Journal of
Experimental Psychology

VOL. 60, No. 3 SEPTEMBER 1960

LEARNING RESISTANCE TO PAIN AND FEAR: EFFECTS OF OVERLEARNING, EXPOSURE, AND REWARDED EXPOSURE IN CONTEXT[1]

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This study grows out of theoretical applications of learning principles to mental health by Dollard and Miller (1950) and to fear in combat by Miller (1954). It is a first step toward systematic experimental investigation of the general problem of whether resistance to stressful situations, especially fear-evoking ones, can be learned. If such learning is possible, what are the laws determining its effectiveness and generality?

One common type of stress situation is that in which *S* is in conflict because he has motivations to approach and also to avoid the same goal. Examples are the person who wants to come forward and express his ideas but is restrained by stage fright or the person who wants to approach and have normal relations with the opposite sex but is restrained by fear. Similarly, a soldier may be in conflict because he is motivated both to advance to complete his mission and to retreat to escape intense fear. Severe conflicts of this kind play an important role in neurotic behavior (Dollard & Miller, 1950).

Since the approach-avoidance conflict seems to be such an important source of stress and also has been extensively analyzed theoretically and studied experimentally (Miller, 1959), it was selected for this study. Hungry albino rats were trained to approach the goal end of an alley to receive food. Then they were placed into conflict by receiving painful electric shocks at the goal. We investigated different ways of training the rats to persist in going to the goal in spite of the fear aroused by the painful shocks.

[1] The author was responsible for the ideas, design, and write-up. James A. Faust performed Exp. I; Nariyuki Agarie and Libby Michel, supervised by Arlo K. Myers, performed Exp. II; Russell Tousley and Hanna Weston, supervised by Gordon Bower, performed Exp. III. This work was supported by a research grant, M647, from the National Institute of Mental Health of the National Institutes of Health, Public Health Service, Department of Health, Education, and Welfare, Bethesda, Maryland. We thank the Harkness Bursary Fund of Yale University for the support of Faust and Tousley.

Experiment I

The first experiment compared the effect on ultimate performance of gradual habituation to increasingly strong electric shocks at the goal with that of the sudden introduction of shock at full strength. A subsidiary purpose was to investigate a problem posed by Miller (1959, p. 225), namely, whether the first noticeable effects of weak electric shocks at the goal will be a reduction in the speed of running as would be expected from simple algebraic summation of approach and avoidance throughout the range, or whether there will be an initial period of dynamogenic effect which facilitates running.

Returning to the main problem, two factors should cause the gradual introduction to shock to help the animals to learn to resist its disruptive effects, while another factor might work in the opposite direction: (*a*) During the weaker shocks *S* will be rewarded for continuing in spite of fear, so that increasingly strong fear will become a cue for approaching. By contrast, when the strong shock is suddenly introduced, the strong fear will change the stimulus situation drastically and produce a stimulus-generalization decrement in the strength of approach in addition to eliciting the competing response of avoidance. (*b*) If Pavlov's (1927, p. 30) observations are correct, the reward occurring after the mild shocks should suppress by counterconditioning some of the fear-evoking effects of pain, and thus help *S* to continue in the face of increasingly strong shocks. (*c*) But, during the process of habituation to increasingly strong shocks, *S*s will receive a greater number of painful shocks, which may tend to make them more fearful than *S*s receiving only a single suddenly introduced strong shock. Perhaps the foregoing opposing factors are behind the two schools of thought among laymen—those who would deal with fear of water by gradual familiarization and those who would throw the victim in to sink or swim.

During the first trials of criterion testing with strong electric shock, we do not have any way of evaluating the strength of Factor *c*, the total number of shocks, relative to those it opposes. Therefore we cannot make any firm prediction. On the other hand, if the criterion tests extend over enough trials, *S*s with suddenly introduced strong shocks will have time to approach their asymptote of learning to avoid. As these *S*s approach their asymptote, the difference in total number of shocks received will become irrelevant. Since we know that learning to avoid occurs rapidly, we may tentatively assume that it occurs faster than the learning to advance to the cue of fear and the counterconditioning. On the basis of this somewhat shaky assumption, we can predict that, during the latter part of an extensive series of test trials, a group gradually habituated to increasingly strong shocks will perform better than one suddenly exposed to strong shocks.

