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STIMULUS CONTROL OF AVOIDANCE BEHAVIOR[1]

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The introduction of a warning signal preceding shocks greatly increased the effectiveness of avoidance responding. Periods of "warm-up" at the beginning of the session were eliminated, and the number of shocks received by the subjects was greatly reduced. With response-shock interval constant, response rate increased as the interval between the response and the onset of the warning signal was shortened. The response tended to occur shortly after the onset of the warning signal regardless of the duration of these "safe" periods. A greatly elevated response rate was maintained even when the duration of the safe period was reduced to 0.3 sec. Thus, the pre-shock signal obtained nearly exclusive control of the responding and overrode the usual "temporal discrimination" of the response-shock interval.

In discriminated avoidance experiments a warning signal appears a fixed duration before a scheduled shock. Responses terminate the warning signal and postpone the shock. Under these conditions avoidance behavior develops a high probability of occurrence during the signal and a low probability in its absence (Sidman, 1955; Sidman, Mason, Brady, and Thach, 1962; Graf and Bitterman, 1963). The present report describes avoidance behavior which resulted as the interval between the response and the onset of the pre-shock warning signal was systematically varied.

METHOD

Subjects

Two female and one male rat, from Sprague-Dawley stock Holtzman strain, approximately 100 days old at the start of the experiment, were maintained on a free-feeding diet.

Apparatus

The experimental space measured 12 in. by 9 in. by 8 in. Two sides were constructed of sheet metal; the back, top, and door were of clear plastic. The floor of the compartment consisted of steel rods, 3/32 in. in diameter and spaced 5 in. apart. A shielded 10 w bulb at the top of the enclosure illuminated the chamber during the sessions. The response lever was a round brass bar ½ in. in diameter and 2 in. long, located 2½ in. above the grid floor and protruding 1 in. into the experimental space. A clearly audible non-aversive buzz served as the warning signal. The experimental compartment was contained within a sound attenuating chest, and a "white" masking noise was presented throughout.

Direct current shocks 5 ma in intensity were delivered through the grid floor for a 0.5 sec duration. An Applegate constant current stimulator generated the shocks, and a scrambler provided a changing pattern of polarities on the floor grids.

Procedure

The *S*s were initially trained to respond by reinforcing successive approximations to the bar press. This reinforcement consisted of interrupting for 20 to 30 sec the shocks which otherwise occurred at regular 5-sec intervals. When *S*s acquired the response, a non-discriminated avoidance schedule with a response-shock interval of 20 sec and a shock-shock interval of 5 sec was introduced. After each *S* had spent a minimum of 20 hr in this non-discriminated avoidance situation, the conditions were changed so that a warning signal appeared before the shock.

The response-shock interval of 20 sec and the shock-shock interval of 5 sec remained constant, but now a warning signal (S_1) oc-

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curred at a fixed duration after responses. This warning continued until terminated by a response. The time each response delayed the shock is termed the R-S_2 interval, and the time each response delayed the warning signal is termed the R-S_1 interval. R-S_1 intervals of 14, 6, 2, and 0.3 sec were employed. Each R-S_1 interval was scheduled until responding showed no appreciable change in at least eight successive sessions. During this portion of the experiment, *S*-194 and *S*-179 ran daily for 2-hr sessions, whereas *S*-198 ran daily for a 4-hr session. After *Ss* had completed this sequence other procedures were investigated. In an individual session, the various R-S_1 intervals were introduced in an unsystematic order for brief periods. In another session, the R-S_1 interval remained constant, but the shocks were discontinued.

RESULTS

Figure 1 shows the performance of *S*-194 at R-S_1=6 sec, during the 15 sessions before and the first nine sessions after the introduction of the warning signal. With no signal the inter-session response rate fluctuated about a mean of 311 responses per hr. The number of shocks per hour varied between a high of 138 and a low of 78 with a mean of 109 shocks. When the signal was introduced, the response rate increased 33% over the mean non-discriminated rate, whereas the number of shocks gradually decreased so that during the final session the *S* received only 13 shocks.

The effect of varying the R-S_1 interval is shown by the representative cumulative response records in Fig. 2. It can be seen that as the R-S_1 interval decreased, response rate increased. The session-to-session mean variability in response rate fluctuated between ±8% at R-S_1=14 and a ±18% at R-S_1=0.3. At an R-S_1 interval of 14 sec *S*-179 responded for 11 consecutive sessions at a rate of 5 responses per min. If each presentation of the signal produced an avoidance response with a zero latency, the rate of responding would be directly known from the frequency of signal presentations. Thus, at R-S_1=14 sec a rate of 4.28 responses per min would result. The response rate of *S*-179 was obviously very close to this rate. Such stability was observed in all *Ss* and was especially apparent at the longer R-S_1 intervals.

Figure 2 also exemplifies the typical pattern of behavior observed at the onset of each session. (Note first 10 min.) The *Ss* would begin responding following the first presentation of the signal, and the usual periods of "warm-up" (Sidman, 1958), in which the initial response rate remained low and *S* received many shocks, were virtually absent. In fact, so powerful was the control exerted by the signal and its removal that *Ss* occasionally went four to five days without receiving a single shock.

