval component; triangles: no exteroceptive stimulus change at termination of fixed-interval components; open circles: redetermination of effects of presenting the white light.

three birds, omitting the white key-light eliminated the characteristic fixed-interval pattern of responding in each component.

The effects of reducing the duration of food presentation from 10 successive 3-sec presentations of grain to a single 3-sec presentation are shown in quantitative summaries in Fig. 10. The marked reduction in duration of access to food decreased the overall rate of responding of each bird; however, the magnitude of the effect was small except with Bird 149.

When the dark key was presented at the completion of only the first 14 fixed-interval components, the patterns of responding were markedly changed. Responses did not occur during the brief presentations of the dark key. Responding occurred at relatively low, steady rates throughout fixed-interval components (left frames of Fig. 11, 12, and 13). The results obtained with brief presentations of the dark key were similar to those when there was no stimulus change at the end of each fixed-interval component (right frames of Fig. 5, 7, and 9). When the red key-light was presented at the completion of only the first 14 fixed-interval components (right panels of Fig. 11,

Fig. 10. Effects of decreasing the magnitude of primary reinforcement on mean rates of responding in each quarter of the fixed-interval component under FR 15 (FI 4:W). Solid circles: 10 3-sec presentations of grain; triangles: one 3-sec presentation of grain; open circles: redetermination of points with 10 3-sec presentations of grain. Note the different scale on the ordinate for Bird 128.

12, and 13), the effects on patterns of responding were not as consistent as those obtained with the dark key. Responding seldom occurred during the brief presentations of the red key-light. With Bird 128, the results with the red key-light were the same as those with the white key-light. With Birds 149 and 4, rates of responding in the third and fourth quarters of the fixed-interval components were clearly decreased.

DISCUSSION

In previous experiments with pigeons under chained fixed-interval schedules or with chimpanzees under fixed-interval schedules of token reinforcement, responding was poorly maintained even when the sequence of fixed-interval components could be completed with relatively short periods of time between food presentations. For example, prolonged pausing developed in the first component of a chained schedule comprising five 1-min fixed-interval components (Gollub, 1958). The pres-

ent experiments have shown that brief presentations of a stimulus occasionally paired with food presentation can maintain recurring patterns of fixed-interval responding for at least 1 hr between food presentations. The results support the conclusion of Kelleher and Gollub (1962) that simply pairing a stimulus with a reinforcer is sufficient to establish the stimulus as a conditioned reinforcer.

In the analysis of conditioned reinforcement in second-order schedules, it is necessary to assess the effects of omitting exteroceptive stimulus changes between food presentations. Thus, most studies of chained schedules have included comparisons with tandem schedules (see Kelleher and Gollub, 1962). Although omitting the briefly-presented stimulus in the present study generally decreased average rates of responding in each sequence under FR 15 (FI 4), responding was remarkably well-maintained throughout each sequence under both FR 30 (FI 2) and FR 15 (FI 4). On the other hand, omitting the briefly-presented stimulus quickly eliminated the fixed-interval

Fig. 11. Effects of presenting a stimulus that was not paired with food presentation on mean rates of responding in each quarter of the fixed-interval (Bird 128). Solid circles: white light terminated each component; triangles: dark key (left panel) or red light (right panel) terminated each component except the last one of a sequence; open circles: final determination of points when white light terminated each component.

pattern of responding that had been recurring throughout each sequence. These recurring response patterns were controlled by the scheduled presentations of the white key-light, and they suggest that the white key-light was a

conditioned reinforcer. If a schedule of stimulus presentation other than a fixed interval had been used, it might have been necessary to evaluate the effects of stimulus presentations solely in terms of changes in rate of responding, and the effects of omitting the stimulus might have been less marked. That omitting the stimulus had relatively large effects on patterns of responding as compared with rates of responding emphasizes the importance of schedule-controlled patterns of responding in evaluating the reinforcing effects of a stimulus.

The amount of food paired with a stimulus might be an important determinant of the effectiveness of the stimulus as a conditioned reinforcer. In the present experiments the duration of food presentation was relatively long (30 sec) to insure that the birds would receive most of their daily food requirements from the three food presentations in each session. When duration of food presentation was reduced to 3 sec, one bird showed decreased rates of responding in the latter half of the fixed-interval components; for the other two birds neither rates nor patterns of responding were markedly changed. Although it is probable that the amount of food presented would be an important variable in certain types of procedure and at extreme parameter values,

Fig. 12. Effects of presenting a stimulus that was not paired with primary reinforcement on mean rates of responding in each quarter of the fixed interval (Bird 149). Solid circles: white light terminated each component; triangles: dark key (left panel) or red light (right panel); open circles: final determination of points when white light terminated each component.

Fig. 13. Effects of presenting a stimulus that was not paired with primary reinforcement on mean rates of responding in each quarter of the fixed interval (Bird 4). Solid circles: white light terminated each component; triangles: dark key (left panel) or red light (right panel); open circles: final determination of points when white light terminated each component.

it was not a critical variable over the range of values studied here.

