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SECOND-ORDER SCHEDULES AND THE PROBLEM OF CONDITIONED REINFORCEMENT

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Thirteen pigeons were exposed to a variety of second-order schedules in which responding under a component schedule was reinforced according to a schedule of reinforcement. Under different conditions, completion of each component resulted in either (1) the brief presentation of a stimulus also present during reinforcement (pairing operation), (2) the brief presentation of a stimulus not present during reinforcement (nonpairing operation), or (3) no brief stimulus presentation (tandem). Brief-stimulus presentations engendered a pattern of responding within components similar to that engendered by food. Patterning was observed when fixed-interval and fixed-ratio components were maintained under fixed- and variable-ratio and fixed- and variable-interval schedules. There were no apparent differences in performance under pairing and nonpairing conditions in any study. The properties of the stimuli presented in brief-stimulus operations produced different effects on response patterning. In one study, similar effects on performance were found whether brief-stimulus presentations were response-produced or delivered independently of responding. Response patterning did not occur when the component schedule under which a nonpaired stimulus was produced occurred independently of the food schedule. The results suggest a reevaluation of the role of conditioned reinforcement in second-order schedule performance. The similarity of behavior under pairing and nonpairing operations is consistent with two hypotheses: (1) the major effect is due to the discriminative properties of the brief stimulus; (2) the scheduling operation under which the paired or nonpaired stimulus is presented can establish it as a reinforcer.

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Conditioned reinforcers are those that derive their reinforcing effectiveness from some

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specified experimental history of conditioning and are distinguished from unconditioned reinforcers that appear to act as reinforcers in the absence of any specified conditioning history (Kelleher and Gollub, 1962).

A persistent research problem has been the establishment of a strong durable conditioned reinforcing effect in the laboratory (*cf.* reviews by Kelleher, 1966*a;* Kelleher and Gollub, 1962; Kimble, 1961; Meyers, 1958; Miller, 1951; Wike, 1966; 1969). Earlier studies involved extinction and chained schedule procedures. However, many procedural problems have been pointed out with these methods (Kelleher, 1966*a;* Kelleher and Gollub, 1962; Marr, 1969; Wike, 1966; 1969). Accordingly, a recent research trend has involved schedule procedures in which brief-stimulus changes occur. Foremost among these procedures are second-order schedules.

Kelleher has defined a second-order schedule as a "schedule which treats a pattern of behavior engendered by a schedule contingency as a unitary response that is itself reinforced according to some schedule of reinforcement" (1966*b*, p. 476). Thus, an animal might be required to complete four fixed intervals of 60 sec (FI 60-sec) schedule requirements in succession before food is delivered. This is a second-order schedule under which a fixed-interval component is scheduled according to a fixed-ratio schedule (FR). Under Kelleher's (1966*b*) notation system the schedule is designated FR 4 (FI 60-sec). Similarly, a schedule designated as FI 600-sec (FI 60-sec) refers to a schedule in which a component FI 60-sec schedule is reinforced according to an FI 600-sec schedule. Under this second-order schedule, the first FI 60-sec component completed after 600 sec will produce food.[2]

Conditioned reinforcement has been studied in second-order schedules by having the completion of each component result in the brief presentation of a stimulus that also accompanies food. Under the schedule FR 4 (FI 60-sec:S) completion of each of the first three components results in a brief presentation of a stimulus; completion of the fourth component results in the presentation of that stimulus and food. Three classes of second-order schedules may be distinguished: (1) those in which a brief stimulus terminates all components and is intermittently paired with reinforcement (paired brief stimulus — S^p); (2) those in which a brief stimulus terminates all components except those ending in food presentation (nonpaired brief stimulus — S^n); and (3) those under which component completion results in no change in stimuli (tandem schedules).

Studies with second-order schedules have demonstrated the effects of paired brief-stimulus presentations on the rate and the pattern of responding within components. Comparison of schedules involving a brief food-paired stimulus and tandem conditions [*e.g.*, FR 4 (FI 60-sec:S^p) *vs.* FR 4 (FI 60-sec)] has shown changes in response rates when tandem schedules are changed to brief-stimulus schedules (Byrd and Marr, 1969; de Lorge, 1967; 1969; 1971; Findley and Brady, 1965; Kelleher, 1966*b;* Marr, 1969; Thomas and Stubbs, 1966; 1967). When a paired brief stimulus terminates components, the within-component pattern of responding resembles the pattern when the component terminates with food (Byrd and Marr, 1969; Davison, 1969; Kelleher, 1966*b;* Thomas and Stubbs, 1967).

One important question is whether the intermittent pairing of the brief stimulus and food is necessary for appropriate schedule performance to occur. Perhaps the presentation of any stimulus accompanying component completion would produce similar effects. The question is, do similar effects on response rate and response pattern occur under second-order schedules involving a paired stimulus and a nonpaired stimulus? The results of research on pairing have been equivocal to date. One group of experiments has demonstrated effects on response rates and patterning within components when a stimulus not paired with food

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[2] Under the terminology of second-order schedules it has become customary to speak of components as reinforced according to some schedule of reinforcement. This way of speaking has the difficulty that it does not emphasize the reinforcement of responses. Alternative ways of speaking would be to say component performance or component responses are reinforced according to some schedule. Although these ways of speaking make explicit the reinforcement of responses, they produce greater difficulties, in that the expressions "component performance" and "component responses" are vague and may be misleading. "Reinforcement of component performance," for example, needs clarification as to whether "performance" implies a pattern of responding. "Reinforcement of component responses" needs clarification that not any component response may produce the reinforcer, but only the response that completes a component.

accompanied completion of schedule components (Ferster and Skinner, 1957; Kelleher, Fry, and Cook, 1964; Neuringer and Chung, 1967; Zimmerman, 1960). Unfortunately, though effects of a nonpaired stimulus in controlling appropriate schedule performance have been demonstrated, a comparison of the effects of pairing and nonpairing operations was not made in the above mentioned experiments. In a second series of studies in which a comparison has been made, the results suggest that pairing of a brief stimulus with food produces different effects from those produced by a nonpaired stimulus (Byrd and Marr, 1969; de Lorge, 1967; 1969; 1971; Kelleher, 1966*b;* Marr, 1969; Stubbs, 1969). Patterning within components in most cases was absent or occurred irregularly when component completion resulted in a nonpaired stimulus. In some circumstances, however, similar effects were observed whether the brief stimulus was paired or not (*e.g.,* de Lorge, 1967; Kelleher, 1966*b*). Since the former series of studies suggests that nonpaired stimuli might have similar effects to paired stimuli, but the latter series suggests that paired and nonpaired stimuli have different effects, the fundamental question is, under what conditions do paired and nonpaired stimuli have similar or dissimilar effects on second-order schedule performance? The present series of experiments was addressed to this question.

In Part I, performance was compared under the three classes of second-order schedules; several different second-order schedules were used. In Part II, different aspects of the brief stimuli were varied: number of stimuli and type of stimuli (*e.g.,* keylight *vs.* blackout). In Part III, several control procedures were studied.

GENERAL METHOD

Subjects

Thirteen male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Experimental histories for the pigeons were varied. Relevant details are given in the individual experiments reported below.

Apparatus

Nine experimental chambers were used. They were obtained from both commercial sources and the New York University Psychology shop. Although some chambers had more than one response key (manufactured by R. Gerbrands Co. except where noted) only one key was used in each experiment. The keys were transilluminated either by light from ac "Christmas Tree" lights or by light from Industrial Digital Display (IDD) units. Only key pecks having a force of 0.15N or greater counted as responses. Each chamber contained a houselight. The feeders were all manufactured by R. Gerbrands Co.; the magazine of each feeder could be illuminated. The color of the magazine light was different from experiment to experiment and differed in color from the keylights in some experiments. In most chambers the feeder light was arranged so that it would not illuminate the response key.

Experimental sessions were controlled by relay circuitry in some of the experiments and by solid-state circuitry in others. Data were recorded on the counters and the cumulative recorders. While noise was present continuously in all of the chambers except the B.R.S. chamber.

Procedure

Over the various experiments the pigeons were exposed to a variety of second-order schedules. Second-order schedule performance was compared under three conditions. First, the completion of each component resulted in the brief presentation of a nonpaired stimulus (S^n); second, completion of each component resulted in the presentation of a paired stimulus (S^p); third, completion of each component simply produced the onset of the next component (tandem). Both the component schedules and the schedule of components were varied over experiments and within the same experiment. The component schedule in most experiments was a fixed interval, which specifies that the first response following the termination of some fixed time period is reinforced. In one experiment, the component schedule was a fixed ratio, which specifies that a fixed number of responses are required before food delivery. For all second-order schedules, the component schedule performance was treated as a unitary response, which was reinforced according to one or more of the following: fixed- and variable-ratio and fixed- and variable-interval schedules.

Analysis

The effects of different procedures were assessed regarding response rates and the pattern of responding within components. The measures that were used included total response rates, response rates during portions of schedule components, and the Index of Curvature.

Total response rates were calculated by dividing the total number of responses occurring during a session by the total session time, exclusive of food delivery or brief-stimulus periods. Responses during brief-stimulus periods in most of the experiments were included in the response total, but responses during these periods were absent or occurred at a low rate.

When fixed-interval component schedules were used, response rates in quarters of the interval were measured (Kelleher, 1966*b*). Thus, for a 60-sec fixed-interval component, rates during the first 15-sec, second 15-sec, third 15-sec, and fourth 15-sec time periods were calculated. The response that terminated the interval (occurring after 60 sec had elapsed) was not assigned to any quarter. In some experiments, response rates per FI quarter were computed across all fixed-interval components. In other experiments, rates per quarter were computed excluding components directly following food; thus in the schedule FR 4 (FI 60-sec), the measure would include rates in the various quarters for the second, third, and fourth components of the ratio. The rationale for excluding those components following food is presented below.

The Index of Curvature was employed to assess patterning within fixed-interval components (Fry, Kelleher, and Cook, 1960; Gollub, 1964). The Index of Curvature is a statistic indicating the extent of rate change in a cumulative response record. In the present case, index numbers could range from −0.75 to 0.75. A measure of 0.0 indicates a constant rate across quarters. The larger the number, the greater the curvature. Negative numbers occur when rates are higher in the early quarters.

In all experiments, medians were used for all measures. Medians were selected because session-to-session variability often was skewed around the medians. Though irregular, the variability generally was not large.

PART I

EXPERIMENT 1: COMPARISON OF PAIRED AND NONPAIRED BRIEF-STIMULUS OPERATIONS: FIXED-INTERVAL COMPONENTS MAINTAINED UNDER INTERVAL SCHEDULES

Experiment 1 was designed simply to assess the effects of brief-stimulus presentations on second-order schedule performance; the specific interest concerned the comparison of pairing and nonpairing operations.

METHOD

Subjects

Pigeons 224, 219, 218, and 208 served. Pigeon 208 had no prior experimental history.

Apparatus

Four chambers manufactured by Grason-Stadler were used, one for each pigeon. Each chamber contained three keys but the side keys were covered.

