**FIXED-RATIO AND VARIABLE-RATIO SCHEDULES OF
BRIEF STIMULI IN SECOND-ORDER SCHEDULES OF
MATCHING TO SAMPLE¹**

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Eight pigeons matched to sample under second-order schedules of food reinforcement. Under fixed-interval unit schedules, the first correct match to occur after a given period of time was followed by the presentation of a brief stimulus. The termination of the last fixed-interval unit schedule was followed by food according to second-order fixed-ratio and variable-ratio schedules. In Experiment 1, as the number of fixed-interval unit schedules increased, long pauses occurred under the second-order fixed-ratio schedules, but not under the variable-ratio schedules. The similarity of performance measures such as local rate and accuracy indicated that the differences engendered by these two types of schedule are in the duration of the periods of not-responding. In Experiment 2, the addition of a brief stimulus at the end of each unit schedule in chained schedules that had different discriminative stimuli present for the duration of each unit did not substantially affect the performance, and long pauses continued to occur. However, few long pauses occurred under schedules with brief stimulus presentations alone. The most inaccurate performances were engendered by chained schedules without brief stimuli.

Kelleher (1966a, 1966b) showed that behavior was maintained by scheduling a briefly presented stimulus that was occasionally paired with food. The results of these experiments have usually been considered a subset of the general findings related to conditioned reinforcement. However, two recent experiments (Byrd, 1972; and Stubbs and Silverman, 1972) suggest that perhaps a more appropriate way to consider conditioned reinforcement is as a subset of the much larger class of phenomena that involve schedules of events. Kelleher defined second-order schedules as follows: "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" (Kelleher, 1966b, p. 476). For example, if an

animal must complete four fixed intervals of 30 sec each before food is presented, the schedule is denoted as FR 4 (FI 30-sec). If a brief stimulus, S, occurs when every fixed interval is completed, the schedule is denoted as FR 4 (FI 30-sec:S). If different discriminative stimuli are present for the duration of each fixed interval, the schedule is called a chained schedule and is denoted as *chain* FR 4 (FI 30-sec). For purposes of clarity, the schedule that specifies the contingency for food presentation will be referred to as the *second-order schedule*. In the examples above, FR 4 is the second-order schedule. The schedule that specifies the contingency for the brief stimulus presentations will be called the *unit schedule*. In the examples above, FI 30-sec is the unit schedule.

The purpose of Experiment 1 was to extend the comparison of variable-ratio and fixed-ratio schedules of reinforcement to second-order schedules with brief stimulus presentations. Studies with chained schedules have shown that responding can be maintained on *chain* FR (VI) and not on *chain* FR (FI) (Golub, 1958) and that responding can be maintained on *chain* VR 4 (y) and not on *chain* FR 4 (y) (Findley, 1962). These data strongly suggest that variable-ratio and variable-interval schedules are more potent in maintaining behavior than comparable fixed-ratio and fixed-interval schedules. Also, previous experi-

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ments have shown that animals choose a variable-ratio or interval over a fixed-ratio or interval schedule with the same mean inter-reinforcement requirement (Davison, 1969; Fantino, 1967; Herrnstein, 1964; Sherman and Thomas, 1968; and Trevett, Davison, and Williams, 1972). Experiment 1 was also a systematic replication of Lee and Gollub (1971), with the interval between brief stimulus presentations defined by time (fixed-interval schedules) rather than by number of responses that must occur over time (fixed-ratio schedules). Seven sets of fixed-ratio and variable-ratio second-order schedules were used.