Method

Subjects.—The *S*s were 28 male Sprague-Dawley rats approximately 90 days old at the outset.

Apparatus.—An enclosed alley 8 ft. long, 3½ in. wide, and 5½ in. high was painted flat white inside and had a hinged transparent top. Its floor was a grid of stainless steel bars $\frac{1}{16}$ in. in diameter spaced ½ in. apart, supported by strips of wood which had been boiled in paraffin.

The first 7 in. of the alley was a startbox which opened by means of a guillotine door released by a catch, pulled down by a spring, and activating a microswitch which started an electric timer. The goal was a wet pellet of Purina mash about the size of a pea placed on an insulated aluminum plate at the end of the alley, and illuminated from above by a 6-w. bulb which was the sole source of light in the alley. When the animal touched the moist pellet, a subthreshold current operated an electronic relay which stopped the electric timer, and, on appropriate trials, turned on the shock.

The electric shock was administered to the animal's feet via the grid floor. The output of a radio transformer was regulated by a 25,000 ohm potentiometer used as a voltage divider. The output of this voltage divider was applied to the grid with a 250,000 ohm resistor in series with the rat. The output of the voltage divider was calibrated with an ac voltmeter and the duration of shock was controlled at 0.1 sec. by an electronic timer.

The rats in this experiment wore a rubber-band harness connected by a snap on the end of a T bar to a cord running along the top of the alley, going around two pulleys at either end of the alley, and back outside to form an endless loop. One of these large pulleys contained a smaller reducing one which operated a recording pen on a polygraph. The setup was like that described by Brown (1948). Since no graphic records were made in this experiment, this part of the apparatus is relevant only as part of the stimulus situation for the rat.

Feeding schedule and approach training.—The *S*s were on ad lib. water and were fed each day after the end of the experiment 10 gm. of ground Purina Lab Chow mixed with 10 gm. of water. After two days on this feeding schedule they were given three training trials, at the rate of one per day, without the starting door or harness. Then the starting door was introduced and the number of trials increased so that by Day 7, which began with Trial 11, the *S*s were running five trials a day. These trials were quasidistributed by completing a given trial on all *S*s before starting the first *S* on its next trial. On Trial 16 the harness was introduced. By approximately 50 trials, the *S*s seemed to reach their asymptote of speed, but they were continued on for a total of 75 approach-training trials.

Habituation to electric shock.—After *S*s had clearly reached their asymptote, they were divided into two groups of 14, matched on the basis of average speed on the last 10 trials and randomly assigned as the Sudden and the Gradual groups which were given the following treatments during Trials 76–150: (*a*) The Sudden group continued the rewarded nonshock training of five trials a day. (*b*) The Gradual group began with a shock of 125 v. for the first day and had the level of shock increased in 15% steps. On the first day there was no noticeable effect during the five trials. On the second day with a shock of 144 v., the first flinching reactions were observed. This level was continued for five days to determine the effect of low-level punishment. From then on the daily voltages of shock were 166, 191, 220, 253, 253, 291, 335, 335, 335. If *S* failed to reach the goal and eat within 3 min., he was removed from the alley but started on subsequent trials as usual.

Test for resistance to electric shock.—After the Gradual group had the foregoing 15 days of habituation to increasing shock and the Sudden group merely 15 days of additional training, both groups were given 20 test trials (5 per day) with the 335-v. shock at the goal.

Results and Discussion

The results are presented in Fig. 1. The part to the left of the dotted line presents the average speed (for daily groups of five trials) on the last three nonshock training days and on all of the days when the Gradual group received habituation training. The part to the right of the dotted line presents the average speed for each of the individual test trials during which both groups received the 335-v. shock at the goal.

