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AN ADJUSTING AVOIDANCE SCHEDULE[1]

MURRAY SIDMAN[2]

WALTER REED ARMY INSTITUTE OF RESEARCH

A shock-avoidance schedule is described in which the animal accumulated 5 sec of safe time whenever it pressed a lever. With this schedule, the animal was not differentially reinforced for long pauses between responses; and, consistent with this property of the schedule, the probability that the animal would press the lever was not related in any regular way to the amount of time that had elapsed since its preceding lever press. Other features of the performance are also described.

If the animal was given a warning stimulus whenever it came within 5 sec of a shock, it tended to spend more time in the close temporal vicinity of the shock and less time at the maximum temporal distance from shock.

In conditioning animals to avoid shocks, the experimenter selects values of shock-shock and response-shock intervals, shock intensity and duration, session length, time between sessions, etc. But the intersubject variability with respect to the optimal values of these and other relevant parameters is considerable. For example, some rats will learn to press a lever when shock-shock and response-shock intervals are both 20 sec, but others will not condition until the shock-shock interval is set as low as 5 sec. Even then, some animals will not learn to press the lever and avoid shocks until the response-shock interval is changed as well, with an increase in the interval appropriate for some animals and a decrease appropriate for others. The procedure to be described here was originally designed to overcome a portion of this difficulty by permitting the animal to select its own optimal response-shock interval. Baer (1960) has successfully used a similar procedure to condition avoidance behavior in children. Instead of shock, the aversive stimulus was a brief interruption of cartoons that the children were watching.

METHOD

Subjects, Apparatus, and General Procedure

The subjects were albino rats. The experimental space was a metal box, 9 in. wide, 10 in. long, and 12 in. deep, enclosed in a sound-resistant outer shell. The floor of the space was composed of 0.25-in. stainless steel rods, spaced 0.75 in. apart, measured from center to center. A modified telegraph-key lever protruded into the narrow end of the box. The lever, the box, and each floor rod were insulated from one another, and each was independently wired into a shock scrambling unit, which irregularly reversed the polarity of each element when shocks were delivered to the animal. The duration of each shock was 0.3 sec, at an intensity of 1.0-2.0 ma. In the rear of the space was a small loudspeaker through which auditory stimuli were delivered. When these stimuli were used, they were a tone for Rats CC-11 and CC-19, and a clicking noise for Rats CB-17 and CB-76.

A system of relays and timers automatically programed the experimental procedures; responses and shocks were recorded on a cumulative recorder and on electrical impulse counters.

Experimental sessions lasted 6 hr, and at least 1 day intervened between each session for a given animal.

The Adjusting Schedule

When the rat was first placed in the experimental space, it received a shock every 5 sec as long as it did not press the lever. Each time it pressed the lever, however, it added 5 sec to the time that would elapse before the next shock. If, for example, the animal were

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[2]Now at Department of Neurology, Massachusetts General Hospital.

to press the lever once when 2 sec remained before the next shock was due, that shock would not come until 7 (2 plus 5) sec had elapsed; if the animal were then to allow 1 more sec to go by before pressing the lever again, it would have lost 1 sec of the 7 it had accumulated, and the next shock would come 11 (6 plus 5) sec later. At any point, then, the time remaining before the rat could receive the next shock was 5n–z+5, where n is the number of times the animal has pressed the lever since receiving the last shock, and z is the number of seconds that has elapsed since the last shock. Whenever the rat permitted a shock to occur, it continued to receive a shock every 5 sec as long as it did not press the lever.

A restriction was placed on the schedule, however, so that the rat could not accumulate an unlimited amount of time. The maximum amount of time that could remain before the next shock, *i.e.*, the maximum response-shock interval, was 50 sec. If the animal pressed the lever after it had accumulated the maximum amount of time, it served only to maintain its temporal position with respect to the shock.

The Discrimination Procedure

The effects of warning stimuli were also explored. During this phase of the experiment, a warning stimulus (tone or clicker) came on whenever the animal allowed itself to reach the point when only 5 sec remained until the next shock was due. As long as the rat remained within 5 sec of a shock, the stimulus remained on, and did not terminate until the animal pressed the lever and took itself out of the 5-sec range.

