Fear-increasing effects of experience with shock

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Rats given inescapable shock or confined but not shocked were then tested in an escape task or in an open field. Shock-experienced rats were least mobile in the open field. Inexperienced rats started off with faster response speeds in the escape task, but experienced rats exhibited significantly more stable improvement in escape performance from trial to trial.

When animals are given postweaning experience with shock stress, their later performance in the face of stress is altered. However, the direction of the residual effect of shock experience on performance is in dispute. Effects facilitative (Miller, 1960; Baron, Brookshire, & Littman, 1957; Sawrey & Sawrey, 1960) and disruptive (Kurtz & Pearl, 1960; Kurtz & Walters, 1962) of performance have both been experimentally demonstrated.

Investigating the possibility of habituation to shock stress, Miller (1960) trained rats to run in a straight alley for a food reward. Following acquisition, an experimental group received a series of shocks in the goalbox, while controls were given further trials without shock. When shock was introduced for controls as well, their running speed was reduced significantly more than that of the shock-experienced rats. From these findings, Miller concluded that the shock-experienced rats had learned to approach in the presence of fear cues. While demonstrating that the rats differed in *performance in the face of fear,* Miller's data leave the question of whether or not the groups differed in *level of fear* as well. Empirically consistent with Miller's results are the findings of Baron, Brookshire, & Littman (1957), which demonstrated that rats given experience with shock subsequently had shorter latencies in both escape and avoidance tests than did inexperienced rats. The authors concluded that "... the early acquaintance with shock mitigates its disruptive effects and permits more integrated behaviour."

The Miller and Baron et al experiments were concerned primarily with an empirical demonstration of the relationship between prior shock experience and later performance. More theoretically oriented are the efforts of Kurtz and his associates (Kurtz & Pearl, 1960; Kurtz & Walters, 1962), who studied the role of fear in mediating this relationship. Kurtz & Pearl (1960) found that, compared to nonshocked controls, rats exposed to inescapable shock showed greater resistance to extinction of a shock-based avoidance response. This suggested to the authors that their shocked rats were more fearful during extinction. Elaborating on the fear hypothesis in a later experiment, Kurtz & Walters (1962) gave one group of rats inescapable shock, while controls were confined but not shocked. Subsequently, both groups were trained to approach for food in a straight alley and learned equally well. When shock was introduced in the goalbox, however, the performance of rats *without* shock experience was less disrupted than that of experienced rats.

The present experiment was designed to clarify three basic issues that are involved in this area. Rats were first exposed to inescapable shock or confined but not shocked. Within each of these groups, half were then tested for performance in a simple escape task. This permitted an assessment of the effect of shock experience on *performance efficiency.* The remainder were given an open-field test of emotionality that permitted an evaluation of the extent to which escape differences might be attributable to *differences in fearfulness.* The latter test further permitted an evaluation of the residual effect of shock experience in a *situation not involving shock or pain.* If, as Kurtz & Walters (1962) claim, the effect of shock experience is to produce latent differences in fearfulness that become manifest in fear-provoking situations, the effect should be general.

PROCEDURE

Subjects

The Ss were 60 female Sprague-Dawley rats, approximately 70 days old at the start of testing. The rats were housed in groups of five in wire-mesh cages, 16 x 10 x 7 in. They were maintained on an ad lib feeding and drinking schedule.

Training with Inescapable Shock

Thirty Ss received 4 days of training with inescapable shock, while the remaining 30 Ss served as nonshocked controls. On each training day, shocked Ss received 20 consecutive 1-mA shocks, separated by randomly interspersed intervals of 3, 4, or 5 sec. These unsignaled shocks had a duration of 2 sec. With each shocked rat, a paired nonshocked control was placed in an identical adjacent apparatus and confined for the duration of the shocked rat's treatment. Thus, except for the shock, all rats received identical stimulation and handling. The two shock boxes were 7 x 9 x 8 in., with one Plexiglas and three aluminum walls and a Plexiglas top that could be latched to prevent escape. The floor of the shock box for experimental animals was electrified via an Applegate constant-current shock source and scrambling device.

Escape Training

On the 5th day of the experiment, 15 shock-experienced rats and 15 nonshocked controls were selected randomly for testing in an escape-learning task. The test apparatus was a modified Miller-Mowrer shuttlebox divided into two compartments with a 3 x 5 in. connecting doorway. Each compartment was 11½ x 10 x 15 in. high. The compartments differed only in that one was painted flat black and the other flat white. The floors of both compartments were composed of 3/16-in. stainless-steel bars set ¾ in. apart; only the floor of the white side was electrified by an Applegate constant-current shock source.

All 30 rats were given 10 consecutive test trials. The grid on the white side of the shuttlebox was electrified with a constant 1-mA shock before an S was placed in it. Ss were introduced into the rear of the compartment parallel to the rear wall and released as they made contact with the grid. The guillotine door separating the two compartments was open on each trial. The correct escape response was passing through the open door into the unelectrified black compartment. The guillotine door was shut following a successful escape, and the rat was confined in the black compartment for 30 sec. It was then picked up and the next trial begun. The measure of performance efficiency was the time following placement into the white compartment until an escape response had occurred. Successful escape was defined as passage of the whole of the rat's body, exclusive of the tail, into the black compartment. Escape latencies were recorded on an automatic timer in hundredths of seconds.

Open-Field Test

The open-field test was selected because it is generally considered (e.g., Denenberg, 1967) to be a fear-provoking situation for rats, providing a fairly direct assessment of emotionality. The 15 shock-experienced rats and 15 controls that had not been used in the escape task were given this test on the 5th day of the experiment. The apparatus was a circular open field, 4 ft in diam, with walls 18 in. high. The wooden floor was marked off with black lines into 49 sections of equal area and approximately equal shape by a series of concentric circles and radii. A 150-W bulb was hung 5 ft above the center of the apparatus.

Table 1
Mean Speed of Escape Response

Group	Trial 1	2	3	4	5	6	7	8	9	10
Shock Experienced	.35	.51	.60	.77	.92	1.12	1.50	1.41	1.57	1.68
Inexperienced	.76	.70	.81	.53	.82	1.10	1.62	1.25	1.43	1.57

Each rat was placed into the open field for a 5-min period. Rats were introduced in the center circle of the field. At 5-sec intervals, the position of the rat in the field was observed. This permitted the calculation of a "freezing" score, which was the number of consecutive intervals in which a rat was observed in the same numbered section. This score ranged from 0 to 59. The higher the score, the greater the freezing, and inferentially, the greater the rat's fear in the open field. A second measure of fear was the number of fecal boluses dropped during the 5-min test period. At the end of each period, these were counted and removed from the field in preparation for the next rat. Higher defecation scores were taken to indicate greater fear. The field was wiped clean with a damp sponge between trials.

RESULTS

Escape Test

Before analysis, latency scores were converted to speed scores by taking reciprocals. The mean speed of the two groups on each trial is shown in Table 1.

Early during acquisition, shock-experienced rats took longer to escape than did inexperienced controls. On Trial 1, experienced rats had a response speed of only .35, compared to .76 for inexperienced rats ($t = 2.08$, $df = 28$, $p < .05$). By Trial 4, however, experienced rats had overtaken and surpassed inexperienced rats in speed on remaining trials, with the exception of a slight reversal on Trial 7. The Condition by Trial interaction was significant beyond the .025 level ($F = 2.26$, $df = 9/252$). There was no main effect of shock experience ($F < 1.00$).

Overall, there was a highly significant improvement over trials ($F = 11.29$, $df = 9/252$, $p < .001$). However, acquisition clearly differed in the two groups, as can be seen, in part, in Table 1. Shock-experienced rats showed regular increments in speed from trial to trial, while inexperienced rats did not improve as consistently. This difference was examined in a trend analysis of the linear component of the Condition by Trial interaction of the analysis of variance. There was some suggestion that the linear components of the two acquisition curves differed ($F = 3.24$, $df = 1/28$, $p < .10$). The difference in acquisition of the experienced and inexperienced groups showed up still more clearly in a further analysis. A quantitative index of the difference was obtained by calculating, for each S, the number of occasions on which response speed on Trial n + 1 was slower than it was on Trial n. For shock-experienced rats, the mean was 3.13, compared to 4.83 for inexperienced rats, a highly significant difference ($t = 4.83$, $df = 28$, $p < .001$). In summary, independent of the overall level of performance, experienced rats "benefited" from shock in that their escape learning was more consistent and stable over trials.

