The Time Course of Learned Helplessness, Inactivity, and Nociceptive Deficits in Rats

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Four experiments are reported which explore the nature of the effects of inescapable shock on subsequent shuttlebox escape learning. The first experiment demonstrated that shuttle escape deficits dissipate within 48 hr after treatment with inescapable shock. Experiment 2 showed that exposure to inescapable shock suppressed unlearned activity in the shuttlebox and that this activity deficit recovered within 48 hr. Experiment 2A demonstrated that this shuttlebox crossing decrement was at least partly attributable to the inescapability of the shocks. These results suggested that activity factors might partly mediate the shuttle escape learning deficit reported in Experiment 1. Experiment 3 explored the possibility that activity and shuttle escape learning deficits are subserved by the effects of inescapable shock on pain sensitivity. The results supported this notion. It was found that rats were less sensitive to painful stimulation 24 hr after inescapable shock and that this analgesic tendency also dissipated within 48 hr after pretreatment. The implications of these results were discussed.

The nature of the changes in an organism which are induced by exposure to inescapable and uncontrollable aversive events has been disputed for some time. