

OPERANT ACCELERATION DURING A PRE-REWARD STIMULUS¹

WENDON W. HENTON AND JOSEPH V. BRADY

WALTER REED ARMY INSTITUTE OF RESEARCH AND
THE JOHNS HOPKINS UNIVERSITY SCHOOL OF MEDICINE

Stimuli of 20, 40, and 80 sec duration terminated with five non-response-contingent food pellets were superimposed upon lever pressing reinforced with single pellets on a DRL 30-sec schedule. Two rhesus monkeys served as subjects. No change in response frequency was observed during the 20- and 40-sec stimuli. During the 80-sec pre-food stimulus, overall response frequency increased to approximately 150% and 220% of pre-stimulus levels, and the temporal distributions of interresponse times shifted toward the shorter intervals. When the 80-sec stimulus was no longer terminated with food, the response frequency decreased and the temporal distributions of interresponse times gradually approached pre-stimulus levels. An increased frequency of short interresponse times and an increase in response rate was again observed when the pellet termination procedure was reinstated with the 80-sec stimulus. No change in response frequency or interresponse times was observed in the absence of the conditioning stimulus, and performance efficiency, as reflected in the ratio of responses to reinforcements during non-stimulus periods, remained stable throughout the experiment.

The rate of positively reinforced responding is suppressed during a stimulus terminated by brief non-response-contingent electric shock (Estes and Skinner, 1941). Several experiments have investigated the reciprocal procedure of terminating a stimulus by the non-contingent delivery of known positive reinforcers. Estes (1943) reported that the rate of responding during extinction following fixed-interval 4-min food reinforcement was accelerated during a 10-min stimulus terminated with pellet delivery. When the pairing of stimulus and food was completed before conditioning of the FI baseline, subsequent presentation of the stimulus during extinction of the operant response also produced an acceleration in the response rate (Estes, 1948). Herrnstein and Morse (1957) reinforced pecking by pigeons on a DRL 5-min food schedule and similarly reported an increase in response rate during a 2-min stimulus in which food was non-contingently delivered after the first minute.

In these studies, the contingent and non-contingent stimuli were quantitatively and qualitatively equal. Brady (1961) trained rats on a variable-interval 2-min water reinforcement schedule and reported an increase in bar

pressing during a 5-min stimulus terminated by non-contingent septal stimulation. However, Azrin and Hake (1969) reported suppression when bar pressing by rats was reinforced with food and water on a variable-interval 1-min schedule during a 10-sec stimulus terminated by non-contingent food, water, or intracranial stimulation. Suppression, rather than enhancement, was reported for all groups receiving quantitatively and qualitatively different non-contingent and contingent stimuli.

The present experiment examined the effects of a positive Pavlovian conditioning procedure upon the DRL performance of two monkeys. Interresponse times and response rates were recorded while stimuli of 20, 40, and 80 sec duration, terminated with five non-contingent food pellets, were superimposed upon lever pressing reinforced with single pellets on a DRL 30-sec schedule. Subsequent observations were made when pellet delivery no longer terminated the 80-sec stimulus and again when the five non-contingent pellets were reintroduced after the 80-sec stimulus was terminated.

METHOD

Subjects

Two male rhesus monkeys (*Macaca mulatta*) weighing 9 and 11 lb served. Water was con-

¹Reprints may be obtained from J. V. Brady, Deputy Director, Division of Neuropsychiatry, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D.C. 20012.

tinuously available except when the DRL sessions were in progress. Each monkey received 120 Dietrich and Gambrill 750-mg food pellets and one piece of whole fruit (apple, orange, etc.) per day.

In conducting this experiment, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care", as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, National Academy of Sciences—National Research Council.

Apparatus

Each monkey was maintained in a pillory primate restraint chair within an isolation housing unit. A microswitch lever was centered 6 in. (15.2 cm) in front of the monkey and a light-display panel was centered 18 in. (45.7 cm) above the lever. In the absence of a "white" masking noise, 5 cm³ of water were delivered after each response on a nose key mounted 4 in. (10.1 cm) to the left of the monkey's head. Each 1-hr session was conducted with the houselight off and a "white" masking noise present. All scheduling and recording was accomplished with conventional electro-mechanical circuits, digital print-out counters, and cumulative recorders located in an adjacent room.

