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CLASSICAL AVOIDANCE WITHOUT A WARNING STIMULUS

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White rats were scheduled to be shocked every 15 sec; but they were given a limited time interval between shocks when they could prevent the next scheduled shock from occurring if they pressed a lever. The duration of this limited avoidance period was varied, as was its location within the interval between scheduled shocks. Response rate, shock frequency, and the temporal distribution of lever presses were examined. Conditions were generated in which the formation of a temporal discrimination prevented the animals from maintaining successful avoidance behavior.

In one type of classical avoidance procedure (*e.g.,* Hunter, 1935), the experimenter may turn on a buzzer in the subject's experimental space and then administer an electric shock if the subject does not respond appropriately within a limited time after the buzzer. Following a fixed intertrial interval, the buzzer again sounds and a new trial begins.

We can modify this sequence of events simply by eliminating the buzzer, leaving the avoidance contingency and the temporal specifications unchanged. The subject can now avoid the shock only by responding during a limited period of time which, in the classical procedure, would be indicated by a warning stimulus, but is now marked by no exteroceptive event. Such a procedure has been described by Hurwitz and Millenson (1961), who systematically varied the length of the period in which the animal could avoid shock. The present experiment extends the analysis of this temporally defined avoidance contingency.

METHOD

Subjects and Apparatus

The subjects were three mature, male, albino rats. The basic apparatus, described in detail elsewhere (Sidman, 1953b,) consisted of a metal box with a grid floor of stainless steel rods. A modified telegraph-key lever protruded into one end of the box. Shock was delivered through a "scrambler" unit that randomly reversed the polarity of the walls, the lever, and each of the grid rods so that the animal could not stand on two elements of the same polarity and thus avoid the shock. The duration of each shock was 0.3 sec. A system of relays and timers automatically programed the experimental procedure; responses and shocks were recorded on cumulative recorders and on electrical impulse counters.

Procedure

The experimental sessions, each 6.5 hr long, were divided into successive 15-sec cycles. Shocks were scheduled to be delivered to the subject at the end of each cycle, *i.e.,* every 15 sec. If the animal responded appropriately (to be explained below), the next scheduled shock was not delivered, but the new cycle began at the same point. This is different from a previously described procedure in which the subject initiated a new cycle each time it responded (Sidman, 1953a). Here, a cycle always began at the point where the animal either was shocked or would have been shocked if it had not successfully avoided.

In the initial conditioning, the animal's first lever press during any 15-sec cycle prevented the shock from occurring at the end of that cycle. The animal had to press the lever only once to avoid the shock; additional responses during that particular cycle had no programed effect. For a response in the next cycle to be effective, the animal had to release the lever and press it again; holding the lever down from one cycle into the next was not effective as an avoidance response. Initially then, the avoidance interval was equal to the total cycle length, *i.e.,* 15 sec. (See Fig. 1A.)

After 15 or 16 sessions, the animals were then exposed for varying numbers of sessions

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to shorter avoidance intervals within the 15-sec cycle. If, for example, the interval was from 4.5 to 15 sec (Fig. 1B), the animal could not prevent the next shock by pressing the lever during the first 4.5 sec of the cycle; the animal could avoid the shock which was due at the end of the cycle only by pressing the lever after 4.5 sec of the cycle had elapsed. Similarly, if the avoidance interval was 12 to 15 sec, only the first response in the last 3 sec of the cycle would prevent the shock. Figure 1A-1E illustrates the intervals that were used.

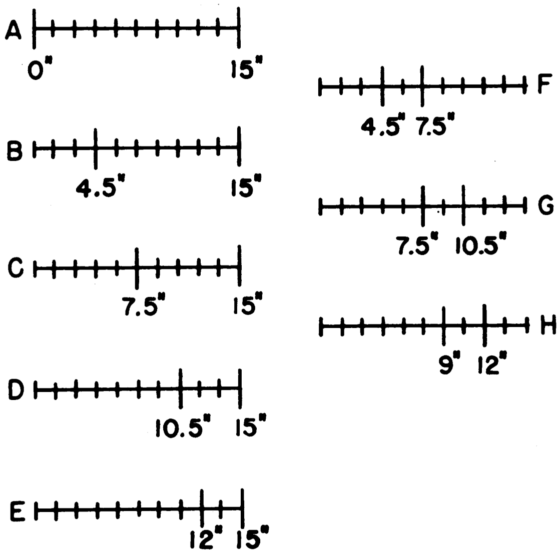

Fig. 1. Schematic diagrams of the experimental conditions. The cycles are divided into ten 1.5-sec intervals, with the avoidance intervals located between the elongated vertical lines. In A-E, the avoidance periods terminate contiguously with the end of the cycle; in F-H, the avoidance periods terminate elsewhere than at the end of the cycle.

The three animals were also exposed to conditions in which a 3-sec avoidance period was located elsewhere than at the end of the cycle, *e.g.*, at 4.5-7.5 sec, 7.5-10.5 sec, and 9-12 sec. (See Fig. 1F-1H.) In the last condition, for example, the animal could not avoid the shock by responding in either the first 9 sec or in the last 3 sec of the cycle; the animal could prevent itself from being shocked at the end of the cycle only by pressing the lever at least once between the 9th and 12th sec.

Figure 2 shows the sequence of conditions to which each animal was exposed and the number of sessions of each condition.

RESULTS

Response Rates and Shocks

The average number of responses per cycle appears in Fig. 2 for each session of the experiment and for each individual subject. Since the cycle length was constant at 15 sec, the number of responses per cycle is also a measure of response rate, *i.e.*, responses/15 sec. Figure 2 begins with the final 10 sessions of the original conditioning procedure, in which the animals could avoid the shock by pressing the lever at any point in the 15-sec cycle.

Let us confine our attention first to those sessions in which the end of the avoidance interval coincided with the end of the cycle. As the duration of the avoidance period decreased, Rat CN-72 increased its number of responses per cycle. The other two animals, Rats CO-40 and CN-7, also increased their response rates with decreasing avoidance intervals, but the increases are not so evident to the eye in Fig. 2. They are more apparent if the final four sessions of each condition are taken as criteria. Note, too, that Rat CN-7, unlike Rat CO-40, was exposed to the 4.5-sec period (10.5-15 sec) before the 7.5 sec period (7.5-15 sec). Rat CN-7's response rate appears to decrease when the avoidance interval becomes as short as 3 sec (12-15 sec). Hurwitz and Millenson (1961) have reported an increase in response rate up to a maximum and a subsequent decline as the avoidance interval becomes briefer. It is reasonable to suppose that the maximum would have appeared in the data of Rats CN-72 and CO-40 if the interval had been lowered beyond 3 sec.

Hurwitz and Millenson noted that the animals received more shocks as the duration of the avoidance interval decreased. A similar finding appears in Fig. 3. When the avoidance interval was equal to the cycle length, all animals successfully avoided more than 95 per cent of the shocks. As increasingly severe temporal limitations were placed on the avoidance interval, the animals prevented smaller proportions of the scheduled shocks.

Figure 2 also shows the changes in response rate that were consequent upon shifting the avoidance period away from the end of the cycle. Immediately after the 7.5-sec avoidance period, Rat CN-72's interval was reduced to 3 sec and was located just past the center of

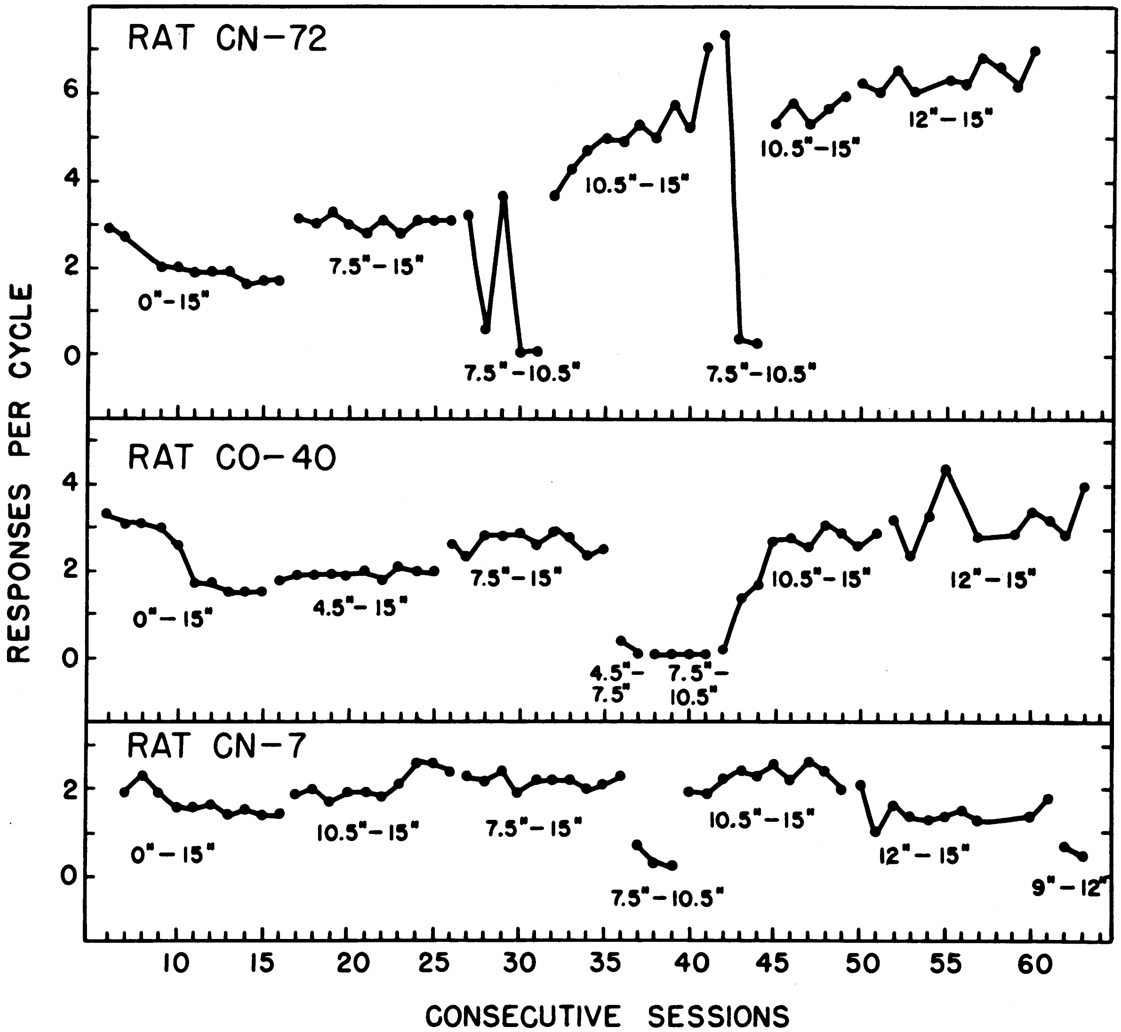

Fig. 2. Average number of responses per cycle for each session and for each individual subject. The location of the avoidance period is indicated beneath each segment of the curves. Occasional sessions were omitted because of apparatus failures.

the cycle, from 7.5-10.5 sec. The number of responses per cycle increased slightly during the first session (Session 27), but not enough to prevent a nearly sevenfold increase in the number of shocks delivered to the animal. In Session 28 the animal averaged only 0.6 response per cycle and avoided less than 10 per cent of the scheduled shocks. Despite the recovery in rate during Session 29, the animal avoided fewer than 50 per cent of the shocks; and during the following two sessions, it practically never responded.

In Session 32 the avoidance interval was increased slightly to 4.5 sec and was again placed at the end of the cycle (10.5-15 sec). Rat CN-72's response rate increased immediately, and it continued to rise gradually during the following nine sessions. In Session 42 the animal was again exposed to the interval at 7.5-10.5 sec. As before, the animal's response rate and the number of shocks it received increased initially; but in the following two sessions, it almost completely ceased to respond. The animal quickly recovered its avoidance behavior when the interval was returned to the final 4.5 sec of the cycle.

Immediately after the 7.5-sec avoidance period, Rat CO-40's interval was reduced to

3 sec and was located just before the center of the cycle, from 4.5-7.5 sec. The animal's rate of avoidance responding dropped precipitously, and remained almost zero when the interval was shifted into the range of 7.5-10.5 sec. The behavior gradually recovered when the avoidance interval was again located at the end of the cycle, from 10.5-15 sec.

Rat CN-7 displayed similar decreases in response rate when the avoidance interval was 7.5-10.5 and 9-12 sec.

