

CONTIGUITY OF BRIEFLY PRESENTED STIMULI WITH FOOD REINFORCEMENT¹

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Pigeons performed on second-order schedules of reinforcement consisting of four fixed-interval components. Only the terminal component ended with food. Performance was studied both when a brief stimulus followed the completion of each of the first three fixed intervals (brief-stimulus schedule) and when the stimulus was omitted (tandem schedule). Variations in the temporal contiguity of the last presentation of the stimulus and the presentation of food indicated that the shorter the delay, the greater was the enhancement of rate of responding in comparison with tandem performance. A positively accelerated pattern of responding within fixed-interval components was a function of the contiguity of the brief stimulus and reinforcement; this pattern was absent for all tandem-schedule performance.

The rate and pattern of responding of animals exposed to sequences of schedule components are markedly enhanced if a stimulus intermittently paired with food reinforcement is briefly presented at the end of each component; such stimuli maintain what often is otherwise weak behavior (deLorge, 1967; Findley and Brady, 1966; Kelleher, 1966*a*, 1966*b*; Thomas and Stubbs, 1967). Kelleher (1966*b*) trained pigeons to respond on a schedule sequence of fixed-interval components to obtain food. When a brief stimulus was presented at the end of each component, the pattern of performance in each component was characteristic of fixed-interval performance for food: responding was positively accelerated within each fixed-interval component. When the brief stimulus was omitted from the terminal component (and thus not paired with food), low and relatively constant rates were observed in each component; the pattern of positive acceleration in each component was weakened or eliminated. According to Kelleher, the ". . . results suggest that it may be necessary to present a stimulus in temporal contiguity with a reinforcing stimulus if the former stimulus

is to become an effective conditioned reinforcer." (1966*b*, p. 84.)

Presumably the effects of the pairing of a brief stimulus and food are not all-or-none phenomena; rather, the enhancement of performance might be a function of the temporal interval interposed between the stimulus and food. Extinction studies (Bersh, 1951; Jenkins, 1950) have demonstrated that the shorter the temporal delay between a stimulus and food, the greater is the conditioned reinforcing effectiveness of that stimulus. No studies, however, have assessed the effects of brief-stimulus presentations on schedule performance as a function of the contiguity of or delay between the brief stimulus and reinforcement; the present study was designed to assess this functional relationship.

Pigeons performed on second-order schedules, consisting of fixed-interval (FI) components. That is, reinforcement was delivered in the fixed-interval schedule components according to a schedule: the birds had to complete four successive (a fixed ratio) fixed-interval components before obtaining food. The response which terminated each of the first three components resulted in the brief presentation of a stimulus. The duration of the terminal fixed interval varied from 1 to 30 sec in different schedules. Thus, the delay between the "last" brief-stimulus presentation and food varied from 1 to 30 sec. Behavior under schedules involving brief stimuli was compared with that occurring under compar-

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able tandem schedules which were equated in their response requirements but involved no brief-stimulus presentations. Differences in performance with and without the brief-stimulus presentation permitted the analysis of the role of these stimuli as they affected the rate and patterning of responding.

METHOD

Subjects

Three adult male White Carneaux pigeons (54, 55, and 57) were maintained at approximately 80% of their free-feeding body weights throughout the experiment. They were experimentally naive at the beginning of the experiment, but after the first schedule reported (FI 30-sec FI 30-sec FI 30-sec FI 30-sec) the birds were trained on a conditional discrimination task, which was not part of the present study.

Apparatus

The experimental chamber was a one-key pigeon box, similar to that described by Ferster and Skinner (1957). The response key (Ralph Gerbrands Co.) could be transilluminated by different colors from a One Plane Digital Display Unit. Grain reinforcers were delivered by means of a Lehigh Valley Electronics pigeon feeder. The experimental chamber was located in a darkened room adjacent to the room which housed the scheduling equipment.

Procedure

Experimental sessions were given daily, except when a bird was above its experimental weight. Each session lasted until a bird produced 50 reinforcements. Each session was preceded and followed by a blackout period during which all chamber lights were off and responding had no scheduled consequences.