The purpose of Experiment 2 was to compare the effects of stimuli that occurred briefly when unit schedules were completed with the effects of discriminative stimuli that were present for the duration of each unit schedule. Two sets of variable-ratio and fixed-ratio second-order schedules from Experiment 1 were used. Byrd and Marr (1969) had shown that responding was well maintained under variable-ratio second-order schedules when a food-paired stimulus was presented briefly at the completion of each unit schedule. Appearance of the same discriminative stimulus or of different discriminative stimuli during consecutive unit schedules did not have a differential effect upon performances when the food-paired brief stimulus was used. Thomas and Stubbs (1967) compared chained schedules and schedules with brief stimulus presentations using FR 3 (DRL 8-sec). When different discriminative stimuli were associated with each unit, response rates were low in the first unit and increased monotonically across units. However, since the unit schedule was a differential-reinforcement-of-low-rateschedule (DRL), the increased rate of responding in the terminal component resulted in a very low frequency of reinforcement in this unit. When a brief stimulus change occurred at the completion of each DRL unit, response rates were similar in the three units and the frequency of reinforcement in the terminal component was three times greater than under the chained schedule.

Correct matches on matching-to-sample procedures rather than single key pecks were the operants in both Experiments 1 and 2. Performances on matching-to-sample procedures have been reinforced under various intermittent schedules (Clark and Sherman, 1970;

Ferster, 1960; Mintz, Mourer, and Weinberg, 1966; Nevin, Cumming, and Berryman, 1963; and Skinner, 1950) and under three-unit chained schedules (Boren and Gollub, 1972). Since matching-to-sample procedures permit the organism to make correct matches that are intermittently reinforced, as well as to make errors that are never followed directly by reinforcement, separate amounts and patterns of responding can be engendered by various intermittent schedules of reinforcement. In the present experiments, the number of correct matches and errors were examined under different response requirements (Experiment 1) and under different discriminative stimulus conditions (Experiment 2).

EXPERIMENT 1

METHOD

Subjects

Four adult White Carneaux pigeons, obtained from the Palmetto Pigeon Plant, were housed in individual living cages and maintained at 80% of their free-feeding weights². Pigeons 72, 94, 126, and 127 had responded under various three-key matching-to-sample procedures for over 3 yr (Boren and Gollub, 1972).

Apparatus

Three Gerbrands pigeon keys were mounted horizontally on the front panel of a pigeon chamber 9.75 in. (24.7 cm) above the floor and 2.75 in. (7 cm) apart center to center. Each key could be transilluminated by red, green, yellow, or blue 6-W bulbs. Three white pilot lights were arranged vertically 0.75 in. (1.8 cm) to the right of the keys. The opening for the feeder was 3.75 in. (9.5 cm) below the center key. The feeder could be illuminated by a white light independently of the feeder operation. Reinforcement was 12-sec exposure to mixed grain in the illuminated feeder. The chamber was illuminated by two 6-W bulbs (houselights) located on the back panel. White noise was present in the experimental room.

²In conducting the research described in this report the investigator adhered to the "Guide for Laboratory Animal Facilities and Care", as promulgated by the Committee on Revision of the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, National Academy of Science-National Research Council.

Procedure

At the beginning of each trial, the center key was red or green. A peck on this key (the sample) darkened it and illuminated the side keys immediately. One of the side keys was red and one was green. If the pigeon pecked the key that matched the sample, the feeder light was turned on for 0.3 sec. During the 0.3-sec feeder light, the three keys were unlit, the houselights were on, and the stimuli for the multiple schedule (see below) were unchanged. If the bird pecked the key that did not match the sample, it received a timeout period for 3.0 sec, during which the keylights and houselights were off, but the multiple schedule stimuli remained unchanged.

The sequences of sample stimuli and correct side keys were arranged with a combination of two 12-trial sequences (Fellows, 1967) to which had been added two single alternations (*i.e.*, L,L,L,R,R,R,L,L,R,L,R,R,L,L,L,R,R,R,L,L,R,L,R,R,L,R,L,R). A correction procedure ensured that the color of the center key and the order of the colors on the side keys changed only after a correct match.

