JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 7, NUMBER 3 MAY, 1964

TIMING BEHAVIOR AND CONDITIONED FEAR

BERNARD MIGLER[1] AND JOSEPH V. BRADY

WALTER REED ARMY INSTITUTE OF RESEARCH

Rats were trained on a two-response timing procedure which required that response B follow response A by at least a minimum specified interval in order to be reinforced with food. Repeated presentation (5 min on, 5 min off) of an auditory warning stimulus terminated by a brief electric shock to the feet (conditioned fear) produced a marked suppression in the frequency of A-to-B response sequences during the warning stimulus. The distribution of A-to-B interresponse times (timing behavior), however, did not change during the warning stimulus.

The suppressing effect of conditioned fear (conditioned emotional response or CER) upon the rate of an ongoing lever-pressing response for food has been well documented in previous reports (Estes and Skinner, 1941; Brady and Hunt, 1955; Stein, Sidman and Brady, 1958). The present experiment examined the effects of the CER procedure upon properties of the operant behavior in addition to the response rate. Specifically, the effects of conditioned fear upon timing behavior using a two-response chain with a time delay required between responses was investigated.

METHOD

Subjects

Three experimentally naive male albino rats served. The principles of laboratory animal care as promulgated by the National Society for Medical Research were observed.

Apparatus

The Ss were housed and tested in the elevator device shown in Fig. 1. It contains eight test cages (7 in. by 6 in. by 11 in.) mounted vertically, three of which were used in the present experiment. A vertically sliding front panel contained a pellet feeder which delivered 45 mg pellets, a speaker, two response keys that could be illuminated from behind (½ in. in diameter, 5 in. apart), and a set of metal contacts for delivery of electric shock to the walls and grid floor of an individual test cage. *Ad libitum* water was provided from a bottle on the wall of each cage. When the test panel was in position in front of a cage, the *S* was presented with a response key on the left and right sides of the front panel, about nose high, a trough between the keys near the grid floor for pellet delivery, and a small speaker mounted in the center of the front panel near the ceiling. Under program control, the panel moved up from the home position at the bottom of the elevator, not facing any cage, to a cage in which an *S* lived for a test session. At the termination of the test for one *S*, the front panel moved up to a second *S*, and so on through the entire series before returning to the bottom of the elevator.

Conventional relay circuitry was used to program the experimental contingencies. The data were recorded on punched paper tape for later sorting and computation by a digital computer. Parallel recording of some of the data by electro-mechanical impulse counters was used to verify the accuracy of the punched tape system.

Procedure

Over the course of several days Ss were food deprived, magazine trained, and shaped to nose-press the illuminated key at the right (key B) for continuous reinforcement. Next, key A, on the left, was illuminated and key B was darkened. Pressing key B when darkened had no effect. Pressing key A when illuminated extinguished the light on key A and illuminated key B. A press on Key B at this time was reinforced, the key B light ex-

[1]Reprints may be obtained from Bernard Migler, Walter Reed Army Institute of Research, Washington, D. C.

