The relationship between shock magnitude and passive avoidance learning

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Three experiments examined the relationship between shock magnitude and the rate of acquisition of a passive avoidance response. Experiment 1 indicated that the use of a relatively large magnitude of shock can disrupt learning to remain on a platform in the center of an open field to avoid shock. The inferior learning of the group trained with high shock was replicated in Experiment 2, which also demonstrated that avoidance learning can occur rapidly with this level of shock if the platform is located in the corner of the apparatus. To explain this, it was proposed that thigmotactic behavior is responsible for the disruption in avoidance behavior when training is conducted in the center with high-magnitude shock. Finally, Experiment 3, essentially a replication of Experiment 1 except that the platform was placed in the corner of the test compartment, demonstrated a direct relationship between shock magnitude and passive avoidance learning. The results are seen as being consistent with accounts which maintain that avoidance learning can be influenced by the occurrence of species-specific defense reactions.

An inverse relationship between shock magnitude and the rate of acquisition of a discrete-trial avoidance response has been demonstrated using both two-way avoidance procedures (Bauer, 1972; Cicala & Kremer, 1969; Levine, 1966; McAllister, McAllister, & Douglass, 1971; Moyer & Korn, 1964; Theios, Lynch, & Lowe, 1966) and leverpress avoidance (Bolles & Warren, 1965; D'Amato & Fazzaro, 1966). The overall concern of the present paper is to determine whether this relationship is unique to these two procedures, or whether it also extends to a rather different discrete-trial avoidance task, specifically, step-down passive avoidance. Accordingly, the first experiment examines the influence of shock magnitude on the rate at which rats learn to remain on a small platform to avoid shock.

One account for the inverse relationship can be developed by referring to the species-specific defense reactions (SSDRs) which a number of authors (e.g., Bolles, 1971) maintain are elicited by aversive stimuli. Bolles (1971) has suggested that two prominent SSDRs in the rat are freezing and fleeing to safety. If it is assumed that the strength of these responses is determined by the intensity of aversive stimulation, then it is possible to provide a relatively straightforward explanation for the disruption of both leverpress and two-way avoidance learning by high magnitudes of shock. There is no reason to suppose that an SSDR

of freezing or of fleeing to safety should be compatible with either leverpressing or returning to an area in which shock has previously been presented, which are the requirements of the avoidance tasks under discussion. Instead, the occurrence of these SSDRs during avoidance training is likely to be disruptive. Furthermore, since a more aversive environment will elicit stronger SSDRs, the extent of the disruption can be expected to be greater with higher levels of shock (Theios et al., 1966).

An implication of this analysis is that the inverse relationship might not be expected to hold in the proposed experiment since the avoidance response of remaining on a platform is compatible with the SSDR of freezing. Thus, although it is difficult to specify in advance under what circumstances freezing can be expected, it is at least plausible that the occurrence of a stronger freezing response with higher levels of shock should facilitate rather than disrupt step-down passive avoidance learning.

EXPERIMENT 1

Method

Subjects. The subjects were 32 male hooded Lister rats bred in the Animal House at the University of Sussex. They were approximately 3 months old at the start of the experiment.

Apparatus. The passive avoidance compartment was a 40-cm-square box, with walls 60 cm high made from 3-mm-thick hardboard sheet. The floor was composed of stainless steel rods 6.4 mm in diameter spaced 1.9 cm center to center. The floor could be electrified by a Grason-Stadler shock generator (E 1064 GS). A 13-cm-square hardboard platform, 5.7 cm high, was placed in the center of the floor. A loudspeaker mounted beside the top of the compartment delivered white noise at a level of 70 dB re 20 μ N/m².

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Procedure. In order to obtain stable baseline levels of performance, the subjects initially received five daily habituation trials. At the start of each trial, the subject was placed in the center of the raised platform and the time taken to place all four paws on the grid was recorded. Ten seconds later, the subject was removed from the compartment and returned to its home cage.