Procedure

Pigeons 219 and 224 were exposed to second-order schedules under which fixed-interval components were maintained under a variable-interval (VI) schedule. The first response after a fixed period of time produced food only if an assigned time period of the variable-interval schedule had elapsed; if such a period had not elapsed, a new fixed interval began. The variable-interval schedule had an average time of 360 sec between assignments of reinforcement and contained seven intervals arranged after the method described by Catania and Reynolds, (1968, pp. 380-381). The basic schedule for Pigeon 219 was VI 360-sec (FI 40-sec) and for Pigeon 224 was VI 360-sec (FI 60-sec). Completion of each component not producing food resulted in the presentation of a nonpaired stimulus, a paired stimulus, or no change in stimulus conditions. The order of conditions and the number of sessions under each are shown in Table 1.

For both pigeons, the response key normally was transilluminated by red light and the houselight was off. Brief-stimulus presentations consisted of a 0.75-sec change in keylight from red to white and, in addition, a white houselight was turned on for the 0.75-

Table 1

Summary of the experimental conditions (in order) for Pigeons 219, 224, 218, and 208 with the number of sessions under each.

	Condition	*Number of Sessions*
Pigeon 219	VI 360-sec (FI 40-sec)	13
	VI 360-sec (FI 40-sec:S^n)	10
	VI 360-sec (FI 40-sec:S^p)	10
	VI 360-sec (FI 40-sec)	7
Pigeon 224	VI 360-sec (FI 60-sec)	15
	VI 360-sec (FI 60-sec:S^p)	10
	VI 360-sec (FI 60-sec:S^n)	10
	VI 360-sec (FI 60-sec:S^p)	10
Pigeon 218	FI 600-sec (FI 60-sec)	14
	FI 600-sec (FI 60-sec:S^n)	10
	FI 600-sec (FI 60-sec:S^p)	10
	FI 60 -sec	10
Pigeon 208	FI 600-sec (FI 64-sec:S^n)	14
	FI 600-sec (FI 64-sec)	10
	FI 600-sec (FI 64-sec:S^p)	10
	FI 64 -sec	6
	FI 600-sec (FI 64-sec:S^n)	11

sec duration. For the nonpaired-stimulus condition (S^n), the keylights and houselight were off during reinforcement. The reinforcer consisted of 4-sec access to mixed grain; during reinforcement the food tray was illuminated by white light. For the paired-stimulus condition (S^p), the keylight again was red, the brief stimulus consisted of 0.75 sec of white keylight plus houselight, and the reinforcer was 4-sec access to food. This condition was the same as the previous except that the white keylight and houselight were on during reinforcement in addition to the magazine light. The response that produced food simultaneously illuminated the lights and operated the feeder.

For the tandem condition, completion of each component resulted in no change in the red key stimulus except when food was delivered; during 4-sec food cycles, the key was dark. Key pecks did not produce a "feedback" relay click. Each session lasted until a bird had received 50 food presentations.

Pigeons 218 and 208 were exposed to second-order schedules in which fixed-interval components were maintained under a fixed-interval schedule. The basic schedule was FI 600-sec (FI 60-sec) for Pigeon 218 and FI 600-sec (FI 64-sec) for Pigeon 208. Nonpaired- and paired-stimulus and tandem conditions were scheduled; the order of conditions and number of sessions are shown in Table 1. The key transillumination for Pigeon 218 normally was red; stimulus presentations consisted of a change in keylight from red to blue and the illumination of the white houselight. For Pigeon 208, the key normally was transilluminated by blue light; stimulus presentations consisted of a 0.75-sec presentation of red light plus the houselight. Pairing, nonpairing, and tandem operations were the same as those described for the previous birds. The reinforcer consisted of 4-sec access to grain, during which the food tray was illuminated by white light.

In addition to second-order schedules, Pigeons 218 and 208 were exposed to fixed-interval schedules of the same value as that of the component fixed-interval schedules (see Table 1). For Pigeon 218, the first response after 60 sec, timed from the completion of the previous food cycle, resulted in 4-sec access to food; for Bird 208, the first response after 64 sec produced food. For Pigeon 218, the keylight was red, for Bird 208, blue; the keylight was off during reinforcement.

Responses did not produce a relay click. Each session lasted until 30 food presentations occurred.

RESULTS

Figure 1 shows response rates as a function of quarters of fixed-interval components. The rates were calculated from the total of responses in the various quarters of all components for each session. The points are the medians of the last three sessions under each condition.

Figure 1 shows that under brief-stimulus schedules, response rate increased over quarters. This result indicates that a positively accelerated rate occurred within components. After presentation of a stimulus, there generally was a pause, followed by an increase in rate. No systematic differences between paired- and nonpaired-stimulus conditions occurred; differences between conditions were no greater than differences between redeterminations of a single condition. Thus, patterning was not more evident under any one condition. Some of the differences observed in Fig. 1 appear to be the result of changes in overall response rate. For example, rates were lower across all

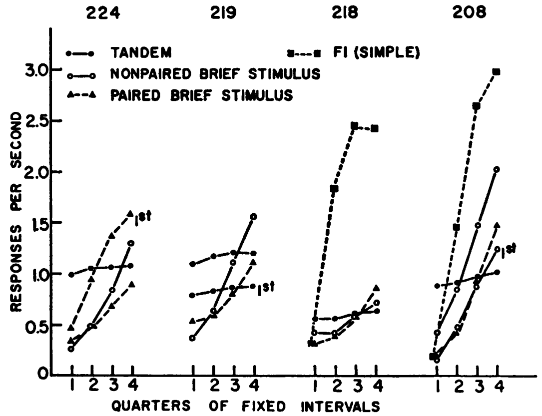

Fig. 1. Responses per second in each quarter of fixed-interval schedules. Rate measures are based on performance in all fixed-interval components. The label "1st" indicates the first determination under those conditions which were replicated (see Table 1).

quarters for Bird 224 in the second determination of the S^p condition than the first. Rates under tandem schedules were approximately constant, indicating that an accelerated pattern was not present within components. The slight increases were due to pauses that followed reinforcements; pauses after food were followed by an acceleration in rate that reached an approximately constant level about 1 min after food (the period of the first availability of food). Pauses after food produced the lowering of rates in the early quarters of particular intervals, and this intermittent lowering of rates affected the total measures shown in Fig. 1.

In general, overall rates were lower under brief-stimulus conditions than under comparable tandem conditions; in two instances (one for Pigeon 224 and one for Pigeon 208) response rates were the same for the brief-stimulus schedule and the tandem schedule. No systematic differences in overall rates occurred under paired- or nonpaired-stimulus schedules.

Changes in overall response rates under the various conditions did not alter reinforcement rates significantly. The use of interval schedules allows response rates to vary over a wide range without changes in reinforcement rates (Catania and Reynolds, 1968; Ferster and Skinner, 1957). Changes in performance could not be attributed to changes in reinforcement rates.

Figure 2 shows cumulative records, one set for VI (FI) second-order schedules and one for FI (FI) second-order schedules. The records under brief-stimulus conditions show a positively accelerated rate within components. The patterns under paired and nonpaired brief-stimulus conditions were similar both for Pigeon 224 and Pigeon 208. Occasionally, especially for Pigeon 224, within-component patterning was absent, and constant rates occurred from component to component.

Patterning within components was absent under tandem conditions. Both birds showed pauses after reinforcement under tandem as well as brief-stimulus conditions. The records for Pigeon 208 indicate an interaction between component performance and performance generated by the FI 600-sec schedule. The FI 600-sec schedule generated a positively accelerated rate of responding over components. Under brief-stimulus conditions, patterning occurred within components and rates within components tended to increase as the FI 600-sec period neared its end. These records are representative of the performance of the other pigeons.

The Index of Curvature measures under the tandem schedules approximated 0.0. The value of the Index under brief-stimulus conditions ranged between 0.20 and 0.30 for the various birds but showed no systematic differences with respect to the pairing and nonpairing operations for any pigeon. Under the FI (FI:S) schedules, Index of Curvature measures were roughly constant over components, despite the general increase in component rates as the FI 600-sec schedule neared completion.

EXPERIMENT 2: COMPARISON OF PAIRED AND NONPAIRED BRIEF-STIMULUS OPERATIONS: FIXED-INTERVAL COMPONENTS MAINTAINED UNDER RATIO SCHEDULES

Experiment 2, like the previous experiment, was designed to compare the effects of paired and nonpaired brief-stimulus presentations on second-order schedule performance. Different second-order schedules were studied in the present experiment.

METHOD

Subjects

Pigeons 228, 214, and 215 served; their prior history consisted of acquisition and extinction