Open-Field Test

The basic measure of fear in the open field was the "immobility index," or the number of consecutive 5-sec intervals in which a rat was observed in the same numbered section of the open field. The mean immobility score of shock-experienced rats was 29.66 and of inexperienced rats, 18.53. This was a significant difference ($t = 2.25$, $df = 28$, $p < .05$). The defecation data were consistent with the immobility index, but the mean of 5.0 boluses dropped by the shock-experienced rats was not significantly higher than the mean of 4.1 for inexperienced rats.

Qualitative Differences

In both groups, the response to shock on the white side of the box consisted of leaping, squealing, and general agitation prior to escape. However, one provocative difference between the groups was in their behavior immediately following an escape response. While both shock-experienced and inexperienced rats apparently found the shock itself aversive, for experienced rats, the agitated behavior was confined to shock reception only. Following a successful escape, these rats remained quietly in the black compartment. When they were picked up to begin the next trial, they offered no resistance to handling.

The pattern following successful escape for inexperienced rats was markedly different. Not infrequently, these rats leaped to the top of the 15-in.-high walls of the "safe" (black) compartment in an attempt to escape and had to be forced back into the black compartment. Often, when they were picked up to begin a new trial, there was fierce resistance to handling and considerable vocalization. Thus, controls appeared more afraid than shock-experienced animals in the black compartment. Perhaps experimental animals, differing from controls only in their experience with inescapable shock, more easily learned the difference between "safety" and "danger."

DISCUSSION

The effect of experience with inescapable shock was to facilitate performance during shock-motivated escape learning, especially in regard to the stability of the escape response. Insofar as experience with shock had a facilitating effect on performance, our results parallel those of Baron et al (1957) and Miller (1960) and are at variance with those of Kurtz & Walters (1962). However, as far as fear is concerned, our findings support Kurtz and Walter's hypothesis that the effect of experience with shock is to increase the strength of the fear response in a fear-provoking situation.

This theoretical conclusion is not dependent on the escape data alone. In fact, these data by themselves are in support of no particular theoretical stance, since there is no way a priori to predict the relationship between fear and performance in a given test situation. The fact that fear may be facilitative in some instances and deleterious in others requires an assessment of fear independent of performance efficiency alone. It was for this reason that the open-field test was included. The increased freezing of the shock-experienced rats suggests that the effect of previous shock stress was to make them respond more fearfully to the open-field situation. That this difference appeared in a situation radically differing from the escape test, both in topological characteristics and *in the absence of shock or pain*, demonstrates the generality of the residual effect of the shock experience, and thereby provides crucial support for the fear hypothesis of Kurtz and Walters.

The escape data illustrate the importance for later behavior of what has been learned during the initial experience with shock. The adaptive response to inescapable shock was leaping off the grid. When shock became inescapable, this behavior was no longer adaptive and, in fact, temporarily interfered with the acquisition of behavior appropriate to the new situation. Only when the maladaptive behavior had extinguished did the greater fear of the shock-experienced rats facilitate performance.

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NOTE

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Failure of visual generalization following auditory avoidance training

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Following avoidance training to an auditory stimulus (buzzer), Ss received generalization testing to changes in a background visual cue (light). Results suggested that changes in avoidance behavior due to the presence of light were related to the aversive properties of light rather than to a generalization phenomenon. It was concluded that light may be an irrelevant stimulus, particularly in an avoidance situation and in the presence of a strong CS, such as a buzzer.