Starting on the day following habituation training, the subjects received eight avoidance trials, one per day. These were identical to the habituation treatment except that all subjects received a shock immediately after they placed four paws on the grid. They were removed from the apparatus 10 sec after the occurrence of shock. During this 10-sec period, it was possible for a subject to return to the platform and then return to the grid, but these subsequent step-down responses were not followed by shock. If, on any trial, a subject remained on the platform for 1 min, it was gently lifted from the apparatus and returned to its home cage. Before habituation training, the subjects were randomly divided into four equal groups, which received different magnitudes of shock during the avoidance training. Shock values for the groups were .3 mA, .2 sec; .5 mA, .2 sec; .5 mA, .5 sec; and 1.0 mA, .5 sec.

Results

The mean step-down latencies for each group for the avoidance training trials are shown in Figure 1. (The first trial was eliminated from the analysis.) This shows that the latency to step from the platform increased for all groups as training progressed. By the final training trials, the distributions of step-down latencies were so skewed in all the groups that it was considered inappropriate to use a parametric test for statistical analysis. Accordingly, the results from all the experiments reported in this paper have been analyzed using nonparametric tests. In order to compare the baseline step-down behavior of the groups, the latencies to step from the platform on the first avoidance trial were analyzed using the Kruskal-Wallis one-way analysis of variance (Siegel, 1956). This revealed that there were no

Figure 1. Mean step-down latencies for the last seven trials of passive avoidance learning of Experiment 1.

Figure 2. Distributions of individual median step-down latencies in Experiment 1.

significant differences between the groups at this stage ($H = 1.2$, $p > .50$). In order to compare the overall avoidance behavior of the groups, mean step-down latencies were computed for each subject averaged across the six remaining avoidance trials. Analysis of these scores revealed that groups differed in their step-down latencies ($H = 9.89$, $p < .02$). Post hoc comparisons between pairs of groups using the procedure suggested by Dunn (1964) indicated that the latencies for the .5-mA, .5-sec shock group were significantly greater than those of the 1.0-mA, .5-sec shock group ($p < .05$). The differences between the .5-mA, .5-sec shock group and the remaining two groups just failed to reach significance at a conventional level ($.10 > ps > .05$).

To examine in more detail the differences between the groups, histograms representing individual median step-down latencies for the final six trials of avoidance training were constructed for each group. These are presented in Figure 2. The striking feature of these histograms is that the response latencies in the 1.0-mA, .5-sec shock group are located at the extremes of the abscissa, while for the other groups the latency scores are either more uniformly distributed (.3-mA, .2-sec and .5-mA, .2-sec shock groups) or they are situated in the interval for the highest latencies (.5-mA, .5-sec shock group). Because of the small number of subjects in each group, these observations are difficult to confirm statis-

tically. However, analysis using the Fisher exact probability test (Siegel, 1956) revealed that significantly more subjects in both the 1.0-mA, .5-sec and the .3-mA, .2-sec shock groups responded with median latencies of less than 20 sec than did subjects in the .5-mA, .5-sec shock group ($ps < .05$).

Discussion

The results suggest that increasing shock intensity up to a point can facilitate passive avoidance learning. However, at the highest magnitude of shock employed, this relationship was found to be reversed, since avoidance learning was significantly faster in the group trained with a moderate level of shock. These results, then, demonstrate that the inverse relationship between acquisition and shock intensity observed in certain active avoidance procedures can also be obtained, given shock of a sufficient magnitude, in a passive avoidance paradigm.

It was argued, in the introduction, that passive avoidance training with high levels of shock might be facilitated by the occurrence of a strong SSDR of freezing. In order to account for the failure to confirm this prediction, it could be argued that the present experiment provided the opportunity for a different and potentially disruptive SSDR to occur. In addition to the SSDRs described by Bolles (1971), Grossen and Kelley (1972) have proposed that an additional SSDR is thigmotactic behavior (tendency to run for contact with objects). In support of this, they have demonstrated that the amount of time rats spend in contact with the walls of an open field can be increased by occasionally presenting footshock in that environment. With this in mind, it is possible that passive avoidance training, with the platform in the center of the apparatus, increases the strength of two incompatible responses. One of these is the avoidance response of remaining on the platform, while the other is a thigmotactic response of fleeing to the side. The above results suggest that it is only with higher levels of shock that the thigmotactic response will predominate and disrupt avoidance learning. In those subjects in which this behavior does predominate, it would be expected that step-down latencies should be comparatively short, while in the remaining subjects step-down latencies would be considerably longer. In passing, it can be noted that this analysis would account for the bimodal distribution of step-down latencies observed in the highest shock group.

If thigmotactic behavior was responsible for the disruption of passive avoidance learning at the highest magnitude of shock, it should be possible to reduce this effect by placing the platform in the corner of the apparatus. Under these circumstances, thigmotactic responses should not be disruptive, since by remaining on the platform the rat can also maintain contact with the walls of the apparatus. In order to test this argument, the next experiment examined passive avoidance learning with

high-magnitude shock in two groups. One group received habituation and passive avoidance training with the platform in the center of the compartment; for the other group, this training was conducted in the corner. According to the preceding discussion, avoidance learning should be disrupted only for the group with the platform in the center.

EXPERIMENT 2

Method

Subjects and Apparatus. The subjects were 20 male hooded Lister rats which were approximately 3 months old at the start of the experiment. The avoidance apparatus described in Experiment 1 was used.

Procedure. This was similar to the procedure of the previous experiment. A center group ($N = 10$) received the five habituation and eight avoidance trials with the platform in the center of the apparatus. For a corner group ($N = 10$), this training was conducted with the platform placed in one corner. The shock was 1.0 mA, .5 sec for both groups.

Results and Discussion

The mean step-down latencies of the last seven trials for the two groups are shown in Figure 3. There was no difference between the step-down latencies for the groups on the first avoidance trial. ($U = 31, p > .10$). Analysis of individual mean step-down latencies for the remaining six trials revealed that avoidance performance was superior in the corner group ($U = 15, p < .02$).

The distribution of individual median step-down latencies for the center group during avoidance training was similar to that of the 1.0-mA, .5-sec group in the first experiment. Four subjects responded with median latencies of less than 20 sec, while for the remainder of the group median latencies exceeded 40 sec. All subjects in the corner group responded with median latencies of

Figure 3. Mean step-down latencies for the last seven trials of passive avoidance learning in Experiment 2.

greater than 40 sec. The difference between the groups in the number of subjects responding with a latency of less than 20 sec was significant ($p < .05$, Fisher test).

The performance of the center group was disrupted in a very similar manner to the group trained with the same level of shock in the previous experiment. This result, together with the satisfactory learning in the corner group, is consistent with the argument that thigmotactic behavior is responsible for the disruption in passive avoidance learning with high levels of shock when the platform is in the center of the compartment.

EXPERIMENT 3

This experiment examined the acquisition of the step-down passive avoidance response at various magnitudes of shock when the platform was placed in the corner of the apparatus. According to the account outlined in the introduction, the occurrence of stronger SSDRs with higher levels of shock, especially freezing and thigmotaxis, should facilitate avoidance learning under these circumstances.

Method

Subjects and Apparatus. The subjects were 32 male hooded Lister rats, approximately 3 months old at the start of the experiment. The avoidance apparatus described in Experiment 1 was used.

Procedure. The procedure was similar to that used for the corner group of the previous experiment. At the start of the experiment, the subjects were randomly assigned to four equal groups. All subjects received five habituation trials and four avoidance trials with the platform in the corner of the avoidance compartment. The shock parameters for the groups were: .5 mA, .2 sec; .5 mA, .5 sec; 1.0 mA, .5 sec; and 2.0 mA, .5 sec.

Results and Discussion

The median step-down latencies for the four groups are shown in Figure 4, which reveals that learning occurred in all groups but most slowly in the group trained with the lowest magnitude of shock. There were no differences between the step-down latencies for the groups on the first avoidance trial ($H = 1.8$, $p > .50$). Analysis of individual mean step-down latencies for the remaining three avoidance trials indicated that there was a significant difference between the groups ($H = 9.1$, $p < .05$). Subsequent multiple comparisons using Dunn's (1964) procedure indicated that step-down latencies in the .5-mA, .2-sec shock group were significantly less than either the 1.0-mA, .5-sec or the 2.0-mA, .5-sec shock groups ($ps < .05$).

On the final trial of avoidance training, seven out of eight subjects in the lowest magnitude shock group remained on the platform for 60 sec and thus avoided shock. All subjects in the other three groups successfully avoided shock on this trial.

