

**SEPARATING THE REINFORCING AND  
DISCRIMINATIVE PROPERTIES OF  
BRIEF-STIMULUS PRESENTATIONS  
IN SECOND-ORDER SCHEDULES**

STEVEN L. COHEN, GEORGE CALISTO, AND BARRY E. LENTZ

BLOOMSBURG STATE COLLEGE

Pigeons' responses were maintained under multiple schedules to study properties of briefly presented stimuli. Responses in one component produced food according to a second-order schedule with fixed-interval components in which food or a brief stimulus occurred with equal probability. In the second component responses produced only the brief stimulus under a fixed-ratio schedule. Under various conditions the brief stimulus in the first component was (a) paired with food, (b) not paired with food, (c) partially omitted, or (d) scheduled simultaneously with the second-order schedule under an independent variable-interval schedule. Paired and nonpaired brief stimuli maintained similar response patterning in the second-order schedule. However, only paired stimuli maintained responses in the second component. The data suggest that nonpaired brief stimuli engender response patterning in second-order schedules as a result of their discriminative properties. When the stimulus is paired with food, these discriminative properties sometime mask a reinforcement effect, and no change in response patterning is observed. When the discriminative properties of the brief stimulus are absent, the reinforcing effects of pairing the brief stimulus with food may be observed.

*Key words:* second-order schedule, conditioned reinforcement, brief-stimulus schedule, multiple schedules, discriminative stimulus, key peck, pigeons

The presentation of brief stimuli in second-order schedules has been shown to generate response patterns within components that resemble those generated by food (Gollub, 1977; Kelleher, 1966a). This finding has stimulated experiments that have examined the role of the brief stimulus in second-order schedules. From this research two major positions have evolved: some studies have emphasized the reinforcing properties of the brief stimulus (e.g., Byrd & Marr, 1969; de Lorge, 1969; Kelleher, 1966a; Marr, 1969), and others have emphasized its discriminative or signaling properties (e.g., Cohen & Stubbs, 1976; Fantino, 1977; Staddon, 1972; Stubbs, 1971). Although these two positions are not necessarily incompatible with the notion of conditioned reinforcement (Boren, 1973), they do emphasize different experimental operations. In the

former, pairing the brief stimulus with food endows the stimulus with the reinforcing properties of food. In the latter, the brief stimulus acquires "reinforcing-like" properties because it signals that food is not immediately available.

The reinforcement interpretation stems from research showing that the brief stimulus must be paired with food before it will generate response patterning that resembles the patterning maintained by food (e.g., Byrd & Marr, 1969; de Lorge, 1967, 1969, 1971; Kelleher, 1966a, 1966b; Marr, 1969). For example, Kelleher (1966b) arranged for responses to produce food after 30 fixed-interval (FI) 2-min components were completed. A .7-sec stimulus terminating each fixed interval generated positively accelerated responding within components only if the stimulus was paired with food. A nonpaired stimulus generated more of a constant response rate between food presentations.

The discriminative interpretation stems from research showing that a stimulus not paired with food may also engender response patterning; and further, that pairing the brief stimulus with food has no effect on response

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The authors wish to thank Bill Creveling and John McVeigh for their help in conducting the experiment. Special thanks goes to Aaron Polonsky for his assistance in this research and to Alan Stubbs who contributed to the inception of this project. Reprints may be obtained from S. L. Cohen, Department of Psychology, Bloomsburg State College, Bloomsburg, Pennsylvania 17815.

