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THE EFFECTS OF BRIEF STIMULI PRESENTED UNDER A MULTIPLE SCHEDULE OF SECOND-ORDER SCHEDULES

JOHN DE LORGE[1]

UNIVERSITY OF SOUTH ALABAMA

The effects of briefly presented stimuli paired or not paired with food reinforcement were investigated in the pigeon on a multiple schedule containing second-order schedules. A stimulus paired with food reinforcement was presented on a variable-interval schedule in one unit of the multiple schedule and either a stimulus not paired with food reinforcement or no stimuli were scheduled in the other unit. Response rates were highest when behavior was followed by the food-paired stimulus. Presentation of the food-paired stimulus at completion of each 1-min variable-interval component maintained a steady rate of responding between consecutive food presentations. Pausing following food reinforcement was greatest in the second-order schedule not containing the paired stimulus. Reversing the stimulus pairings led to a reversal of the relative response rates and patterns of responding for each stimulus.

Numerous recent investigations have demonstrated that a brief stimulus occasionally paired with food reinforcement can acquire reinforcing characteristics (Zimmerman, 1963; Kelleher, 1966; de Lorge, 1967; Stubbs, 1969). The brief stimuli in these studies maintained patterns of responding similar to those maintained by food reinforcement. The experiments showed that pairing the stimulus with food reinforcement was essential in producing the conditioned reinforcing effects. These studies not only explored the phenomena of conditioned reinforcement, but also contributed information on second-order schedules. The present study extends the generality of previous findings obtained under second-order schedules of conditioned reinforcement by studying the effects of presenting brief stimuli during units of a multiple schedule. The brief stimuli were presented under a 1-min variable-interval schedule (VI 1-min), and responding during the VI 1-min components was reinforced by food presented under a five-component fixed-ratio schedule (FR 5), *i.e.*, an FR of VI schedules. Unlike previous studies, the effects of the brief stimulus were studied before its pairing with food, and later, while it was paired with food.

METHOD

Subjects

Two male adult White King pigeons, P 17 and P 18, were maintained at approximately 80% of mean body weight. Both pigeons had an experimental history of 200 daily sessions on a second-order schedule in which they pecked keys transilluminated with colored lights.

Apparatus

The experimental chamber was a three-key Grason-Stadler animal chest, Model E 3125AA-300. Only the center, transparent, Plexiglas response key was operative. The other two keys were covered with metal plates. A Grason-Stadler Model E 4580A-159 inline digital display unit transilluminated the key with different letters. A 7-w houselight illuminated the chamber during each session. A white masking noise was continuously present. Conventional relay and timing circuitry controlled the experiment, and responses were recorded on a Gerbrands cumulative recorder.

A Foringer tape puller and a Scientific Prototype Model 4020J probability generator arranged the schedules. A distribution of intervals having a mean of 20 sec was punched on

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the tape input to the probability generator, which was set to produce an output pulse on only 30% of the input pulses. Since the tape puller operated during the 6-sec reinforcement cycle, the outcome was a distribution of intervals having a mean of approximately 1 min, and will be referred to as a variable-interval schedule of 1 min (VI 1-min).

Procedure

Five daily sessions were conducted weekly for approximately 40 weeks. Each daily session ended after 30 presentations of Purina pigeon grain. Water was available continuously in the chamber.

Throughout the experiment, a two-unit multiple schedule was in effect. Each unit was a second-order schedule under which food was presented for 6 sec after completion of every fifth VI 1-min component. Each unit of the multiple schedule remained in effect for three consecutive food presentations. During each food presentation, the food opening was illuminated with a 7-w light. The effect of scheduling brief stimuli on the VI 1-min schedule was studied during three phases of the experiment. The brief stimuli were 0.5-sec illuminations of the food opening.

During the initial 68 sessions (Phase A), the response key was transilluminated by either the letter N or the letter C. In the presence of N on the key, a 0.5-sec white light illuminated the food opening at the completion of each VI 1-min component. The fifth presentation of this 0.5-sec stimulus was followed by both food presentation and white illumination of the food opening for 6 sec. When the letter C was on the key, no stimulus was presented at completion of each of the first four VI 1-min components, but completion of the fifth VI 1-min component was followed by 0.5-sec white illumination of the food opening, which was followed by both food presentation and white illumination of the food opening.