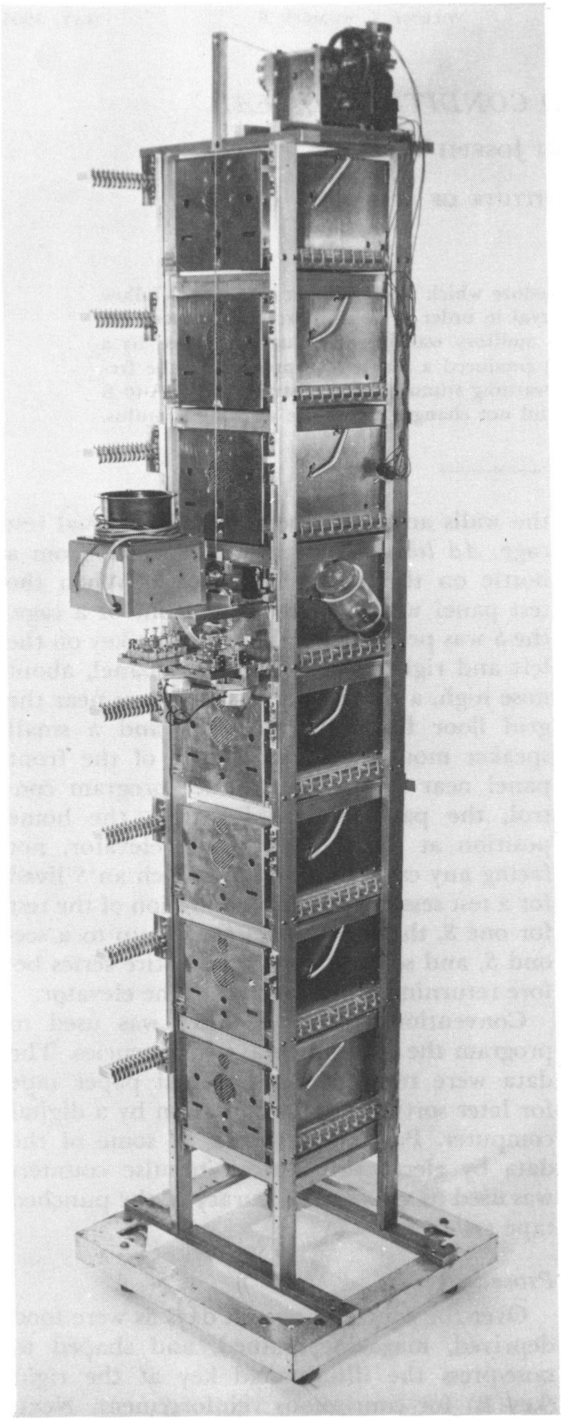

Fig. 1. Elevator used to house and test the rats. The sliding panel is positioned in front of the fifth cage, where a water bottle is mounted. Note shock contacts extending from each cage, pellet feeder, and retractible levers (which were replaced with pigeon keys for this experiment) on sliding panel and motor on top of elevator for raising and lowering the sliding panel.

tinguished, and the key A light turned on. Preliminary training continued with the introduction of a minimum delay requirement between the response on key A and the subsequent response on key B. Only if the rat pressed key B at least 1.5 sec after it had first pressed key A was the food pellet delivered. A-to-B response times shorter than 1.5 sec were not reinforced; key A was illuminated and key B extinguished. As training progressed this minimum A-to-B time was gradually increased to 3.5 sec and finally, to 5 sec. Subsequently, the reinforcement for A-to-B times exceeding the required minimum delay interval was delivered intermittently using a variable ratio of 2. There was no indication whether or not the unreinforced response had met the delay requirement. A-to-B times under the minimum delay were never reinforced.

Introduction of the conditioned fear procedure occurred initially during the 3.5-sec A-to-B delay interval phase. The *Ss* were first adapted to a 15-min duration clicking sound alternating with 10 min of no clicking sound until no systematic rate changes could be observed during the clicker. Subsequently, a .85-sec, fixed-duration scrambled foot shock of about 1 ma at the end of each 5-min clicking period was added to the procedure. On alternate days, the CER procedure was omitted. Under these conditions responding during the clicking period was very rare. Shock duration was then reduced to .35 sec and the CER procedure was used during every session, with a 5-min warning stimulus alternating with only 5 min of no clicker. This procedure produced and maintained responding during the warning stimulus in the course of daily experimental sessions which extended for 7.5 hr. Seventy-four sessions were run under these conditions, after which the minimum A-to-B time was increased to 5 sec for another 21 sessions. The food pellets delivered as reinforcements during testing sessions were the only source of nourishment during the experiment.

RESULTS

Each *S* maintained a relatively stable body weight, as indicated by weekly weighings. At the end of the experiment, *Ss* were given access to food *ad libitum* and weighed after two months. A comparison of the two-month *ad* *libitum* weight and the weight on the last day of testing revealed that C-1 had been running at 80% body weight, C-2 at 78%, and C-4 at 88%.