patterning (e.g., Cohen, Hughes, & Stubbs, 1976; Cohen & Stubbs, 1976; Corfield-Sumner & Blackman, 1976; Staddon & Innis, 1969; Stubbs, 1971; Stubbs & Cohen, 1972). Stubbs (1971) has argued that in a second-order schedule with a fixed temporal relationship between brief-stimulus and food presentations (e.g., fixed interval or fixed ratio) the brief stimulus acquires discriminative properties. For example, in a schedule with FI 60-sec components, food cannot follow a nonpaired brief-stimulus presentation for at least 60 sec, and thus the stimulus signals that food is not immediately available. The nonpaired stimulus may then acquire S<sup>A</sup>-like (cf. Stubbs, 1971) or temporal-inhibitory properties (cf. Staddon, 1972) that control pausing followed by a positively accelerated response rate. Further, if the nonpaired brief stimulus already generates considerable positive acceleration in responding (i.e., most of the responses within the component are emitted toward the end of the 60-sec interval), a reinforcing effect from pairing the brief stimulus with food (e.g., greater curvature in the cumulative record) might be masked by its discriminative effects (cf. Stubbs, 1971).

This final argument, that the discriminative properties of the stimulus mask a pairing effect, suggests that research showing no differences between paired and nonpaired stimuli may not be incompatible with a reinforcement interpretation of paired brief stimuli in second-order schedules (i.e., the pairing hypotheses, cf. Fantino, 1977). Although the masking argument seems plausible, particularly in light of the findings of Stubbs, Vautin, Reid, and Delehanty (1978) that pairing a brief stimulus with food may increase acceleration of responding within fixed-interval components if the nonpaired brief stimulus does not already generate a high degree of curvature, no research has clearly differentiated between the reinforcing and discriminative effects of the brief stimulus in second-order schedules.

The present study attempted to separate these effects by examining second-order schedules in the context of multiple schedules under which responses produce food in one component but produce only a brief stimulus in the other (Cohen & Lentz, 1976; Thomas, 1969; Thomas & Johanson, 1970). Cohen and Lentz, for example, arranged for key pecks to produce food in the first component according to a fixed-interval schedule. In the second

component, responses produced a brief stimulus according to a fixed-ratio schedule. Responding was maintained in the scheduled absence of food only when the brief stimulus was paired with food in the first component. Here, differences between paired and nonpaired stimuli were observed in a context that was not confounded by a fixed temporal relationship between food and brief-stimulus presentations.

The present study resembled the Cohen and Lentz (1976) study except that food was scheduled in the first component according to a second-order schedule with fixed-interval components. Here, 50% of the fixed intervals ended in food and 50% ended in a brief stimulus. Responding in the second component produced only the brief stimulus according to a fixed-ratio schedule. In the first condition, the brief stimulus was not paired with food. We expected the nonpaired stimulus to maintain fixed-interval patterning in the first component as a result of its discriminative properties. However, the brief stimulus was not expected to reinforce responding in the second component because it was not yet paired with food. In the second condition, the stimulus was paired with food: no change in response patterns within fixed-interval components was expected, because the pairing effect would be masked by the discriminative properties of the brief stimulus. However, responding was expected to increase in the second component because the reinforcing effect would not be masked by temporal constraints.

## METHOD

### *Subjects*

Four male White Carneaux pigeons were maintained at 80% of their free-feeding weights. The birds had prior experience under a second-order schedule with fixed-interval components in which responding on a white key produced food or a red brief stimulus.

### *Apparatus*

The left key (Gerbrands) of a two-key pigeon chamber was used (Cohen & Lentz, 1976). A minimum force of .06 N operated the response key that was transilluminated with red, white, or green light by a IEE one-plane readout. A 28 V white houselight was located above and slightly to the right of the key. Grain was

presented by a Lehigh Valley Electronics pigeon feeder that was illuminated red during the 4-sec feeder cycle. White noise masked extraneous sounds. A combination of electro-mechanical and solid state circuitry (Coulbourn Instruments) controlled the sessions.

### Procedure

Because of their prior experience, animals were placed directly under a second-order schedule where key pecks maintained under FI 40-sec components were reinforced under a random-ratio 2 schedule of grain presentations. Here, the first response on a red key after 40 sec produced either grain or a brief stimulus with equal probability. The brief stimulus was not paired with food: fixed intervals ending in food resulted in the key going dark during the food cycle, and those ending in the brief stimulus resulted in the key changing from red to white, the houselight coming on, and interruption of the white noise for 5 sec. Sessions, conducted daily, ended after 60 food presentations. Because of the pigeons' prior experience this condition was in effect for only 13 sessions.