The birds were initially trained to respond on the key for food. Over the course of several sessions the requirement was changed to four successive fixed-interval components. Each interval was 30 sec (FI 30-sec). During the four components the houselight was illuminated and the key was transilluminated by red light. The response which completed the fourth fixed interval resulted in 4-sec access to grain. During reinforcement, the houselight and key lights were turned off and the food magazine light was turned on. Once behavior stabilized

(as determined visually with no apparent trends in performance) a new schedule was introduced. The response which completed each of the first three components changed the key color from red to blue for 0.5 sec. The response which completed the fourth resulted in access to grain. The birds were kept on this schedule until performance stabilized.

The schedule was then changed again. The animal had to complete three successive FI 30-sec components followed by an FI 5-sec component. The response which terminated each FI 30-sec component initiated the 0.5-sec key color change from red to blue. Once behavior stabilized the schedule was changed: the brief stimulus was omitted at the end of the first three FI components. That is, no change in stimuli accompanied the change from one component to the next. The next schedule involved presentation of a stimulus directly paired with food at the completion of each FI 30-sec component. The response that terminated each of the three components resulted in a 0.5-sec illumination of the magazine light while the houselight and key light were turned off.

Next, the birds were given a schedule consisting of three FI 45-sec components and an FI 1-sec component. The key light was blue. Completion of the FI 45-sec components resulted in a 0.5-sec change from blue to yellow. Once performance stabilized, the schedule was changed: the brief stimulus presentation no longer occurred. For this schedule, and the previous ones omitting the brief-stimulus presentation (the tandem schedules), the 0.5-sec period still occurred so that the scheduled requirements of each pair of brief-stimulus and tandem schedules would be equal.

Table 1 shows the number of sessions under each condition.

RESULTS

Figure 1 shows the rate of responding in each schedule component for all schedules of reinforcement. The points represent median rates. The use of mean rates would have yielded similar results. Medians were chosen due to skewed variability which occasionally resulted in an isolated day's performance. Variability was largest within the initial component. For each condition, performance under the brief-stimulus schedule is presented