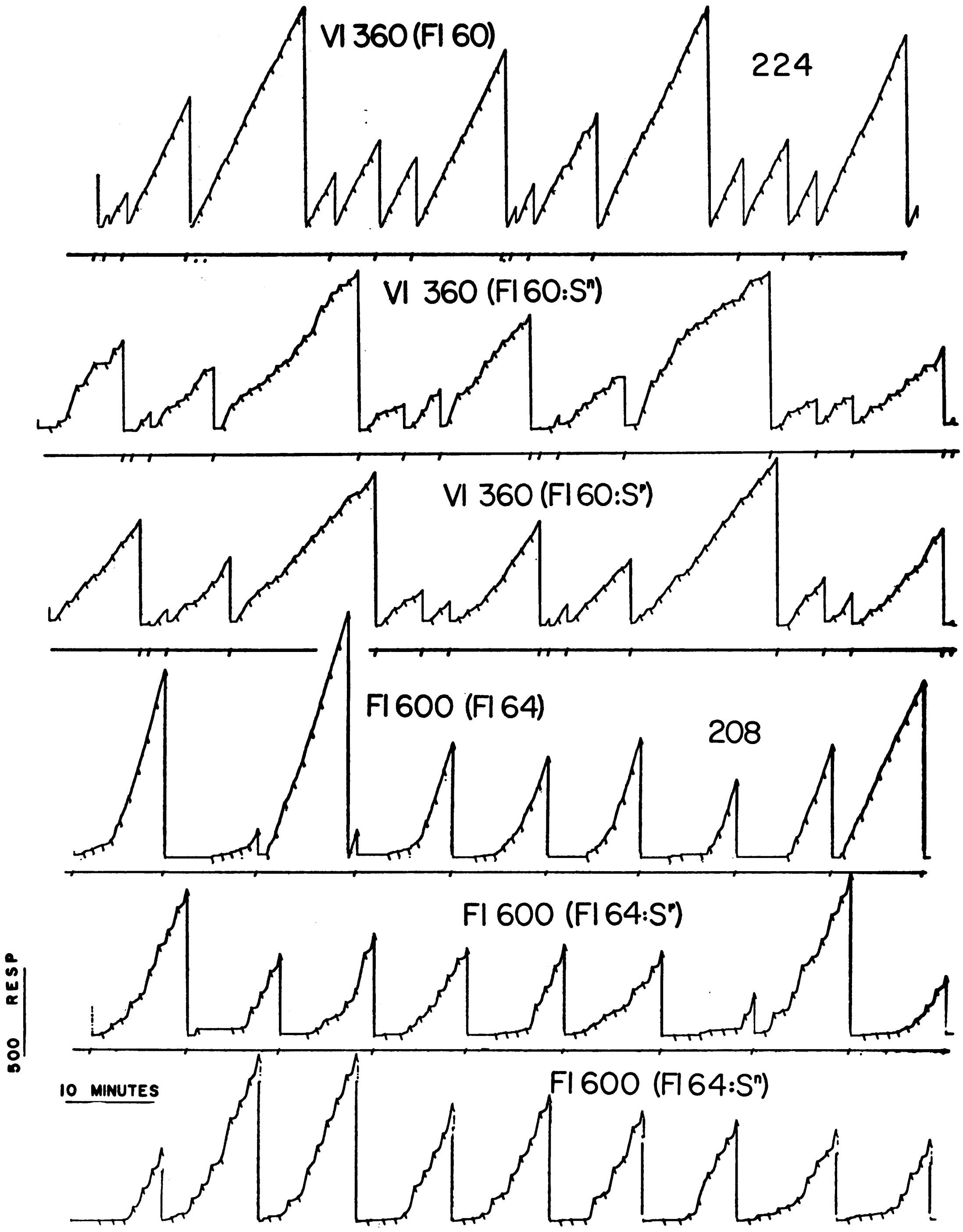

Fig. 2. Portions of cumulative records for two subjects. For each pigeon, a record was selected when the completion of a component resulted in the brief presentation of a paired stimulus (S^p), a nonpaired stimulus (S^n), or no stimulus. Where two determinations under a condition were taken, the record is from the second determination. Downward deflections on the cumulative curve indicate the completion of a component (whether a stimulus was presented or not). Food deliveries are indicated by deflections on the horizontal curve plus the vertical reset of the cumulative curve.

of a key-pecking response in an undergraduate laboratory course.

Apparatus

A one-key chamber was used.

Procedure

Fixed-interval (FI 60-sec) components were maintained under ratio schedules. Two fixed-ratio schedules, FR 2 and FR 4, and two variable-ratio schedules, VR 2 and VR 4, were employed. The variable-ratios were scheduled by a 33-position stepping switch; the range and order of ratios comprising the variable-ratio schedules were varied periodically over the course of study. Under each schedule, the pigeons were exposed to paired-stimulus, nonpaired-stimulus, and tandem conditions. Table 2 shows the conditions in order of presentation.

Table 2

Summary of conditions (in order) for Pigeons 228, 214, and 215.

Schedule	*Schedule*
1. VR 2 (FI 60-sec)	8. FR 2 (FI 60-sec)
2. VR 2 (FI 60-sec:S^n)	9. FR 2 (FI 60-sec:S^p)
3. FR 2 (FI 60-sec:S^n)	10. VR 4 (FI 60-sec:S^p)
4. FR 4 (FI 60-sec:S^n)	11. VR 2 (FI 60-sec:S^p)
5. VR 4 (FI 60-sec:S^n)	12. FR 4 (FI 60-sec:S^p)
6. VR 4 (FI 60-sec)	13. VR 2 (FI 60-sec)
7. FR 4 (FI 60-sec)	14. FI 60-sec

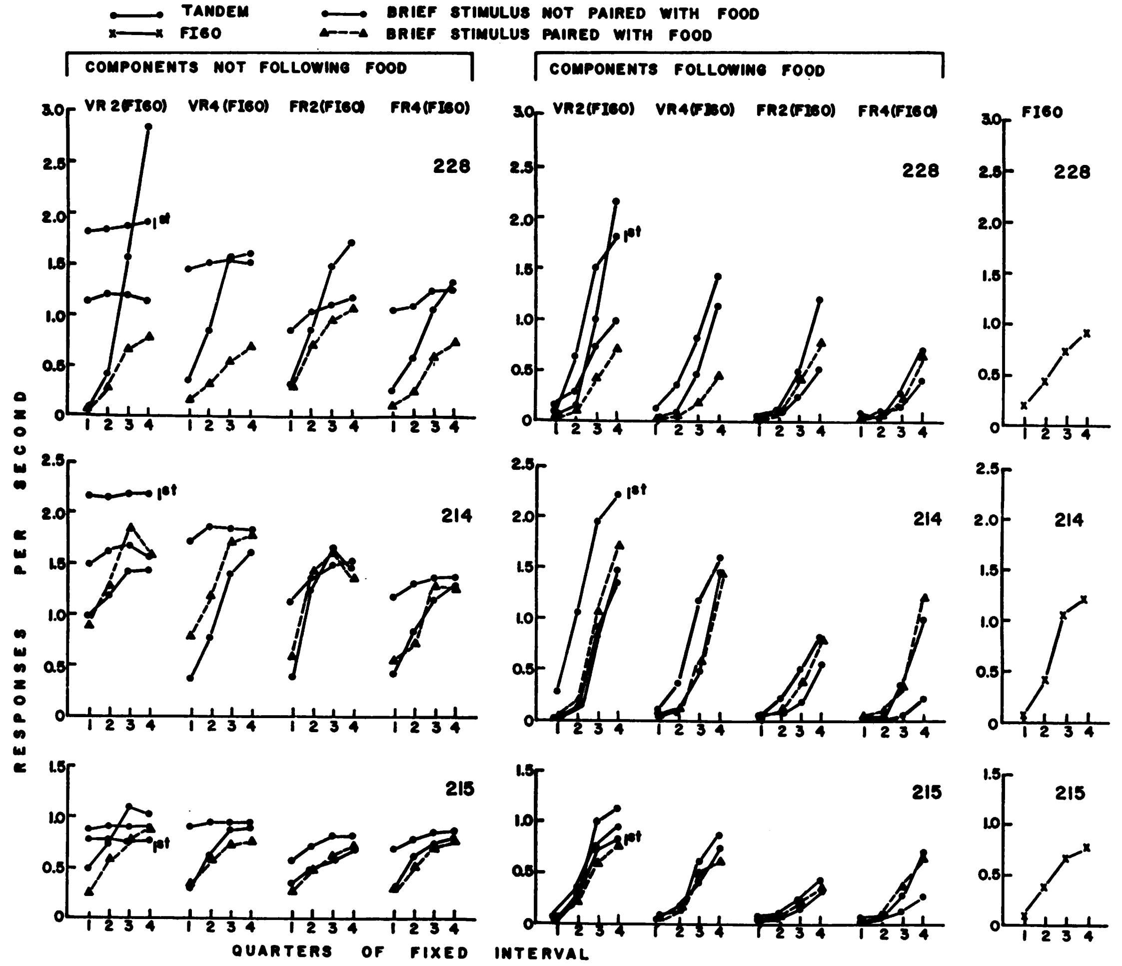

Fig. 3. Responses per second across quarters of fixed-interval components over the various conditions. On the left, rate measures include performance for FI 60-sec components except those that directly followed food. In the center, the measures include performance only for FI components directly following food. The labels, FR 2 (FI 60) *etc.*, show the basic schedule requirements; the points show the different stimulus conditions. The right-hand portion shows performance on simple FI 60-sec schedules. T—tandem conditions.

Under all conditions, the keylight normally was orange and the houselight was off. Under tandem conditions, completion of a component produced no change in stimuli except when food was delivered. The reinforcer consisted of 3-sec access to mixed grain, during which the keylight was off and the food tray was illuminated by blue light. Under brief-stimulus conditions, the completion of FI 60-sec components resulted in a 0.75-sec change in keylight from orange to white, coupled with the presentation of the white houselight. For the paired-stimulus conditions the white key and houselight were on during reinforcement; for the nonpaired-stimulus conditions the white lights were off during reinforcement. The final condition consisted of a simple fixed-interval (FI 60-sec) schedule. As before, the keylight was orange and the feeder cycle was 3 sec, during which the food tray was illuminated by blue light and the keylight was off.

Each response produced a relay click; the relay was functional during brief-stimulus and feeder periods, though responses rarely occurred. Each session lasted 2 hr. The first condition was in effect for 35 sessions; thereafter, each condition was run, arbitrarily, for 14 sessions.

RESULTS

Figure 3 shows response rates as a function of quarters of fixed-interval components; the points are medians of the last five sessions. The data in the left-hand portions are from all components except those that directly followed food; the data in the middle portions are from only the components directly following food. Under the schedule FR 4 (FI 60-sec), for example, only data from the initial component would be included in the measures plotted in the middle portion; only data from the terminal three components would be included in the left portion of the figure.

The left-hand portion of Fig. 3 shows fixed-interval patterning to be evident for all com-

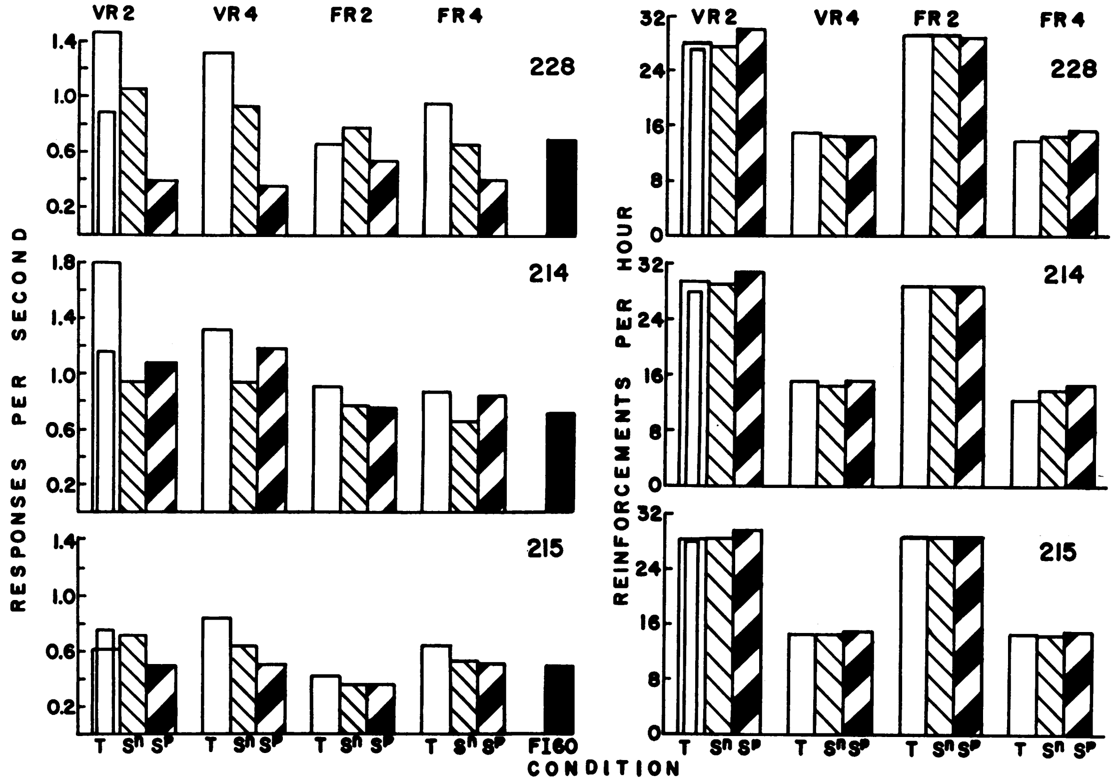

Fig. 4. Total response rates and reinforcement rates under the different second-order schedules. The labels VR 2, VR 4, FR 2 and FR 4 indicate the schedule of components. The narrower bar under VR 2 (FI 60-sec) indicates the second determination under that condition. Response rate measures include rates on all fixed-interval components. Response rates under the simple FI 60-sec schedule are included for comparative purposes.

ponents in the brief-stimulus schedules but absent from those under the tandem schedules. There were differences across schedules but the differences largely resulted from changes in overall response rates. No systematic difference occurred between paired and nonpaired brief-stimulus conditions. The middle portion shows an increase in rates across quarters and this increase occurred regardless of schedule or condition. The pattern of performance in initial components resulted from a pause following each food delivery, regardless of condition. Although patterning was apparent under all conditions, rates in the initial component of a fixed ratio generally were higher under brief-stimulus conditions than under comparable tandem conditions (except for Pigeon 214); this effect was not present under variable-ratio schedules.