During the next 69 sessions (Phase B), the response key was transilluminated by either the letter N or the letter S. The schedule in effect when the letter N was on the key was the same for Phases A and B. When the letter S was on the key, the food opening was illuminated red for 0.5 sec at completion of each of the first four VI 1-min components. The fifth VI 1-min component was followed by 0.5-sec white illumination of the food opening, which was immediately followed by food presentation plus white illumination of the food opening.

The arrangement of the red and white illuminations of the food opening, which occurred in Phase B, was reversed during the 59 sessions of Phase C. The food opening was red during the presentation of food, and white illumination of the food opening was no longer paired with food. The schedule was the same as in Phase B and the letters on the key that signalled the different multiple units were the same as in Phase B. N on the key still signalled the unit with the food-paired stimulus; S signalled the unpaired stimulus unit. The only change was in the color of the light paired with food.

The procedures were the same for both birds, but the light associated with food in the various phases were reversed for one bird.

RESULTS

Figure 1 shows running response rates of the two birds during the last seven sessions of each phase. Running response rates were calculated by dividing the number of responses

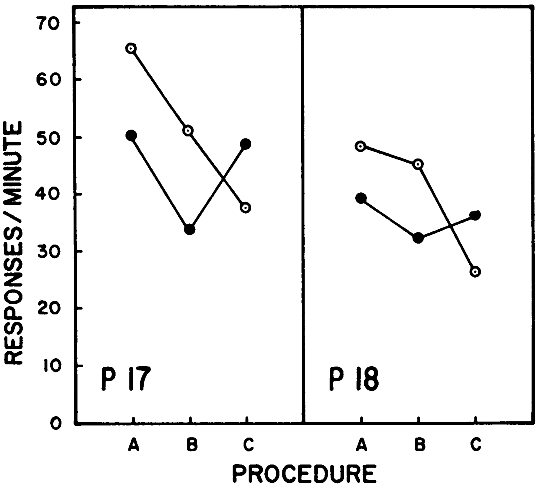

Fig. 1. Response rates of P 17 and P 18 in the three phases of the experiment. During Phase A, one multiple schedule unit was a second-order schedule reinforcing VI 1-min responding with a food-paired stimulus (open circles), and the other unit was a second-order schedule in which no stimulus appeared on a VI 1-min (closed circles). During Phase B, a non-food-paired stimulus appeared on a second-order schedule (closed circles) in one multiple unit, and the food-paired stimulus appeared in the other unit (open circles). During Phase C, the previously unpaired stimulus was paired (closed circles), and the previously paired stimulus was no longer paired (open circles).

by the time elapsed from the first key response after food presentation to the next food presentation. This procedure omitted the post-reinforcement pause from the calculations. Mean running response rates were calculated for each session under each stimulus condition and the median of the means during the last seven sessions provided the data for the figure. Both animals responded at their highest rates during Phase A and showed a decrement in response rate from Phase A to Phase C. The birds gradually increased their rates of responding during the first 70 sessions and as the rates increased so did the difference between rates in the two units of the multiple schedule. Figure 1 shows that during Phase A, responding reinforced with a brief stimulus intermittently paired with food (open circles) was maintained at a higher rate than responding on a similar schedule without the brief stimulus (closed circles). During Phase B, responding was also maintained at a higher rate under food-paired stimulus (open circles) than under the stimulus not paired with food (closed circles). Furthermore, when the pairing conditions were reversed during Phase C, responding remained at a higher rate for the food-paired stimulus (closed circles).