The comparison of fixed-ratio and variable-ratio schedules was carried out in Experiment 1 by using two-ply multiple schedules. One component of the multiple schedule was FR x (FI y -sec:Y), and xy (the minimum interreinforcement time) was always 480 sec. The other component of the multiple schedule was VR x

(FI y -sec:B), and the average scheduled interreinforcement time was also 480 sec. The values of the schedules, the order in which they were presented, and the number of sessions for each pigeon are in Table 1. Each condition was in effect until the total number of correct matches, the total number of errors, and the pause after food reinforcement showed no systematic changes for five days.

A different brief stimulus was used for each component. For one component, the brief stimulus was 0.5-sec illumination of all three keys by yellow lights; for the other, the brief stimulus consisted of all three keys being blue for 0.5 sec. One component was signalled by the illumination of the three white pilot lights located to the right of the keys; the other was signalled by the non-illumination of these lights. The presentations of the two different brief stimuli and the two component stimuli were counterbalanced for the four pigeons and are in Table 2. The brief stimulus at the end of the fixed-interval unit occurred after the 0.3-sec feeder light that followed a correct match. When food was scheduled at the end of a unit, the feeder operated after the 0.5-sec brief stimulus. These relationships are diagrammed in Figure 1.

The components of the multiple schedule alternated. Each component remained in effect for three consecutive food reinforcements. The stimulus signalling a component was continuously present for the duration of that component. The values of the variable-ratio schedules were chosen so that the mean value occurred with every three reinforcements (*e.g.*, under VR 4 the values during one component were 3, 2, 7, the mean of which is 4). Therefore, the number of fixed-interval units and, consequently, the number of brief stimulus presentations were identical for the variable-ratio and fixed-ratio schedules.

Table 1
Order of Conditions in Experiment 1

Schedules	Pigeons			
	(Numbers of Sessions)			
	72	94	126	127
1. mult FR 8 (FI 60-sec:Y) VR 8 (FI 60-sec:B)	42	40	38	39
2. mult FR 4 (FI 120-sec:Y) VR 4 (FI 120-sec:B)	21	22	22	22
3. mult FR 2 (FI 240-sec:Y) VR 2 (FI 240-sec:B)	22	20	20	21
4. mult FR 1 (FI 480-sec:Y) VR 1 (FI 480-sec:B)	21	20	20	21
5. mult FR 4 (FI 120-sec:Y) VR 4 (FI 120-sec:B)	16	16	16	15
6. mult FR 16 (FI 30-sec:Y) VR 16 (FI 30-sec:B)	21	20	20	20
7. mult FR 32 (FI 15-sec:Y) VR 32 (FI 15-sec:B)	18	16	18	16
8. mult FR 64 (FI 7.5-sec:Y) VR 64 (FI 7.5-sec:B)	22	21	20	21

Table 2
Stimuli Used in Experiment 1

Pigeons	Component Stimuli (Three Lights)		Color of 0.5-sec Brief Stimuli	
	FR	VR	FR	VR
72	On	Off	Yellow	Blue
94	On	Off	Blue	Yellow
126	Off	On	Blue	Yellow
127	Off	On	Yellow	Blue

A session was defined as two presentations of each component of the multiple schedule, *i.e.*, FR, VR, FR, VR. This meant that each session contained 12 grain reinforcements of 12 sec each. Exceptions to this occurred in Condition 8 [*mult* FR 64 (FI 7.5-sec:Y) VR 64 (FI 7.5-sec:B)]. Several of the pigeons paused so long in the fixed-ratio component that sessions were terminated after one occurrence of each component (six food reinforcements). Occasionally, the pauses were so extensive that a fixed-ratio component was terminated after one or two food reinforcements. Every session during Condition 8 ended with a complete variable-ratio component containing three reinforcements.