Response rates increased across quarters under the simple fixed-interval schedule. The pattern appears more similar to those seen in the initial rather than in the later components of the second-order schedules.

The left portion of Fig. 4 shows the total response rates under each schedule. The rates, which are medians of the last five sessions, include the performance in all components. Rates under tandem schedules were higher than rates in comparable brief-stimulus schedules in almost every case; there were only three exceptions in the 45 possible comparisons. Comparison of paired and nonpaired brief-stimulus conditions does not allow a statement that either operation engendered higher rates. Pigeon 228 showed lower rates under the paired-stimulus conditions in every case. But the paired-stimulus schedules were given after the nonpaired and the decrement in rate with the redetermination of the tandem schedule, VR 2 (FI 60-sec), suggests a lowering of rate over the course of the study. Reinforcement rates are presented on the right of Fig. 4 (except for FI 60-sec). Response rates were sufficiently high under all schedules that changes in reinforcement rates were slight for schedules having equal minimum interreinforcement intervals.

Figure 5 shows Index of Curvature measures. The data, which are medians of the last five sessions, represent performance only for components not directly following food; performance under the simple fixed-interval schedule is shown on the right. Figure 5 shows little curvature under tandem schedules. Under the two brief-stimulus conditions curvature was comparable and the measures did not differ to a great degree under the four ratio schedules. Index measures were higher for two of the three pigeons under the FI 60-sec schedule than under any second-order schedule. Curvature measures, though not presented, were higher in the initial components than in later components. The measures were high in initial components under all conditions, resulting from the pause after food presentations.

EXPERIMENT 3: COMPARISON OF PAIRED AND NONPAIRED BRIEF-STIMULUS OPERATIONS: FIXED-RATIO COMPONENTS MAINTAINED UNDER FIXED-RATIO SCHEDULES

In the previous experiments, paired and nonpaired brief-stimuli had similar effects on second-order schedule performance. Fixed-interval schedules were the component schedules in the previous two experiments. Fixed-ratio schedules were the component schedules in the present experiment.

METHOD

Subjects

Pigeons 201, 202, 203, 228, 214, and 215 served. Pigeons 228, 214, 215 had previously served in Exp. 2. Pigeons 201, 202, and 203 had prior histories on chained, tandem, multiple, and mixed schedules.

Apparatus

The chamber for 228, 214, and 215 was the same as described in Exp. 2. The chamber for 201, 202, and 203 was a three-key chamber; the center key was used while the two side keys were covered.

Procedure

Experiment 3 consisted of two sub-experiments. Pigeons 228, 214, and 215 were exposed to multiple (*mult*) schedules in which each segment consisted of a second-order schedule. The first schedule was *mult* [FR 4 (FR 40:S^n)] [FR 4 (FR 40)]; the two second-order schedules had equal response requirements while the brief stimulus occurred in only one. The conditions alternated irregularly from rein-

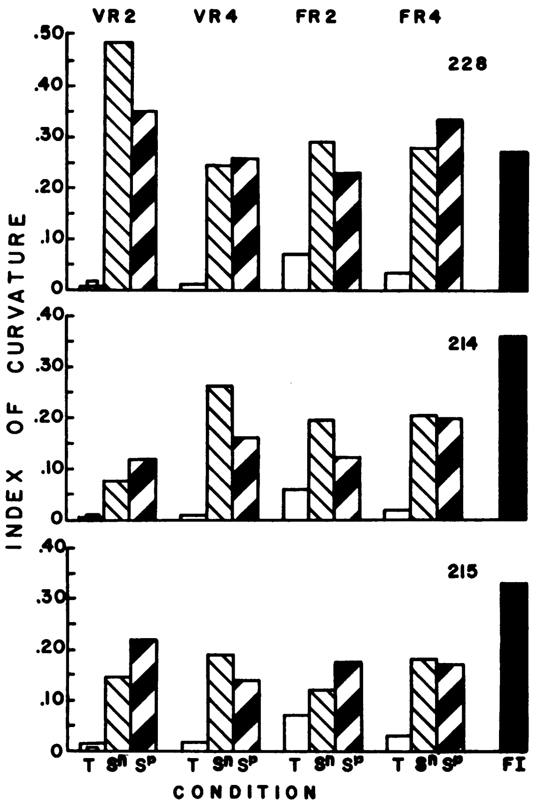

Fig. 5. Index of Curvature measures under the different second-order schedules and the simple FI 60-sec schedule. The measures include data from fixed-interval components except those following food (except in the case of the FI 60). The narrow bar under VR 2 represents the measure under the second determination. The labels VR 2, VR 4, FR 2, and FR 4 are the schedules of the component FI 60-sec schedule.

forcement to reinforcement. For the brief-stimulus schedule, completion of four FR 40 components produced food. The key stimulus was green and the houselight was off. Completion of each of the first three components produced a 1-sec change in the key stimulus to white accompanied by illumination of the white houselight. During food delivery, which lasted 3 sec, only a blue magazine light was on.

For the tandem schedule, the key was orange and the houselight was off. No change in stimuli accompanied component completion until food was presented after the fourth. The conditions of food delivery were the same as stated above. After 20 sessions the schedule was changed so that the brief stimulus was now also present during food cycles following brief-stimulus or tandem schedule performance. Other than the pairing operation, all conditions were the same as in the previous condition. Under this second condition, the multiple schedule was in effect for 10 sessions.

Key pecks produced a relay click, even during brief-stimulus periods. In addition, key pecks during brief-stimulus periods counted towards the completion of the succeeding ratio. Each session lasted 2 hr.

Pigeons 201, 202, and 203 were exposed to schedules in which the completion of four FR 20 components produced food. The order of conditions and the number of sessions under each are shown in Table 3. Comparison was made of the effects of a paired stimulus, a nonpaired stimulus, and no stimulus following component completion. Under all conditions, the key stimulus was blue and the houselight off. Under the tandem, the only stimulus change resulted when food was presented for 4 sec, during which the key stimulus was off and the food tray was illuminated by red light. Brief-stimulus presentations consisted of a 2-sec change in the key stimulus to white accompanied by white houselight illumination. For the nonpaired-stimulus condition these lights were off during reinforcement; for the paired-stimulus condition they were on during reinforcement.

Table 3

Summary of conditions (in order) for Pigeons 201, 202, and 203 and the number of sessions under each.

Condition	*Number of Sessions*
FR 4 (FR 20:S^n)	20
FR 4 (FR 20:S^p)	10
FR 4 (FR 20:S^n)	10
FR 4 (FR 20)	12

Each response produced a relay click. The relay click did not occur during brief-stimulus periods nor would responses during these periods count towards the completion of the ratio. Each session terminated after 50 reinforcements or after approximately 2 hr, whichever occurred first.

RESULTS

Figure 6 shows response rates for Pigeons 228, 214, and 215 across the eight successive halves of the four component ratio requirements and total response rates. The data are medians of the last five sessions. Since ratio

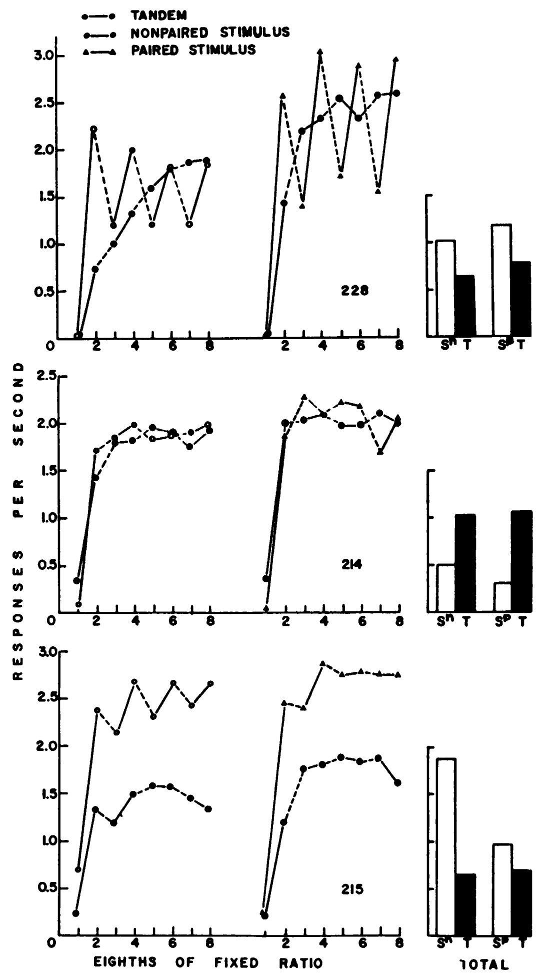

Fig. 6. On the left, responses per second as a function of eight of the total ratio requirement (the requirements of individual components were added for the total ratio requirement). The first and second eighths comprise the first component, broken into halves; the third and fourth eighths comprise the second component, *etc.* Solid lines connect first and second halves of components; broken lines connect the last half of a component with the first half of the following component. On the right, total response rates are shown as a function of the different conditions.

responding is characterized by a pause-and-run pattern, patterning would be indicated here by two things: there should be an increase in response rate from the first to the second half of each component; second, the pause might produce a lower rate in the first half of a component than was observed in the last half of the previous component. These indices of patterning are present for the performance of Pigeons 228 and 215 under brief-stimulus conditions. For Pigeon 228, rate increased over the halves of each component; rate in the first half of each component was lower than in the last half of the previous component. Thus, rates were low, then increased, but decreased after a brief stimulus was presented. Rates under tandem conditions tended to increase regardless of component halves. The data for Pigeon 215 were similar, though not as striking as those for Pigeon 228; there was one exception (paired stimulus) to the general finding of an increase in rate from first to second half: rate decreased from first to second halves of the last component under the paired-stimulus condition. The data for Pigeon 214 failed to show the pause-and-run pattern whether the brief stimulus was paired or not. All subjects paused after reinforcement regardless of the condition.