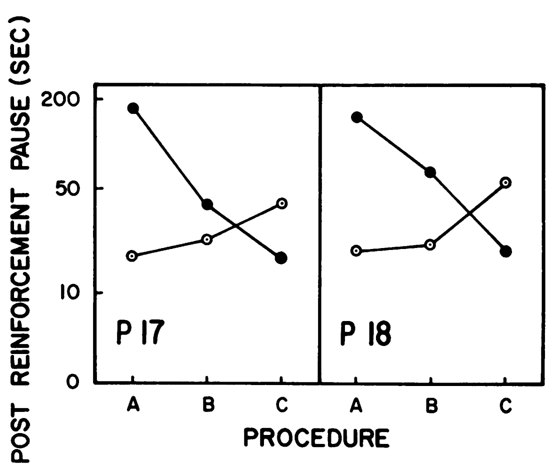

Fig. 2. The average length of time no key responses occurred following food presentation is shown for P 17 and P 18. As in Fig. 1, open circles refer to data from the multiple unit containing the stimulus paired with food in Phases A and B but not paired with food in Phase C. In Phase A the closed circles refer to the multiple unit with no stimulus; in B the closed circles refer to the multiple unit with an unpaired stimulus, and in C the closed circles refer to the multiple unit containing the paired stimulus.

Figure 2 illustrates the average duration of the post-reinforcement pause in each unit of the multiple schedule during the three phases of the experiment. Mean post-reinforcement-pause time was calculated for each session, and the median of the last seven sessions in each condition is shown in the graph. Extremely long pauses occurred during Phase A in the multiple component that did not schedule a brief stimulus presentation (closed circles). The order of magnitude of pausing in each phase was approximately the same for both birds, and a reversal occurred when the stimulus pairing conditions were reversed in Phase C. The pauses were not due to the change from one unit of the multiple schedule to the other. Pauses that followed each of the three reinforcements within a unit of the multiple schedule were approximately equal during each phase of the experiment. No systematic differences in length of the three post-reinforcement pauses were seen. If the multiple units had alternated with each food reinforcement, this observation could not have been made.

Figure 3 illustrates responding in the various components and phases for the two birds. When the experiment began, there were no observable differences between the two units of the multiple, but as seen in Fig. 3, by the end of Phase A there were marked and consistent differences. Rates during the paired-stimulus unit were quite high, between 50 and 65 responses per minute, but response rates in the other unit were generally much lower, and extensive pauses occurred following food, as indicated by the arrows.

The post-reinforcement pause was not as long when, in Phase B, the non-paired stimulus was presented, although there were discernible differences in rates between the two components. The record of P 18 denoted by W in Phase B showed a few instances of decreased response rate following a brief stimulus presentation. Such decreases in rate occurred only occasionally when the briefly presented stimulus was the one paired with food and seldom, if ever, occurred when the stimulus was the unpaired one.

Figure 4 illustrates the mean response rates in each of five consecutive VI 1-min components interposed between food reinforcements. In most of the VI components, the response rate was higher when the stimuli were