RESULTS

Variable-ratio second-order schedules maintained behavior under fixed-interval unit schedules such that the rate of food reinforcement was nearly as high as possible. On the other hand, fixed-ratio second-order schedules

engendered pausing, which resulted in a lower rate of food reinforcement. Representative cumulative response records of correct matches and errors for Pigeon 72 are shown in Figure 2. There were no differences in obtained rates of reinforcement between the variable-ratio and fixed-ratio second-order schedules for any bird until there were at least eight unit schedules. Pigeon 94 showed no differences until there were 64 unit schedules in each fixed ratio. In general, the performances of all pigeons were controlled by the stimuli associated with each second-order schedule, as evidenced by short pauses that occurred immediately after the 0.5-sec brief stimulus was presented. The extended pauses under the fixed-ratio second-order schedules did not always occur in every fixed ratio of a given value.

Quantification of the differences in the obtained rates of food reinforcement under the two second-order schedules is presented in Figure 3 for all four pigeons. The slight decreases under the variable-ratio second-order schedules resulted from the fact that fewer reinforcements per hour were scheduled as more unit schedules and, consequently, more brief stimuli occurred. In addition, the pigeons often did not complete a correct match until 1 or 2 sec after the fixed-interval time had elapsed at the shorter fixed-interval values (7.5 sec under VR 64). As the number of unit schedules required for reinforcement increased, the accumulation of the additional time for each unit became substantial. The lower rates for the fixed-ratio second-order schedules reflect the extended pauses that were seen in the cumulative records.

Comparisons of the pause lengths in the fixed-ratio and variable-ratio components are depicted in Figure 4. Note that the ordinates are log scales. Three types of pause are presented for each component at every schedule value. The pauses after correct matches showed no systematic trends between components or across conditions. The same finding of no systematic differences also occurred with the pauses after the 0.5-sec brief stimulus presentations. These two measures indicate that the local rates of responding were similar under the two types of second-order schedule. The pauses after food presentations, however, formed a decreasing function for the variable-ratio second-order schedules: as the lengths of

EXPERIMENT 1

EXPERIMENT 2

Fig. 1. Experiment 1, a. Sequence of events that terminated a fixed-interval unit schedule. b. Sequence of events that terminated the fixed-interval unit schedule that completed the fixed-ratio or variable-ratio requirement. Experiment 2, a. Sequence of events that terminated a fixed-interval unit schedule. b. Sequence of events that terminated the fixed-interval unit schedule that completed the fixed-ratio or variable-ratio requirement.

Fig. 2. Representative cumulative records of correct matches and errors for Pigeon 72. The records for FR 8 and VR 8 include only correct matches. The samples were taken from the final session at each value. A diagonal mark of the response pen indicates presentation of the brief stimulus for 0.5 sec. A continuous deflection of the response pen indicates delivery of grain for 12 sec. The pen reset at the end of each component.

the fixed-interval unit schedules decreased and the number of unit schedules increased, the pauses after food presentations decreased. The general trend held for the fixed-ratio second-order schedules until long pauses developed at large fixed-ratio values.

Correct matches per food reinforcement and errors per food reinforcement showed no systematic differences between fixed-ratio and variable-ratio second-order schedules. These are shown in Figure 5. Both of these measures that were calculated without respect to time demonstrated that similar amounts of behavior were engendered by the two second-order schedules. The increase in the rate of correct matches was due mainly to the increased fixed-ratio and variable-ratio requirements. Generally, errors per food reinforcement remained fairly constant over most of the fixed-ratio and variable-ratio values.

EXPERIMENT 2

METHOD

Subjects

Four adult White Carneaux pigeons, obtained from the Palmetto Pigeon Plant, were housed in individual living cages and maintained at 80% of their free-feeding weights. Pigeons 8G, 16, 204, and 208 had responded under various two-key matching-to-sample procedures for over 1 yr.