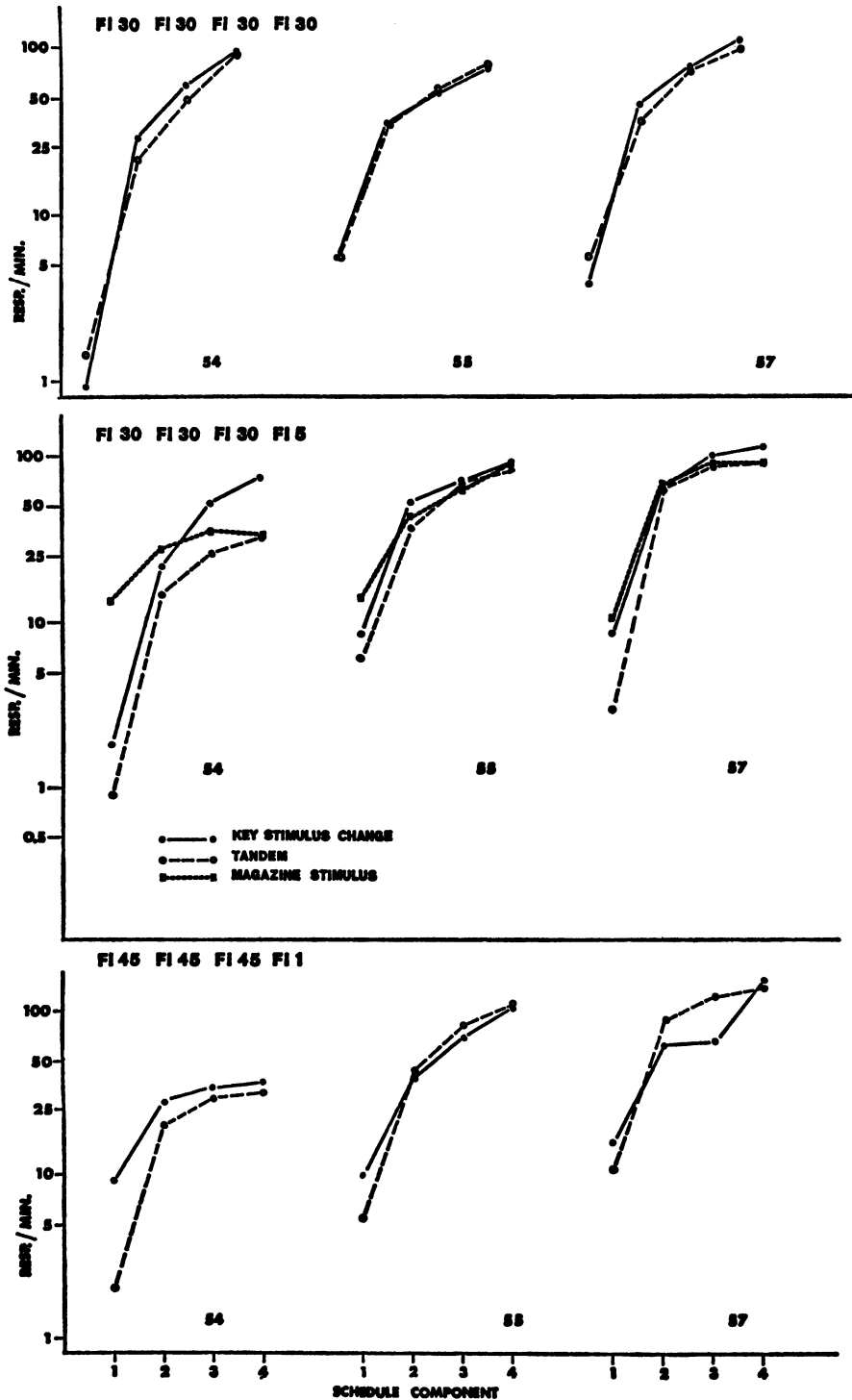


Fig. 1. Median response rates for three subjects for the four components of various fixed-interval schedule sequences. The median scores are the medians of the last five sessions on a particular schedule. Rates are ordered logarithmically.

Table 1

Number of sessions for each bird under the different schedules, in order.

Schedule		Birds		
		54	55	57
FI 30 FI 30 FI 30 FI 30:	T	42	40	38
	S	12	12	11
FI 30 FI 30 FI 30 FI 5:	S	21	23	23
	T	24	21	21
	MS	13	13	13
FI 45 FI 45 FI 45 FI 1:	S	18	18	19
	T	9	10	10

"S" refers to schedules with a change in key color at the end of the first three components.

"T" refers to the tandem schedules.

"MS" refers to the schedule involving the presentation of magazine stimuli.

along with the performance under the comparable tandem schedule. When the 0.5-sec presentation of the blue stimulus was separated from food by at least 30 sec (upper portion of Fig. 1) rates were similar to those under the comparable tandem schedule. The brief stimulus presentation had no marked effects on response rate. However, when the separation between the blue stimulus and food was shortened to 5 sec (middle portion of Fig. 1), rate of responding in the initial component increased slightly, compared to the tandem rate. Where the occasional separation between the stimulus and food was 1 sec (bottom portion of Fig. 1), rates were higher in the initial component, compared to tandem performance. Comparison of the tandem schedules with those involving brief-stimulus changes showed that the enhancement in rate of responding was related to the separation between the stimulus and reinforcement. There was a greater enhancement with the 1-sec separation than with the 5-sec separation and more with 5 sec than with 30 sec.

Another schedule involved presenting the food-magazine stimulus at the end of each FI 30-sec component (middle portion of Fig. 1). This condition permitted a comparison of the effects on behavior when the brief stimulus was directly paired with food with situations involving a delay. The brief stimulus should have maximum conditioned reinforcing properties when there is no delay (Kelleher, 1966a). The middle portion of Fig. 1 shows that the magazine stimulus, which was directly paired

with food, resulted in the highest rates in the initial component for each of the three birds.

Figure 2 shows the enhancement of rate under the brief-stimulus schedules (for the initial component) as a function of the temporal proximity of the stimulus and food. Figure 2 shows the median response rate in the initial component for each of the brief-stimulus schedules minus the median response rate for the initial component of the comparable tandem schedule. The enhancement in rate was directly related to the temporal proximity of the stimulus and food. The functions for all three birds were negatively accelerated.