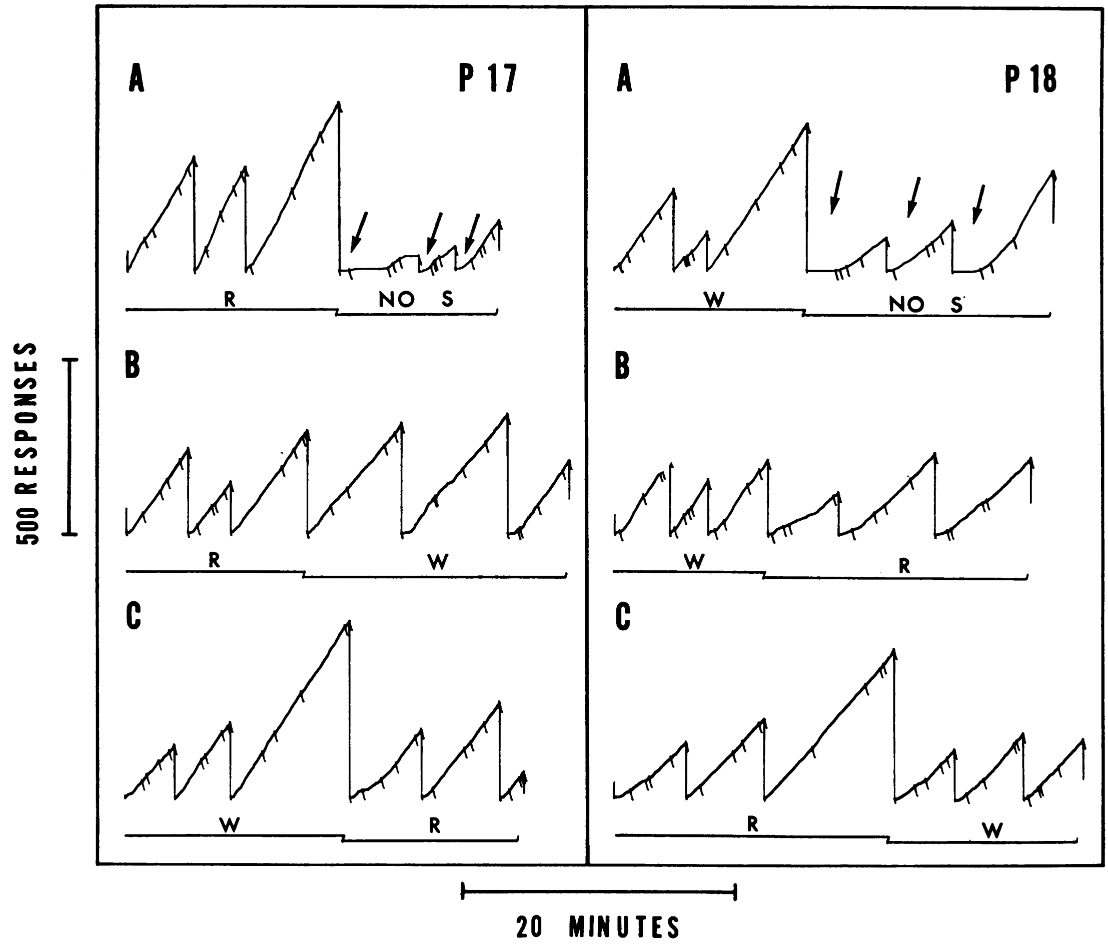

Fig. 3. Cumulative records of P 17 and P 18 obtained from sessions illustrating terminal behavior during each experimental phase. Frames A, B, C show records from sessions 68, 136, and 189, respectively. Diagonal marks denote the end of a VI 1-min component, and pen reset designates food presentation. The two multiple units are denoted by the event pen line. *No S* is that unit of the multiple when no stimulus occurred at the end of a VI 1-min component. When the event line is up, it indicates the multiple unit containing the stimulus paired with food. In B and C the event line down indicates the multiple unit containing a stimulus not paired with food. W refers to the white food aperture light and R refers to the red food aperture light. Arrows designate long post-reinforcement pauses. To reduce the size of the figure, each portion of cumulative record shows responding during only the seventh through twelfth food cycles. Later portions were no different, but initial portions of the records occasionally showed warm-up effects.

paired with food, although minor exceptions appeared in Phase C. The figure also shows that the response rates tended to be negatively accelerated even when no brief stimuli were given in Phase A. These patterns of responding illustrate the control exerted by food presentation, but they show also that when the brief stimulus was paired with food, the influence of food presentation was attenuated. This attenuation was demonstrated by the smaller slope of the lines representing the paired stimulus unit and also by the pattern changes between Phases B and C.

The overall difference in response rates between the two units of the multiple schedule tended to generate a corresponding difference in reinforcement rates. This difference was small, but rate of reinforcement was higher in the multiple unit containing the paired stimulus. Table 1 presents the mean reinforcement rates from the last seven sessions in each experimental phase. In all cases, except for P 18 in