Apparatus

Two Gerbrands pigeon keys were mounted horizontally on the front panel of a pigeon chamber 9.35 in. (24 cm) above the floor and 2.0 in. (5.1 cm) apart center to center. Lights and patterns were projected on the rear of each key by an Industrial Electronics Engi-

Fig. 3. The rate of reinforcement (reinforcements per hour) for every number of unit schedules in the fixed-ratio and variable-ratio second-order schedules. Each point is the median value of the last five sessions under a condition.

neers' One Plane Readout cell (BRS-Foringer # IDD-001). Five yellow pilot lights were arranged horizontally 1.13 in. (2.8 cm) above the response keys. Fifteen white pilot lights were arranged vertically 2.5 in. (6.3 cm) to the right

of the right key. The opening for the feeder was 4.25 in. (10.7 cm) below the keys. Reinforcement was an 8-sec exposure to mixed grain in the illuminated (white) feeder. The chamber was illuminated by two 6-W bulbs

Fig. 4. Three types of pause from each component for every number of unit schedules in the fixed-ratio and variable-ratio second-order schedules. The first group of bars represents the mean pause after correct matches that were not followed by 0.5-sec brief stimulus presentations or food presentations. The second group represents the mean pause after 0.5-sec brief stimulus presentations that were not followed by food presentations. Note that no 0.5-sec brief stimuli occurred alone under FR 1 or VR 1. The third group of bars represents the mean pause after food presentations. Each bar is the median value of the last five sessions under a condition.

located on the rear wall. White noise was present in the experimental room.

Procedure

When a trial began, the left key (the sample) was red, green, or blue. The right key (the

choice) was dark. A peck on the right key illuminated that key with one of five colors (red, green, blue, yellow, or white). Each successive peck on the right key operated a stimulus programmer, and each of the five colors had an equal probability of occurring after

Fig. 5. Overall correct matches per food reinforcement and errors per food reinforcement in each component for every number of unit schedules in the fixed-ratio and variable-ratio second-order schedules. Each point is the median value of the last five sessions under a condition.

any peck. When the colors on the two keys matched, a peck on the left key was followed by an "X" on the left key for 0.25 sec. If the bird pecked the left key when the two key colors did not match or when the right key was dark, the peck was followed by a 5-sec timeout period (keylights and houselight off). A correction procedure ensured that the previous stimulus array was presented after a timeout period. In other words, the pigeon had to peck at least once on the right and once on the left before a trial was completed after a timeout period. No timeout period followed pecking the right key when the two colors matched.

The comparison of second-order fixed-ratio and variable-ratio schedules was carried out in Experiment 2 by using each type of second-order schedule alone at different parameter values. The values of the schedules, the order in which they occurred, and the number of sessions of exposure for each pigeon are in Table 3.

Phase 1 was a systematic replication of Experiment 1. As in the first experiment, the scheduled interreinforcement time for each condition was 480 sec. Phase 2 involved the addition of a different discriminative stimulus for each fixed-interval unit schedule of Phase 1. The discriminative stimuli were 15 white pilot lights down the right side of the front panel that were illuminated singly. The top pilot light always illuminated first after rein-

forcement. The next one down was on alone during the second unit, *etc.* In other words, under *chain* FR 4 (FI 120-sec:S), food always occurred after the fourth pilot light. However, on *chain* VR 4 (FI 120-sec:S) (range of 1 to 7) food occurred after any one of the first seven pilot lights with equal probability. The same brief stimulus, S, occurred at the termination of each fixed-interval unit schedule. This was a 0.5-sec illumination of the five yellow pilot lights located above the keys. This brief stimulus occurred after the 0.25-sec "X" that followed a correct match on the left key. When food was scheduled at the end of a fixed-interval unit, the feeder operated after the 0.5-sec illumination of the yellow lights. These relationships are diagrammed in Figure 1. In Phase 3, only one basic schedule was used: FR 8 (FI 60-sec). This was studied first with a discriminative stimulus for each fixed-interval unit schedule, then with discriminative stimuli and briefly presented stimuli following each unit schedule, and finally with only the brief stimulus presentations.