Figure 2 illustrates the performance of a single rat for a single session during the 5-sec minimum requirement. The time from the response on key A, which started the delay interval, to the response on key B is shown on the abscissa. The raw frequency of each A-to-B time is given by the ordinate. The large solid curve represents the total performance during the safe periods, and the smaller dashed curve the performance during the warning stimulus periods. The total responses (an A-to-B response sequence was considered a response), the mean, median, and standard deviation are given to the left of each curve (arrows). To compare the two curves percentages were derived by the method shown on the right side of the figure. For example, the number of responses during the warning stimulus were divided by the number of responses during the safe stimulus and multiplied by 100 to remove the decimal, giving 28%. One hundred percent would indicate no difference in performance in all cases. Therefore, during the warning stimulus this animal emitted only about one-fourth (28%) of the number of responses it emitted during the safe stimulus. The same procedure for the median and mean yielded percentages of 104% and 108%. This indicates very little change in the temporal distribution of A-to-B responses, although in this case the rat was slightly slower in A-to-B times during the warning stimulus. Finally, there was more variability in A-to-B times during the warning stimulus than the safe stimulus (188%).

This finding of increased variability in A-to-B times during the warning stimulus was not a general one as shown in Fig. 3. Figure 3 presents the results of the percentage transformation for the standard deviations for all the rats during the 21 sessions under the 5-sec minimum A-to-B time delay requirement. The data shown in Fig. 2 were taken from session 19 for rat C-4. As Fig. 3 indicates, this *S* generally showed greater variability during the warning stimulus than during the safe stimulus. No systematic differences in variability were seen with the other two *S*s, however, since both curves fluctuate around the 100% or no-difference line.

The main finding is shown in Fig. 4. On the left side, the data during the 3.5 sec minimum A-to-B time requirement are shown. The right side shows the data during the 5-sec minimum delay requirement. The ordinate is the percentage transformation described above. Two aspects of performance are shown for each *S*. For example, for rat C-1 (top set of data) the lower dashed curve presents the A-to-B response frequency data, indicating sustained suppression in the frequency with which A-to-B sequences were emitted during the warning stimulus. The upper curve presents the transformed data for the median A-to-B times during the warning stimulus and safe stimulus. This curve fluctuates around the 100% or no-difference line, indicating

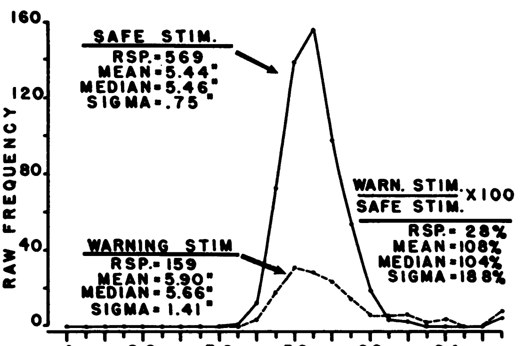

Fig. 2. Raw frequency distribution of A-to-B times for rat C-4, session 19, during 5-sec minimum, in the safe stimulus (solid curve) and warning stimulus (dashed curve).

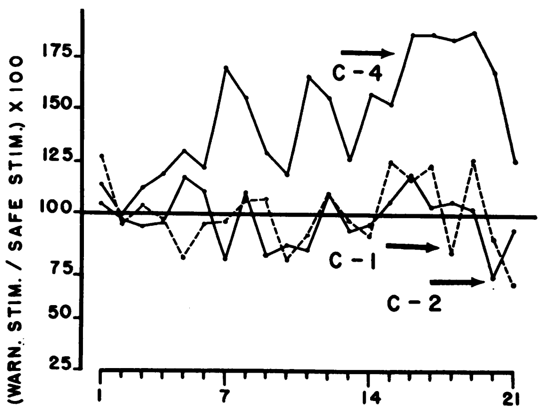

Fig. 3. Relative variability of A-to-B times in the warning and safe stimuli for all *S*s during the 5-sec minimum sessions. No difference in variability = 100; over 100 is the result of greater variability in the warning stimulus.