It can be seen that the groups were reasonably well equated during the last three days of training. The first day of five shocks at the 125-v. level produced little, if any, effect. The first noticeable effect of the shock was a slight decrement produced by the days with 144 v.[2] From then on, increasingly stronger shocks produced greater decrements until the speed of the Gradual group was reduced

[2] Scores for the last two of these four days were distorted by apparatus trouble and have been omitted. To compensate for a change in the apparatus, a correction constant of .07 has been added to the average scores of both groups on all trials before these days.

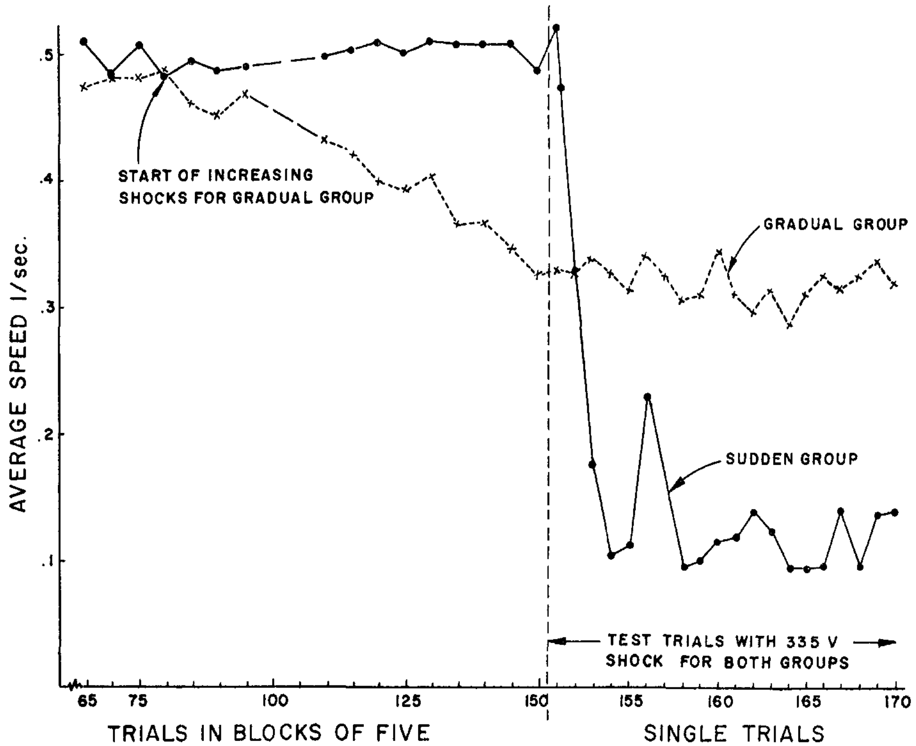

FIG. 1. Effect on speed of approach of gradual vs. sudden introduction of electric shock at the goal.

($P < .01$) approximately 30% by the 335-v. shocks.[3]

The foregoing results show no evidence of an initial dynamogenic effect of weak shocks, but rather show algebraic summation as soon as any effects appear. Through an unfortunate misunderstanding, however, the initial levels of shock were higher than had originally been planned. Thus there is some possibility that the 125-v. shock, which showed no effect, is at just the level where a dynamogenic effect (which might have showed up with weaker shocks) and the interfering effect of a stronger shock, are canceling each other out.

Looking at the right side of the figure, it can be seen that on the first test trial the *S*s in the Sudden group, not yet having experienced what is in store for them at the goal, continue to run much faster than those in the Gradual group. After one shock, their performance is reduced to approximately that of the Gradual group, and with subsequent shocks, their performance drops considerably below that of the Gradual group ($P < .001$). On the first trial of the second day the Sudden group makes

[3] All reliabilities in this paper are two-tailed and, unless otherwise indicated, based on *t* tests. When a number of trials are combined, each *S* is given the sum of speeds on these trials as a single score; when trials are compared, a difference-score is computed for each *S*. The foregoing probability is for Trials 71–75 minus Trials 146–150. The next probability is for independent groups of Trials 166–170, and the final one is for Trial 156 minus Trial 155.

a temporary partial recovery ($P < .01$) —perhaps because the overnight rest introduced new cues that had less association with shock—followed by a rapid decline without any recovery on the first trials of the third or fourth days.