Figure 6 shows that for Pigeons 228 and 215, total response rate was higher under brief-stimulus schedules than under the tandem schedule. Also, rates were higher in the first component of the brief-stimulus schedules. For Pigeon 214, both total rates and rates in the initial component were higher under tandem conditions.

Figure 7 shows for Pigeons 201, 202, and 203 response rates in each half of each ratio component on the left and total response rates on the right. Data are the medians of the last five sessions under each condition. Only the data for Pigeon 203 suggest a pause-and-run pattern under brief-stimulus conditions. For the last two components, rates were lower in the first half as compared with the last half and rates in the first half were lower than rates in the last half of the prior component. The data for the other two pigeons do not clearly show a pause-and-run pattern. Though patterning might have been occurring under some conditions (such as Pigeon 201 under the second determination of S^n), Fig. 7 shows that there were almost as many instances where patterning did not occur. Whether or not patterning occurred, no noticeable differences were observed between paired and nonpaired conditions; the patterning by Pigeon 203 appeared to the same degree under the two different brief-stimulus conditions.

The right-hand portion of Fig. 7 shows total response rates. Rates were variable from condition to condition. Total rates were not consistently higher under any of the three conditions.

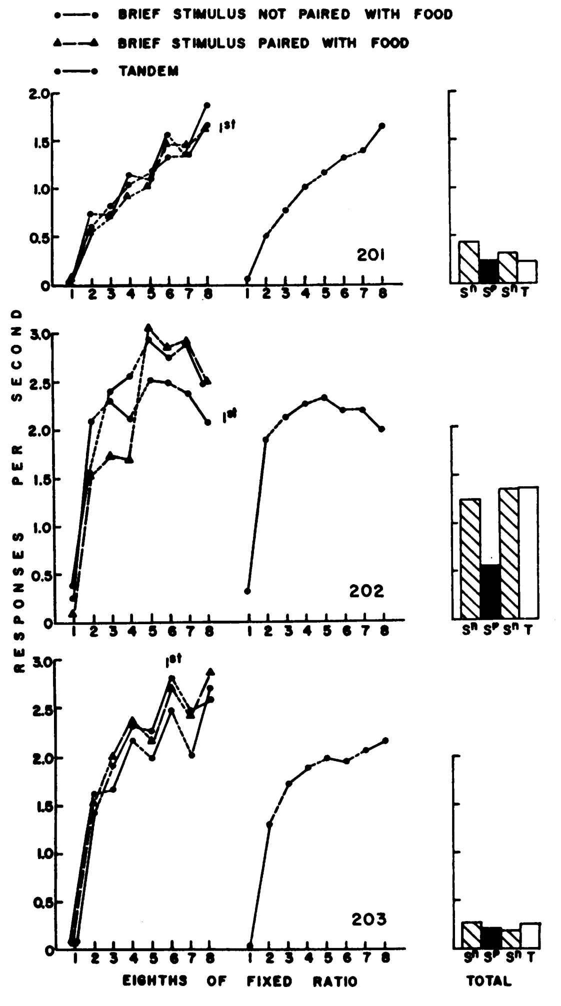

Fig. 7. On the left, responses per second as a function of portions of the total ratio requirement. The first two eighths comprise the first FR 20 component, the second two eighths, the second component, *etc.* The solid lines indicate first and second halves of a FR 20 component. Broken lines connect the last half of a component with the first half of the next component. On the right, total responses per second are shown under the different procedures.

Discussion of Part I

In the present series of experiments, the effects of brief-stimulus presentations on second-order schedule performance were assessed. Over a wide variety of schedules, patterns of responding appropriate to schedules of food presentation resulted when components terminated in either paired or nonpaired brief stimuli. The extent of patterning was the same whether or not the brief stimulus was intermittently paired with food.

When brief-stimulus presentations terminated fixed-interval components, component performance was characterized by a positively accelerated rate. Fixed-interval components were maintained under fixed- and variable-ratio and fixed- and variable-interval schedules; over the range of schedules studied, patterning occurred to the same extent under paired and nonpaired brief-stimulus operations. Patterning was not as noticeable when the component schedules were fixed-ratio. The pause-and-run pattern was apparent with only three of the six birds.

There are two possible explanations of why the pause-and-run pattern was not always observed. First, the pre-ratio pause is a function of fixed-ratio size (Felton and Lyon, 1966; Ferster and Skinner, 1957). Pre-ratio pauses tend to increase as the size of the ratio increases; with small ratios, the pause would be small. Possibly the use of larger component ratios would have resulted in more apparent pauses. (Interestingly, pausing was less when the component schedules were FR 20 than when they were FR 40.) Second, the breakdown of response rates into component halves in the present experiment might have been insufficient to detect small pauses. Possibly, preratio pauses might have occurred for all birds following brief-stimulus presentations, but changes in rate generated by the second-order schedule could mask pausing if they were sufficiently small. More detailed recording might have detected pauses.

The present results agree with those of Ferster and Skinner (1957), Kelleher, *et al.*, (1964), Neuringer and Chung (1967), Staddon and Innis (1969), and Zimmerman (1960) in that patterning can be engendered within components due to the presentation of a stimulus not paired with food. In the above mentioned studies in which nonpaired stimuli were used, the effects of nonpaired and paired stimuli were not compared. The present results demonstrated equivalence between the two operations. In the few cases where patterning was not apparent under nonpaired-stimulus schedules, patterning also was not observed under paired-stimulus schedules.

The present results appear to be in disagreement with those of Byrd and Marr (1969), de Lorge (1967; 1969; 1971) Kelleher (1966*b*), Marr (1969), and Stubbs (1969). Their results suggest that the pairing operation produces higher response rates and more prominent patterning of responses than the nonpairing operation. When a nonpaired stimulus accompanied component completion, patterning generally did not occur, or was variable (occurring only sometimes) and was not as great as patterning engendered by presentation of a paired stimulus. These studies have employed a variety of second-order schedules, which are summarized in Table 4. (Table 4 omits a number of details of the studies *e.g.,* de Lorge, 1969, employed multiple schedules similar to those of Exp. 3.) Table 4 shows that the schedules employed in previous studies are comparable to those employed in the present studies. In the present and previous experiments, fixed-interval components were maintained under fixed-interval, fixed-ratio, and variable-ratio schedules and fixed-ratio components were maintained under fixed-ratio schedules. While present and past second-order schedules differ in the schedule values, there is no apparent difference that would suggest a difference in results. In general, reinforcement rates were lower in earlier studies, but the present findings suggest that reinforcement rates probably are not a critical factor for patterning under nonpaired-stimulus conditions; in the present studies, patterning occurred over a wide range of reinforcement rates across the different experiments.

Table 4

Summary of second-order schedules in which the effects of nonpaired and paired stimuli have been compared.

1. Byrd and Marr (1969)	VR 12 (FI 120-sec)
2. deLorge (1967)	FI 1080-sec (FI 180-sec)
3. deLorge (1969)	A. VR 10 (FI 60-sec)
	B. FR 5 (DRL 10-sec)
4. deLorge (1971)	FR 5 (VI 20-sec)
5. Marr and deLorge (Marr, 1969)	FR 10 (FI 120-sec)
6. Kelleher (1966*b*)	FR 15 (FI 240-sec)
7. Stubbs (1969)	FR 4 (FI 30-sec)
	TAND FR 3 (FI 30-sec) FR 1 (FI 5-sec)
	TAND FR 3 (FI 45-sec) FR 1 (FI 1-sec)

Although there are a number of procedural differences between the present and past experiments, a noticeable difference concerns the stimuli used in the brief-stimulus operations. In the present study, the same stimulus was used for both paired and nonpaired brief-stimulus operations. In the previous studies, typically one stimulus was used for the pairing operation and a different stimulus was used for the nonpairing operation. Since nonpaired-stimulus schedules generally were in effect before paired-stimulus schedules in the present studies, patterning under nonpaired-stimulus schedules could not have resulted from a prior history of pairing. In prior studies, different effects under pairing and nonpairing procedures were confounded by differences in the stimuli used in pairing and nonpairing operations. Different stimuli might have greater or lesser effects on performance regardless of whether the stimulus is intermittently paired with food or not. The next experiment was designed to assess the effects of a variety of brief stimuli on second-order schedule performance.

PART II

EXPERIMENT 4: VARIATION IN THE NUMBER AND TYPE OF STIMULI USED IN BRIEF-STIMULUS OPERATIONS

For Exp. 4, only nonpaired brief-stimulus operations were studied. Under the same schedule requirements, the properties of the brief stimulus were varied to assess whether different stimuli would have different effects on performance.

METHOD

Subjects

Pigeons 218 and 208 served; these pigeons previously served in Exp. 1.

Apparatus

A B.R.S. Foringer chamber with a B.R.S. Foringer response key was used; the experiment was controlled by solid-state circuitry.

Procedure

Fixed-interval components were maintained under a fixed-interval schedule, FI 300-sec (FI 40-sec:S^n). The key was transilluminated by a horizontal white line on a dark ground. The first response after an FI 40-sec component had elapsed resulted in the 1-sec presentation of a nonpaired stimulus or, once the FI 300-sec period had elapsed, 4-sec access to grain. Under all conditions except one, all lights were off except a white food magazine light during reinforcement. Table 5 shows the experimental conditions in order of occurrence. For the first condition, the key stimulus changed to red and a white houselight was illuminated at the completion of each component. For the "red keylight" condition, only the key stimulus changed; the houselight was never on. For the "houselight" condition, each component terminated in the 1-sec presentation of the houselight; during this period the horizontal line remained on the key. Blackout 1 consisted of turning off the key stimulus; since the keylight was the only light in the chamber, this operation resulted in a 1-sec period of total darkness. Blackout 2 was the same as Blackout 1 except that the horizontal-line key stimulus remained on during food presentations. Although blackouts resulted in total darkness, the key stimulus was off during blackouts and food cycles in the Blackout 1 condition; thus, the blackout could be viewed as a paired stimulus. Blackout 2 made the blackout a nonpaired stimulus in the strictest sense.

Table 5

Summary of experimental conditions (in order) for Pigeons 218 and 208.

Schedule	*Brief Stimulus*
FI 300-sec (FI 40 sec:S^n)	red keylight plus houselight
FI 300-sec (FI 40 sec:S^n)	red keylight
FI 300-sec (FI 40 sec:S^n)	houselight
FI 300-sec (FI 40 sec:S^n)	red keylight plus houselight
FI 300-sec (FI 40 sec:S^n)	Blackout 1
FI 300-sec (FI 40 sec:S^n)	Blackout 2
FI 300-sec (FI 40 sec:S^n)	houselight

A relay click was not used nor was white noise present. Each session lasted until 30 reinforcements occurred. After 20 sessions' exposure to the first condition, each condition was in effect, arbitrarily, for 14 sessions.