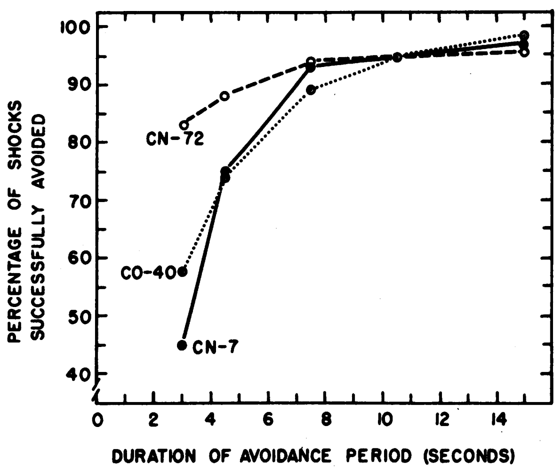

Fig. 3. Percentage of shocks successfully avoided by each animal as a function of the duration of the avoidance period, when the avoidance period terminated at the end of the cycle.

Temporal Distribution of Responses

The number of responses in successive 1.5-sec segments of the 15-sec cycle was recorded during each session. Figures 4, 5, and 6 illustrate the temporal distribution of the animals' lever-pressing responses within the 15-sec cycle. If the responses were evenly distributed throughout the 10 subintervals of the cycle, each interval would contain 10 per cent of the total; the data are therefore presented in the form of deviations from 10 per cent. Arrows indicate the boundaries of the avoidance period, and the shaded bars are located within that period.

The first four distributions in Fig. 4 represent the final two sessions for Rat CN-72 in which the duration of the avoidance interval was 15 and 7.5 sec, respectively. These distributions show little or no systematic deviations from 10 per cent, indicating that the animal was equally likely to press the lever during any segment of the cycle.

The next five distributions (Sessions 27-31), however, are quite different. When the avoidance period was between 7.5 and 10.5 sec, a marked temporal discrimination became apparent, with the animal responding much more frequently near the end of the cycle than at the beginning. Although this shift in response probability is evident in all five sessions, it is most pronounced in those sessions (28, 30, and 31) in which the response rate was very low. (See Fig. 2.) The low probability of responses early in the cycle has some face validity, since such responses were ineffective in avoiding the shock; but the same is true of those responses which occur in the final 4.5 sec of the cycle. The preponderance

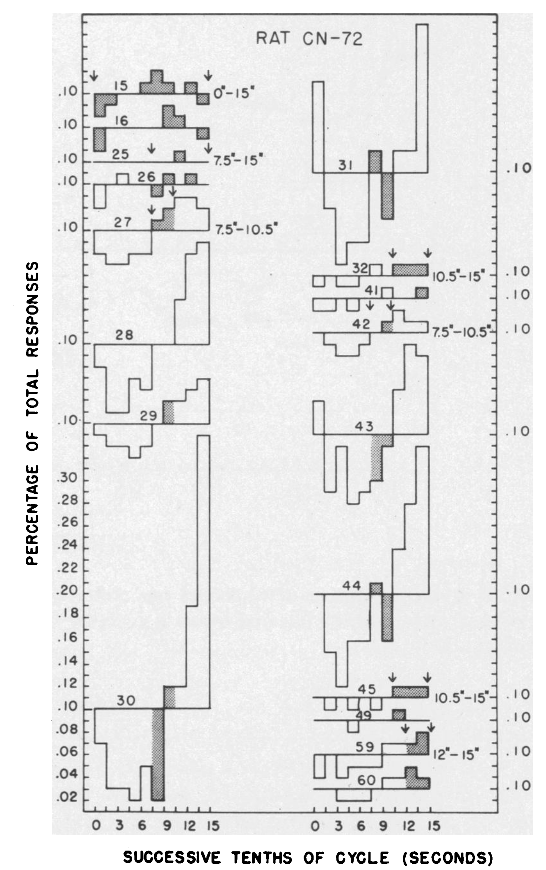

Fig. 4. The temporal distribution of lever-pressing responses within the 15-sec cycle for Rat CN-72. The percentages of responses in successive 1.5-sec intervals are drawn as deviations from 10 per cent. Session numbers are indicated on each distribution, and the location of the avoidance interval is indicated beside the first distribution in which the interval appears. The intervals are also marked by the arrows and the shaded bars.