To present the results in a different way, on the last day of testing the 14 *S*s in each group received 5 trials for a total of 70 tests to a group. On only three such tests were there failures to achieve the goal within the 3-min. limit in the Gradual group, while there were 14 times as many (i.e., 43) such failures in the Sudden group.

Further differences were apparent from watching the characteristic reactions of the two groups to the shocks. The *S*s in the Gradual group flinched and sometimes squealed but remained at the goal and continued to eat. Those in the Sudden group seemed much more disturbed, lurching violently back, running away and crouching a distance from the goal. Theoretically (Miller, 1959, p. 268) *S*s should learn the type of response they make to the shock and the responses of the Sudden group should interfere with running more than those of the Gradual group.

The results were in accord with our theoretical expectations in that a superiority of the Gradual group emerged during the later test trials. According to our theoretical analysis, the factors favoring the Gradual group were (*a*) learning to advance to the cue of fear instead of suffering a stimulus-generalization decrement, and (*b*) counterconditioning. According to our analysis both of these effects depended on reward in the fear-evoking training situation. It is conceivable, however, that mere exposure to a sequence of increasingly strong shocks will help *S* to adjust irrespective of whether these shocks are associated with reward or administered in the training situation. The following experiments investigate this and other possibilities.

Experiment II

The main purpose of this experiment was to determine whether exposure to a series of gradually increasing shocks would be as beneficial when given outside of the test apparatus as when given as part of the rewarded training in it. A subsidiary purpose was to get a first approximation of the function relating the length of the habituation series to its effectiveness.

Method

The general procedure was the same as that in the preceding experiment with the following exceptions:

The apparatus was an alley 60 in. long, the last 12 in. of which were grid floor. At the goal *S*s pushed back a little transparent plastic door hinged at the top until an iron strip on it came within range of a small permanent magnet which snapped the door open, exposing a food tray containing 10 P. J. Noyes Co. pellets weighing .045 gm. each, and actuating a microswitch which stopped a clock and, on appropriate trials, triggered the electric shock. For further details see Bower and Miller (1960).

The *S*s did not wear harnesses. The initial training consisted of 70 trials after which *S*s were divided into four matched groups. In order to cover a wider range of values and to fit into available schedules, E_M (Michel) increased the shocks in her groups twice as fast as did E_A (Agarie). The resultant groups were:

(*a*) *Gradual in alley.*—For *S*s run by E_A, shocks began at 50 v. and were increased 13% on each day (i.e., 5 trials), to the eventual test level of 353 v. on Day 17. For *S*s run by E_M, the sequence started and ended at the same levels, but included only every other step of E_A's sequence, except that both the 11th and 12th values were included.

(*b*) *Gradual outside alley.*—The *S*s run by each *E* received exactly the same sequence of shocks as their partners in the foregoing group, but all of the shocks below the test level of 353 v. were given outside of the alley approximately 30 min. after the end of the

TABLE 1

AVERAGE SPEED DURING 20 TEST TRIALS WITH 353-V. SHOCK

Previous Treatment	Experimenter A	Experimenter M
Gradual in alley	.48	.61
Faster in alley	.37	.55
Sudden in alley	.35	.53
Gradual outside alley	.33	.47

daily trials in the alley. These shocks were given in a distinctive box 10 in. × 14 in. × 10½ in. deep with aluminum sides, a grid floor and a hinged Plexiglas lid. The *S*s were put into this box for each of their five daily trials which were distributed like the trials in the alley.