The effects of stimuli occasionally associated with reinforcement are most noticeable on the performance of animals in the early components (Findley and Brady, 1965; Kelleher, 1966a, 1966b; Thomas and Stubbs, 1967). In the present experiment, the brief-stimulus presentation had inconsistent effects on rates in the second, third, and fourth components. For Bird 54, rates in all components were above those of the tandem schedule. For Bird 55, rates generally were equivalent in the final three components. For Bird 57, in the second and third components, rates were sometimes lower than the tandem control rates (see lower portion of Fig. 1).

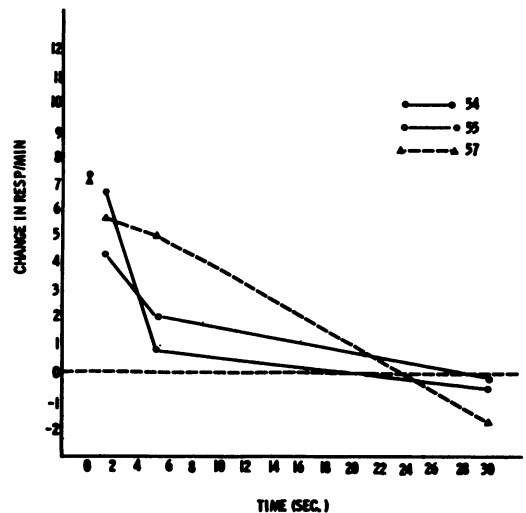


Fig. 2. The increase in response rate for brief-stimulus schedules (key color change and magazine stimulus) over comparable tandem schedules. The points are from the responding in only the initial components. Points are based on initial component responses only. Lines connect the medians of the three schedules involving key-color changes.

Data on the pattern of responding are shown in Fig. 3 and 4. Figures 3 and 4 are cumulative records for performance on the brief-stimulus schedules and comparable tandem schedules. The records are representative of the performances for all three subjects.

Figure 3 shows records for the brief-stimulus schedule and tandem schedule when the minimum delay between the stimulus and food was 30 sec. There is little essential difference between the patterns of responding under the two schedules. Each schedule sequence was characterized by a pause initially, followed by a gradual acceleration of response rate. Under the brief-stimulus schedule, there was no tendency for a pause after a brief stimulus. That is, there was not a characteristic FI pattern of performance within each component (*cf* Fester and Skinner, 1957). Figure 4 shows portions of records under schedules when the terminal components were 5 sec and 1 sec. For the two schedules, the brief-stimulus records are the bottom portions, the tandem records are the top portions. The records showing tandem performance for the two schedules were similar to the tandem record shown in Fig. 3. Each schedule sequence was characterized by

a pause after reinforcement followed by an acceleration in response rate. The pattern of performance under the brief-stimulus schedules was somewhat similar; however, there was a tendency for a pause after a brief-stimulus presentation. In other words, performance in each component tended to show similarities to the pattern of performance of animals on FI schedules for food. The tendency was more pronounced when the delay between the stimulus and food was 1 sec than when it was 5 sec; in fact, the tendency was very slight when the delay was 5 sec (see the first and sixth schedule sequences). The smaller the delay between the stimulus and food, the greater the tendency for the performance in each component to be characteristic of FI performance for food. For Bird 57, given the FI 45- FI 45- FI 45- FI 1-sec brief-stimulus schedule, the FI pattern within components was correlated with a decrease in rate in the second and third components relative to tandem rates. Bird 55 showed a similar, though minimal, effect. Bird 54, however, had higher rates, given the brief stimulus in all components, despite pausing. When pauses occurred after brief-stimulus presentations, they did not occur immediately; rather, several