Observations were also made of the effects of a stimulus that came on whenever the animal put 45-50 sec (the maximum distance) between itself and shock, but there was no convincing evidence that the animals' behavior came under the control of this stimulus, and the data will not be reported.

RESULTS AND DISCUSSION

The adjusting schedule was used with seven animals, and all conditioned successfully within the first session. Although not all rats condition so rapidly with the fixed response-shock interval procedure, this is not as yet a large-enough sample to justify a normative comparison.

With a fixed response-shock interval, rats ordinarily develop an efficient temporal discrimination after they have had many hours of experience with the procedure. Having pressed the lever once, or several times rapidly, the animal rarely presses it again within the next few seconds; but as the shock becomes imminent, the likelihood that the animal will respond increases sharply (*e.g.*, Sidman, 1958). With the adjusting schedule, long pauses have a greater probability of ending with a shock than do short pauses. Consequently, here, too, the animal might be more likely to respond as a longer interval elapses since the last time it pressed the lever. But two features of the adjusting schedule mitigate against a precise temporal pattern of behavior.

First, the response-shock interval is variable, depending on the animal's own behavior. The length of time it can pause before receiving a shock will be a function of the number of times it pressed the lever before pausing, and of the rate at which it pressed the lever. Sidman and Boren (1957b), however, have demonstrated that a variable response-shock interval, by itself, need not prevent the animal from spacing its responses relatively consistently.

A second feature of the adjusting schedule is that the amount of "safe time" the animal gains each time it presses the lever is independent of the interval that has elapsed since its preceding response. Every time it presses the lever, regardless of when it responded previously, the animal receives an additional 5 sec free of the possibility of shock. In contrast, with a fixed response-shock interval, or with the variable-interval procedure used by Sidman and Boren, the animal gains a smaller additional amount of shock-free time if it responds soon after its preceding lever-press than if it waits almost until the next shock before pressing the lever again. When the response-shock interval is fixed, therefore, the more widely the animal spaces its responses in time, the more it will reduce shock density (shocks per unit time) with each response. This differential reinforcement of long inter-response times could account for the more efficient spacing that develops. The adjusting schedule, however, gives each lever press equal weight in reducing the shock density, and should not generate any consistency in the animal's temporal distribution of responses.

Figure 1 gives the inter-response–time probabilities for the final three recorded sessions of five animals whose entire experimental experience had been with the adjusting schedule. All of the animals except Rats RS-99 and CB-17 had been exposed to the discrimination procedure, but the forms of the curves of Fig. 1 probably did not result from this history. (See below.) The probabilities were calculated by dividing the absolute frequency of each inter-response interval by the total number of occasions the animal paused long enough to make each interval possible. No probabilities are given unless there were 10 or more such occasions (opportunities).

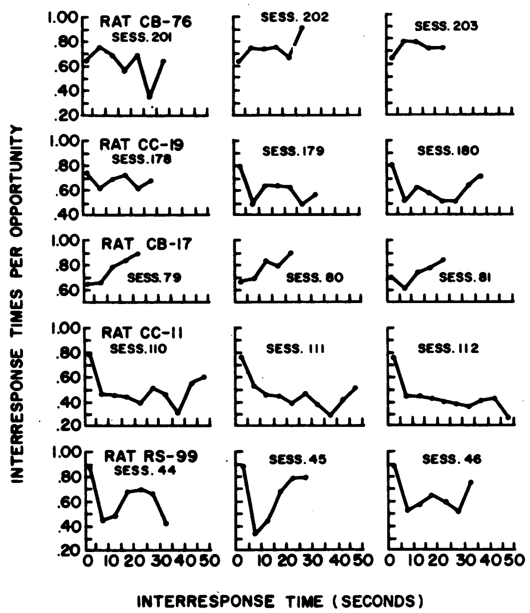

Fig. 1. Inter-response–time probabilities for the final three recorded sessions of five animals.