RESULTS

Figure 8 shows the effects of different brief-stimulus operations on rates in quarters of fixed-interval components. Rates included performance in all FI 40-sec components. The points are medians of the last five sessions under each condition. Rates increased across most conditions. Rates increased to a lesser degree for both pigeons under blackout conditions as compared with the other conditions. Rates for Pigeon 218 under both blackout conditions were nearly constant across quarters, indicating negligible patterning.

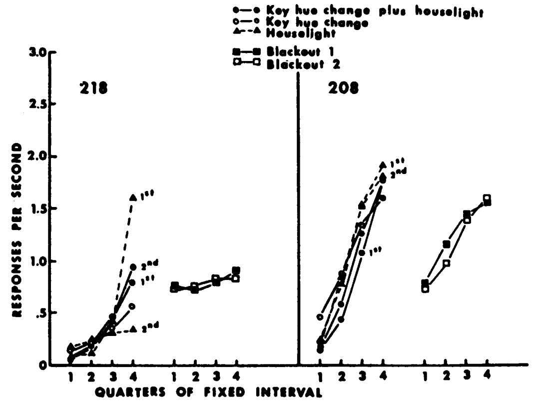

Fig. 8. Responses per second as a function of quarters of fixed-interval components, using data from all components. The first and second determination under particular conditions are indicated. In all cases, the completion of each component resulted in a nonpaired stimulus.

Index measures (Fig. 9) were lower under the blackout condition as compared with the

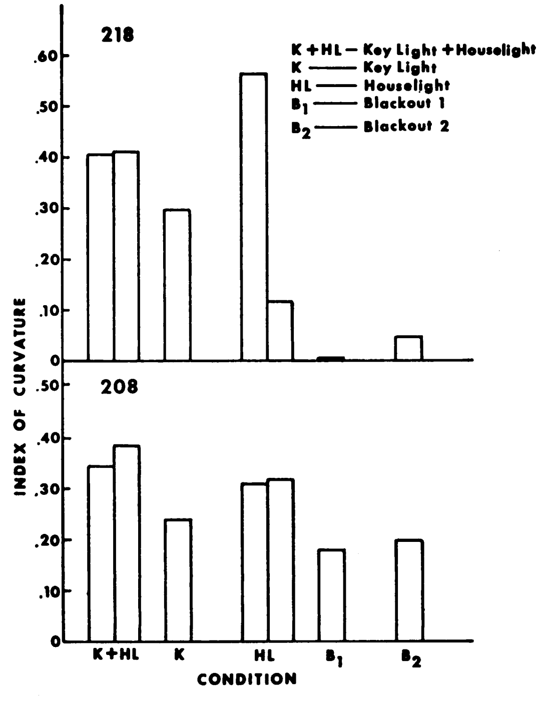

Fig. 9. Index of Curvature measure under the various conditions. Where two determinations were made for a particular condition, the first determination is on the left.

other conditions. Figure 9 also shows that highest Index measures were obtained under the keylight plus houselight conditions, with one exception for Pigeon 218. This result suggests that patterning was greater when two stimuli were used than when either one of the two stimuli occurred alone. The result is somewhat tentative, however, for two reasons: (1) in one instance for Pigeon 218, the Index was higher under the houselight than keylight plus houselight conditions; (2) though the keylight plus houselight condition showed highest Index measures for Pigeon 208, the differences between the various conditions were considered small.

DISCUSSION OF PART II

The results of Exp. 4 demonstrated that patterning within components of second-order schedules is a function of the particular stimulus that accompanies the completion of schedule components. Depending on the stimulus that was used, patterning was observed to a greater or lesser degree and in some cases not at all. The type of stimulus and possibly their number may affect component performance.

The experiment suggests the need to use the same stimulus in both pairing and nonpairing operations. In previous studies, when the effects of paired and nonpaired brief-stimulus presentations were compared, different stimuli were used for pairing and nonpairing; stimulus differences confounded differences due to pairing or nonpairing. In some cases, the present results suggest that differences in previous studies may have resulted in part from the particular stimuli used. Byrd and Marr (1969) compared performance under tandem, paired-stimulus and nonpaired-stimulus schedules (See Table 4 for the schedule). A greater degree of within-component patterning was observed when a paired stimulus was used than when a nonpaired stimulus was used. For the pairing operation, the key stimulus was turned off, the houselight was turned off, and the feeder light was turned on; for the nonpairing operation the key stimulus changed to red. Thus, the pairing operation involved different stimuli and a greater number of stimuli than the nonpairing operation. Similarly, de Lorge (1969) in one study reported greater effects on both rates and patterning when brief stimuli were paired than when they were not. But the paired stimulus was the feeder light (whether houselights and keylight went off was not specified) while the nonpaired stimulus was the onset of a red light to the side of the key. Differences in the type and possibly number of stimuli might have produced the difference. Marr and de Lorge (Marr, 1969) reported greater effects on rates and patterning under paired-stimulus schedules. The paired stimulus was a houselight while the nonpaired stimulus was a tone. Possibly response patterns might not be as strong with an auditory stimulus as with a visual stimulus. Kelleher (1966*b*) reported patterning within components when the paired stimulus was a change in key color but no patterning when the nonpaired stimulus was a dark key. The present results suggest that a blackout apparently might be a relatively ineffective stimulus (see, however, Neuringer and Chung, 1967). In the study by Stubbs (1969), different key stimuli and the feeder light were used in different conditions, so the results might have been due to stimulus differences.

When paired and nonpaired stimuli have been more similar physically, the past experiments have shown more similar effects on performance. Kelleher (1966*b*), besides using a dark key as the nonpaired stimulus, also used a nonpaired red key stimulus as compared with a paired white key stimulus. With the red key stimulus, patterning was observed, though not necessarily to the same degree as that generated by the paired stimulus. de Lorge (1967) used a yellow key stimulus as the paired stimulus and a green key stimulus as a nonpaired stimulus. The effects of the green stimulus were similar to those of the yellow. In this same study, de Lorge normally used the yellow stimulus as the paired stimulus but in one condition employed the same yellow stimulus as a nonpaired stimulus. Patterning and response rates were weaker when the stimulus was nonpaired. Here, pairing and nonpairing were not confounded by stimulus differences; the data for de Lorge's one bird are in disagreement with the present results. In another study, de Lorge (1969) employed a white feeder light as the paired stimulus and a red feeder light as the nonpaired stimulus. The pairing operation generally produced greater effects on behavior. Why the color difference in stimuli would produce the differences in performance is not clear (see also

Marr, 1969). But in any case, the present results demonstrate the need to use the same stimulus for pairing and nonpairing operations. Otherwise, an interpretation in terms of pairing *vs.* nonpairing appears difficult to maintain.

In a recent study, de Lorge (1971) provided a control for the use of different stimuli on pairing and nonpairing operations. Using a multiple schedule procedure, de Lorge employed a paired stimulus in one component and a nonpaired stimulus in the other; the stimuli were white and red feeder lights, respectively. The conditions were then reversed: the red feeder light was paired and the white feeder light was unpaired. Under both conditions, the paired stimulus resulted in higher rates. The results seemingly differ with the present results with regard to the effects of a nonpaired stimulus. One possibility for the difference in results concerns de Lorge's use of variable-interval schedules as component schedules; this possibility is considered in the discussion below.

The present results suggest that pairing is not necessary for a brief stimulus to affect performance at least under certain schedules. And problems in the design of the previous studies weaken the argument that pairing operations are necessarily more effective than nonpairing in maintaining second-order schedule performance. It is possible, however, that in some circumstances pairing operations might produce greater effects on second-order schedule performance; not all possibilities have been eliminated. The present procedures differ in many as yet unexplored ways from past procedures. For example, in the present pairing procedure, the response that produced food also produced the simultaneous onset of the paired stimulus. In other experiments, the paired stimulus preceded food (*e.g.*, de Lorge 1967; 1969; Kelleher, 1966*b*). As a second possibility, in the present studies the brief stimulus was generally a key color plus houselight. Differences in the effect of pairing *vs.* non-pairing might have resulted with other stimuli. However, this possibility is unlikely. In an unpublished study, Philip Silverman and I found similar degrees of patterning when fixed-interval components were maintained under a variable-interval schedule, VI 240-sec (FI 60-sec:S), with electric shock as the brief stimulus.

PART III

EXPERIMENT 5: COMPARISON OF RESPONSE-DEPENDENT AND RESPONSE-INDEPENDENT SCHEDULING OF THE BRIEF STIMULUS AND THE INDEPENDENCE OF BRIEF-STIMULUS AND FOOD SCHEDULES

The previous experiments raised questions regarding the conditions that might control patterning within component schedules. First, does it make a difference whether brief-stimulus presentations are response produced? Would a positively accelerated response rate occur if a stimulus were presented every x sec regardless of what behavior occurred? Second, is a dependent relation between brief-stimulus presentations and food presentations necessary? If, for example, brief-stimulus presentations were scheduled according to a fixed-interval schedule independent of the food schedule would patterning occur?

METHOD

Subjects

Pigeons 225, 226, and 227 served; all had prior histories in several experiments.

Apparatus

The chamber was a three-key chamber. The center key was used and the side keys remained uncovered.

Procedure

The brief stimulus was presented when component completion was response-dependent or response independent. Under the response-dependent procedures, fixed-interval components (FI 60-sec) were maintained according to a variable-interval schedule (VI 240-sec). As in previous experiments, the response completing a fixed-interval component produced a paired stimulus, a nonpaired stimulus, or no stimulus (tandem). Under the response-independent procedures, a brief stimulus occurred at 60-sec intervals regardless of behavior. Technically, this is a fixed-time (FT 60-sec) schedule (Zeiler, 1968). Food was presented according to the following restriction: once an interval of the variable-interval (VI 240-sec) schedule had elapsed a response was reinforced according to a fixed-interval schedule (FI 60-sec) timed from the previous brief-stimulus presentation or reinforcement. Thus, the response-independent procedures were equivalent to the response-dependent in three respects: (1) the brief stimulus occurred at 60-sec intervals; (2) 60-sec intervals intervened between a brief stimulus and food; and (3) the rate of reinforcement was similar. Table 6 shows the summary of conditions in order for each subject for response-dependent and response-independent procedures.

Table 6

Summary of Conditions for Pigeons 225, 226, and 227

Pigeon	*Schedule of brief stimuli*	*Brief stimulus procedure*
225	response-dependent	S^n
	response-independent	S^n
	TAND	TAND
	response-dependent	S^n
	response-dependent	S^p
	response-independent	S^p
	response-dependent	S^n
226	TAND	TAND
	response-dependent	S^n
	response-independent	S^n
	TAND	TAND
	response-dependent	S^p
	response-independent	S^p
	response-dependent	S^n
227	response-independent	S^n
	TAND	TAND
	response-dependent	S^n
	response-independent	S^n
	response-dependent	S^p
	response-independent	S^p
	response-dependent	S^n

Paired stimulus, nonpaired-stimulus, and tandem conditions were scheduled. For all conditions, the keylight normally was red and the houselight was off. Under the tandem condition, the only change in stimuli occurred during the 4-sec food cycle, at which time the keylight was off and the food tray was illuminated by orange light. Brief-stimulus presentations consisted of 0.75-sec changes in keylight from red to blue accompanied by presentations of a white houselight. For the nonpairing operation, the blue light and houselight were off during reinforcement; these lights were on during reinforcement for the pairing operation.