Generalization testing to changes in background cues has been demonstrated on several occasions. Changes in light, tone, stimulus size, and other background cues have been shown to produce decrements in both approach (Fink & Patton, 1953; Healey, 1965) and avoidance (Desiderato et al, 1966) behavior. But some studies were not able to demonstrate this phenomenon. Hearst (1965) demonstrated that lever pressing in an avoidance situation was unaffected by the presence or absence of a light. Ferster (1951) was unable to demonstrate generalization to a light cue, using a lever-pressing-approach response. It was the purpose of this study to examine the generalization gradient to changes in a visual background cue of an avoidance situation where sound was the CS. Since generalization is often greater at some acquisition levels than at others, the number of training trials was included as a parameter.

SUBJECTS AND APPARATUS

The Ss were 50 male Sprague-Dawley-Wistar rats, weighing 200-250 g. The apparatus was a 22 x 10 x 6 in. shuttlebox, painted flat black except for a 6 x ½ in. observation window. A 4-in.-wide guillotine door divided the box into a grid-floor conditioning compartment and a smooth-floor escape compartment. The grid could be charged with 1.0 mA from a Grason-Stadler Model E1064GS shock apparatus. A 100-dB buzzer rested in the center of and immediately behind the shuttlebox. A potential light source of 120 W came from a 6-in. circular opening in the escape-compartment wall opposite the door. Light intensity could be regulated with a Variac. Background noise and light were provided by an overhead fan and a 6-W overhead bulb, respectively. The door, buzzer, and light were hand-operated. A standard electric clock that started with CS onset and stopped with CS termination measured response latency.

PROCEDURE

Four groups of 12 Ss received a 3-min exploration in both compartments. Immediately thereafter, the door was opened simultaneously with the presentation of a 4-sec buzzer CS, followed by and continuous with a 1-sec-on/1-sec-off UCS for a maximum of five shocks or until S escaped. The light stimulus was off during training trials. The intertrial interval averaged 30 sec, following which S was manually returned to the conditioning compartment. Ss were trained to one of four criteria: (a) until 2 out of the last 3 trials were avoidances, (b) 8 out of the last 10 trials were avoidances plus 10 additional training trials, (c) 8/10 criterion plus 30 additional trials, and (d) 8/10 criterion plus 60 trials. Generalization testing began 24 h later by placing S in the conditioning compartment facing the door. Thirty seconds later, the door was opened simultaneously with the presentation of a continuous CS plus one of three light intensities (110 V, 55 V, 0 V). When S entered the escape compartment, the door was closed, CS and light were terminated, and the latency was noted. Thirty seconds later, S was returned to the conditioning compartment. A total of 18 such test trials were given to each S, 6 trials to each light intensity. Light intensity greater than 0 but less than 55 V was not included because a pilot study indicated that light of weaker intensity did not seem to have an effect on avoidance. The order of light intensities was random within blocks of three. If no response occurred within 30 sec of the test trial, CS and light were terminated, the door was closed, and S was handled for 3 sec before commencing the next intertrial interval of 30 sec.

In order to determine whether latency differences reflected differences in the noxious properties of varying light intensities rather than generalization, a control group was used. Eight Ss were trained to a 2/3 criterion with a buzzer CS and a continuous 110-V-light background cue. Testing was identical to that for the experimental groups.

RESULTS

The mean reciprocal latency to each light intensity for each S became the score unit employed in the analysis of variance. The mean reciprocal latency for each group is plotted as a function of the light intensity in Fig. 1. The reciprocal latency to the training background cue (0 V, no light) tended to increase with increasing training trials ($p < 0.1$) except for the 2/3 group, which had a greater reciprocal latency than the 8/10 + 10 group (although not statistically significant). The reciprocal latency of all groups, including the control group, tended to decrease with increasing light intensities ($p < .01$), but there was no significant interaction between the slopes.

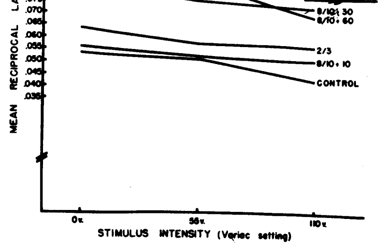

Fig. 1. Mean reciprocal latencies to three light stimuli as a function of training criterion. Control group was trained with 110-V light to a 2/3 criterion.