The probability functions are quite variable, both within and among animals; but except for Rat CB-17, there is no consistent indication that the animals were more likely to press the lever as time passed since their last response. This is true even after more than 200 6-hr sessions, as in the case of Rat CB-76. Animals given such prolonged exposures to a fixed response-shock interval normally show a pronounced tendency toward higher response probabilities after longer pauses (Sidman, 1954.) In the absence of any such consistent tendency in Fig. 1, the most general descriptive statement would be that the probability of a response is independent of the amount of time that has elapsed since the animal last pressed the lever.

These data, then, are consistent with the suggestion that response probability, expressed as inter-response times per opportunity, is

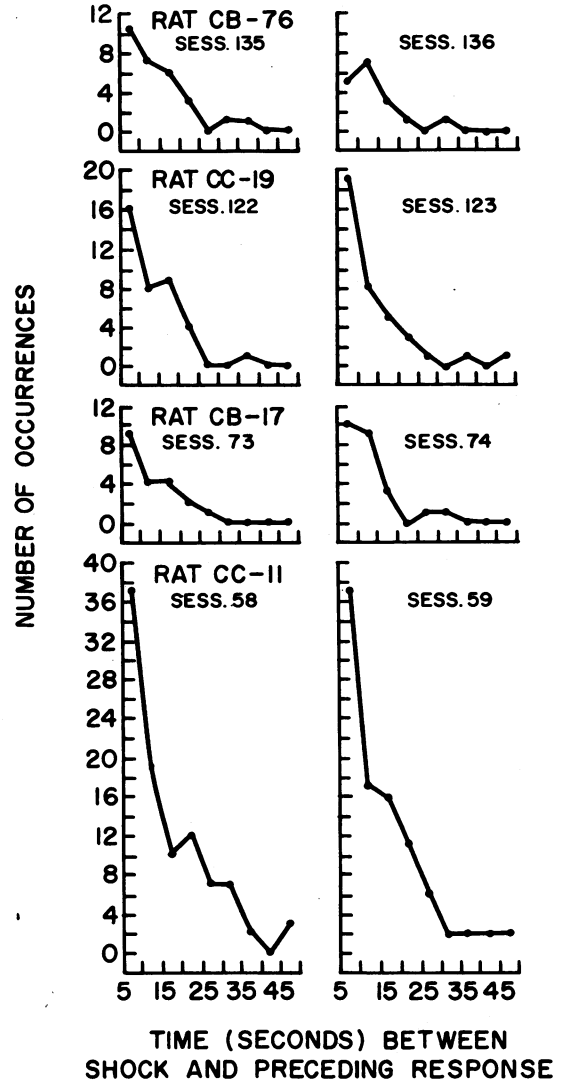

Fig. 2. Frequency distributions of the time intervals that had elapsed between each shock and the animal's preceding response.

governed by the extent to which a given inter-response time permits the animal to reduce shock density. With the adjusting schedule, the animal reduces shock density by a constant amount with each response, regardless of when it responds. However, although the functions yielded by Rat CB-17 do not extend

