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EFFECTS OF INESCAPABLE SHOCK UPON SUBSEQUENT ESCAPE AND AVOIDANCE RESPONDING[1]

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Exposure of dogs to inescapable shocks under a variety of conditions reliably interfered with subsequent instrumental escape-avoidance responding in a new situation. Use of a higher level of shock during instrumental avoidance training did not attenuate interference; this was taken as evidence against an explanation based upon adaptation to shock. Ss curarized during their exposure to inescapable shocks also showed proactive interference with escape-avoidance responding, indicating that interference is not due to acquisition, during the period of exposure to inescapable shocks, of inappropriate, competing instrumental responses. Magnitude of interference was found to dissipate rapidly in time, leaving an apparently normal S after only 48 hr.

Exposure to inescapable shocks, as in Pavlovian fear conditioning, subsequently interferes with the initial acquisition of escape or avoidance responses (Brown & Jacobs, 1949; Carlson & Black, 1960; Leaf, 1964). This proactive interference has been attributed to the learning, during the exposure to inescapable shocks, of instrumental skeletal-motor responses which later prove to be incompatible with the response to be learned (Adams & Lewis, 1962; Dinsmoor & Campbell, 1956; McAllister & McAllister, 1962; Mullin & Morgenson, 1963). An alterative hypothesis is that *S*s adapt to the shock during the pretreatment and are subsequently not motivated sufficiently to perform the appropriate escape or avoidance response (MacDonald, 1946).

The present experiments (*a*) demonstrate the interference phenomenon under a variety of conditions, (*b*) test the validity of the two hypotheses, and (*c*) investigate the time course of the interference effect.

Experiment 1

This experiment varies shock duration, number of shocks, and shock density in an attempt to find determiners of the interference phenomenon, and it tests whether interference with subsequent instrumental responding is dependent upon the presence in the training situation of a signal present in the inescapable shock session.

Method

Subjects. The *S*s, 32 adult mongrel dogs with shoulder heights of 15–19 in. and weights of 11–13 kg., were maintained on ad-lib food and water in individual cages. They were randomly assigned to four experimental groups of 8 *S*s each.

Apparatus. The apparatus consisted of two separate and distinctively different units; each unit was used for a different phase of the experiment.

The unit in which *S*s were exposed to inescapable shocks was a rubberized, cloth hammock located inside a shielded, white, sound-reducing cubicle. The hammock was constructed so that *S*'s legs hung down below its body through four holes. The *S*'s legs were secured in this position, and *S* was strapped into the hammock. In addition, *S*'s head was held in position by panels placed on either side with a yoke between them across *S*'s neck. The shock source for this unit was a 500-v. ac transformer and parallel voltage divider with the current applied through a fixed resistance of 20 K ohms. The 6.0-ma. shock was applied to *S* through brass plate electrodes coated with electrode paste and taped to the footpads of *S*'s hind feet. Stimulus presentations were controlled by automatic relay circuitry located outside the cubicle.

The unit in which *S* was tested for interference with escape or avoidance responding was a two-way shuttle box with two black compartments separated by an adjustable barrier (described by Solomon & Wynne, 1953). The barrier height was set at approximately *S*'s shoulder height. Each shuttle-box compartment was illuminated by one 7½-w. and two 50-w. lamps. The CS consisted of the turning off of the four 50-w. lamps, which resulted in a sharp decrease in the level of illumina-

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tion. The US, electric shock, was administered through the grid floor. A commutator shifted the polarity patterns of the grid bars four times per second. The shock was 550 v. ac applied through a variable current limiting resistor in series with *S*. The shock was continuously regulated by *E* at 4.5 ma. (except for the high-motivation group in Experiment 2, where it was 6.5 ma.). Whenever *S* crossed the barrier, photocell beams were interrupted, a response was automatically recorded, and an ongoing trial was terminated. Latencies of barrier hurdling were measured from CS onset to the nearest 0.01 sec. by an electric clock. Stimulus presentations and temporal contingencies were controlled by automatic relay circuitry housed in an adjoining room.

White masking noise at approximately 70-db. SPL was present in both units.

Treatments. Each *S* was allowed 5 min. to adapt to the apparatus before any treatment was begun. The two treatments, exposure to inescapable shock and instrumental avoidance training, were administered on successive days approximately 24 hr. apart.