In the first experimental condition, a multiple schedule of reinforcement was in effect. In the first component, responding was maintained under the second-order schedule described above. After two food presentations the key changed from red to green for 60 sec. Responding in the presence of the green key produced the brief stimulus according to a fixed-ratio (FR) 9 schedule: the ninth peck changed the key from green to white, turned on the houselight, and interrupted the white noise for 5 sec. After 60 sec the first component was reinstated. Sessions ended after 17 red-green cycles. If the 60-sec component timed out during a brief-stimulus presentation, the brief stimulus continued to time before the red component came on. Fixed ratios partially completed in the green component counted toward completion of the FR 9 in the next green component. Responding during brief-stimulus presentations had no scheduled consequences.

Table 1 summarizes the sequence of multiple schedules. In the second experimental condition the brief stimulus was paired with food. Pairing was accomplished by turning on the white key and houselight and interrupting the white noise for 4 sec during each food presen-

Table 1

Sequence of conditions in order of occurrence and the number of sessions under each for Subjects 36 to 39.

Condition	Number of Sessions			
	#36	#37	#38	#39
Brief Stimulus—Nonpaired	13	13	16	13
Brief Stimulus—Paired	20	22	20	12
Brief Stimulus—Nonpaired	10	10	16	18
Brief Stimulus—Paired	22	33	15	23
No Stimulus—Paired	23	25	12	12
Conjoint—Paired	10	11	24	17
Brief Stimulus—Paired	23	16	28	33

tation in the first component (i.e., simultaneous pairing, cf. Stubbs & Cohen, 1972). In the third and fourth conditions the brief stimulus was again not paired and paired respectively.

Analysis of performance under the first four conditions revealed that response rate in the green component was typically 15 to 20 responses per min lower than that observed by Cohen and Lentz (1976) under a similar schedule. The last three conditions explored this discrepancy. These conditions used paired brief-stimulus presentations, and responses produced the brief stimulus during the green component. In Condition 5, responding produced food according to the second-order schedule; however, responses ending components not scheduled to produce food turned on the 5-sec timer, but the key stayed red and the white noise was not interrupted. This is referred to as the "no-stimulus" condition.

In Condition 6, designated as a conjoint schedule, the no-stimulus schedule of Condition 5 remained in effect; however, responses on the red key also produced the 5-sec brief stimulus according to an independent, simultaneously operating, variable-interval 85-sec schedule. In this case, the brief stimulus occurred at the same rate as in Conditions 1 to 4, but there was no longer a fixed temporal relationship between food and brief-stimulus presentations. The variable-interval schedule contained 11 intervals and was arranged according to an arithmetic distribution. If food and a brief stimulus were both scheduled, the same response produced both events. The variable-interval schedule did not operate during the green component.

The last condition was a replication of the brief-stimulus schedule of Conditions 2 and 4. Conditions were changed when no systematic