The last experimental procedure involved the presentation of the brief stimulus according to a fixed-interval schedule (FI 60-sec) and presentation of food according to an independent variable-interval schedule (VI 240-sec). Thus, the interval between food presentations and brief-stimulus presentations could range from 0 to 60 sec. Technically, this schedule is a conjoint schedule (*cf.* Catania, 1968), although it has also been labelled a concurrent schedule (*cf.* Zimmerman, 1969); the schedule is not a second-order schedule. Only the nonpaired-stimulus condition was given. (If both schedule requirements were satisfied together, a response would produce the brief stimulus and food together, but this event was not observed.) The stimulus conditions were the same as in the previous procedures: red key stimulus, 0.75-sec presentations of a blue key stimulus plus houselight, and 4-sec presentations of food.

Each response produced a relay click (even during brief-stimulus periods). The first two experimental conditions were in effect for 30 sessions; all subsequent conditions were in effect for 14 sessions.

RESULTS

Figure 10 shows median response rates across FI quarters under the various conditions. The data exclude responses in components directly following food except for the conjoint schedule (where such an exclusion of data is not appropriate). With respect to brief-stimulus second-order schedules, comparisons of pairing and nonpairing operations and response-dependent and response-independent procedures show little difference between conditions other than changes in overall rate. Rates increased across quarters for Pigeons 225 and 227. The degree of patterning appears similar over conditions. Pigeon 226 showed little difference in performance between brief-stimulus and tandem conditions. For this subject, brief-stimulus presentations had a negligible effect under all conditions. Pigeons 225 and 226 showed higher rates across quarters under paired-stimulus conditions than under nonpaired, but this result did not obtain with Pigeon 227. Under the conjoint procedure, response rates did not increase across quarters for any bird; a positively accelerated rate did not occur within fixed-interval schedule components.

Index of Curvature measures were calculated under the different conditions but are not shown. The measures are similar for each bird under brief-stimulus second-order schedules. The similarity held regardless of pairing *vs.* nonpairing operations, whether the brief stimulus was response-dependent or -independent, and regardless of changes in rates (Fig. 10). Curvature measures under the conjoint procedure were close to 0.0. There was little difference between any of the measures for Bird 226, indicating little or no patterning under any condition.

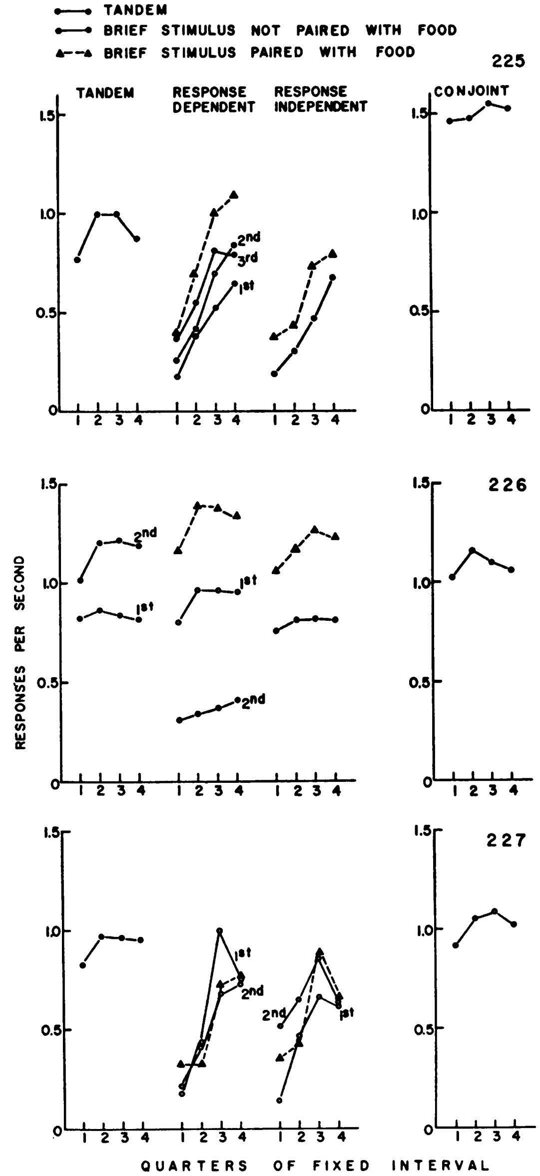

Fig. 10. Responses per second across fixed-interval quarters over the experimental conditions. The brief stimulus was presented on second-order schedules according to response-dependent and response-independent scheduling. Also, under the conjoint schedule, brief stimulus and food presentations were scheduled independently. The labels indicate which determination under a particular condition. Except for the conjoint schedule, data from components directly following food were excluded.

There were no significant differences in reinforcement rates between response-dependent and response-independent procedures. Under response-dependent procedures, response rates were such that components were completed in just over 60 sec, or at the same rate as in the response-independent procedures. Reinforcement rates, however, were higher under the conjoint procedure than under the second-order schedules. The difference in reinforcement rates resulted from the difference in schedule requirements: in the conjoint procedure the requirement was simply VI 240-sec. Under the conjoint procedure, reinforcers were delivered on the average of once every 240 sec; under the second-order schedules reinforcers were delivered on the average of once every 270 sec.

Figure 11 shows representative cumulative records for one pigeon. The records, taken from one of the last five sessions under various conditions, show performance when the brief stimulus was response dependent, response independent, and scheduled independently of the food schedule. The records show similar patterning within components under second-order schedules. Patterning was absent under the conjoint procedure; pausing did not occur following brief-stimulus presentations or food presentations.

DISCUSSION OF PART III

Experiment 5 demonstrated that similar results obtained whether brief stimuli were response-produced or were response-independent. The requirement that a brief stimulus be response produced was not necessary for response patterning to occur. The results are similar to those of Dews (1962; 1965*a*; 1965*b*; 1966*a*; 1966*b*). Dews partitioned fixed-interval schedules into different time periods; in one study (Dews, 1962) a fixed-interval 500-sec schedule was segmented into alternating time periods of 50 sec. Different stimuli were associated with different time periods; the stimuli were S^D, or a stimulus in the presence of which a response occasionally produced food, and S^Δ, or a stimulus in the presence of which responses never produced food. Dews found that response rates were higher during S^D periods and that rates increased the nearer the end of the FI 500-sec. More important for the present discussion, Dews found that a positively accelerated rate occurred within each S^D and S^Δ period. Dews' results and the present results indicate that patterning occurs in different situations when a stimulus is presented

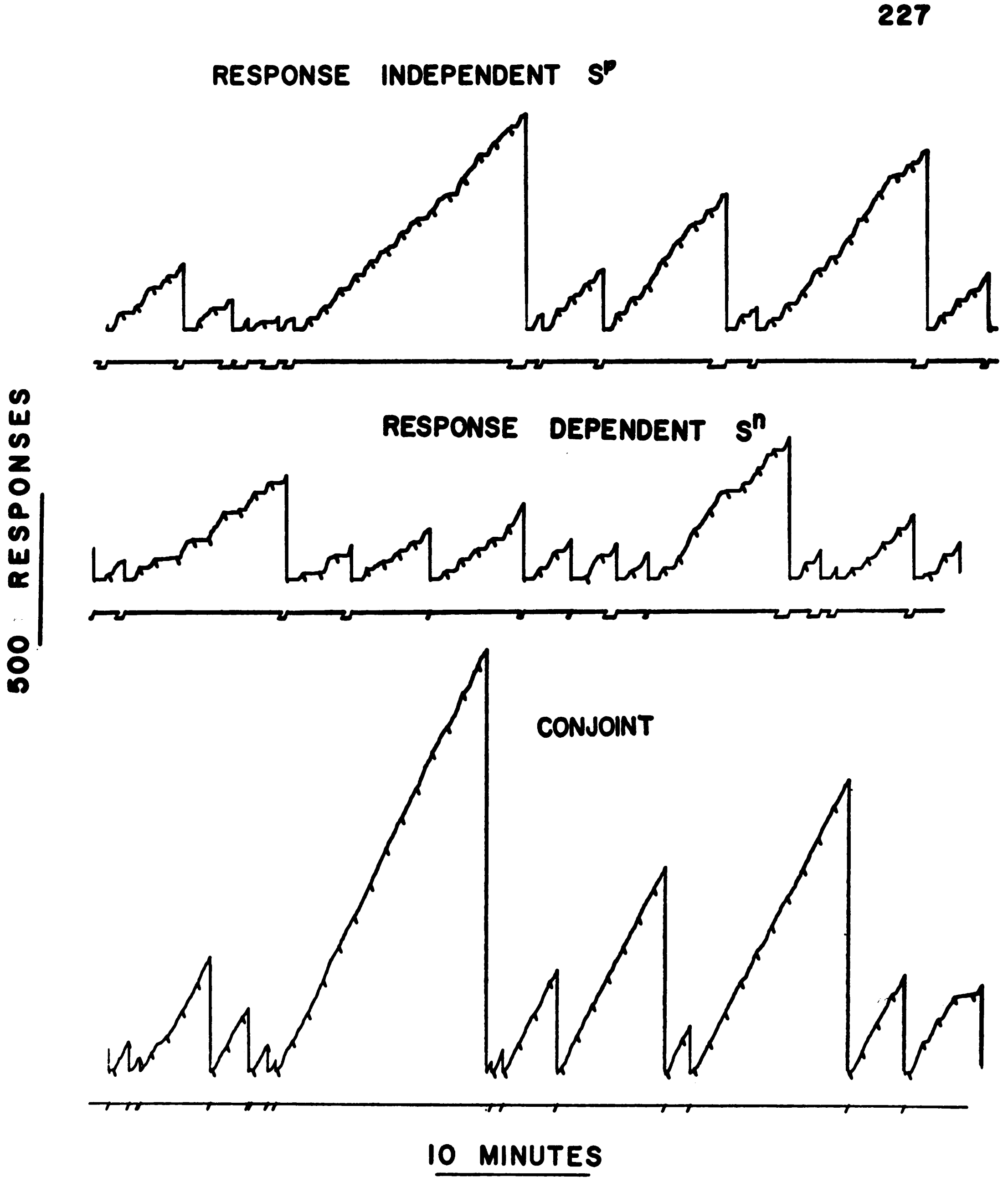

Fig. 11. Portions of cumulative records under second-order schedules involving response-dependent and response-independent scheduling of the brief stimulus, and under the conjoint schedule. Each record was taken from one of the last five sessions under a particular condition. Each response stepped the pen once. Downward deflections indicate brief stimulus presentations. Downward deflections of the event pen occurred once a particular interval of the VI had elapsed and remained deflected until a reinforcer was presented. Under the second-order schedules, the response pen reset at each reinforcement.

independently of performance (see also Farmer and Schoenfeld, 1966; McKearney, 1970*b*).