Three of the four groups received exposure to unsignaled, inescapable shocks. Group I received no treatment prior to escape-avoidance training. Group II received 64 presentations of inescapable shock, each of 5-sec. duration; intershock intervals of 60–120 sec. averaged 90 sec. Group III received 640 presentations of inescapable shock, each of 0.5-sec. duration; intershock intervals of 4.5–18 sec. averaged 9 sec. Group IV received 64 presentations of inescapable shock, each of 0.5-sec. duration; intershock intervals of 60–120 sec. averaged 90 sec.

Approximately 24 hr. after the shock exposure treatment, all four groups received 10 trials of instrumental escape-avoidance training in the shuttle box by the traditional method of emergence. The onset of the CS (dimmed illumination) initiated each trial and the CS remained on until trial termination. The CS-US onset interval was 10 sec. If *S* jumped the barrier during this interval, the CS terminated and no shock was presented. Failure to jump the barrier during the CS-US interval led to shock which remained on until *S* did jump the barrier. If no response occurred within 60 sec. of CS onset, the trial was automatically terminated and a 60-sec. latency of response recorded. Intertrial intervals of 60–120 sec. averaged 90 sec.

Results

Table 1 summarizes the shuttle-box performance data. An analysis of variance indicated that the groups differed in their mean median latencies of response ($F = 5.84$, $df = 3/28$, $p < .01$).[3] Paired comparisons indicated that each of the three groups which were exposed to inescapable shocks were significantly slower in their escape-avoidance responses than Group I, which was not exposed to inescapable shock ($t = 3.91, 3.18$, and 2.05, $df = 28$, $p < .05$). The three groups which received inescapable shocks did not, however, differ significantly among themselves ($t = 0.76, 1.88$, and 1.13, $df = 28$). The same analyses of mean latencies yielded results similar to those obtained with mean median latencies.

TABLE 1

INDICES OF RESPONSIVENESS

Group	Latency (in sec.)		Number of failures to escape shock	Percentage of *S*s which never escaped shock
	Mean median	Mean		
Experiment 1				
Group I	16.38	22.19	16	12.5
Group II	55.48	54.21	68	62.5
Group III	48.07	46.19	55	50.0
Group IV	36.71	38.67	42	37.5
Experiment 2				
Curare-no shock	19.97	24.12	13	0.0
Curare-shock	41.57	40.57	47	37.5
High motivation	41.23	41.09	54	25.0
Experiment 3				
24 hr.	50.00	47.91	57	50.0
48 hr.	24.12	24.95	18	12.5
72 hr.	26.14	26.82	23	12.5
144 hr.	23.42	24.35	19	12.5

Although failure to escape was an infrequent occurrence in the group which did not receive inescapable shock, it was commonplace in the groups pretreated with inescapable shock. The four groups differed in the number of failures to escape from shock ($F = 3.81$, $df = 3/28$, $p < .05$). Groups II and III differed significantly from Group I in number of failures to escape from shock ($t = 3.23$ and 2.43, respectively, $df = 28$, $p < .05$). Group IV was intermediate between Group I and Groups II and III, and was not significantly different from any of them ($t = 1.66, 1.64$, and 0.84, $df = 28$).

Discussion

This experiment demonstrates that prior exposure to inescapable shock under a variety of conditions subsequently results

[3] All p values are based upon two-tailed tests.

in interference with the acquisition of instrumental escape-avoidance responding. The fact that the high shock-density groups show more interference (but not significantly more) than the low shock-density group suggests that shock density may be a determiner of the magnitude of the interference effect. The interference phenomenon does not, however, appear to be dependent upon the use of specific shock exposure parameters, but appears to be a general phenomenon resulting from exposure to inescapable shock. Furthermore, the interference is not peculiarly dependent upon pairing of the inescapable shocks with some explicit stimulus and the subsequent presence of that stimulus during the instrumental response training. Heretofore, all demonstrations of this phenomenon, with the exception of that by Dinsmoor and Campbell (1956), have used signaled shocks during the exposure to inescapable shocks. This experiment indicates that the interference phenomenon is not dependent upon prior Pavlovian fear conditioning even though it can be produced by it.