Procedure

Conditioning sessions were conducted from 10 a.m. to 11 a.m. daily. Each monkey was food-deprived for 24 hr before the first session in which food was made contingent upon each lever press (CRF). During the next seven sessions, pellets were delivered only if 5 sec had elapsed since the preceding response (DRL 5-sec). The schedule of differential reinforcement of low rates was increased to 15 sec for the next seven sessions, and subsequently to 30 sec for the remainder of the experiment. Each monkey was trained on the DRL 30-sec schedule until the total number of responses and the interresponse times had stabilized according to the six-session stability criteria described by Schoenfeld, Cumming, and Hearst (1956). Stability of the interresponse times was measured by comparing the number of responses in the IRT category with highest frequency over sessions according to the criterion formula.

After the DRL performance had stabilized, five conditioning trials and one control trial were given per session. Each conditioning trial consisted of presenting a red light (CS) on the display panel for 20 sec that terminated with five non-response-contingent food pellets (US). A control trial consisted of recording the number of responses in a randomly selected 20-sec period with no CS or US. A delay procedure prevented onset of a trial within 7.5 sec of a previous response. The US was also delayed for at least 7.5 sec after a previous lever press. During this latter delay period, the visual stimulus remained on until the pellet delivery cycle was initiated.

This procedure was continued for a block of 15 sessions, followed by 15 sessions in which CS duration was increased to 40 sec and, subsequently, 15 sessions in which CS duration was increased further to 80 sec. The 80-sec CS was then presented for 15 additional sessions with no US, followed by 15 sessions in which CS and US were again paired. The intertrial interval varied from 1 to 15 min randomly under all stimulus presentation conditions.

The number of lever-pressing responses and DRL reinforcements during CS periods were compared with the frequency of responses and reinforcements during the immediately preceding equivalent time period. Also, the distribution of interresponse times for the full session, the pre-CS period, and the CS period were recorded for each session. The infrequent responses made during the post-response delay periods before CS presentation or US presentation were separately recorded but not included in the analysis.

RESULTS

Performance on the baseline DRL schedule met the criterion of stability after 33 sessions for Subject 5 and 37 sessions for Subject 7. The mean efficiency ratio of reinforcements divided by responses (Brady and Conrad, 1960) was 0.80 for Subject 5 and 0.78 for Subject 7 over the last six pre-criterion sessions. No change in the frequency of lever pressing was recorded during the sessions with CS durations of 20 and 40 sec for either monkey. Initial sessions with the 80-sec CS produced only slight increases in response frequency during the CS. However, by the seventh session with an 80-sec CS for Subject 5, and the ninth session for

Subject 7, approximately 70% more responses were recorded during the CS periods than during the pre-CS periods. Figure 1 shows the cumulative records of both monkeys for the final session with CS duration of 80 sec. Response frequency during the CS increased to approximately 220% for Subject 7 and 150% for Subject 5 relative to pre-CS periods in each of the last five sessions. The range of response frequencies during the CS periods (15 to 22 for Subject 5; 25 to 34 for Subject 7) showed no overlap with the range of response frequencies during the pre-CS periods (11 to 13 for Subject 5; 12 to 15 for Subject 7) over the last five sessions for either monkey. In addition, the efficiency ratio of reinforcements divided by responses decreased to near zero for both monkeys during the 80-sec CS periods, and remained between 0.75 and 0.84 for Subject 5 and between 0.72 and 0.85 for Subject 7 throughout the pre-CS periods.

When food no longer terminated the CS, the response frequency during the CS remained at approximately 150% (Subject 5) and 220% (Subject 7) of the pre-CS frequencies for three sessions. During the fourth "extinction" session, the ratio of CS responses divided by pre-CS responses decreased to 1.20 for Subject 5 and 1.70 for Subject 7. The CS response rate further decreased to pre-CS levels by the sixth session for both monkeys, and remained stable throughout the remaining CS-only sessions.

Pairing of the CS and US again produced no increase in responses during the CS for

nine sessions for Subject 5, and five sessions for Subject 7. However, by the tenth reacquisition session, the ratio of CS responses to pre-CS responses again increased to approximately 1.50 for Subject 5 and 1.80 for Subject 7 and remained at these levels for the remaining sessions. Again, over the last five reacquisition sessions, the range of response frequency during the CS periods (16 to 20 for Subject 5; 21 to 27 for Subject 7) showed no overlap with the range of response frequencies during the pre-CS periods (10 to 12 for Subject 5; 12 to 15 for Subject 7) for either monkey.

Analysis of the distributions of interresponse times (IRTs) revealed marked differences between the CS and pre-CS periods for both monkeys. Figure 2 and Fig. 3 present a comparison of the 80-sec CS and pre-CS IRT distributions for Subject 5 and Subject 7, respectively, during the last acquisition session, the last extinction session, the third reacquisition session, and the final reacquisition session. The IRT distributions were typically bimodal during both the CS and pre-CS intervals, though a markedly higher incidence of short IRTs (0 to 5 sec and 25 to 30 sec) characterized the CS distributions.