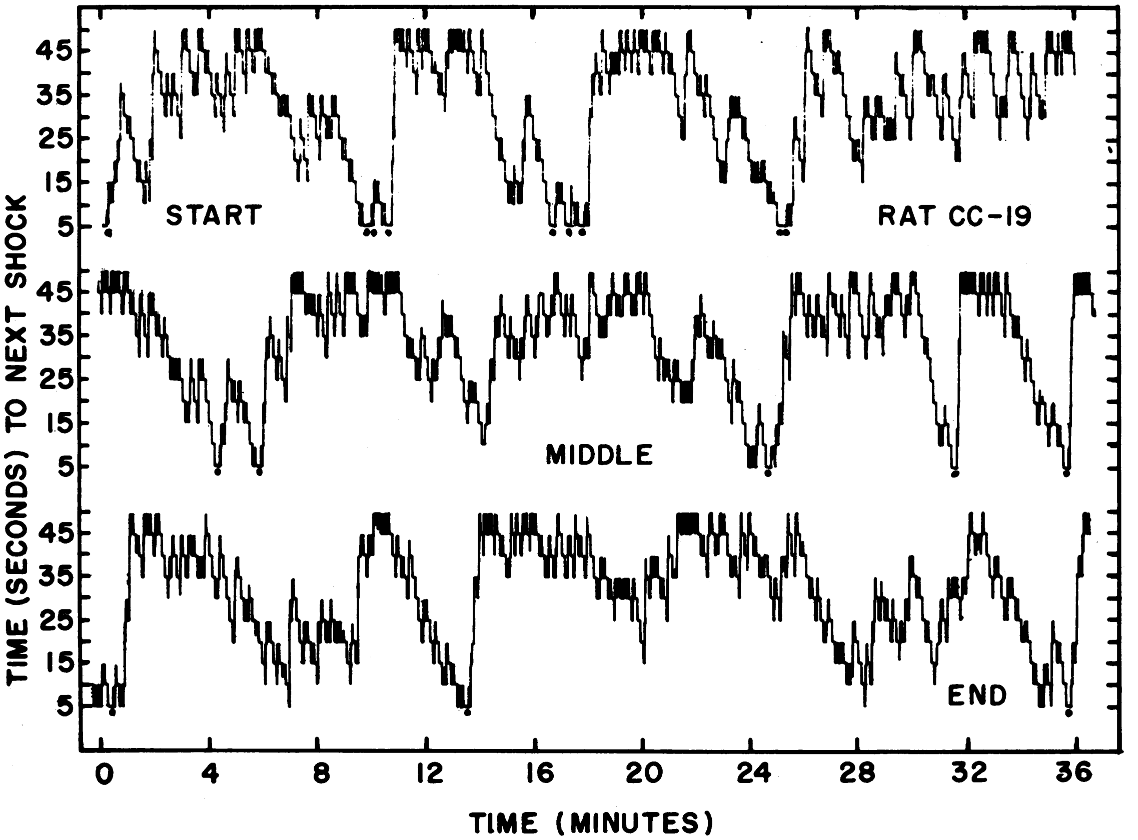

Fig. 3. Records taken from the beginning, middle, and end of a session, giving a continuous picture of the temporal distance the animal kept between itself and shock. The pen moved up one 5-sec step each time the animal pressed the lever, and moved down an equal distance whenever the animal allowed 5 sec to elapse without pressing the lever. Shocks are indicated by the dots below each segment of the record.

over a wide range of probabilities, they indicate that the increasing likelihood of shock when the animal pauses for longer periods cannot be ruled out as a controlling factor.

During a few sessions, the actual response-shock intervals the animals experienced were recorded. Figure 2 presents frequency distributions of the interval that elapsed between each shock and the last response immediately preceding each shock, for the first two sessions in which such recordings were made. The modal frequency is nearly always in the 5- to 10-sec range, the smallest intervals that could possibly elapse between response and shock. Since inter-response times were not recorded during these sessions, probabilities cannot be presented in terms of response-shock intervals per opportunity.

Figure 2 also reveals that the animals did not accumulate long periods of safe time and then stop pressing the lever. Shock most frequently followed 5- to 10-sec pauses, indicating that the rats responded so as to dissipate their accumulated time gradually. Figure 3 provides a more direct confirmation of this pattern of responding. These sample recordings, taken from the beginning, middle, and end of a session, depict the temporal distance the animal kept between itself and shock. Whenever the animal pressed the lever, the pen moved up one 5-sec unit; every 5 sec, the pen automatically moved one comparable unit in the opposite direction; whenever the pen remained at the base line for 5 sec, the animal received a shock. Shocks are indicated by the dots below each segment of the record. In almost every instance, responses interrupted the approach of the pen to the base line; therefore, when a shock does occur, the animal is highly likely to have pressed the lever 5 to 10 sec earlier. The picture is generally one of rapid buildup of safe time and gradual backsliding.