Not only do statistical differences appear between the performances of *S*s exposed to inescapable shock and those of unshocked *S*s during subsequent instrumental avoidance training 24 hr. later, but large qualitative behavioral differences appear which are dramatic to observe. Whenever *S*, which was not treated with inescapable shock, first received shock in the course of instrumental training, it typically barked, yelped, ran, and jumped until it escaped. An *S* previously exposed to inescapable shock initially reacted to the first shock during instrumental training in much the same way. In contrast, however, it soon typically stopped vocalizing and moving in an agitated fashion and would remain silent until shock terminated. On succeeding trials, *S* would typically continue in a maladaptive pattern of behavior—not necessarily the same on each trial—and passively "accept" the severe, pulsating shock. In addition, the occurrence of an escape response by *S* previously exposed to inescapable shock did not reliably predict the further occurrence of escape responses, whereas the occurrence of an escape response in *S* not previously exposed to inescapable shock typically predicts further escape responses of shorter latencies.

All *S*s (in this and succeeding experiments) were physically capable of jumping the barrier during the instrumental escape-avoidance training phase and were not physically debilitated by the prior exposure to shock. In fact, *S*s which did not escape shock occasionally jumped the barrier between trials and some jumped the barrier at the end of the session in order to leave the shuttle box.

Experiment 2

This experiment explores two explanations of the interference phenomenon: (*a*) adaptation, and (*b*) learning of incompatible instrumental motor responses.

If *S*s have adapted to shock during the presentations of inescapable shock and subsequently do not perform the escape-avoidance response because they are not sufficiently motivated, then raising the level of motivation during instrumental training should attenuate the interference.

For the high-motivation group in the present experiment, a higher level of shock was employed during the instrumental avoidance training phase; this presumably resulted in an increased level of motivation during that phase of the experiment.

It is unlikely that *S*s in Experiment 1 could have made any instrumental motor response which reduced the goodness of contact with the shock electrodes during the exposure to inescapable shocks, because the electrodes were firmly attached to *S* and coated with electrode paste. It is not clear, however, that certain patterns of muscle tonus or movement might not have the effect of reducing the psychological severity of the shocks. Such patterns could then be learned as instrumental responses and might subsequently interfere with escape-avoidance responding. To rule out this possibility, the skeletal-motor musculature of *S*s in the curare-shock and curare-no shock groups was immobilized by a neuromuscular blocking agent, tubocurarine chloride, which prevented these *S*s from making any instrumental responses.

Method

Subjects. Twenty-four adult mongrel dogs similar to *S*s of Experiment 1 were assigned randomly to three groups of 8 *S*s each.

Apparatus. The apparatus consisted of the two units described in Experiment 1. The paralyzed *S*s were respirated through an endotracheal catheter with an inflatable cuff. The inspiration-expiration ratio was 1:3, and the respiration rate was 12 cpm.

Treatments. The high-motivation *S*s, treated exactly as were those of Group II of Experiment 1 during the exposure to inescapable shock, received 64 5.0-sec. presentations of 6.0-ma. inescapable shock at intervals of 60–120 sec. In contrast, however, during the instrumental escape-avoidance training the shock level was increased.

In both curarized groups, *S*s were placed in the hammock and EKG and shock electrodes were attached. Then 6 mg. of tubocurarine chloride was injected intravenously. As respiration began to fail, the endotracheal catheter was inserted and artificial respiration was begun. An additional 6 mg. of curare was injected intravenously, and the hammock was inclined approximately 12.5° to allow saliva to drain from the mouth. Recovery from paralysis required 3–6 hr.

While thus paralyzed, one group (curare-shock) received 64 unsignaled presentations of inescapable shock, at 6.0 ma., each of 5-sec. duration; intershock intervals of 60–120 sec. averaged 90 sec. The other group (curare-no shock) was simply allowed to recover from the effects of curare without additional treatment.

Approximately 24 hr. after the curarization and shock exposure, all three groups received 10 trials of instrumental avoidance training as described in Experiment 1, except that for the high-motivation group shock intensity was 6.5 ma., a 40% increase above the level of shock used in the second phase in Experiment 1.

Results

The mean median latencies of response for the high-motivation group and Group II did not differ significantly ($t = 1.39$, $df = 14$). A similar comparison of the high-motivation group and Group I shows that the performance of the high-motivation group was significantly retarded ($t = 2.23$, $df = 14$, $p < .05$). In addition, the high-motivation group did not differ from Group II on total number of failures to escape from shock ($t = 0.98$, $df = 14$), whereas it did differ from Group I on this measure ($t = 2.74$, $df = 14$, $p < .02$).

