AVOIDANCE CONDITIONING WITH SHOCK CONTINGENT UPON THE AVOIDANCE RESPONSE¹

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Rats learned either a lever-press response, a shuttle response or a one-way crossing response, which produced one immediate shock but was instrumental in avoiding five identical shocks scheduled to occur later. These responses were acquired both with and without support of an escape contingency. These results support shock-frequency reduction as a sufficient condition for the acquisition and maintenance of avoidance.

Most modern accounts of avoidance conditioning involve two factors or processes, one based on Pavlovian conditioning in which a neutral stimulus acquires aversive properties; and the other on an operant paradigm in which an instrumental response removes these conditioned aversive stimuli. Theorists holding this point of view have described avoidance as essentially an escape contingency. It is not the avoidance of shock, *per se*, that reinforces the avoidance response. Rather, in two-process terms, it is termination of the conditioned aversive stimulus that serves as the principal source of reinforcement for avoidance conditioning. Some recent avoidance techniques, such as that of Sidman (1953), have served to question the importance of Pavlovian influences in avoidance conditioning. Sidman's procedure, for example, has no explicit stimulus to signal an impending shock. That is, the conditioned aversive stimulus is not directly observable, and can be identified, if at all, only by inference. Sidman originally chose to infer the existence of the conditioned aversive stimulus in his procedure and accepted a proposal by Schoenfeld (1950) that the avoidance response emerges because all other responses in the situation are suppressed by punishment. By a Pavlovian conditioning process, all be-

havior other than the avoidance response itself becomes aversive through pairing with shock. According to this early position, reinforcement occurs when the avoidance response terminates the aversive stimuli produced by non-avoidance behavior.

Anger (1963), consistently favoring a two-process approach, argued that, in addition to the aversiveness produced by non-avoidance in Sidman's procedure, time correlated stimuli also play a critical role. Successive time intervals since the last avoidance response become increasingly aversive due to their increased proximity to shock. According to Anger, the avoidance response is reinforced by a shift to a post-response time, which is less aversive because shock never follows the avoidance response immediately.

Recently, some investigators in the area of avoidance conditioning (*e.g.*, Herrnstein, 1969) have questioned these extensions of two-process theory resulting from the discovery of new avoidance procedures. Two-process theory's assertion that the avoidance of shock itself is only an incidental aspect of avoidance conditioning has also been challenged. For example, a proposal by Sidman (1962) cited the overall reduction in shock-frequency as the principal source of reinforcement for the avoidance response. However, this proposal suggests that delay of shock onset might also be a factor in avoidance conditioning.

Herrnstein and Hineline (1966) provided data supporting the importance of shock-frequency reduction in avoidance conditioning by showing that an avoidance response will indeed be acquired and maintained if it is instrumental in reducing the overall frequency of randomly occurring shocks. Unfortunately,

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their procedure confounded shock-frequency reduction with average delay of shock onset. In a more recent experiment, Hineline (1970) succeeded in disentangling delay of shock onset from shock-frequency reduction. He found that lever pressing was maintained when it delayed shock, even though it failed to change overall shock frequency. That delay of shock is a sufficient basis for avoidance conditioning now seems clear. Whether it is a necessary condition still, however, remains to be determined.

The present study was designed to examine the feasibility of shock-frequency reduction without delay of shock onset. Conditioning with such a procedure would at once establish the sufficiency of shock-frequency reduction and deny the necessity of shock delay as a source of reinforcement for avoidance. At the same time, it would pose major problems for the early Schoenfeld (1950) view of avoidance, as well as for Anger's (1963) position. The procedures used in this study shared two features: (a) a single shock was made contingent upon the avoidance response, and (b) this punished response was instrumental in avoiding a series of five shocks. Thus, the subjects in this experiment could reduce the overall frequency of aversive events, but only by making a response that produced an immediate shock.

The procedures also varied the roles played by an escape contingency and by the topography of the avoidance response itself. Because, at times, the avoidance response has been considered the conditioned form of the escape response, the role of the escape contingency in the punished-avoidance procedure was studied. In some cases the escape contingency was incorporated; in others it was not. Because some

responses have been shown to be more easily learned than others in an avoidance situation, various response topographies were also studied with the punished-avoidance procedure.