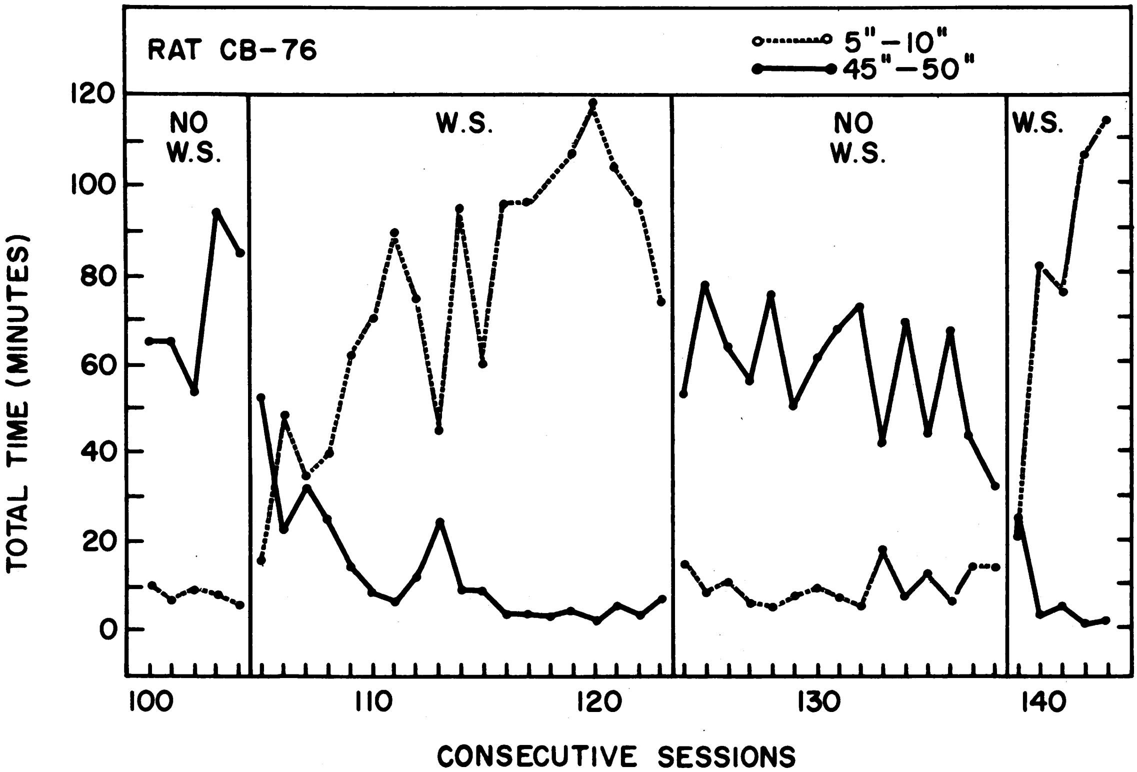

Fig. 4. Total time the animal spent in each session at distances of 5 to 10 and 45 to 50 sec from shock, with (W.S.) and without (no W.S.) the warning stimulus.

Effects of Warning Stimuli

When the avoidance procedure involves a fixed response-shock interval and the animal is given a warning stimulus prior to shocks, it tends to wait until the stimulus comes on before pressing the lever (Sidman, 1955; Sidman & Boren, 1957a). A similar result is observed when the adjusting schedule is used, and a warning stimulus comes on whenever the animal is within 5 sec of a shock. The effect of this operation was assessed by recording the amount of time the animal spent in each session at a distance of 5 to 10 sec from shock, and the amount of time it kept itself 45 to 50 sec away from shock. It should be noted that the 5-to 10-sec interval is one through which the animal must pass both on its way toward and away from the shock.

Figure 4 gives the results for Rat CB-76. When there was no warning stimulus, this animal spent more time at the maximum temporal distance from shock than it did close to the minimum distance. With the introduc-

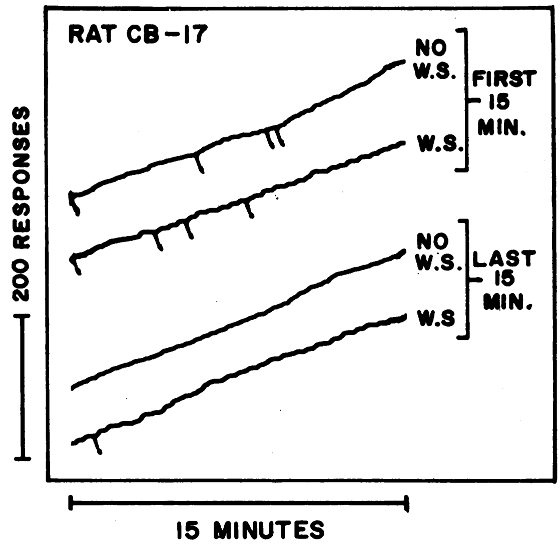

Fig. 5. Segments of cumulative records from the beginning and end of sessions with and without the warning stimulus.