(*c*) *Faster in alley.*—As with Group *a*, *S*s received shocks in the alley, but the series was shorter and increased at a faster rate. With E_A the increases were approximately 63%, generating the following sequence of voltages: 50, 82, 133, 217, 353. For E_M the sequence of voltages was 50, 133, and 353.

(*d*) *Sudden in alley.*—For both *E*s this group received a 353-v. shock in the alley on the same day that the other groups first reached this voltage level.

There were 5 rats in each group for each *E*, making a total of 40 *S*s. For each *E* trials with shock were started so that the final test level was reached on the same day by all groups and so that all groups had received the same number of trials in the alley by that day.

Results

The average speeds for the 20 test trials with a 353-v. shock at the goal are presented in Table 1. It can be seen that there is a large difference between the speeds of *S*s run by the two *E*s, but that for each *E* the rank order of the groups is exactly the same. The *S*s given the gradually increasing series of shocks in the alley were better in the test series than those given the faster series of shocks in the alley, which in turn were better than those suddenly introduced to the shock for the first time. These differences are in the same direction as those secured in Exp. I. In both cases *S*s exposed to shocks outside of the alley showed the poorest performance. There was so much variability among *S*s, however, that only the difference between *E*s (which was confounded with a difference in the weight of *S*s in the two batches of *S*s) was statistically reliable. Therefore, an additional experiment was run.

EXPERIMENT III

The purpose of Exp. III was to compare the effect of three procedures on subsequent resistance to stress in the conflict test situation. The three procedures were gradual increase of shock in the rewarded conflict-training situation, gradual increase of shock outside of the conflict situation, and sudden introduction of shock for the first time in the test situation. In addition a control was added for the effects of the number of rewarded training trials.

In the preceding experiments *S*s in the Sudden group received rewarded training trials in the alley while their partners received increasing shock and regular rewards in the alley. This procedure equated the number of training trials before the test with strong shock was introduced, but meant that the Gradual group received its first experience with shocks after fewer training trials than did the Sudden group. Since all groups had reached the asymptote of speed, any effects of this difference in the number of rewarded training trials was expected to be minor. Furthermore, any such minor effect of the fewer trials was expected to work against the Gradual Group, and hence to be in the opposite direction to our experimental results.

In the meantime, Karsh (1959) secured evidence in our laboratory suggesting that additional training trials beyond the asymptote may decrease (rather than increase) the resistance of a rat's performance to disruption by shock. To control for this surprising possibility, the present experiment used an additional Sudden group which started to receive its test with strong shocks in the alley as soon as the habituation series was started for the two Gradual groups.

Method

The *S*s were 32 male albino Sprague-Dawley rats, approximately 90 days old at the beginning of the experiment. They were on ad lib. water and were fed 13 gm. of Purina Lab Chow approximately 15 min. after the experimental session each day. This feeding cycle started 7 days before the experiment proper.

The apparatus was the same as in the previous experiment.

For each trial in the alley the reward was 5 P. J. Noyes pellets. First each *S* was trained to push open the door over the food cup and eat pellets by being placed directly into the goalbox until it started to eat within 15 sec. on three consecutive trials. Then *S*s were trained to run down the alley by being given two trials each day, separated by approximately 45 min. in the home cage with water. This training was continued for a total of 42 trials. It was started by Tousley, but four of the last trials were run by Weston, who also did the testing. After this training *S*s were assigned to four groups of 8 *S*s each. These groups were matched for mean speed on the last 10 trials and randomly assigned to the following conditions:

(*a*) *Gradual in alley.*—The *S*s were given a 60-v. shock of 0.1 sec. duration at the goal on both of their trials on Day 22 and given shock increased by 20 v. each day until they received a 380-v. shock on Day 38. The shock sequence was changed from a percentage increment (power series) to a constant increment (linear series) because the first part of the former series seemed to be too weak while its final steps seemed to be too large.

(*b*) *Gradual outside alley.*—The *S*s were given exactly the same sequence of shocks outside of the alley in the distinctive box. They were taken out of the home cage and given this shock approximately 15 min. after a run in the alley and immediately returned to the home cage.