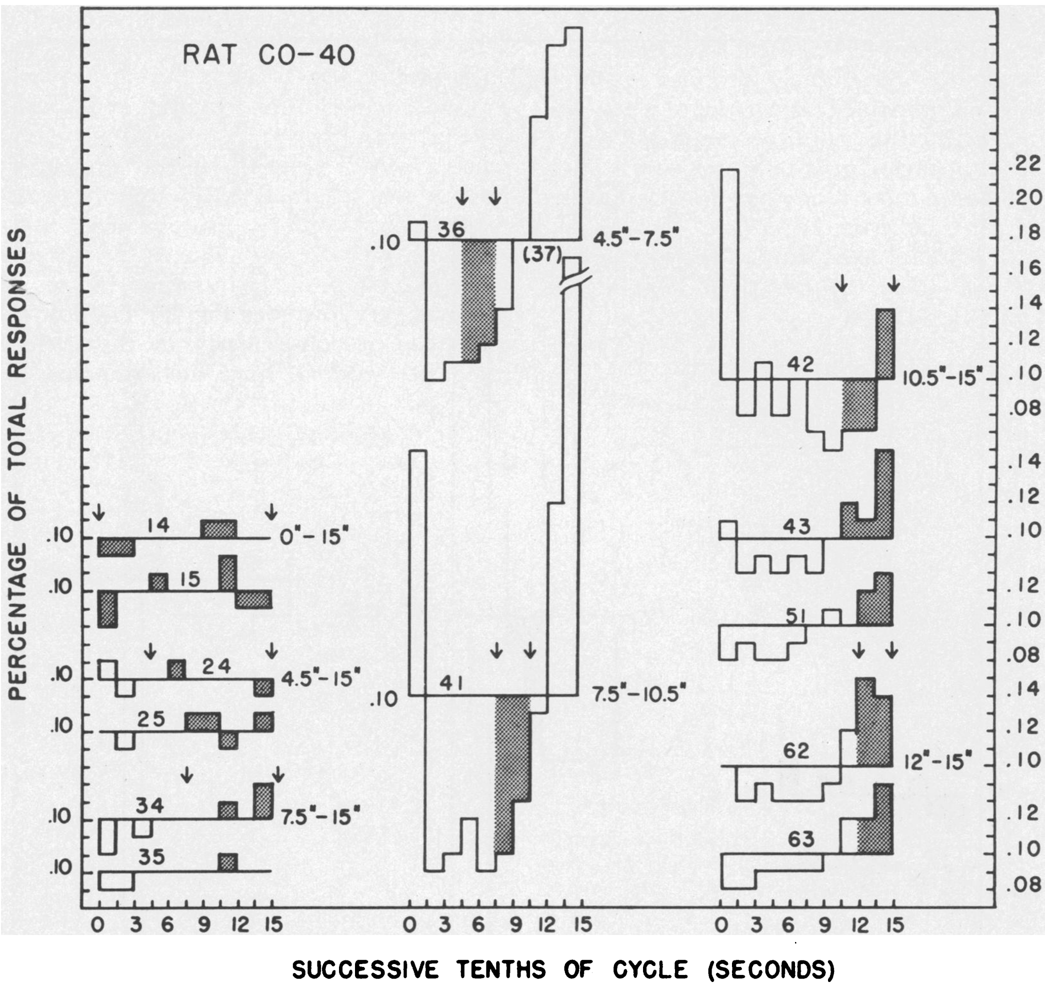

Fig. 5. Rat CO-40. See legend of Fig. 4.

of responses at the end of the cycle did not extend back as far as the avoidance period.

When the avoidance interval was returned to the end of the cycle (Session 32), the temporal discrimination all but disappeared, and the animal distributed its responses relatively evenly as long as the interval remained unchanged, *i.e.*, through Session 41. In Sessions 42-44 the avoidance period was again moved back to the range of 7.5-10.5 sec; again, as its response rate declined, the animal began to respond most frequently at the end of the cycle. As before, a return to the interval between 10.5 and 15 sec restored the relatively even temporal distribution of responses. When the avoidance period at the end of the cycle was reduced to 3 sec, the response probability at the end of the cycle increased slightly but reliably, as Sessions 59 and 60 show.

Rat CO-40 confirms these data in their essentials (Fig. 5). Avoidance periods of 15, 10.5, and 7.5 sec yielded little or no evidence of temporal discrimination. The final two sessions at each of these values are shown. As soon as the interval was shifted back to the range of 4.5-7.5 sec (Session 36), the animal placed 60 per cent of its responses in the final 4.5 sec of the cycle. The temporal discrimination continued and even became more accentuated after the avoidance interval was changed to the range of 7.5-10.5 sec (Session 41). The temporal discrimination reduced markedly when the avoidance interval was again placed at the end of the cycle (Sessions 42-51), but it did not completely disappear and was slightly accentuated when the interval was reduced to 3 sec (Sessions 62-63). At the same time, shock density increased (Fig. 2).