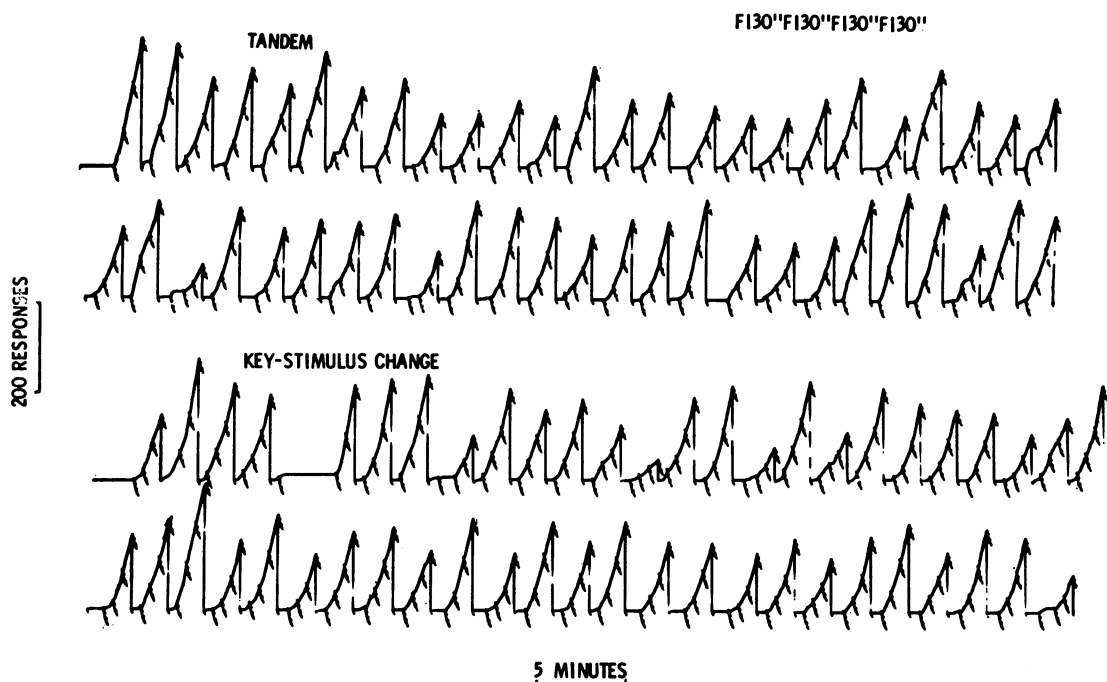


Fig. 3. Cumulative record for Bird 55 under brief-stimulus and tandem schedules. Each response stepped the response pen. Downward deflections occurred at the completion of each of the four components. The response pen was reset at the completion of end reinforcement. The recorder motor ran continuously except during reinforcement cycles.