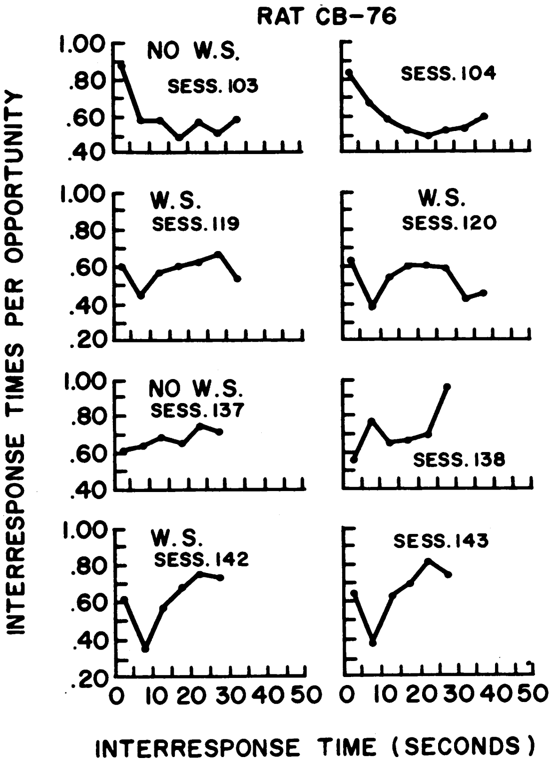

Fig. 6. Inter-response–time probabilities during sessions with and without the warning stimulus.

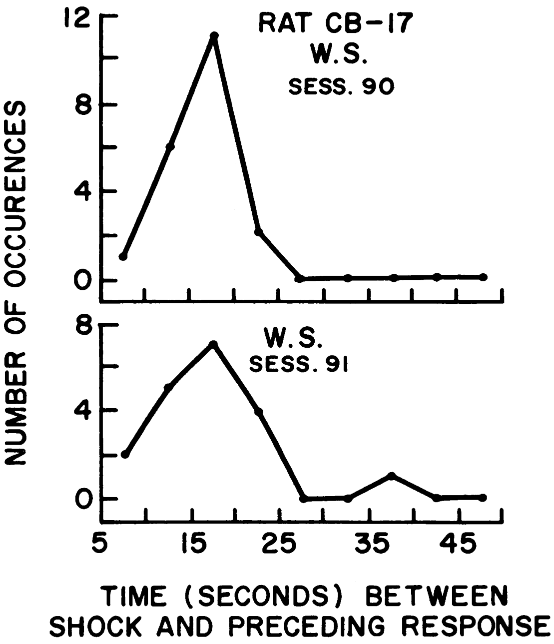

Fig. 7. Frequency distributions of the time intervals between each shock and the animal's preceding response, during sessions with the warning stimulus. (See Fig. 2. for comparison with sessions in which there was no warning stimulus.)

tion of the warning stimulus, however, the animal markedly increased the amount of time it spent close to the shock. Also, with the warning stimulus, the animal rarely responded so as to impose the maximum temporal distance between itself and shock.

Rat CB-17 behaved in a similar manner, and the difference between the two patterns of behavior was clear enough to be discernible in the fine detail of the cumulative-response record. Figure 5 shows segments of cumulative records from the beginning and end of sessions with and without the warning stimulus. With the warning stimulus, the picture is one of cyclic approaches to, and partial withdrawals from, the shock. Although the animal sometimes alternated between high and low response rates when it had no warning stimulus, the cyclicity is neither so prominent nor so regular.

The changes brought about by the warning stimulus also show up in the inter-response–time probability functions. Figure 6 shows that during the sessions that included the warning stimulus, there was a relatively high probability that the animal would press the lever in rapid bursts; a lower probability of 5- to 10-sec inter-response intervals; and a gradually increasing probability of longer inter-response intervals. These data are consistent with the appearance of the cumulative-response records of Fig. 5.