A t test on the mean median latencies of response reveals that the curare-shock *S*s were significantly slower in their escape-avoidance responses than curare-no shock *S*s ($t = 2.50$, $df = 14$, $p < .05$). The same analysis of the mean latencies of response yielded similar results. The curare-shock *S*s failed to escape from shock significantly more often than the curare-no shock *S*s ($t = 2.40$, $df = 14$, $p < .05$).

The curare-no shock *S*s were not significantly different in their mean median latencies of response from Group I *S*s ($t = 0.13$, $df = 14$). Also, the curare-shock *S*s were not significantly different from Group II *S*s in their mean median latencies of response ($t = 1.47$, $df = 14$, $p > .10$).

Discussion

The interference phenomenon still occurs and is essentially unaffected by the use of an increased level of shock during instrumental escape-avoidance training. To maintain the adaptation hypothesis in the face of these results, one would have to argue that 6.5 ma. was not sufficient to motivate responding in the preshocked *S*s. It should be noted that prolonged shock at levels higher than 6.5 ma. is often tetanizing and physically prevents *S* from jumping the barrier during shock. We feel justified in questioning the adaptation hypothesis because the magnitude of the interference was not attenuated despite the use of a more intense shock during escape-avoidance training.

The prevention of instrumental motor responses during exposure to inescapable shocks does not prevent the occurrence of the interference phenomenon. The curarized *S*s given inescapable shocks subsequently showed much interference with the acquisition of the escape-avoidance response. This interference was not the result of paralysis alone, because curarized *S*s which did not receive inescapable shocks did not show interference. The *S*s in this experiment responded during instrumental avoidance training very much like their counterparts in Experiment 1 which had not been paralyzed by tubocurarine chloride. Because the skeletal-motor system was paralyzed by curare during exposure to inescapable shock, it is difficult to argue that any instrumental motor responses could occur which alleviated the severity of the inescapable shocks and which were learned and subsequently responsible for the observed interference. This experiment places the "incompatible instrumental response" hypothesis in serious doubt.

Experiment 3

The passage of time has commonly been observed to result in changes in behavior established by shock (Bindra & Cameron, 1953; Kamin, 1957). McAllister and McAllister (1962, 1963) have reported that escape from a fear-producing signal occurs normally when 24 hr. is introduced between Pavlovian fear conditioning and instrumental avoidance training but is interfered with when only 3 min. elapses between the two treatments. Our Experiments 1 and 2, demonstrating the interference phenomenon, have uniformly used a 24-hr. interval between exposure to inescapable shock and escape-avoidance training, however. This experiment is designed to investigate the interference phenomenon as a function of the delay between the two treatments.

Method

Subjects and apparatus. Thirty-two adult, mongrel dogs, similar to *S*s of the previous experiments, were assigned randomly to eight equal groups of 4 *S*s each. The apparatus has been fully described in Experiments 1 and 2.

Treatments. The eight groups were divided into two sets of four groups. All groups within a set were treated identically with the exception of the elapsed time interval between the exposure to inescapable shocks and the subsequent instrumental escape-avoidance training.

One set of four groups, treated like Group II in Experiment 1, received 64 5-sec. presentations of unsignaled inescapable 6.0-ma. shock, at intershock intervals of 60–120 sec., averaging 90 sec.

The other set of four groups, paralyzed by curare during exposure to inescapable shock, also received 64 5-sec. presentations of inescapable 6.0-ma. shock. One-half the shocks were signaled, 10 sec. before onset, by 15 sec. of either 150- or 1,200-cps tone at 75-db. SPL, while the other half of the shocks were unsignaled. There were an equal number of 15-sec. presentations of the contrasting tone, but these were never followed by shock. The intertrial intervals were 45–75 sec., averaging 60 sec.; the average intershock interval was 90 sec., as in the preceding experiments.

All groups received 10 trials of instrumental avoidance training as described in Experiment 1. The four groups in each set differed, however, in the length of the time interval between the two treatments. The intervals between exposure to inescapable shock and instrumental escape-avoidance training were 24, 48, 72, and 144 hr. The two 24-hr. conditions served as replications of Group II, Experiment 1, and the curare-shock group, Experiment 2.