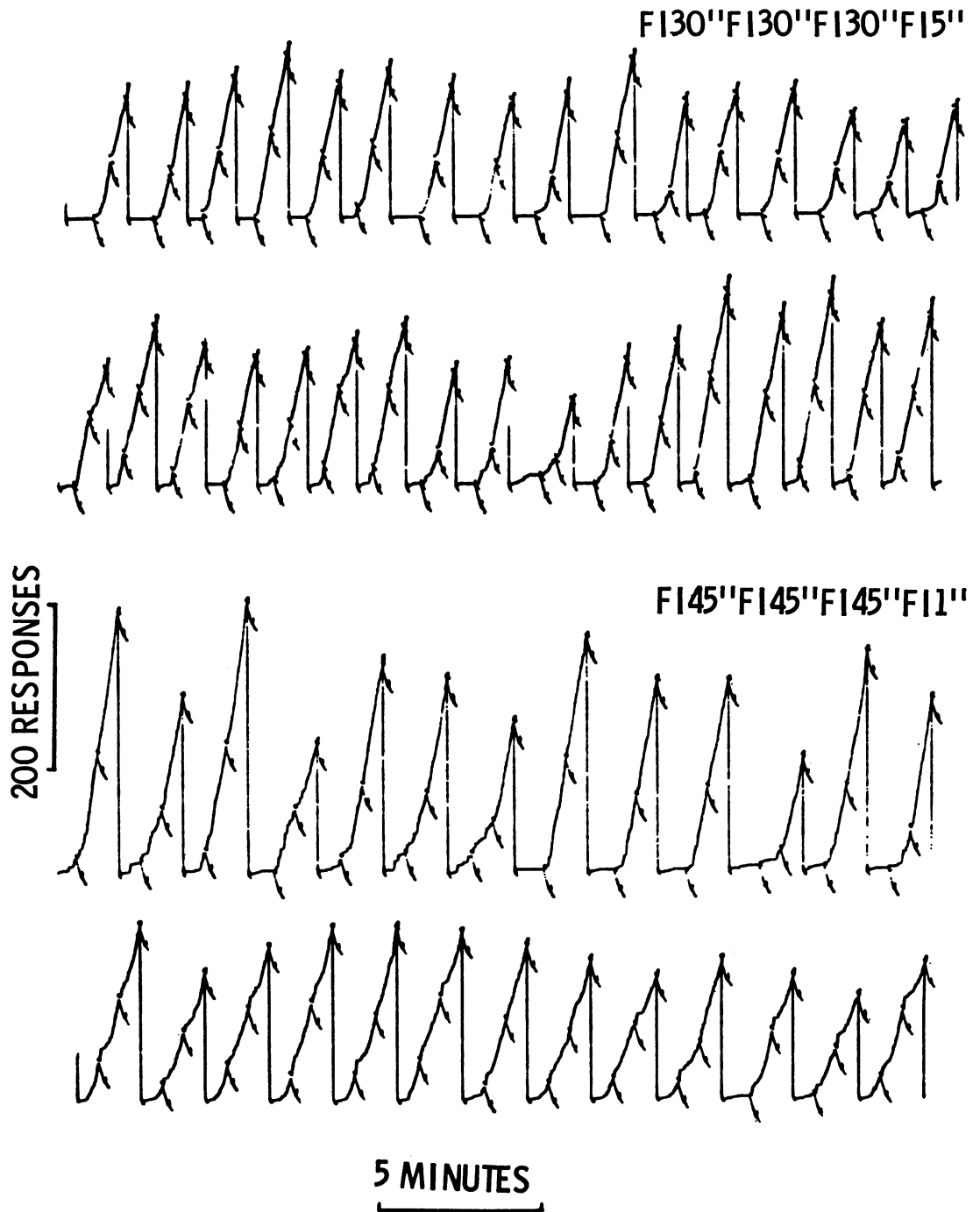


Fig. 4. Portions of cumulative records for Bird 57. For each schedule a portion of the tandem performances is above a portion of brief-stimulus schedule performance. Each response stepped the response pen. Downward deflections occurred at the completion of each of the first three components. The response pen was reset at the completion of each reinforcement cycle. The recorder motor ran continuously except during reinforcement cycles.

seconds elapsed (during which responding was maintained at a high rate) after the brief stimulus before the pause occurred.

Reinforcement rates were calculated for the different schedules, and reinforcement rates under brief-stimulus schedules and comparable tandem schedules were compared. Increases in response rate on brief-stimulus schedules, as compared with tandem schedules, were not necessarily correlated with increases in reinforcement rate. For Bird 54, the increase in response rate under the brief-stimulus schedule was accompanied by an increase in frequency of reinforcement. However, for Birds 55 and 57, the increase was negligible—less than one reinforcement per hour under the schedules in which the minimum delays were 5 sec and 1 sec. The difference between Bird 54 and Birds 55 and 57 was correlated with different overall response rates. Bird 54 emitted responses at a lower overall rate (see Fig. 1) and consequently had a lower reinforcement rate. The rates emitted by Birds 55 and 57 were such that their reinforcement rates under all schedules were nearly as high as possible.

DISCUSSION

The rate of responding in the early components of a schedule of reinforcement is enhanced if a stimulus occasionally directly paired with reinforcement is briefly presented at the end of each component (deLorge, 1967; Findley and Brady, 1965; Kelleher, 1966*b*; Thomas and Stubbs, 1966). The present study extended these findings: response rate was enhanced by the presentation of a stimulus not directly paired with reinforcement. When the brief-stimulus presentation was temporally separated from food, response rate in the earliest component was increased over that maintained in the absence of the stimulus. However, the enhancement of rate was not as great as that observed when the brief stimulus was paired with food. The results suggest that even with delays between a stimulus and reinforcement, the stimulus may develop the properties of a conditioned reinforcer; however, the effects on behavior are less than when the stimulus is simultaneously presented with food. The present study agrees with studies employing extinction procedures (Bersh, 1951; Jenkins, 1950). The studies demonstrated that the conditioned reinforcing effectiveness of a stimulus is

a negatively accelerated function of the delay between the stimulus and food (Fig. 2).