Each condition throughout all three phases was in effect until the total number of correct matches, the total number of errors, and the pause after food reinforcement showed no systematic changes for five days. A session was defined as 14 reinforcements for the FR 4 and VR 4 schedules and as 15 reinforcements for the FR 8 and VR 8 schedules.

RESULTS

The presentation of brief stimuli at the end of each fixed-interval unit schedule of the chained schedules did not maintain behavior at very high rates. Figure 6 shows the rate of reinforcement under all conditions of Experiment 2. Generally, there were no systematic differences under the two values of second-order variable-ratio schedules between sessions with only brief stimulus presentations and sessions with discriminative stimuli and brief stimulus presentations. Under the two values of second-order fixed-ratio schedules, the addition of discriminative stimuli to the schedules with brief stimulus presentations caused a decrement in rate of reinforcement for three of the four pigeons. Under the FR 8 schedules, the omission of brief stimulus presentations produced a further decrement for three of the four birds. When the brief stimuli were replaced in the schedule, there was some degree

Table 3
Order of Conditions in Experiment 2

Schedules	Pigeons			
	(Numbers of Sessions)			
	8G	16	204	208
PHASE 1				
1. VR 4 (FI 120-sec:S)	16	17	18	17
2. FR 4 (FI 120-sec:S)	25	20	22	23
3. FR 8 (FI 60-sec:S)	20	18	21	18
4. VR 8 (FI 60-sec:S)	36	36	34	37
PHASE 2				
5. <i>chain</i> FR 4 (FI 120-sec:S)	32	31	27	28
6. <i>chain</i> VR 4 (FI 120-sec:S)	17	18	18	18
7. <i>chain</i> FR 8 (FI 60-sec:S)	21	19	19	20
8. <i>chain</i> VR 8 (FI 60-sec:S)	14	15	14	14
PHASE 3				
9. <i>chain</i> FR 8 (FI 60-sec)	16	16	15	16
10. <i>chain</i> FR 8 (FI 60-sec:S)	11	11	8	11
11. FR 8 (FI 60-sec:S)	11	11	11	11

of improvement for all birds. However, only Pigeon 16's performance approximated that attained under the original condition of brief stimulus presentations without discriminative stimuli. All four pigeons showed recovery when the discriminative stimuli for each unit

were removed. Representative cumulative records of correct matches and errors under FR 8 and VR 8 second-order schedules for Pigeon 8G are shown in Figure 7. The long pauses that were engendered by the two types of fixed-ratio chained schedule are easily seen.

Fig. 6. The rate of reinforcement (reinforcements per hour) in each condition for four sets of second-order schedules. Each bar is the median value of the last five sessions under a condition and vertical lines through the tops of the bars represent the ranges.

Fig. 7. Representative cumulative response records of correct matches and errors for Pigeon 8G under two sets of second-order schedules. The samples were taken from the final session at each value. A diagonal mark of the response pen indicates presentation of the brief stimulus for 0.5 sec. A continuous deflection of the response pen indicates presentation of food for 8 sec.

Further analyses of the FR 8 second-order schedules are presented in Figure 8. Generally, correct matches per food reinforcement were greater when brief stimulus presentations were used alone. The most inaccurate performances for three birds out of four were engendered by the schedule that involved only discriminative stimuli. The high error values were the result of fewer correct matches and more errors per reinforcement.

GENERAL DISCUSSION

Experiment 1 extended the comparison of variable-ratio and fixed-ratio schedules of reinforcement to second-order schedules with brief stimulus presentations. Since the mean response requirements were equal in the fixed-ratio and variable-ratio second-order schedules, differences that emerged are attributable to the different second-order schedules. Ferster and Skinner (1957) demonstrated that key pecking was maintained at high rates under VR 360, but that long pauses developed when

the schedule was changed to FR 360. Inspection of the cumulative records for Experiment 1 showed similar results, even though food reinforcement was delivered when the first correct match was completed after a given number of fixed intervals had elapsed, rather than after a single key peck. The performances under fixed-ratio and second-order fixed-ratio schedules showed another similarity. Even though long pauses occurred before some of the large fixed ratios, in other instances the pauses were quite short (*cf.* Ferster and Skinner, 1957, p. 51).