METHOD

Subjects

Nine male, Sprague-Dawley rats, weighing 250 to 350 g at the start of the experiment, were housed individually and given free access food and water in their home cages.

Apparatus

For lever pressing, a Lehigh Valley Electronics (LVE) test chamber, Model 11414 was used. The lever was either a permanently mounted type, LVE Model 1352, or a retractable type, LVE Model 1405 R. Shock was delivered via a LVE shock scrambler Model 1311S, in series with a 150 K ohm resistor. The overhead houselight was a Dialco amber lens containing a Tung-Sol lamp, No. 1829. Events were scheduled through standard switching relay circuitry. For shuttle avoidance, two LVE shuttleboxes, Model 146-14 were used. They were modified in such a way that a guillotine door automatically closed when the animal shuttled or when it failed to respond in an appropriate time interval after tone onset. A 4500-Hz tone was supplied by a Sonalert with a resistor in series to reduce the sound level to 72 dB re., 0.0002 dynes/cm². For one of the shuttleboxes, the shock apparatus and intensity were the same as used for the operant conditioning chamber; for the other; the shock was supplied by a BRS Foringer shock generator Model 901 SG and a BRS Foringer Shock scrambler Model 901 SC.

Fig. 1. A diagram depicting contingencies of the punished avoidance procedure. (A) the no-escape contingency, (B) the punished avoidance contingency, (C) the scheduled series of five shocks and (D) the escape contingency.

Procedure

Figure 1 depicts two basic aspects of the avoidance procedure used in this study. In one case, escape from the series of five shocks was possible, while in the other the possibility of escape was precluded. In the no-escape condition, when no response was emitted in the first 10 sec of an avoidance cycle, (A) the opportunity to respond was eliminated by either lowering the guillotine door or retracting the lever. These events were followed by a train of five shocks delivered one per second from the eleventh to the fifteenth second. However, if the subject did respond, (B) one shock was delivered, the stimulus terminated, the door lowered or the lever retracted, and the five-shock series was avoided. In the escape condition, if a response was not made within the first 10 sec, the five-shock series began (C) and if a response was made during this series, one added shock was delivered and the remaining scheduled shocks were eliminated (D).

Table 1 summarizes the procedures used in this experiment. Rats 1 and 2 were trained by the method of successive approximations to press a lever with termination of a train of 0.8-mA 0.6-sec shocks as the reinforcement. After this escape response was acquired, discrete trial avoidance training was begun. Each daily session consisted of 33, 75-sec cycles initiated by a 10-sec light-on period. If the rat pressed within 10 sec, the light terminated, one 0.8-mA 0.6-sec shock was delivered immediately, but five identical shocks scheduled to occur from the eleventh to the fifteenth second were avoided. If the rat failed to press during the first 10 sec, the light terminated and the five-

shock series began at the eleventh second. A press during this train of five shocks terminated the series. During the remainder of the cycle, lever presses would have produced shock, but none of the rats responded during this part of the cycle.

For Rats 3 and 4, the relations of responses to shocks were essentially the same as that described above, but here, no shaping of the escape response occurred. Concomitant with the onset of the light, the retractable lever was introduced. The lever retracted when pressed or at the end of the train of five shocks. A lever press during the first 10 sec terminated the light; otherwise, the light terminated at the end of 10 sec.

The retractable lever avoidance response was also used for Rats 5 and 6. As before, a lever press resulted in an immediate shock, termination of the light, and avoidance of the five-shock series. However, if the rat failed to press during the first 10 sec, the light terminated, the lever retracted, and five inescapable shocks occurred.

Rats 7, 8, and 9 were run in the shuttlebox with shock intensity and avoidance contingencies identical to those employed in the operant conditioning chambers.

Rats 7 and 8 were run in a procedure equivalent to that used for Rats 5 and 6—the no-escape procedure. Concomitant with the onset of a 10-sec tone, a guillotine door lifted automatically. A shuttle response during the tone resulted in its termination, the lowering of the door, and the immediate delivery of one shock. If a response was not made during this period, the tone terminated, the door lowered, and five inescapable shocks were delivered.

Table 1
Summary of Procedures, Apparatus, and Contingencies

Subjects	Apparatus	Pretraining	Escape or No escape Contingency	Special Feature
1 & 2	lever press chamber	escape shaping	escape	-----
3 & 4	lever press chamber	no shaping	escape*	retractable lever
5 & 6	lever press chamber	no shaping	no-escape	retractable lever
7 & 8	shuttle box	no shaping	no-escape	-----
9	shuttle box	no shaping	no-escape	one-way avoidance

*Following training under the escape contingency the rats were exposed to the no-escape contingency.

A one-way avoidance procedure was used for Rat 9. The procedure and apparatus were identical to those used for Rats 7 and 8, except that approximately 15 sec after a crossing response, the animal was manually returned to the side from which it had crossed. That is, each cycle began with the animal on the same side of the apparatus.

Animals that responded appreciably were exposed to extinction procedures. For Rats 1, 4, and 9 the extinction procedure constituted delivery of the previously avoidable shocks whether the avoidance response was made or not. For Rat 2, extinction involved the elimination of the five scheduled shocks even on trials when animals failed to make the avoidance response. Under both procedures, a response during the first 10 sec still resulted in one immediate shock. Further descriptions of these procedures are provided below.

Rat 1 (preshaped to lever press) avoided the train of five shocks by lever pressing on 50 to 60% of the cycles. On Day 11, extinction was begun. A response in the light-shock interval was followed immediately by one shock and light termination, but did not avoid the train of five shocks. A response during the five shocks, however, continued to terminate the series. After 10 extinction days, the avoidance response had fallen to a level of about 16%. The avoidance contingency was then reintroduced, and responding returned to its former level. Rat 2's performance was lower and more erratic than that of Rat 1. When Rat 2 had responded at about a 40% level for seven days, extinction was begun. Responding during the light-shock interval still resulted in one immediate shock, and light termination, but failure to respond was no longer followed by the train of five shocks. It can be seen that responding immediately dropped to the near-zero level. With reintroduction of the train of shocks, responding immediately rose to the 30 to 40% level.

RESULTS

Figure 2 reveals that, after the second day,

Fig. 2. Per cent avoidance responses in acquisition and extinction for two subjects preshaped to lever press.

Figure 3 shows the performance of Rats 3 and 4 on the retractable lever with no pre-shaping to escape, but with a shock-escape contingency in effect. Rat 3 acquired very slowly, attaining a level of only 40% by the twenty-third session. On the other hand, acquisition was much more rapid for Rat 4 and reached a high stable level of 85% for Days 10 to 13. Both animals were then exposed to a no-escape procedure, in which failure to respond during the first 10 sec led to lever retraction, offset of the light, and delivery of five inescapable shocks. Rat 3 showed a rapid disappearance of the response as the result of this procedure; however, for Rat 4 the decline in responding was much more gradual and erratic, and, in fact, the response was fairly well maintained from Day 14 to Day 36.

Later insertions and deletions of the escape contingency were consistent in elevating and

depressing the response level for Rat 4. The final manipulation for Rat 4 was an extinction procedure in which a response in the light produced one immediate shock, light termination, and lever retraction, but this response was no longer instrumental in avoiding the five shocks. With reintroduction of the avoidance contingency, the gradual decline of responding in extinction quickly gave way to responding at the 80% level.

Figure 4 provides data for the two animals trained on the retractable lever with a no-escape procedure in effect from the start. From Day 1, both animals avoided on 55 to 60% of the cycles. However, in both cases the performance definitely tended to deteriorate.

In view of the failure of this last procedure to maintain responding with the no-escape contingency, it was repeated with shuttle avoidance, a response supposedly closer than

Fig. 3. Per cent avoidance responses in acquisition and extinction for two subjects trained on the retractable lever with the insertion and deletion of the escape contingency.

Fig. 4. Per cent avoidance responses for two subjects trained on the retractable lever with the no-escape contingency in effect from the start.

is lever pressing to a species-specific defense reaction (Bolles, 1970).