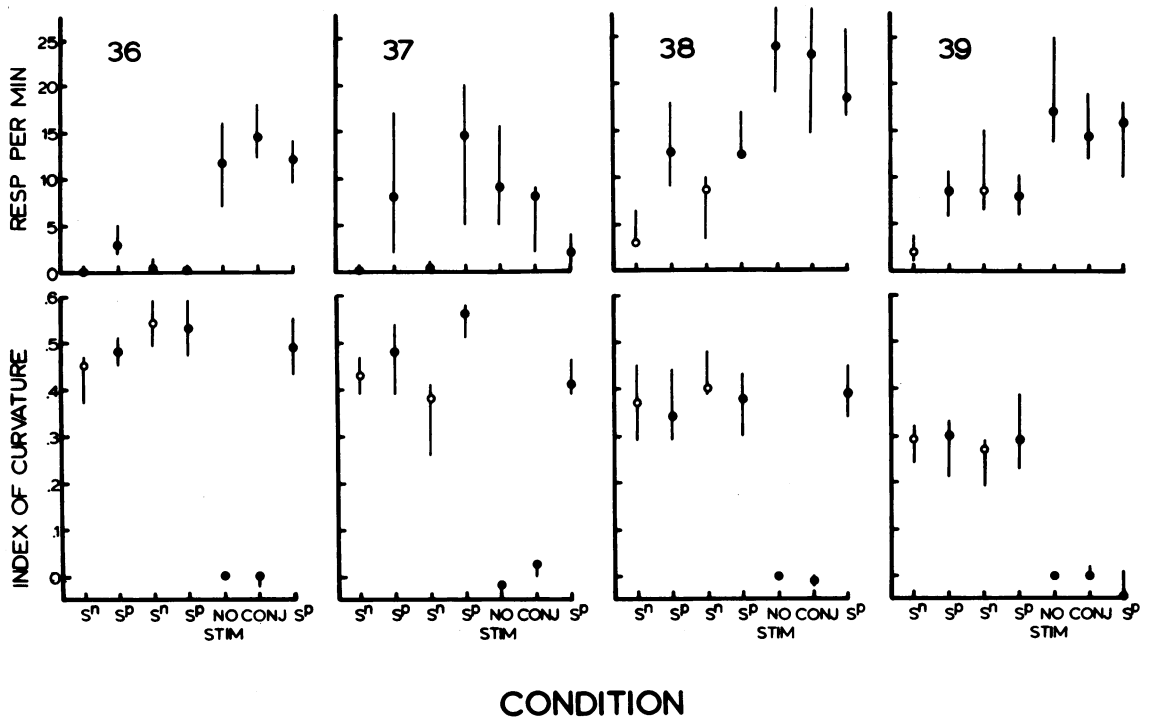


Fig. 1. Response rate in the green component and Index of Curvature in the red component for the seven conditions under the multiple schedule. Index of Curvature is a measure of response patterning within FI schedules. A value of 0 indicates a constant response rate across quarters of the FI components, while larger values (reaching a maximum of .75) indicate greater curvature. Data are medians and ranges of the last five sessions of each condition. Open circles represent nonpaired brief-stimulus presentations (S<sup>n</sup>) and filled circles represent paired-stimulus presentations (S<sup>p</sup>). "No Stim" indicates the no-stimulus schedule of Condition 5, and "Conj" indicates the conjunct schedule of Condition 6.

increase or decrease in Index of Curvature (see Figure 1) in the red component and response rate in the green component was observed for at least five consecutive sessions.

## RESULTS

The two major dependent variables were Index of Curvature in the red component and overall response rate in the green component. Responses within the FI 40-sec components were divided into 10-sec quarters. Index of Curvature was derived only from those responses that followed a brief-stimulus presentation: fixed intervals initiated by the onset of the red component or food were excluded. Index of Curvature (Fry, Kelleher, & Cook, 1960; Gollub, 1964) is a measure of response patterning within fixed-interval schedules. A value of 0 indicates a constant response rate across quarters of the fixed interval while larger values (reaching a maximum of .75)

indicate positively accelerated responding. Index of Curvature was used because it seems to be a more reliable measure of performance under paired and nonpaired stimuli in second-order schedules than overall response rate (Stubbs, 1971).

Figure 1 shows Index of Curvature in the red component and response rate in the green component. Analysis of the first four conditions reveals no consistent differences across subjects between paired and nonpaired brief stimuli with Index of Curvature. Pigeon 37 showed slightly greater curvature with the paired stimulus, but the reverse was true for Pigeon 38. In all cases, overlap in the ranges of the last five sessions was evident.