The pauses after food presentation (see Figure 4) in the second-order variable-ratio schedules became shorter as the number of fixed-interval unit schedules increased. In other words, the duration of the pause reflected the duration of the fixed-interval unit schedule that followed a food presentation, rather than the duration of the inter-food interval. This result extends Shull's findings (1970a, 1970b, and 1971) that the duration of the post-reinforcement pause under a fixed-in-

Fig. 8. Bottom: overall correct matches per reinforcement (first bar of each pair) and errors per reinforcement (second bar) under each condition for all FR 8 second-order schedules. Top: the ratio of errors to correct matches and errors under each condition for all FR 8 second-order schedules. Each bar is the median of the last five sessions under a condition.

interval schedule can be controlled by the duration of the interreinforcement interval and is approximately one half of it. A similar result was reported by Sheldon (1971) for second-order schedules that were *chain* FR x FR y where x plus y was equal to 100. As in Experiment 1, the size of the unit schedule controlled the pause after food presentations as long as behavior was well maintained. This same result occurred under second-order fixed-ratio schedules until the size of the fixed ratio became large enough to control the pause after food presentations. This lengthening of the pause generally occurred at 32 or 64 units, which is in the same range in which Felton and Lyon (1966) and Powell (1968) reported increases in post-reinforcement pauses for their subjects under fixed-ratio schedules of key pecking.

In the data presented by Lee and Gollub (1971), the maximum effect of the brief stimulus presentations (greatest rate increases and appropriate patterning) occurred when the ratio of food presentations to brief stimulus

presentations alone was 1:3 or 1:1. Experiment 1 provided two systematic replications of the schedule used by Lee and Gollub, FR x (FR y :S). First, FR x (FI y -sec:S) defined the interval between brief stimulus presentations by time (fixed-interval schedules), rather than by number of responses that must occur over time (fixed-ratio schedules). Since the rate of reinforcement declined substantially as the number of brief stimulus presentations increased, it could be argued that the more times the brief stimuli occurred alone, the less they controlled a high rate of responding. However, the other component of the multiple schedule, VR x (FI y -sec:S) provided a more indirect replication in that the second-order schedule was a variable ratio as opposed to a fixed ratio. Since behavior was well maintained at all variable-ratio values, it becomes difficult to argue that the percentage of paired occurrences of brief stimuli and food presentations *per se* is the critical variable in maintaining a high level of performance under second-order schedules. Rather, it appears that irregular

versus regular scheduling of food contributes to maintaining behavior at high rates.

Experiment 2 compared the effects of stimuli that occurred briefly when fixed-interval unit schedules were completed with the effects of different discriminative stimuli that were present for the duration of each schedule. The basic second-order schedule on which these manipulations were performed was FR 8 (FI 60-sec). While the major finding of this experiment was that the addition of brief stimuli at the end of each unit schedule in extended chained schedules did not substantially affect the performance, behavior was maintained, albeit at a low rate, on both types of chained schedules. This differs from other experiments using chained schedules because of the large number of unit schedules used (*cf.* Byrd, 1971; Ferster and Skinner, 1957; Findley, 1962; and Gollub, 1958). The physical nature of the discriminative stimuli in the chained schedule was probably the determining variable. Unlike most of the previous experiments that involved different colors on the key itself as the discriminative stimuli, the present experiment used the white pilot lights that were mounted vertically down the right side of the front panel. These stimuli may have functioned more like tokens that were used to maintain the behavior of chimpanzees on large fixed-ratio schedules of conditioned reinforcement (Kelleher, 1958) or like the cumulative deflections of a voltmeter that maintained the behavior of pigeons on a second-order schedule, FR 10 (VI 1-min:S), (Zimmerman and Ferster, 1964). As in the token experiments, it was probably difficult for the animal to distinguish exactly which unit of the chained schedule was in effect at any particular time after the first or second unit. This meant that the last five or six units occurred in the presence of somewhat similar stimuli and the main event that demarcated a unit was the flash of lights as one stimulus light went off and the next one came on. This set of events resembles those in the second-order schedules with only brief stimulus presentations; and, in fact, the behavioral results were quite similar. Once the pigeon completed the first few units, responding occurred without extensive pausing until the next presentation of food.