Results

The mean median latencies of response were subjected to a Sets × Intervals × *S*s analysis of variance. The two sets of groups (normal vs. curarized) were not significantly different in their instrumental responding ($F = 1.00$, $df = 1/24$), nor did the sets differ from each other across the four time intervals (Sets × Intervals, $F = 1.21$, $df = 3/24$). Therefore, no further distinction will be made between the curarized and the uncurarized *S*s. Table 1 summarizes the shuttle-box performance data for each time interval condition, with curarized and uncurarized *S*s combined.

The *S*s did differ in mean median latencies of response as a function of the interval between exposure to inescapable shock and instrumental avoidance training ($F = 3.02$, $df = 3/24$, $p < .05$). The 48-, 72-, and 144-hr. groups responded significantly faster than the 24-hr. group ($t = 2.49$, 2.29, and 2.55, respectively, $df = 24$, $p < .05$), although they did not differ among themselves (t's < 0.26, $df = 24$). A comparison of mean median latencies of the *S*s in the 48-, 72-, and 144-hr.-interval conditions with those of *S*s not exposed to inescapable shock in Experiment 1 (i.e., Group I) reveals no difference ($t = 0.77$, 0.98, and 0.73, respectively, $df = 14$).

The interval groups also tended to differ with respect to total number of failures to escape from shock ($F = 2.88$, $df = 3/28$, $p < .06$). The 48-, 72-, and 144-hr. groups escaped significantly more shocks than the 24-hr. group ($t = 2.51$, 2.19, and 2.45, respectively, $df = 28$, $p < .05$).

Discussion

The effects of inescapable shocks upon subsequent instrumental escape-avoidance responding dissipate rapidly, leaving an apparently normal *S* after only 48 hr. This result is compatible with the observations by McAllister and McAllister (1962, 1963) that a delay between exposure to inescapable shocks and instrumental avoidance training facilitates the subsequent acquisition of the avoidance response. The length of the delay seems now to be in question, however.

In addition, neither the magnitude of the interference phenomenon nor the time course of the recovery from the effects of inescapable shocks was different for *S*s whose inescapable shocks were signaled or unsignaled or were paralyzed or not paralyzed.

General Discussion

The proactive interference of inescapable shock with subsequent instrumental escape-avoidance responding is a reliable phenomenon. The "incompatible instrumental response" and "adaptation" hypotheses do not account satisfactorily for the phenomenon. Because the present experiments were transsituational, a search for a discriminative, mediating stimulus common to both apparatus treatment units yields very few candidates. The only elements common to both situations were the *E*s, electric shock, and white noise, but perhaps one of these is sufficient to mediate the interference processes, whatever they may be.

There are other mechanisms to which one might appeal in order to explain this phenomenon. Massive parasympathetic reaction following the exposure to inescapable shock is one. This mechanism has been proposed and supported as an explanation of the proactive interference effect of instrumental avoidance training upon subsequent avoidance responding and the dissipation of this interference during long delays between the two stages of avoidance training—the "Kamin effect" (Brush & Levine, 1965; Brush, Myer, & Palmer, 1963). The Kamin effect, though, appears to be specifically dependent upon the contiguity of a signal and shock, Pavlovian fear conditioning, in Stage 1 and to completely disappear within 24 hr. (Brush et al., 1963). Our phenomenon, on the other hand, is not dependent upon such explicit Pavlovian fear conditioning and does not disappear within 24 hr. But, because the demonstrations of the Kamin effect used rats while we used dogs, these differences may be attributable to species differences. The similarities between the two interference phenomena make the parasympathetic reaction a plausible explanation.

Alternatively, we suggest that the source of the interference is a learned "helplessness." Learned helplessness might well result from receiving aversive stimuli in a situation in which all instrumental responses or attempts to respond occur in the presence of the aversive stimuli and are of no avail in eliminating or reducing the severity of the trauma. This interpretation generates a new kind of experiment. It suggests that the degree of control allowed to *S* over the shock exposure conditions is an important parameter for future investigation; high degrees of control over shock presentation allowed to *S* might "immunize" *S* against proactive interference and might possibly result in proactive facilitation.

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