A pairing effect, however, was observed in the green component. In the first condition, responding was not maintained for Pigeons 36 and 37 and was very low for Pigeons 38 and 39. Pairing the brief stimulus with food increased response rate for all subjects. No over-

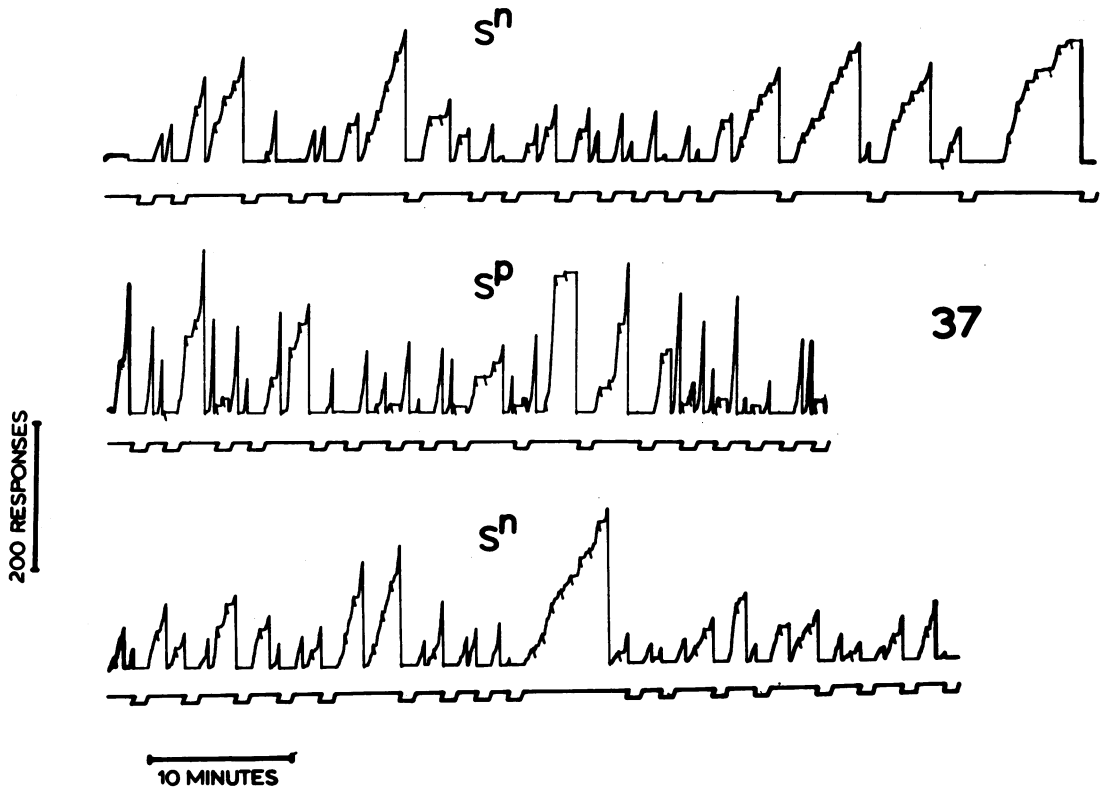


Fig. 2. Cumulative records of Subject 37 from the last session of Conditions 1, 2 and 3. The first and third records show nonpaired brief stimuli ( $S^n$ ) and the second record shows paired brief stimuli ( $S^p$ ). Each response stepped the pen once; it reset to the baseline after each food presentation and after each component. The event pen was up during red components and down during green components. Downward deflection of the response pen shows brief-stimulus presentations. The brief stimulus presented simultaneously with food in the  $S^p$  condition is not indicated on the record.

lap in the ranges was observed between Conditions 1 and 2. Replicating the nonpaired condition resulted in decreases for three subjects, but response rates were unchanged for Pigeon 39. Pairing the stimulus once again increased response rates for Subjects 37 and 38. Subject 36, however, failed to respond in Condition 4.