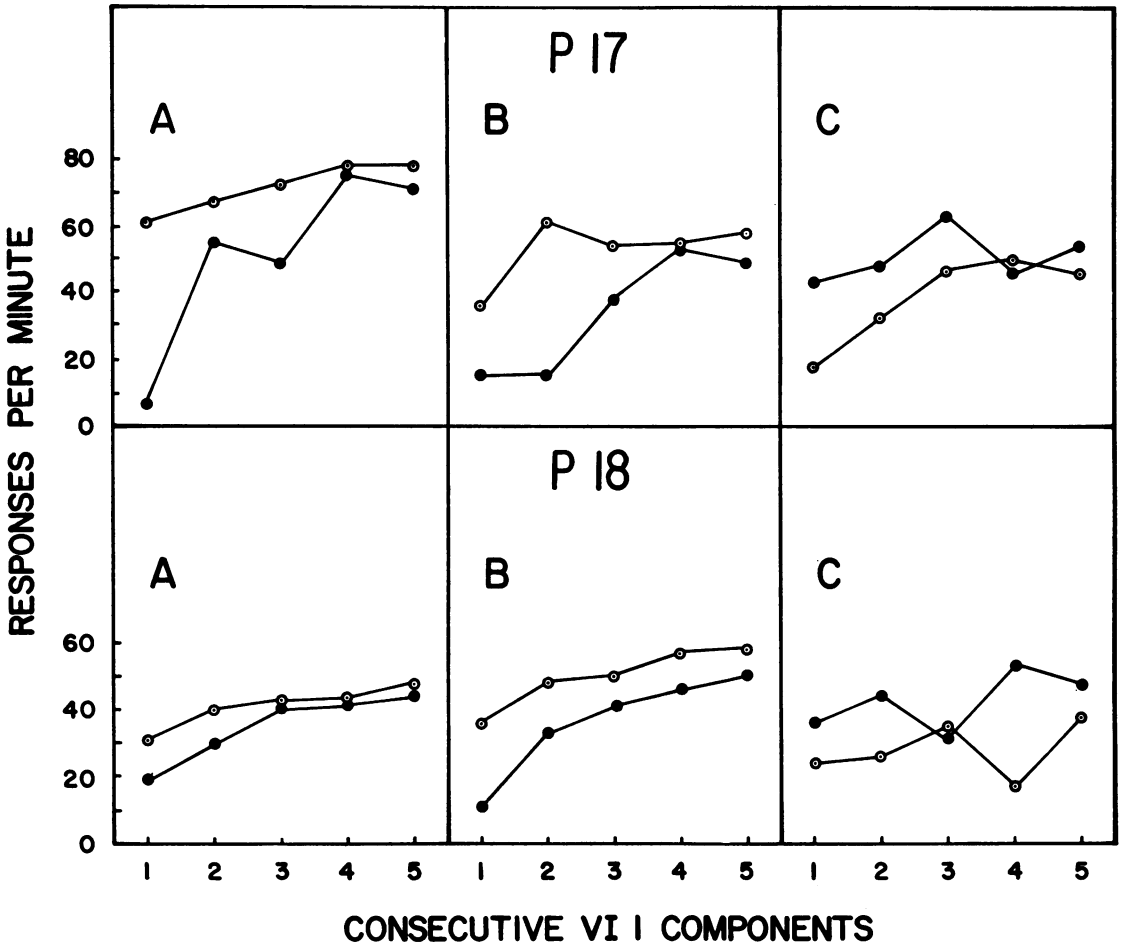

Fig. 4. Mean response rates of P 17 and P 18 in each VI 1-min component as a function of the three experimental phases. The data show the mean response rate in each VI 1-min component in one of the two units of the multiple schedule during a single daily session. As in Fig. 1 and 2, the open circles in A and B refer to the paired stimulus unit of the multiple and in C refer to the unpaired stimulus unit of the multiple. The closed circles represent the no stimulus unit in A, the unpaired stimulus unit in B, and the paired stimulus unit in C. Food occurred at the end of component 5.

Phase C, the reinforcement rates were higher in the paired-stimulus unit of the multiple. The relationship was obviously due to the dependence of reinforcement rate upon response rate in this schedule, since there was the FR 5 requirement imposed on the VI 1-min components. There also existed a possibility for reinforcement rates to exceed 0.20 reinforcements per minute due to the randomness of the probability generator arranging the VI 1-min schedule.

Table 1

Mean reinforcement rate (reinf/min) in each of the two units of the multiple schedule under the three experimental phases.