The superior performance of the high shock groups compared with the lowest shock groups suggests, given the appropriate circumstances, that it is possible to

obtain a direct relationship between shock magnitude and passive avoidance learning. The failure to find a disruption in avoidance learning with the highest levels of shock extends the results of Experiment 2, and therefore provides further support for the thigmotactic explanation that the second experiment was designed to test.

GENERAL DISCUSSION

The relationship between shock magnitude and step-down passive avoidance behavior has been shown to depend critically upon the location of the platform. An inverted-U relationship was observed when the platform was placed in the center of the apparatus and a direct relationship was obtained with the platform in the corner.

It has been assumed so far that the response of remaining on the platform was at least in part a consequence of instrumental avoidance learning. However, rather than reflecting the existence of such learning, it could be the case that this response was due entirely to the occurrence of an SSDR of freezing. Bolles and Collier have defined freezing as "the absence of bodily movements together with the absence of the whisker and nose movements characteristic of sniffing" (Bolles & Collier, 1976, p. 6). It is clear that if this response were to occur as soon as subjects were placed on the

Figure 4. Mean step-down latencies for the four trials of passive avoidance learning in Experiment 3.

avoidance platform then this would be sufficient to avoid shock. However, the subjects in Experiment 1 and in the center group of Experiment 2 were observed while they remained on the platform in the center of the apparatus, where only the SSDR of freezing could be expected to account for avoidance behavior. It was apparent that, although most subjects spent at least some of the time on the platform in a freezing posture, they also engaged in other behaviors. Two frequent behaviors were (1) rearing and (2) starting to step onto the grid and then withdrawing to the center of the platform. In view of these observations, it is reasonable to conclude that some additional factor to freezing was responsible for the successful avoidance behavior and that this factor was avoidance learning.

Support for this conclusion can be found in an experiment by Barcik (1972), which compared step-down passive avoidance behavior of the two groups. One group received an avoidance training trial in which stepping from a platform was punished by electric shock. The other group experienced one trial in which subjects were placed in front of the platform and received a similar electric shock. Barcik (1972) argued that if freezing is solely responsible for passive avoidance behavior, then subsequent step-down performance should be the same for both groups. In fact, he found that avoidance behavior was superior in the group which had received the initial conventional passive avoidance training trial, which suggests that the contingency between the step-down response and shock is responsible for an instrumental component of step-down passive avoidance behavior.

If it is accepted that an instrumental avoidance response is acquired by some subjects during passive avoidance training, then the influence of variations in shock magnitude on the acquisition of this response should be considered. Although there is no generally accepted account of the passive avoidance learning process, most explanations assume that the conditioning of fear to cues produced by feedback from the punished response plays a central role in maintaining avoidance behavior (e.g., Mowrer, 1960). According to this class of account, therefore, increasing shock magnitude should increase the strength of the conditioned fear response and facilitate step-down passive avoidance learning. Clearly, this analysis can account for the direct relationship found both in Experiment 3 and in the lower shock group of Experiment 1. It is, however, unable to explain the disruption in avoidance learning with high levels of shock when the platform is in the center of the compartment. Instead, the most plausible account for this result appears to be the thigmotactic argument developed in the Discussion of Experiment 1.

There is an obvious alternative to the preceding explanation for the direct relationship between shock intensity and step-down passive avoidance learning. The use of stronger shock could have elicited a more intense SSDR of freezing, and this would clearly facil-

itate avoidance behavior. Unfortunately, on the basis of the present evidence, it is not possible to choose between these two alternatives. Parenthetically, it should be noted that McAllister et al. (1971) have developed a theory specifically to account for the relationship between avoidance learning and shock intensity. Although this differs from the accounts discussed above, it has not been applied to the present results, since it is not at all clear whether their theory is in fact appropriate for instances of passive avoidance behavior.

In conclusion, the present results are consistent with those accounts which attribute inferior avoidance learning with higher levels of shock to the disruptive influence of SSDRs. Furthermore, in addition to the more frequently cited responses of freezing and fleeing to safety, the results from Experiments 1 and 2 indicate that under the appropriate circumstances thigmotactic behavior should also be considered as a potentially disruptive SSDR.

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