Figure 5 shows the performance of the two animals given this no-escape punished avoidance training in the shuttlebox. It can be seen that both subjects responded quite erratically (from 5 to 70% for approximately 26 sessions) with no indication that responding would extinguish with further trials.

Because of the erratic response level with the no-escape shuttle avoidance procedure, one other procedural manipulation was employed in the shuttlebox: a one-way avoidance procedure with the no-escape contingency. Figure 6 shows the performance of Rat 9 on this procedure. It will be seen that, on the whole, this animal's performance, with some fluctuation, remained in the 70 to 80% range for approxi-

Fig. 5. Per cent shuttle avoidance responses for two subjects with the no-escape contingency in effect from the start.

mately 22 sessions. After 28 acquisition sessions, extinction was begun for this animal. Here, responding during the 10-sec tone resulted in one immediate shock, lowering of the door, but did not result in the termination of the tone, nor did this response avoid the five-shock series. Figure 6 shows that after two sessions of extinction, response level had fallen to the near-zero level. With reintroduction of the avoidance contingency, responding rose to its former level. A later deletion and insertion of the avoidance contingency were equally effective in depressing and elevating the response level of Rat 9.

DISCUSSION

Clearly, some acquisition of a punished response that reduces overall shock-frequency occurred under a variety of procedures. Several of the procedures were also fairly successful in maintaining the response. To interpret these

Fig. 6. Per cent one-way avoidance responses for a subject with the no-escape contingency in effect from the start.

results, we must consider whether responding was supported by the avoidance contingency or by adventitious or generalized escape. Morse and Kelleher (1970) showed that termination of a brief shock may reinforce, adventitiously, a shock-producing response. It is also possible that response generalization occurred on the basis of escape from the train of five shocks. That neither form of escape contingency is sufficient to maintain the punished response is revealed by the data for Rats 1, 2, 4, and 9. Removal of the avoidance contingency was accompanied by a rapid or gradual extinction of the punished response, while its re-introduction led to an immediate increase in the level of responding. At least in the case of lever pressing, on the other hand, escape from the train of five shocks was apparently necessary to the maintenance of the punished response, as indicated by the data for Rats 3 to 6. Thus, both escape and avoidance contingencies seemed necessary to maintain the punished lever-press response, but neither was sufficient by itself. The case for the shuttle response is quite different, however. Avoidance of five shocks by the punished crossing response was effective in the complete absence of escape from the five-shock series. Furthermore, an even higher level of responding was maintained by a no-escape, one-way avoidance procedure. These results parallel findings generally obtained with avoidance procedures. That is, difficulty of conditioning increases progressively from one-way avoidance to shuttle avoidance to lever pressing. Bolles (1970) provided much evidence for the importance of compatibility between the avoidance response and species-specific defense reactions for the ease of avoidance conditioning. In combination with the results of the Hineline (1970) experiment, the present study demonstrated that either shock-frequency reduction or delay of shock onset is a sufficient basis for avoidance conditioning.

As stated in the introduction, successful conditioning of a punished avoidance response creates difficulties for certain interpretations of avoidance conditioning. Thus, the early Schoenfeld (1950) view [now abandoned by Schoenfeld himself (1969)] would have to be modified to suggest that the avoidance response may survive, even though punished, because its consequences are still the least aversive of the available response alternatives.

More important for current theory, the impact upon a two-process interpretation, including that of Anger (1963), seems even greater. Presumably the pre-response to the post-response shift in the present investigation is in the direction of greater aversiveness. It is recognized that two-process theorists may not be convinced by this interpretation, insisting that avoidance responding in this study, even though punished, represents a net (perhaps averaged over time) decrease in aversiveness or "fear" relative to the aversiveness that accompanies failure to respond. While such a possibility cannot be ruled out completely, the present results emphasize further the tenuous status of traditional two-process avoidance theories. In the final analysis, this theoretical issue may not be resolvable, a consideration that points to the need for emphasizing empirical determinants of avoidance conditioning, like shock-frequency reduction or delay of shock-onset.

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