In Condition 5 the brief stimulus was removed from the second-order schedule but continued to accompany food. The Index of Curvature became zero, indicating a constant response rate between food presentations. In the green component, response rates increased for three of the four subjects with no overlap in ranges between Conditions 4 and 5. Pigeon 37 showed no effect. This subject's responding continued to decrease in the green component for the remainder of the study.

Under the conjoint schedule the brief stimu-

lus was reinstated but without a fixed temporal relation to food. The Index of Curvature remained zero, and no change was observed in the green component.

Finally when Conditions 2 and 4 were redetermined, response patterning returned to its former level for all subjects but Pigeon 39. For some unknown reason, the brief stimulus failed to reinstate response patterning for this pigeon. In the green component, response rates remained high in the last condition, indicating a failure to redetermine Conditions 2 and 4 in the green component.

Figure 2 shows representative cumulative records for Subject 37 from the last session of Conditions 1, 2 and 3. Responding under the second-order schedules shows the characteristic pause after the brief stimulus followed by an increase in response rate. This pattern was generated by both paired- and nonpaired-

stimulus presentations. During the third ( $S^n$ ) condition, the record shows several instances where responding was not characterized by the "typical" pause followed by an increase in response rate but was characterized by bursts of responses throughout the interval. This pattern was representative of this pigeon's performance in the third condition and is reflected in the lowered Index of Curvature shown in Figure 1. However, this reduction in response curvature was not characteristic of the other pigeons' performance under the third condition (see Figure 1). In the green component, responding was not observed when the stimulus was not paired with food. When the stimulus was paired, responding occurred in 9 of the 17 components. Responding was characteristic of patterns seen under fixed-ratio schedules of food presentations, i.e., a pause followed by a high constant response rate.

### DISCUSSION

Several experiments have failed to find differences between paired and nonpaired brief-stimulus presentations in second-order schedules. Stubbs (1971) and others (e.g., Cohen, Hughes, & Stubbs, 1973, 1976; Cohen & Stubbs, 1976; Stubbs & Cohen, 1972) have argued that a nonpaired stimulus maintains response patterning because of the discriminative or  $S^A$ -like properties derived from its fixed temporal relation with food. Additionally, when the stimulus is paired with food, the discriminative properties may mask a reinforcement effect (i.e., pairing will not produce an increase in response curvature). Thus, while this approach emphasizes the discriminative aspects of the stimulus, it does not contradict a reinforcement interpretation.

Results from Conditions 1 to 4 support this argument. Consider the first condition. When the stimulus was not paired with food, little or no responding was observed in the green component; yet response patterning was seen in the second-order schedule. To the extent to which a reinforcer may be transsituational (Meehl, 1950), the failure to maintain responding in the green component suggests that the brief stimulus was not a reinforcer in Condition 1. The stimulus became a reinforcer when it was paired with food as shown by the fixed-ratio response patterns observed in the green component and the continued fixed-interval

patterning. Failure to observe a change in Index of Curvature when the stimulus was paired suggests that the reinforcing effect was masked by the discriminative properties of the stimulus.

Conditions under which the discriminative properties of stimuli in second-order schedules may or may not mask a pairing effect are clearly illustrated in studies by Cohen and Stubbs (1976) and de Lorge (1971). Cohen and Stubbs (1976) arranged for pigeons' responses to produce a brief stimulus according to a variable-interval schedule, and for food to follow some brief-stimulus presentations after 2 min had elapsed. Thus, while the brief stimulus was presented following varying time intervals, it signaled the unavailability of food for at least 2 min. It was reasoned that if the stimulus were a reinforcer it would generate a constant response rate characteristic of variable-interval schedules; if it were a discriminative stimulus, its occurrence would generate a pause followed by a positively accelerated response rate. Both paired and nonpaired brief stimuli engendered a similar pause followed by positive acceleration, suggesting that the fixed temporal relation to food masked any reinforcing effect that resulted from pairing the stimulus with food. de Lorge (1971), however, also arranged for brief-stimulus presentations to occur following varying time intervals but in the absence of a fixed temporal relation to food. Under these conditions, brief-stimulus presentations generated a high constant response rate, with higher rates under the paired conditions. These results suggest that second-order schedules may be used to detect the reinforcing effects of food pairing if temporal constraints are absent (e.g., with variable-interval or variable-ratio components).