	P 17		*P 18*	
Phase	*Unit with Paired Stimulus*	*Unit without Paired Stimulus*	*Unit with Paired Stimulus*	*Unit without Paired Stimulus*
A	0.20	0.17	0.19	0.17
B	0.20	0.19	0.21	0.18
C	0.21	0.18	0.17	0.18

DISCUSSION

The results of Phases A and B of this experiment are consistent with similar findings in studies using a multiple schedule (Kelleher, 1966; Byrd and Marr, 1969) and also with investigations using multiple schedules (Thomas and Stubbs, 1966; Marr, 1969). Similarly, the observation that changing the temporal relation between the brief stimulus and food in Phase C decreased the effect of the brief stimulus also concurs with previous work (Zimmerman, 1969; Stubbs, 1969). The finding that reversing the pairing conditions in Phase C led to a reversal of response rates and pause times has not previously been reported.

Although earlier experiments have demonstrated reversal of discriminative stimuli (Deterline, 1960), none has demonstrated reversal of conditioned reinforcing stimuli *per se*. Perhaps conditioned reinforcer reversal and discriminative stimulus reversal produce similar behavioral effects, since the two stimuli share many other similarities. The food-paired stimulus apparently acquired discriminative properties in the present study. Observation of the birds during the sessions revealed that presentation of the food-paired stimulus frequently was the occasion for the birds to inspect the food aperture. Occurrence of the unpaired stimulus occasioned no observable response other than continued key pecking. Reversal of the stimuli led P 18 not to eat or inspect the aperture during the first three opportunities in Phase C, indicating that the previously unpaired stimulus did not signal food. In the other multiple component, P 18 inspected the aperture at the onset of the previously paired stimulus but it did not inspect when food was present because food was preceded by the previously unpaired stimulus. As the session progressed, P 18 began to eat occasionally when food was presented. P 17 performed similarly with regards to behavior occasioned by the brief stimuli, but whenever food occurred, P 17 always ate. Near the end of the first session in Phase C, P 17 inspected the food aperture whenever either brief stimulus occurred. During the second session of Phase C, both birds inspected the food aperture when either of the brief stimuli occurred. Close inspection of the raw data showed that the response rates in the two multiple components were not well differentiated and approximately a week of transition occurred from Phase B to C. The above observations support the interpretation that the brief stimuli exerted much more discriminative control than did the stimuli signaling the two multiple components.

The second-order schedules in the present study were expected to preclude reinforcement rate differences between the multiple units. However, this did not occur. The large difference in post-reinforcement pauses generated different reinforcement rates. According to recent studies with VI schedules (Catania and Reynolds, 1968), it is highly unlikely that the results in the two multiple units could be attributed to the small differences in reinforcement rates. A maximum difference of fewer than two reinforcements per hour was the largest that was observed during the present experiment.

Previous work (de Lorge, 1967) suggested that the effects of presenting an unpaired stimulus might depend on a bird's exposure to that specific stimulus. Generalization from the paired to the unpaired stimulus might account for the substantial influence the unpaired stimulus exerted on the post-reinforcement pause in Phase B. However, Phase C showed that when the paired stimulus became unpaired, its influence was no greater than that of the initially unpaired stimulus. If generalization were of primary importance, one might expect that the post-reinforcement pause during Phase C would be even less differentiated between the two stimulus conditions. That is, the previously paired stimulus should have retained much of its effect on behavior. The data failed to demonstrate this conclusively in either response rate or post-reinforcement pause.

The change in post-reinforcement pause as a function of pairing arrangements was the most systematic and regular effect observed and may be highly relevant for future studies of the conditioned reinforcement value of brief stimuli. Thomas and Stubbs (1966), who also studied brief stimuli in a multiple schedule, presented cumulative records showing similar effects on post-reinforcement pause, and Findley and Brady (1965) reported systematic relationships between pause time and a paired stimulus *versus* tandem condition. These studies, however, did not include an unpaired stimulus control.

In conclusion, the present experiment supplements the growing number of research articles dealing with both second-order schedules and briefly presented stimuli. The study provides further evidence of the conditioned reinforcing effects of stimuli paired with food reinforcement and points to promising routes for future investigation in this area.

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