The ratio of reinforcements to responses remained at approximately 0.10 or less during the CS for all sessions with 80-sec CS periods for both monkeys. During extinction, the CS interresponse times gradually increased over sessions until the IRT distributions during the CS and pre-CS periods were approximately

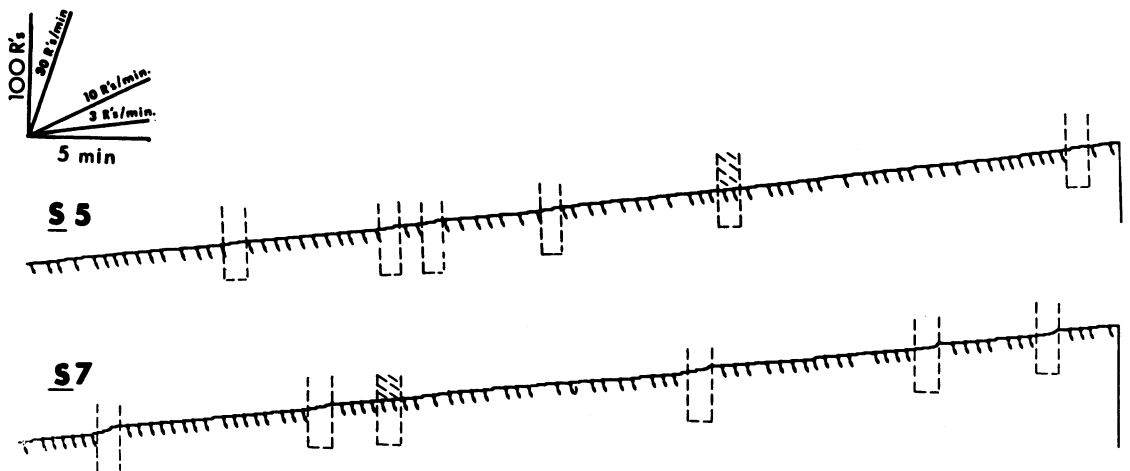


Fig. 1. Sample cumulative records for Subject 5 and Subject 7 during the final 1-hr session with the 80-sec stimulus terminated with non-contingent food pellets. Open vertical lines indicate positive Pavlovian conditioning trials. Hatched vertical lines indicate control trials.

equal by the tenth extinction session. The modal IRT during both the CS and pre-CS periods was 30 to 35 sec for both monkeys over the last five extinction sessions. Pairing of the CS and US during reacquisition shifted the peak IRT during the CS from the 30- to 35-sec category to the 25- to 30-sec category by the third session. The frequency of CS responses increased over subsequent reacquisition sessions and the shape of the IRT distribution further shifted toward the bimodal distribution observed during the latter stages of original acquisition. Interresponse times in the 1- to 5-sec and 25- to 30-sec categories again appeared with highest frequency during the CS. The IRT distributions recorded during the pre-CS periods remained relatively unchanged throughout the experiment for both monkeys.

DISCUSSION

The present results clearly indicate that the superimposition of a positive Pavlovian conditioning procedure upon a positively maintained operant performance can change both the frequency and temporal patterning of that performance. Consistent and reproducible increases in response frequency, and significant

changes in the distribution of IRTs, were repeatedly demonstrated during the 80-sec CS examined most extensively. This acceleration in DRL response rate during the CS is consistent with similar rate increases observed during relatively long duration pre-reward stimuli superimposed upon positive operant reinforcement schedules as varied as FI 4-min EXT (Estes, 1943, 1948), DRL 5-min (Herrnstein and Morse, 1957), and VI 2-min (Brady, 1961). More recently, however, Azrin and Hake (1969) reported suppression rather than acceleration of bar pressing maintained on a VI 1-min schedule with a brief pre-reward stimulus of only 10 sec. This finding and the failure to observe a significant change in the baseline DRL rate with 20- and 40-sec stimuli in the present experiment suggest the possibility of a temporal function relating change in pre-reward response rate to stimulus duration. Indeed, changes in response frequency produced by a negative Pavlovian procedure superimposed upon a positively maintained operant performance have been shown to depend upon such temporal parameters (Stein, Sidman, and Brady, 1958) as well as other observable variables.