In the conjoint procedure, the independent scheduling of the brief stimulus and food resulted in a lack of patterning within the fixed-interval components. This finding is important in demonstrating that some relation apparently must exist between the schedule of brief-stimulus presentations and food presentations (at least when a nonpaired stimulus is scheduled); scheduling of a brief stimulus is not by itself sufficient to produce patterning. This finding parallels the findings of Neuringer and Chung (1967) that independent scheduling of nonpaired brief stimuli and food does not produce patterning within components. Several interpretations to explain the conditions under which patterning within components might occur are presented in the General Discussion.

GENERAL DISCUSSION

Three more areas are discussed. The first concerns aspects of the experiments that did not produce patterning under nonpaired-stimulus procedures. The second concerns the present emphasis on patterning meaures, rather than response rate measures. The third concerns possible interpretations of the results in light of the equivalent effects of paired and nonpaired brief-stimulus presentations.

The present experiments taken together suggest that several factors are irrelevant for producing patterning under the nonpaired-stimulus procedures. (1) The effects did not depend on the animal's prior history (*cf.* Kelleher, 1966*b*). Similar results were observed with a naive animal and with animals having extensive and varied histories. And, the effect was not altered by exposure to pairing operations; in most cases patterning was observed under non-pairing operations prior to pairing operations. Though patterning increased over conditions in some cases, these increases were not correlated with exposure to pairing operations. (2) The effects did not depend on indirect "pairing" of a brief stimulus and food. Lights of different color were used as the brief stimulus and magazine stimulus in Exp. 2, 3, and 5. Use of different colored lights argues against an interpretation due to color generalization between the brief stimulus and the magazine-light stimulus. Also, there was no subtle temporal pairing. The suggestion (Stubbs, 1969) that patterning results from close temporal proximity of a brief stimulus and food needs reevaluation because in many of the present experiments there was a temporal separation of 60 sec between the brief stimulus and food. (3) The effects were not the result of a particular class of stimuli. Though different stimuli produced differences in performance, patterning was observed when several visual stimuli were used. (4) The effects did not depend on the experimental hardware; similar effects were observed regardless of the type of response key, key stimulus, type of chamber, scheduling equipment (relay and solid state), magazine stimuli, use of a feedback relay click, and presence or absence of continuous white noise. (5) Finally, the effects did not depend on the reinforcement schedule and reinforcement rates over the range studied. The effects occurred over a wide variety of schedules and a wide range of reinforcement rates. Changes in performance under different conditions usually occurred in the absence of changes in reinforcement rates.

Emphasis in the present experiments was placed on the effect of a brief stimulus on the pattern of responding within components. Little emphasis was given to measures of total response rates. In previous studies, more emphasis has been given to rate measures than in the present study. The measures included total response rates (Byrd and Marr, 1969; de Lorge, 1967; 1969; 1971; Marr, 1969; Neuringer and Chung, 1967) and rates in the initial components of a sequence of schedule components (Byrd and Marr, 1969; Kelleher, 1966*b;* Thomas and Stubbs, 1966; 1967). The results obtained from total response rate measures have been inconsistent. The results of de Lorge (1967; 1969; 1971), Marr (1969), and Neuringer and Chung (1967) suggest that brief-stimulus presentations may result in an increase in total rate over rates under tandem schedules (though there are differences reported between paired and nonpaired stimuli in some experiments). The results of Byrd and Marr (1969), however, suggest that rates under brief-stimulus schedules can be lower than rates under tandem conditions. The present results are in general agreement with the results of Byrd and Marr. However, the finding of lower rates under brief-stimulus schedules did not always hold in the present experiments. The lack of consistent findings across past experiments and within the present series of experiments raises some question concerning the utility of total rate measures.

The effects of brief-stimulus presentations on initial component performance have been more consistent. Initial component rates are higher and the pause following reinforcement shorter under brief-stimulus conditions than under tandem (Byrd and Marr, 1969; de Lorge, 1971; Findley and Brady, 1965; Kelleher, 1966*b;* Stubbs, 1969; Thomas and Stubbs, 1966; 1967). Higher rates in initial components under brief-stimulus as compared with tandem schedules might occur, however, only when a fixed sequence of components is scheduled (*e.g.,* when the schedule of components is a fixed-ratio or fixed-interval schedule). With the exception of the Byrd and Marr study (1969) the other studies have used fixed-ratio or fixed-interval schedules of components. In Exp. 2, rates were higher in the initial FI component under paired and nonpaired conditions than under tandem when the schedules of components were fixed-ratio schedules. Higher initial component rates under brief-stimulus conditions did not occur in Exp. 2, however, when FI 60-sec components were reinforced according to variable-ratio schedules (see Byrd and Marr, 1969). Accordingly, the use of initial component rate measures probably should be restricted to certain schedules.

The main finding of the present experiments was that no difference existed between the effects of a paired and nonpaired stimulus over the range of schedules studied. How are these results to be interpreted in view of previous discussions of conditioned reinforcement? Several explanations should be considered. First, one could argue that all brief stimuli, whether paired or not, acted as conditioned reinforcers. Kelleher and Gollub (1962) spoke of a conditioned reinforcer as a stimulus that develops reinforcing properties through some specified history of conditioning. A nonpaired as well as paired stimulus may be conceptualized as a reinforcer due to a specified conditioning procedure. Pairing might not be an essential operation. To speak of all paired and nonpaired stimuli as conditioned reinforcers, however, presents some problems. Some experiments, not involving second-order schedules, have shown differences between paired and nonpaired procedures (Clark and Sherman, 1970; Schuster, 1969; Thomas, 1969; Zimmerman, D. W., 1969; Zimmerman, J., 1969; Zimmerman and Hanford, 1966; Zimmerman, Hanford, and Brown, 1967). D. W. Zimmerman (1969), for example, reinforced rats' responses according to a fixed-interval schedule. Responses also produced a brief stimulus according to variable-interval and variable-ratio schedules. Response rates were higher when the brief stimulus was paired than when it was nonpaired. And, J. Zimmerman and his associates have used concurrent schedules in which one response produced food while a second response produced a brief stimulus, paired or not paired (unfortunately different stimuli for the two operations). Rates under the brief-stimulus schedules were higher when the brief-stimulus was paired than when it was not. Thus, there appear to be differences between second-order schedules and other brief-stimulus procedures regarding the effects of paired and nonpaired stimuli.

A reinforcement interpretation of the data derives from recent discussions by Kelleher and Morse (1968) of schedules of shock presentation (see also Morse and Kelleher, 1966). Under certain conditions, schedule performance when responses produce shocks is similar to that normally observed when responses produce food (Byrd, 1969; Kelleher and Morse, 1968; 1969; McKearney, 1968; 1969; 1970*a*). Such results suggest a reevaluation of the traditional view that some stimuli are reinforcers and some are aversive stimuli. Kelleher and Morse point out: "a reinforcer or punisher should not be conceptualized independently of the way it controls behavior" (1968, p. 837). Kelleher and Morse have stressed the schedule of reinforcement as an important factor controlling whether a stimulus may have reinforcing or punishing properties. Thus, shock might serve as a punishing stimulus or as a reinforcer depending on the way in which shocks are scheduled. If, under appropriate scheduling, shocks might function as reinforcers, "neutral" stimuli might also act as reinforcers. The lack of difference between paired and nonpaired stimuli in the present experiments might have resulted from equal reinforcing effects engendered by schedules of reinforcement. And, just as food and shock might have similar effects under one set of schedule parameters, but different effects under others, paired and nonpaired stimuli might have similar effects under one set of procedures yet different effects under others. The present results are consistent with the idea that any (or almost any) stimulus will serve as a reinforcer under appropriate scheduling conditions.

Another explanation concerns the discriminative as opposed to reinforcing functions of brief-stimulus presentations. Since there was a fixed relation between brief-stimulus presentations and food, patterning might have resulted from discriminative functions of the brief stimulus. Response rates might have been maintained due to the intermittent presentation of food. When brief-stimulus presentations were scheduled, the presentation of the stimulus was associated with a period of nonreinforcement. When, for example, the component schedules were FI 60-sec, the occurrence of a brief stimulus was separated from food by at least 60 sec. Pauses following brief-stimulus presentations might have resulted from the fact that the brief stimulus always preceded a period of nonreinforcement.

An explanation in terms of discriminative functions is consistent with the findings on patterning, the lack of difference between paired- and nonpaired-stimulus operations, the lack of difference between response-dependent and response-independent scheduling of the brief stimulus, and the failure of patterning to occur under the conjoint procedure.

A related interpretation stressing discriminative functions of stimuli has been suggested by several authors (Dews, 1965*b;* Kelleher, 1966*b;* Neuringer and Chung, 1967). According to this interpretation, responding in a component is conceptualized as a "macroresponse", which is reinforced according to some schedule of reinforcement. The presentation of a brief stimulus at the completion of each component might serve to preserve the unity of this macroresponse. The intermittent presentation of food might reinforce the macroresponse in the terminal component and preserve the same pattern of responses in other components. Accordingly, when the same response sequence sometimes produces a stimulus and sometimes food, patterning develops in all components like that maintained in the food-reinforced component. The present results are consistent with this interpretation regarding patterning, the similar effects of pairing and nonpairing operations, and the similar effects of response-dependent and response-independent procedures. In the present experiments, the same or similar schedule requirements sometimes produced a stimulus and sometimes food. The lack of response pattern under the conjoint schedule may be explained by the fact that one behavior sequence produced a brief stimulus while another sequence produced food.

Although the macroresponse interpretation is related to the previous one, there is a major difference. The macroresponse view emphasizes the importance of the reinforcement of terminal component performance and the similarity of components terminating with a brief stimulus and those terminating with food. On the other hand, the discriminative stimulus view does not stress the similarity of the components. Responding may not be maintained by intermittent reinforcement of the macroresponse; rather, key pecks are maintained by food and brief-stimulus presentations simply serve to produce pauses because the presentations are always followed by periods of nonreinforcement.

Consideration of the discriminative functions points to a possible reason why differences between pairing and nonpairing operations occur in other brief-stimulus procedures (Clark and Sherman, 1970; Schuster, 1969; Thomas, 1969; Zimmerman, D. W., 1969; Zimmerman, J., 1969; Zimmerman and Hanford, 1966; Zimmerman, *et al.,* 1967). In these studies, a brief stimulus was not presented at fixed periods (or in terms of a fixed number of responses) from reinforcement. The probability of occurrence of food was approximately constant whether or not a brief stimulus had occurred. In the present experiments, the discriminative function of a brief stimulus might have produced pauses that could have masked possible conditioned reinforcing effects of a paired stimulus. And, the lack of these discriminative effects in the other studies might allow for different effects of paired and nonpaired stimuli to appear. In this regard, de Lorge (1971) reported differences between a paired and nonpaired stimulus on response rates in second-order schedules with variable-interval components. The use of variable-interval components eliminates the possible discriminative functions of the type that might occur when fixed-interval and fixed-ratio components are used. Reinforcement of variable-interval and variable-ratio components under second-order schedules might provide the conditions for differences between paired and nonpaired stimuli to occur.

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