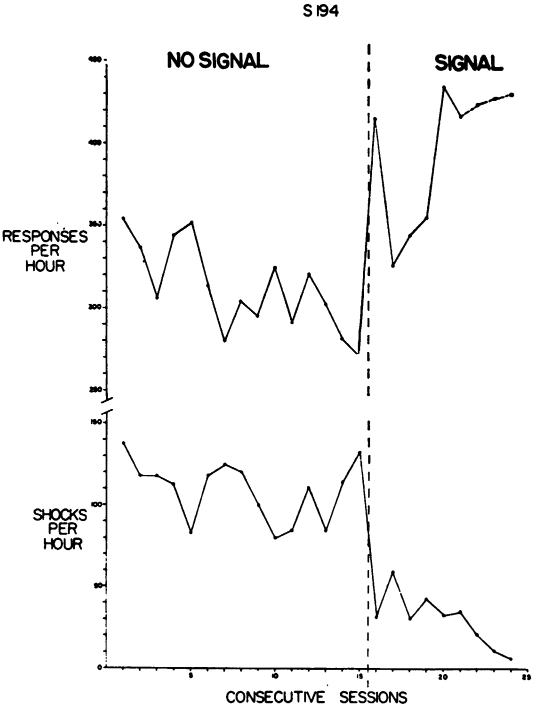

Fig. 1. A comparison of the rate of responses and shocks received during non-discriminated and discriminated avoidance. The left portion shows the response rate and the high frequency of shock during non-discriminated avoidance. The right portion shows the rate of response and shock after the warning stimulus procedure was introduced.

Figure 3 shows the overall picture of the IRT pattern for each *S*. It will be noted that the majority of the responses occurred abruptly within the first two class intervals following the onset of the signal. The figure also shows that the largest per cent of responding in the first two class intervals following the signal appeared at the shorter R-S_1 intervals (R-S_1= 2 and 0.3 sec). In comparison, the responding prior to the onset of the signal was not only

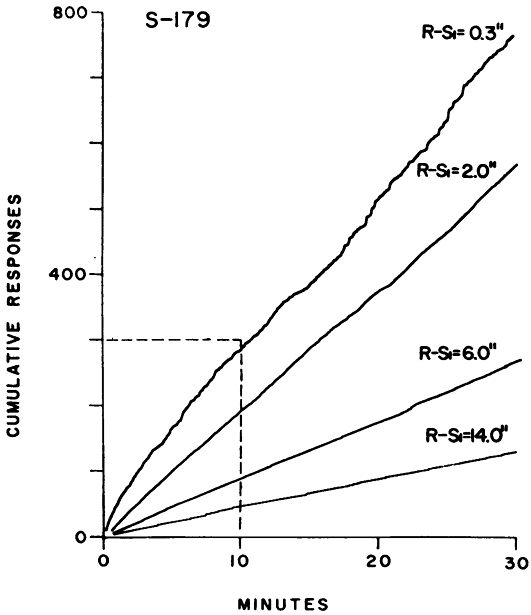

Fig. 2. Typical cumulative response records for a single *S* at each of the various R-S_1 intervals. Those records illustrate the response rate which occurred as a result of shortening the R-S_1 interval and the absence of the usual period of warm-up at the beginning of the session.

lower but fairly constant from interval to interval. During the discriminated avoidance procedure less than 1% of the responses occurred after the 20-sec R-S_2 interval for all but one *S*. This is in contrast to the performance of *S*-194 during non-discriminated avoidance. When there was no signal presented the percentage of responses in each class interval was fairly constant with only a slight decrease in percentage as the 20-sec R-S_2 interval progressed. In this non-discriminated avoidance the abrupt change in responding occurred only after the R-S_2 interval had been completed and *S* had received a shock. The first IRT distribution for *S*-194 (lower left Fig. 3) illustrates this point.

Another example of the amount of control exerted by the warning signal upon responding is given in Fig. 4. This shows the cumulative response curves for *S*-179 during a later session, after many trials with the signal, in which the R-S_1 interval was varied. In the early portion of the session, no warning signal was presented. It can be seen that under these conditions the response rate was low and the *S* received many shocks. Immediately following the introduction of the warning signal