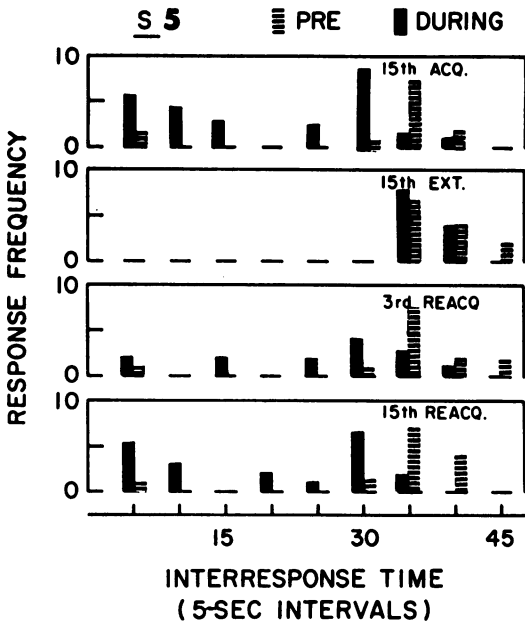


Fig. 2. Distribution of interresponse times in 5-sec intervals for Subject 5 during the stimulus (solid bars) and pre-stimulus (hatched bars) periods for the acquisition, extinction, and reacquisition phases of the 80-sec positive Pavlovian conditioning procedure.

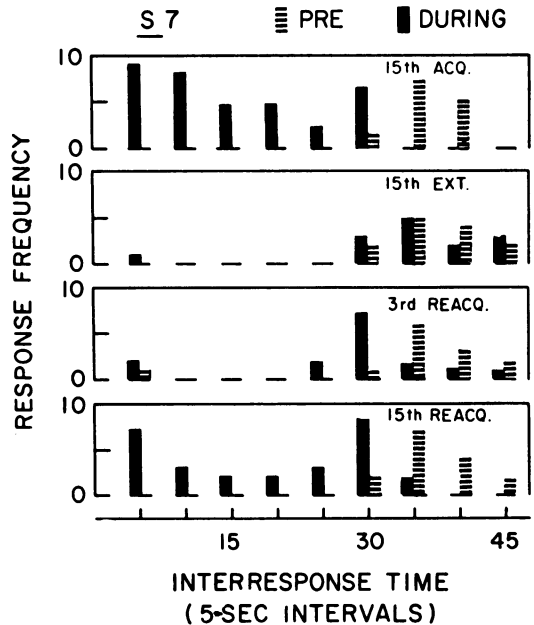


Fig. 3. Distribution of interresponse times in 5-sec intervals for Subject 7 during the stimulus (solid bars) and pre-stimulus (hatched bars) periods for the acquisition, extinction, and reacquisition phases of the 80-sec positive Pavlovian conditioning procedure.

That the present results can be explained solely on the basis of adventitious reinforcement or discriminative interactions due to the similarity of the contingent and non-contingent reinforcers seems unlikely. Although the delay procedure that prevented onset of the CS and delivery of the US within 7.5 sec of a preceding response provided no absolute safeguard against accidental contingencies, the IRT distributions failed to reveal the predominance of IRTs approximating this 7.5-sec value that might have been expected had adventitious maintenance of the performance been a factor in producing high CS response rates. In addition, the quantitative difference between the contingent (one pellet) and non-contingent (five pellets) reinforcers could be expected to limit the interaction between the two (Azrin and Hake, 1969). The observed acceleration may have resulted at least in part, however, from disruption of the response sequence mediating the DRL, or an interaction between response inhibition during the DRL performance and non-contingent reinforcement.

Certainly, the present results fail to support the "general emotional state" interpretation offered by Azrin and Hake (1969) to account for the effects of both positive and negative Pavlovian procedures upon concurrent operant behavior. First, the CS acceleration effects on the DRL baseline contrasts sharply with the suppressing effects of a negative Pavlovian procedure upon a two-response DRL performance described by Migler and Brady (1964). Secondly, Migler and Brady (1964) reported no change in the modal A-B IRT distribution during the negative CS despite suppression of the response rate, while an increase in the frequency of short IRTs was recorded during the positive CS in the present experiment. In addition, the same negative Pavlovian procedures have been shown to both accelerate and suppress DRL behavior as a function of US intensity (Finocchio, 1963; Blackman, 1968). The same negative Pavlovian procedure has also been shown to suppress reinforced responding and concurrently accelerate non-reinforced responding (Hearst, 1965; Henton, Salzberg, and Jordan, 1969). Clearly, the interpretive construct "general emotional state" cannot provide an adequate account of this divergence in the effects of positive and negative Pavlovian procedures upon similar operant per-

formances. A wide range of observable events including schedule parameters, reinforcement variables, response rate characteristics, and the temporal properties of controlling stimuli would seem to require thorough analysis before a systematic formulation of Pavlovian conditioning effects upon concurrently maintained operant performances can be provided.

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