In two conditions in Experiment 2, chained schedule stimuli were added to second-order

variable-ratio schedules with brief stimulus presentations at the end of each unit schedule. For three of the four pigeons there were slight rate decreases with the additional discriminative stimuli. While varying the number of units and varying the order of the discriminative stimuli have been thought of as ways to eliminate pausing in chained schedules (Ferster and Skinner, 1957; Findley, 1962; and Kelleher and Fry, 1962), it appears inappropriate for them to be considered as chained schedules at all. This is to say that discriminative stimuli in fixed-ratio chained schedules are always correlated with the distance to the next reinforcement. On the other hand, even though variable-ratio chained schedules meet the formal definition of chained schedules, the discriminative stimuli are associated with the number of units from the previous reinforcement, or they are totally uncorrelated with the distance to or from reinforcement. In either case, they function as irrelevant stimuli with little control of behavior.

It now appears that events that are not considered to be primary reinforcers may be used to control and maintain behavior under certain scheduling procedures. For example, Thomas (1969) maintained appropriately patterned key pecking in pigeons by presenting brief stimuli in the signalled absence of primary reinforcement. Zimmerman (1963) maintained pecking in a two-key situation where pecks on the right key were followed only by a 0.5-sec operation of the feeder. While these pecks occurred at a much lower rate than pecks on the left key, which are followed intermittently with food, the pecks on the right key that were never followed by food were sustained indefinitely.

The current trend that emphasizes the schedule under which an event occurs does not discredit the notion of conditioned reinforcement. Rather, it shifts the emphasis away from the variables that involved pairing with primary reinforcement. This is not at odds with the Kelleher and Gollub (1962) definition of conditioned reinforcement: "Some stimuli are positive reinforcers because of a specified experimental history of conditioning. We shall call these stimuli conditioned reinforcers, and refer to the presentation of this type of reinforcer as conditioned reinforcement, [p. 545]." The schedule under which an event occurs is as much a part of an

"experimental history of conditioning" as many other variables. The present findings indicate that the number of unpaired occurrences of the brief stimulus (as many as 125 under VR 64) was not a critical factor in maintaining behavior as long as the second-order schedule did not engender long pauses. This result would not have been predicted from a traditional view of conditioned reinforcement.

Two types of behavior occurred on the matching-to-sample procedures: correct matches and errors. In Experiment 1, a comparable number of correct matches and errors were engendered by both fixed-ratio and variable-ratio schedules at each parameter value. This finding differs from previous studies (Nevin, *et al.*, 1963; and Stubbs, 1968) in which performance was more accurate under variable-ratio schedules than under fixed-ratio schedules. The data from Experiment 1 were not presented as an accuracy measure (per cent correct or per cent error) because any specific accuracy value can be obtained in a number of ways. It appears that a more detailed and informative way to consider these data is to look at the rates of the two types of behavior separately (*cf.* Boren and Gollub, 1972). In Experiment 2, when the same basic second-order schedule was used for several conditions, and therefore, the response requirements were constant, the chained schedule with different discriminative stimuli for each unit and no brief stimulus presentations engendered fewer correct matches and more errors per reinforcement for three of four pigeons. This effect may be partially the result of the very low rates of reinforcement that occurred under the chained schedule.

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