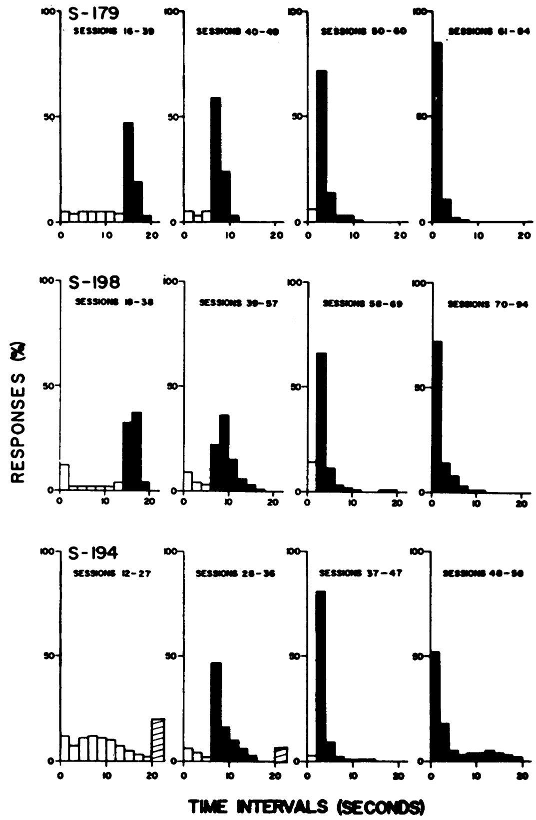

Fig. 3. Frequency distribution of IRTs for the three *Ss*. The white portions indicate responses emitted prior to the warning stimulus; the dark portions indicate responses emitted in the presence of the stimulus and the hatched portions indicate responses emitted during shock (S_2-S_2 interval).

(R-S_1=0.3 sec) the response rate increased markedly and shocks were virtually eliminated. Visual observation showed that the *S* stayed very close to the bar, seldom moving more than a few inches away. The high response rate generated by R-S_1 interval 0.3 sec was immediately altered by extending the R-S_1 interval to 2 sec. As the R-S_1 interval was extended to 6 sec and then to 14 sec the response rate in each case lowered. In all cases the response rate immediately followed changes in the R-S_1 interval. Responding was eventually eliminated however, when the shock contingency was removed, and only the warning signal contingency remained.

DISCUSSION

Using a similar procedure, Sidman (1955) found that avoidance responses soon became

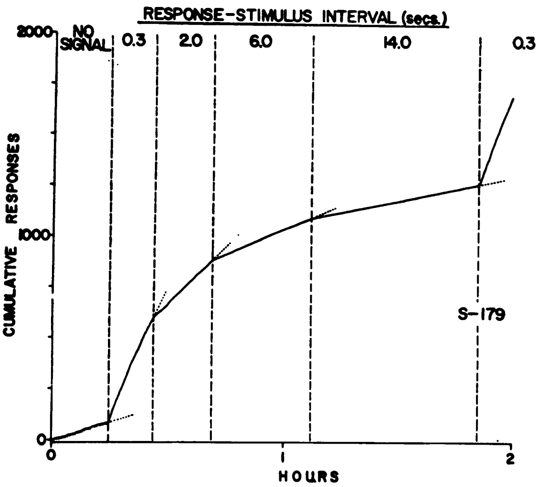

Fig. 4. Cumulative record of the avoidance responses of one *S* during a single session in which the R-S_1 interval was varied.

channeled into the period of the signal with a low response rate in its absence. The stimulus control was much greater, however, in the present investigation. The degree of control exerted by the signal was evidenced by the greatly reduced number of shocks received by the *S*s, and the fact that the signal completely overrode any temporal discrimination of the response-shock interval. In addition, Sidman found a gradual build-up in the frequency of avoidance responses during the R-S_1 interval which made the number of responses just prior to the signal only slightly lower than during the signal itself. In the present experiment the number of responses emitted prior to the signal was relatively constant from second to second with an abrupt change occurring at the onset of the signal.

Another indication of the control exerted by the stimulus was the fact that warm-up periods at the beginning of the session were virtually absent. These findings concerning warm-up are somewhat contrary to those of Hoffman, Flesher and Chorny (1961) who found that the warm-up occurred within a large number of their subjects. No explanation for this difference in warm-up effects is apparent.

Certain differences in results, however, may be related to the following differences in procedure. In the Sidman study the warning signal was terminated by either a response or a shock, whichever occurred first. If the animal permitted 15 sec to elapse without a lever press, a warning signal appeared. If an additional 5 sec elapsed, still without a response, a shock was presented, the signal terminated, and the cycle was repeated. In the present investigation the signal was terminated only by a response. If *S* allowed 20 sec to elapse without a response, a shock was delivered every 5 sec and the signal remained on until a response was made. It is possible that the increased frequency of shocks in the presence of the warning signal increased its effectiveness as a conditioned aversive stimulus. If the signal was a conditioned aversive stimulus, it might be expected that the subjects would work to avoid it (Sidman and Boren, 1957). Since this was not the case, it may be that as a conditioned aversive stimulus the signal was too weak to maintain avoidance but sufficiently strong to maintain escape. Another possible reason for the slight disparity between this and the Sidman experiments relates to the differences between stimulus modalities. Sidman used a flashing light; the stimulus in the present study was a buzzer.

In both Sidman's and the present experiment the absence of the warning signal defined a period of safety from shock. Previous findings (Azrin, Holz, Hake, and Ayllon, 1963) have shown that the safe period must be made contingent upon a specific response and that this safe period be selectively associated with the absence of shocks. The greater control observed in the present experiment could be expected since a consistent response-stimulus relationship of this sort was required.

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