Omitting the brief stimulus in Condition 5 resulted in an increase in response rate in the green component. This increase could be explained in the following ways. First, in the second-order schedules of Conditions 2 and 4, brief-stimulus and food presentations occurred according to a 2 to 1 ratio, but in Condition 5 they occurred according to a 1 to 1 ratio. Previous research on conditioned reinforcement (D'Amato, Lachman, & Kivy, 1958) and on respondent conditioning (Grant & Schipper, 1952) suggests that optimal conditioning occurs when a stimulus is continually paired with reinforcement. The lower response rates

in Conditions 2 and 4 (compared to Condition 5 or rates observed in the Cohen & Lentz, 1976, study) could stem from the stimulus not being a perfect predictor of food. The second explanation, while not unrelated to the first, is derived from an analysis of excitation and inhibition (Rescorla, 1975; Rescorla & Wagner, 1972). In respondent conditioning, a stimulus that reliably predicts food is said to have excitatory properties, and a stimulus that predicts its nonoccurrence is an inhibitory stimulus. In Conditions 2 and 4 the brief stimulus may have contained excitatory properties by being temporally paired with food and inhibitory properties by also signaling the nonoccurrence of food. These properties may have interacted to attenuate the overall excitatory (i.e., reinforcing) effects of the brief stimulus in the green component.

The results of Condition 5 cannot differentiate between these two possibilities: the brief stimulus was continually paired with food and lacked inhibitory properties. In Condition 6, however, the brief stimulus was presented according to a variable-interval schedule, yet continued to be paired with food. In this case, the stimulus and food occurred according to a 2 to 1 ratio, but the stimulus lacked inhibitory properties because of the absence of a fixed temporal relation to food. No differences were observed between Conditions 5 and 6, suggesting that excitation and inhibition may have interacted to reduce the reinforcing effects of the stimulus. Unfortunately, this statement cannot be made with confidence because response rate in the green component was unchanged in the last condition of the experiment. Perhaps, once response rate was increased in Condition 5, it became insensitive to future manipulations.

The results of this study resemble those obtained by Cohen and Lentz (1976). First, in both studies fixed-ratio patterns of responding were obtained in the green component with paired brief-stimulus presentations. Secondly, in that study pairing the stimulus with food produced partially irreversible effects so that a nonpaired stimulus continued to reinforce responses (see also Marr & Zeiler, 1974). A similar effect was observed here for Pigeons 38 and 39. A second type of irreversibility was obtained in the present study. Condition 5 resulted in an increase in response rate in the green component. When the brief stimulus

was reinstated in Condition 7, responding remained high. This suggests that with this type of schedule, once responding is obtained it is sometimes difficult to reduce to its former level. In the Cohen and Lentz study, various control procedures were conducted to show that the brief stimulus reinforced responses (e.g., a timeout was imposed between components). Due to the similarity between studies, such control procedures were not conducted here.

Finally, it should be noted that although the brief stimulus was not paired with food in the first condition of this experiment, a white key served as a discriminative stimulus in a previous experiment. However, this experience did not appear to play a role in the present study. Figure 1 shows that in the first nonpaired condition little, if any, responding occurred during the green component. Only when the brief stimulus was directly paired with food in the second condition did it begin to reinforce responses. Also, several studies (e.g., Stubbs, 1971) have shown that a nonpaired stimulus will generate response patterning in second-order schedules with experimentally naive animals.

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Received October 18, 1978

Final acceptance March 25, 1979