The characteristics of stimulus changes that will control responding in components of second-order schedules should be fully studied. Three previous studies indicated that stimuli that had not been paired with primary reinforcement could maintain some fixed-ratio responding in second-order schedules. Ferster and Skinner (1957, p. 67 ff.), using pigeons, and Zimmerman (1960), using rats, studied "percentage reinforcement" schedules in which fixed ratios were reinforced according to a variable ratio. In one of the Ferster and Skinner experiments, for example, every 30th response (FR 30) was immediately followed by either a 2-min time out or food presentation. Food was presented after every second FR 30 on the average. Thus, the basic schedule was VR 2 (FR 30), but the time out did not immediately precede food presentations. Although many FR 30 components were characterized by pauses and decreasing response rates, responding was generally well-maintained. Kelleher, Fry, and Cook (1964) studied the performance of squirrel monkeys under schedules in which fixed-ratios were reinforced according to a DRL. In one experiment, for example, every 100th response was immediately followed by either a 0.5-sec time out or food presentation. Food was presented only when the pause at the start of a fixed-ratio component exceeded 2 min. Thus, the basic schedule was DRL 2-min (FR 100), but the 0.5-sec time out did not immediately precede food presentation. Initial pauses averaging slightly less than 2 min alternated with sequences of 100 responses occurring at very high rates. None of these earlier studies with second-order schedules compared the effects of stimuli that did not immediately precede primary reinforcement with the effects of stimuli that did.

Relations between the stimulus presented at the termination of each fixed-interval component and the presentation of food were investigated in one part of the present study. When a stimulus not paired with food presentation was presented at the completion of all fixed-interval components except the last one of each sequence, fixed-interval patterns of responding were not as well maintained as they had been with a stimulus intermittently paired with food presentation. This effect was

much clearer when the stimulus was a dark key than when it was a red key-light. The results obtained with the red key-light may have depended on the experimental histories of the birds. For example, Bird 128 had been conditioned in the presence of a red light and had responded under a fixed-interval schedule in the presence of a red light for many months; it is probable that the other birds had also had some exposure to a red key-light. On the other hand, a completely darkened key would probably never have been associated with a schedule of food presentation.

It is possible that the results obtained with the dark key or with the red key-light would have been different if the birds had been exposed to these conditions for a very large number of sessions; however, the data did not show any trend during the relatively short exposure in the present study. Further experiments should be conducted with stimuli that have never been paired with food presentation. The present results suggest that it may be necessary to present a stimulus in temporal contiguity with a reinforcing stimulus if the former stimulus is to become an effective conditioned reinforcer.

In the present study a response-produced stimulus was established as an effective conditioned reinforcing stimulus by pairing it with a reinforcing stimulus. The pairing of a stimulus and a reinforcing stimulus is similar to the pairing of CS and US in respondent (Pavlovian) conditioning. Some of the variables known to be important in respondent conditioning may also be important in establishing a conditioned reinforcer. Respondent conditioning experiments have generally indicated that the optimal CS-US interval is 0.5 sec to 1 sec (Hilgard and Marquis, 1940). In the present experiments the interval between presentation of the white key-light and food was 0.7 sec. Further experiments should be conducted to determine the functional relations between the conditioned reinforcing effectiveness of a stimulus and the delay between the presentation of a stimulus (to be established as a conditioned reinforcer) and a reinforcing stimulus. Some results with chained schedules suggest that conditioned reinforcers can be established even with relatively long delay intervals between presentation of a stimulus and a reinforcing stimulus (Kelleher and Golub, 1962). Such differences might indicate

different conditioning processes, or they might indicate differences in sensitivity of the different procedures used to study respondent conditioning and conditioned reinforcement. In any event, available evidence suggests that conditioned reinforcers are established by stimulus contiguity.

In addition to the advantages they provide for studying conditioned reinforcers, second-order schedules of the type described here should be useful in analyzing schedules of reinforcement in general. Second-order schedules can be used to magnify certain characteristics of a particular kind of schedule of reinforcement. For example, the time required for a response determines the maximum frequency of reinforcement under a fixed-ratio schedule. Is the maximum frequency of reinforcement a critical determinant of the general characteristics of fixed-ratio performance? Under an FR 30 schedule, for example, the average rate of responding might be six responses per second; thus, the average frequency of reinforcement would be 1 per 5 sec. Under FR 30 (FI 2:W), behavior under the FI 2 schedule is treated as a unitary response that is reinforced under an FR 30 schedule of food presentation. Under FR 30 (FI 2:W), the maximum frequency of reinforcement is 1 per hr. Because the response under FR 30 is a single key-peck and the response under FR 30 (FI 2:W) is a sequence of key-pecks, it is necessary to make an assumption in order to compare responding under these two schedules. It is assumed that the interresponse time is the important property of responses under FR 30 and that the number of key-pecks in each FI 2 component is the important property of responses under FR 30 (FI 2:W). The comparison indicates that some of the characteristics of performance under FR 30 are similar to those under FR 30 (FI 2:W). Under FR 30, the first few interresponse times are relatively long and subsequent interresponse times are relatively short and variable (Waller and Morse, in press). Under FR 30 (FI 2:W), the first few fixed-interval components have relatively few key-pecks and subse-

quent components have a relatively high and variable number of key-pecks (see Fig. 2). The sequential interresponse times in the conventional schedule and the sequential numbers of key-pecks in components of the second-order schedule seem to be similarly controlled by FR 30 schedules of food presentation. Further studies are being conducted to determine other characteristics of conventional schedules which can be generalized to second-order schedules of reinforcement.

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