(*c*) *Early sudden in alley.*—The *S*s received their first shock, which was a 400-v. test trial, on the same day (Day 22) that the foregoing groups received their first weak shocks.

(*d*) *Late sudden in alley.*—The *S*s received their first shock, which was a 400-v. test trial, on the same day (Day 39) that the first two groups received their first test trial.

Throughout the part of the experiment during which shock trials were given, any *S* failing to open the food door within 60 sec. after the start was returned to the home cage, given a speed score of zero, and run as usual on all subsequent trials.

Test trials were the same as training trials, except that all groups were given a 400-v. shock at the goal. Groups *a*, *b*, and *d* had 28 such trials, distributed over 14 days, *S*s in Group *c* had 62 trials distributed over 31 days.

Results

The results are shown in Fig. 2. It can be seen that all groups were approximately equal by the end of training. As in Exp. II, the group given gradually increasing shocks during rewarded training in the alley performs the best during the test series of strong shocks at the goal. In order to test for the statistical reliability of this superiority, the speed scores for each *S* were summed for the 25 test trials following the first shock. Since the distributions of total speed scores were not normal, the difference between each pair of groups was tested by tabulating the proportion of scores above and below the median of the combined pair. The differences between the gradual group and each of the other three were reliable ($P < .01$). The differences among the other groups did not approach statistical reliability except that the Mann-Whitney *U* test yielded a *P* of less than .02 for the difference between the speeds of the Early Sudden and the Late Sudden groups during the first 25 shocks received. This difference confirms Karsh's (1959)

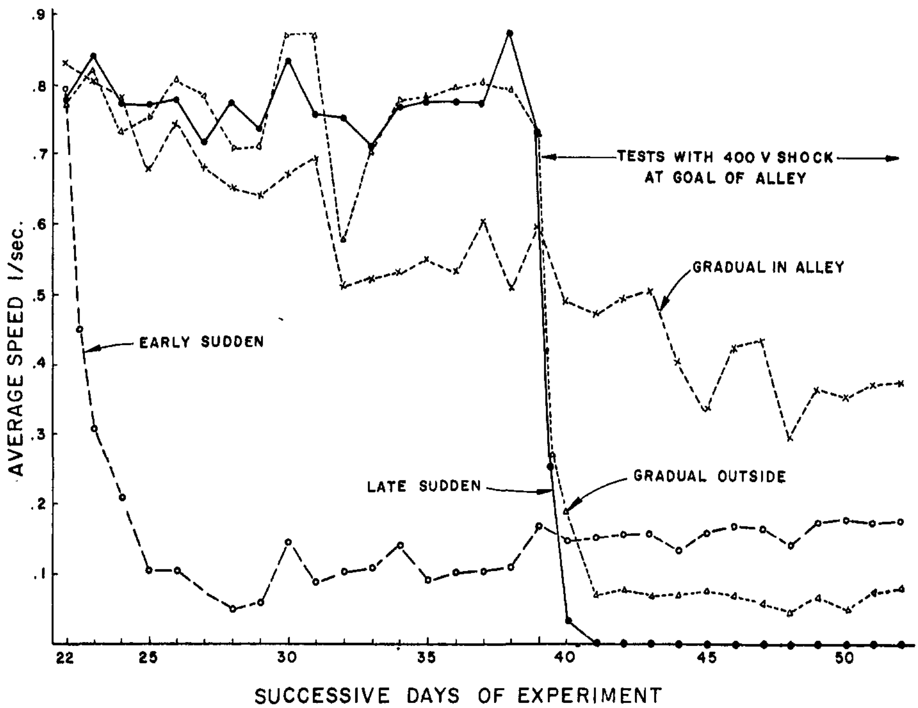

FIG. 2. How speed of approach in a conflict situation is affected by following treatments: Early Sudden group given 400-v. test shocks at goal after 21 days of approach training; Late Sudden group given similar test shocks after 38 days of approach training; Gradual in Alley group habituated to series of increasingly strong shocks at goal before test shocks; Gradual Outside group habituated to similar series of shocks in distinctive box outside of alley. Each point is average of the two trials given each day, but on the day shock is suddenly introduced producing a sharp drop, each trial is plotted separately.

suggestive results and shows that overtraining with additional rewarded trials can paradoxically *decrease* the resistance of the habit to disruption by painful electric shocks.