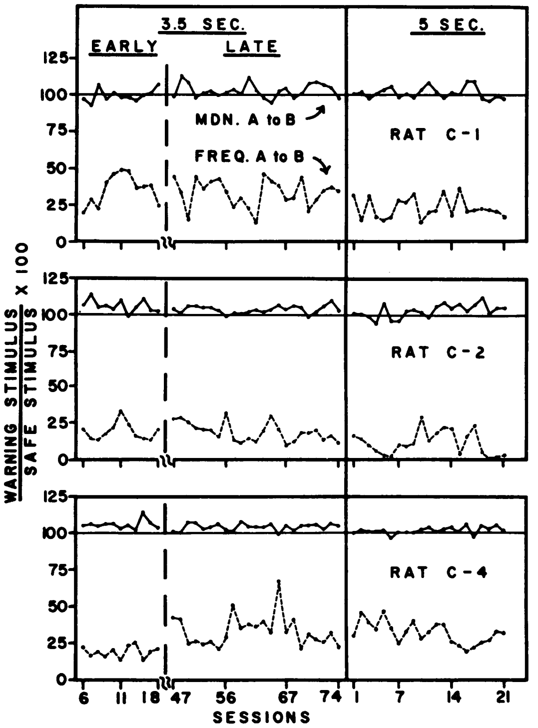

Fig. 4. Transformations illustrated in Fig. 2 for all *Ss* for median A-to-B times (solid curve) and frequency of A-to-B sequences (dashed curve) in safe stimulus and warning stimulus. Performance during 3.5-sec minimum A-to-B times requirement shown on left side (early and late in testing) and during 5-sec minimum shown on the right. Data gaps shown by missing sessions on abscissa were due to difficulties in the recording system.

no systematic effect of the warning stimulus on this aspect of the behavior. Rat C-2 showed the greatest suppression of the three, yet again very little change in A-to-B time during the warning stimulus. There appears to be a small but reliable slowing effect in the A-to-B time during the warning stimulus, however, particularly during the 3.5 sec minimum delay requirement. Rat C-4 showed some attenuation of suppression late in testing on the 3.5-sec minimum requirement, and also showed a small but reliable slowing effect in the A-to-B time during the warning stimulus. This difference disappeared, however, during the 5-sec minimum delay performance.

DISCUSSION

The results of this experiment confirm the general finding that a major effect of the warning stimulus in the conditioned fear situation is a reduction in the frequency with which the ongoing baseline response is emitted. Specifically, a major effect observed in the present study was the decrease in the rate of response A to response B sequences during the warning stimulus as compared to the no-clicker periods. Significantly, however, the temporal distribution of intervals between response A and response B (the timing behavior) remained relatively unaffected by the warning stimulus.

In the present study, the use of a two-response chain provided a means of separating those effects of the CER procedure upon the rate of the ongoing baseline response sequence from the effects upon the temporal distribution of responses within the sequence. The more traditional method of studying timing behavior using a single response DRL schedule has been utilized in a report by Finocchio (1963) on the effects of the CER procedure on temporally spaced responding. Finocchio's procedure involved an alternating 5-min warning stimulus, 5-min no-stimulus sequence as in the present study. His results indicated that response rate facilitation occurred during the warning stimulus when a lower shock intensity (1.2 ma) was used, although response rate suppression developed during the warning stimulus when a higher shock intensity (5 ma.) was employed. Finocchio also reported that changing the warning stimulus on-off ratio from the alternating 5-min sequence to 2 min on and 8 min off also produced response suppression during the warning stimulus even with the lower (1.2 ma) shock intensity.

The results reported by Finocchio suggest that performance on certain schedules of reinforcement using a single lever procedure may involve behaviors which could profitably be separated if brought under explicit control in a multiple-response situation (Mechner and Guevrekian, 1962). In the DRL schedule, for example, eating, drinking, response bursting after non-reinforcement, and long pauses between responses could all be considered as separate from the timing behavior or timing process *per se*. Thus, response rate facilitation or suppression observed when the single lever procedure is used might be related specifically to changes in timing behavior, to non-specific effects on the other behaviors, or to both. The two-response procedure utilized in the present experiment attempts to make this separation, and the reported findings indicate clearly that the suppressing effects of the warning stimulus were in fact related predominantly to behaviors other than timing.

REFERENCES

Brady, J. V. and Hunt, H. F. Some effects of punishment and intermittent "anxiety" on a simple operant. *J. comp. physiol. Psychol.*, 1955, **48**, 305-310.

Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. *J. exp. Psychol.*, 1941, **29**, 390-400.

Finocchio, D. Changes in temporally-spaced responding as a measure of conditioned emotional behavior. Paper read at Eastern Psychological Association meetings, New York, 1963.

Mechner, F. and Guevrekian, L. Effects of deprivation upon counting and timing in rats. *J. exp. Anal. Behav.*, 1962, **5**, 463-466.

Received October 4, 1963