Figure 7 indicates that the warning stimulus caused the modal response-shock interval for Rat CB-17 to shift from the 5- to 10-sec range (see Fig. 2) to the 15- to 20-sec range. This, again, is consistent with the pattern of alternate bursts and pauses shown in the cumulative record.

Animal CC-19 showed similar but less radical changes in the amount of time it spent close to and far from the shock when it had a warning stimulus. Rat CC-11 reacted more slowly to the introduction of the warning stimulus; and, as Fig. 8 shows, the effect of the stimulus was largely to cause the animal to spend more time in the 5- to 10-sec range without markedly decreasing the duration of its stay at the maximum temporal distance from shock. If this animal had been permitted to accumulate a greater amount of time than 50 sec, it, too, might have attained the maxi-

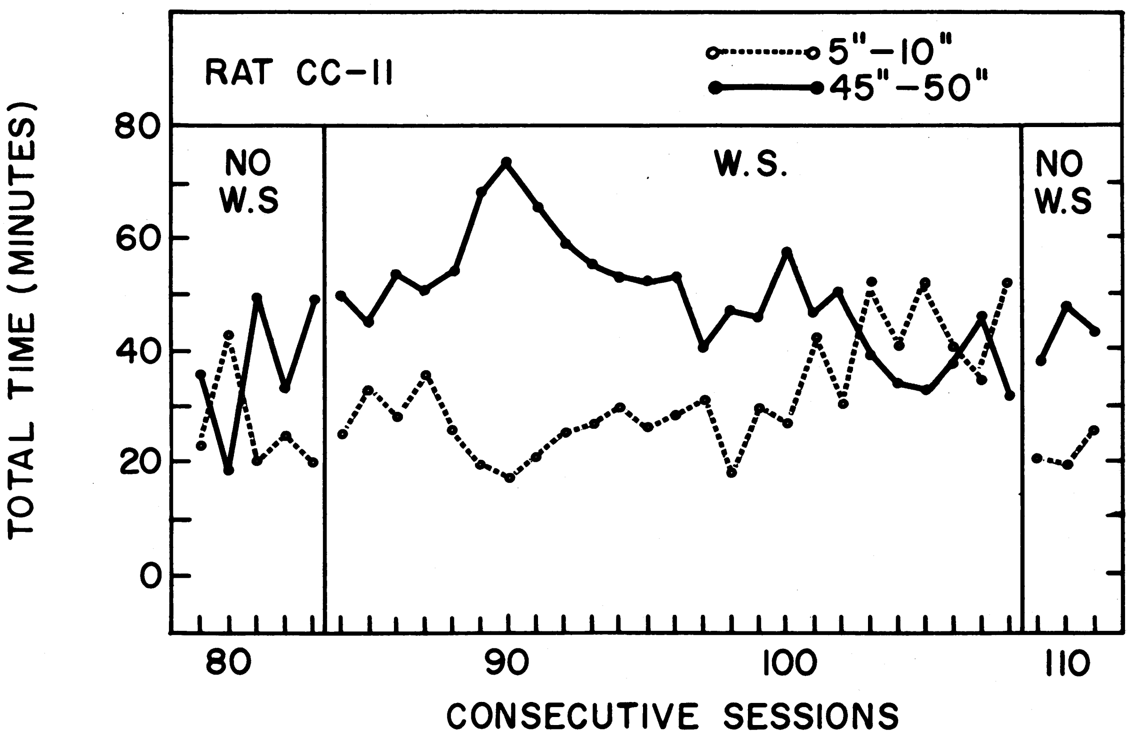

Fig. 8. Total time the animal spent in each session at distances of 5 to 10 and 45 to 50 sec from shock, with and without the warning stimulus.

mum less frequently when it had the warning stimulus. The changes in the behavior of Rats CC-11 and CC-19 were not sufficiently great or complete to produce any notable changes in the cumulative records, the inter-response–time probabilities, or in the frequency distributions of response-shock intervals.

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