Finally, one unusual feature of the results should be mentioned. One of the animals in the Early Sudden group which had failed to run on 11 successive trials, gradually resumed running and by the 60th shock trial was the second fastest rat in the experiment. The fastest rat of all happened to be also in this same group in which all of the rest of the rats eventually stopped running.

Discussion

The results of these experiments show that rats can be trained to resist stresses such as pain and fear. It should be profitable to study the laws governing such learning and also to study learning to resist other stresses such as frustration, fatigue, noise, nausea, and extremes of temperature. Studies of partial reinforcement are relevant, of course, to the problem of learning to resist frustration.

Parallel studies could be designed at the human level to investigate the laws governing the way people learn to resist various stresses known to be important in civilian and military activity. Human studies should investigate especially the effect of mediating, symbolic factors, the importance of which in neurosis, psychotherapy, and problem solving I have emphasized elsewhere (Dollard & Miller, 1950; Miller, 1959).

Summary

In three experiments a total of 100 hungry rats were trained to run an alley for food reward and then given electric shocks at the goal to induce an approach-avoidance conflict. These experiments yielded the following results and conclusions:

1. During all but the first one or two trials of an extended test series with strong electric shocks at the goal, *S*s which previously had been habituated to a gradually increasing series of shocks at the goal performed markedly better than those suddenly exposed to the test shocks for the first time. Under the conditions of these experiments we were able to teach rats considerable resistance to the stress of quite strong electric shocks at the goal.

2. A similar gradually increasing series of shocks given outside of the rewarded conflict situation produced little, if any, effect; *S*s receiving this treatment were similar to the nonshock controls and reliably poorer than those habituated to the shocks in the rewarded training situation. Apparently, mere exposure to tough treatment will not necessarily improve resistance to stress in a different criterion situation.

3. Contrary to original expectation, additional rewarded training trials given to *S*s which had reached the asymptote of speed reduced, rather than increased, the resistance of their running habit to disruption by shocks at the goal. Although widely advocated, mere overtraining may not always be helpful preparation for subsequent stress.

4. The results of these experiments suggest that it should be feasible and profitable to analyze further at both the animal and human level the laws governing the learning of resistance to stresses such as pain, fear, fatigue, frustration, noise, nausea, and extremes of temperature.

References

Bower, G. H., & Miller, N. E. Effect of amount of reward on strength of approach in an approach-avoidance conflict. *J. comp. physiol. Psychol.*, 1960, **53,** 59–62.

Brown, J. S. Gradients of approach and avoidance responses and their relation to level of motivation. *J. comp. physiol. Psychol.*, 1948, **41,** 450–465.

Dollard, J., & Miller, N. E. *Personality and psychotherapy.* New York: McGraw-Hill, 1950.

Karsh, E. B. The effect of intensity of punishment and number of rewarded and punished trials on running speed in a conflict situation. Unpublished doctoral dissertation, Yale Univer. Library, 1959.

Miller, N. E. Fear. In R. H. Williams (Ed.), *Human factors in military operations.* Chevy Chase, Md.: Johns Hopkins Univer., Operations Res. Office, 1954. Pp. 269–281.

Miller, N. E. Liberalization of basic S-R concepts: Extensions to conflict behavior, motivation and social learning. In S. Koch (Ed.), *Psychology: A study of a science,* Study I, Vol. 2. New York: McGraw-Hill, 1959.

Pavlov, I. P. *Conditioned reflexes.* (Trans. by G. V. Anrep) London: Oxford Univer. Press, 1927.

(Received September 14, 1959)