The functional relation shown in Fig. 2 possibly has a confounded feature. The stimulus directly paired with food was the magazine light, whereas the stimulus in all other schedules was a key light. Presumably the enhancement of rate, when the magazine stimulus was used, was the result of the direct pairing with food; however, the degree of enhancement might have resulted, in part, from the type of stimulus, *i.e.*, magazine stimulus *vs* key hue.

Not only might a conditioned reinforcer enhance rate of responding; it might also enhance the patterns of responding: the patterns of responding in individual schedule components take on characteristics of schedule performance reinforced by food (deLorge, 1967; Kelleher, 1966*b*). In the present study, characteristic fixed-interval patterns of responding were noted within brief-stimulus schedule components, but the positively accelerated pattern was a function of the delay between the stimulus and reinforcement. The fixed-interval pattern within components was nonexistent when the delay was 30 sec, minimal when the delay was 5 sec, and pronounced when the delay was 1 sec.

Kelleher (1966*b*) demonstrated the effects of conditioned reinforcement on fixed-interval component performance in second-order schedules. Within each component there was a pause followed by a gradual acceleration in rate. In other words, the presentation of each conditioned reinforcer was correlated with a subsequent pause. In the present study, high rates continued for some time after presentation of the brief stimulus; then the characteristic FI pause occurred and was followed by a gradual acceleration in rate. The failure of the pause to occur immediately after the stimulus is probably the result of the positive discriminative function of the brief stimulus. The brief stimulus functioned as a conditioned reinforcer and also to "signal" either the beginning of a 45-sec component or 1-sec component resulting in food. The pattern is similar to that found on mixed schedules consisting of a short and a long FI schedule (Catania and Reynolds, 1968).

The value of the FI was changed from 30 to 45 sec in order to eliminate a correlation between decreases in the delay between the brief

stimulus and food and decreases in the frequency of reinforcement. When the minimal delay between the stimulus and food was 30 sec the minimum time between reinforcements was 120 sec; when the minimum delay was 5 sec the minimum time was 95 sec. Thus, when the delay was shortened to 1 sec, the total response requirement was increased to 136 sec (45-sec components) to eliminate the correlation of delay and frequency of reinforcement. The effects of frequency of reinforcement were not related to the enhancement of rate and pattern in the present study.

Also, changes in reinforcement rate between brief-stimulus and tandem schedules could not explain the different effects on response rate. The fixed-interval schedule permitted changes in rate without necessarily causing changes in frequency of reinforcement. The enhancement of rate was a function of the presentation of stimuli, rather than a decrease in reinforcement frequency.

While proximity of a stimulus to food is important in affecting behavior it probably is only one of a number of factors. Three lines of evidence bear on this point. (1) Other second-order schedules have employed stimuli not paired with food at the completion of schedule components (deLorge, 1967; Kelleher, 1966b). Kelleher reinforced behavior in FI components according to FR schedules of reinforcement; deLorge reinforced behavior in FI components according to an FI schedule. In general, the results of stimuli not paired with food were similar to those when the stimuli were omitted. However, in certain cases, the stimuli affected rate and pattern of responding, though not as much as when stimuli were paired with food. It was suggested that determinants of the effectiveness of a stimulus might include the animal's past history (Kelleher, 1966b) and lack of discrimination between stimuli and food-paired stimuli (deLorge, 1967). (2) Percentage reinforcement studies have demonstrated the effects of stimuli not paired with food or the rate and pattern of responding (Neuringer and Chung, 1966; Ferster and Skinner, 1957; Zimmerman, 1960). In these studies, component responding resulted nonsystematically either in the presentation of a stimulus or reinforcement. It is possible, at least in the studies of Ferster and Skinner (1957) and Neuringer and Chung (1966), that proximity of the stimulus and food

played a role in enhancing behavior. However, the effects probably resulted from other factors as well. Neuringer and Chung discounted the proximity factor entirely for the following reason. (3) Neuringer and Chung demonstrated that proximity of a stimulus to food does not necessarily lead to an enhancement. When a stimulus was presented in a non-systematic relation to food (e.g., every eleventh response produced a stimulus, food being presented independently on a variable-interval schedule) the stimulus did not enhance responding. The results suggest that a systematic relation must exist between a briefly presented stimulus and food in order for behavior to be enhanced. If such a relation exists, proximity of the stimulus and food affects, in part at least, the degree of enhancement.

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