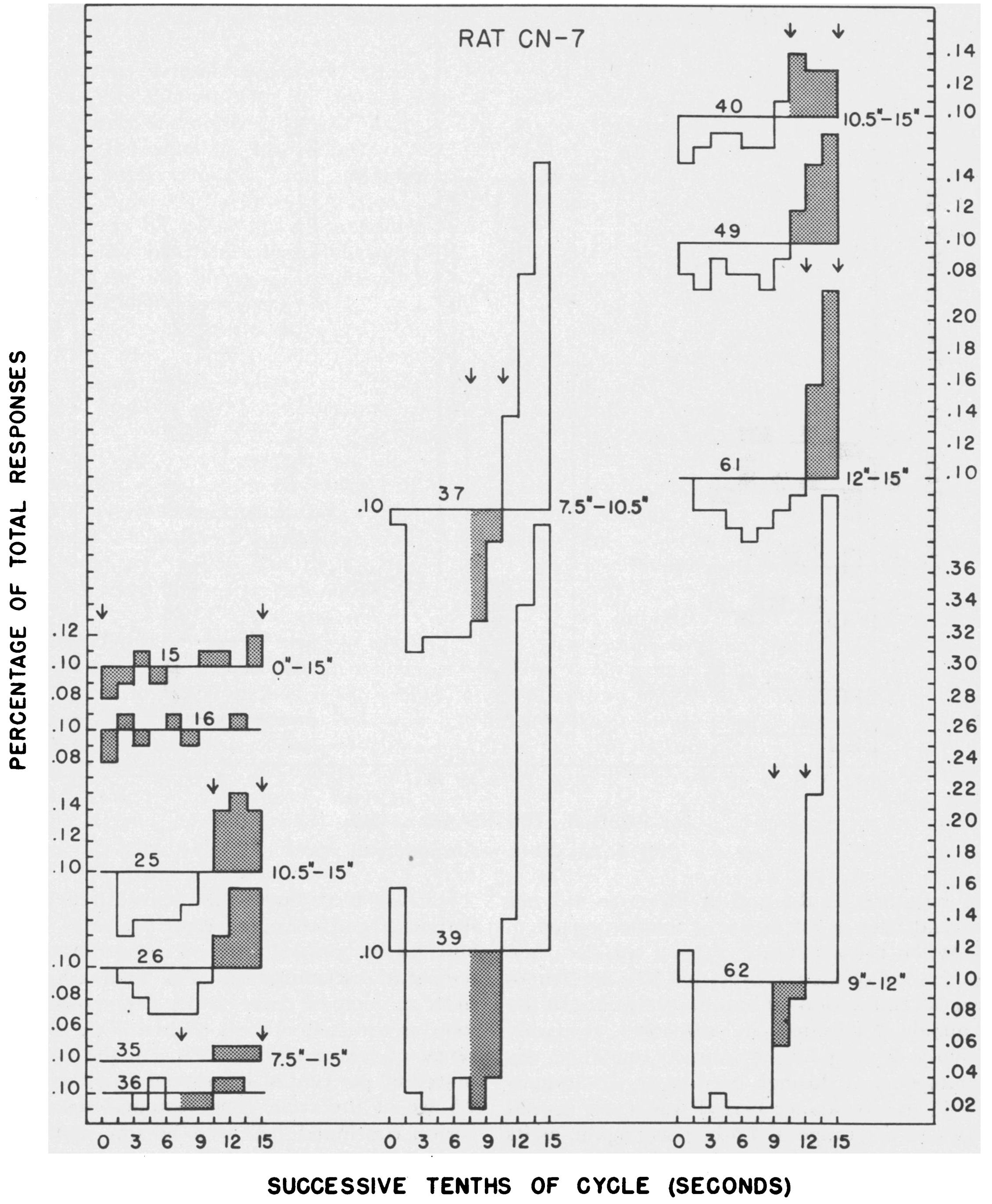

Fig. 6. Rat CN-7. See legend of Fig. 4.

With the avoidance interval equal to the duration of the cycle, Rat CN-7 showed no evidence of temporal discrimination (Fig. 6, Sessions 15 and 16). When the interval was reduced to 4.5 sec, however, response probability rose sharply at the end of the cycle (Sessions 25 and 26). Lengthening the interval to 7.5 sec all but abolished the temporal discrimination. As with the other animals, it appeared in pronounced form when the avoidance interval was shifted away from the end of the cycle (Sessions 37-39). Upon the return to the range of 10.5-15 sec, the discrimination returned to its previous state under this condition (Sessions 40-49), and became even more accentuated when the interval was reduced to 3 sec (Session 61). Again, when the interval was moved back 3 sec to the range of 9-12 sec, the discrimination appeared in extreme form (Session 62).

DISCUSSION

The procedure used in this experiment may be viewed as a method of programing variable response-shock intervals. The time that will have elapsed between any shock and the last preceding response will be a function of both the animal's temporal distribution of responses and the duration and location of the avoidance period. When the avoidance interval terminates contiguously with the end of the cycle, the duration of the interval sets a lower limit on the time that can elapse between response and shock. If, for example, the avoidance interval equals the cycle duration of 15 sec (Fig. 1A), the animal cannot be shocked sooner than 15 sec after it has pressed the lever; when the avoidance period lies between 12 and 15 sec (Fig. 1E), the animal can be shocked within 3 sec after a response, but not sooner.

As we decrease the duration of the avoidance period, therefore, the average response-shock interval is likely to decrease; this is probably sufficient to explain the rate increase that is correlated with the decreasing avoidance interval (Sidman & Boren, 1957).

But along with the increase in rate of response, the animals show a corresponding decline in the efficiency with which they avoid the shocks (Fig. 3). The increasing shock frequency holds the key to an understanding of the changes that take place in the distribution of the animals' lever-pressing responses within the cycle. Once the animal has pressed the lever within the avoidance interval, thereby eliminating the shock that would have marked the beginning of the next interval, it no longer has a reference point from which to locate itself within the cycle. The only time interval of consistent duration is the one between shocks when no successful avoidance response has intervened. For a temporal discrimination to be evident within the cycle, therefore, the animal must receive a substantial number of shocks.

With the avoidance interval terminating at the end of the cycle, two of the animals, CN-7 and CO-40, did not receive enough shocks to demonstrate a substantial temporal discrimination until the interval was reduced to 4.5 sec (Fig. 5 and 6). When the interval was subsequently raised to 7.5 sec for Rat CN-7, shock frequency declined and the temporal discrimination could not be observed. Rat CN-72, which avoided shocks more efficiently than the other subjects at short avoidance intervals, showed only the barest indication of a temporal discrimination when the avoidance interval was reduced to 3 sec (Fig. 4).

By moving the avoidance interval away from the end of the cycle, we set into motion a complex spiralling process that ends up with the disappearance of the animal's avoidance behavior. Let us analyze what happens when we shift the avoidance interval from the range of 7.5-15 sec to one of 7.5-10.5 sec.

First, as we have already seen, reduction of the avoidance interval increases the number of shocks the animal receives and accentuates the temporal discrimination. And now, by locating the interval near the center of the cycle, we remove the lower limit from the response-shock interval. If the animal fails to respond between 7.5 and 10.5 sec, it may be shocked immediately for responses during the final 4.5-sec portion of the cycle. The lever press begins to lose its advantage over other behavior. As response rate declines, shock frequency increases still more, furthering the development of the temporal discrimination, and the animal presses the lever relatively more frequently at the end of the cycle than at the beginning.

When the avoidance interval is at the end of the cycle, the temporal shift in responding permits the animal to avoid shocks. But with the avoidance interval located near the center of the cycle, the concentration of responses at the end of the cycle not only decreases the likelihood that the animal will avoid the shock but also increases the chances that shock will come soon after the animal has pressed the lever. The rate of lever pressing declines still further; shock frequency goes up; the temporal discrimination becomes sharper, making it even more probable that when the animal presses the lever it will do so after the avoidance period has passed. The animal is caught in a vicious cycle. The "danger" period and the avoidance period become more distinctly separated; as the temporal discrimination becomes more sharply defined, the animal's operant response becomes less likely to avoid the shock and more likely to be punished. The process perpetuates itself and the animal eventually stops pressing the lever.

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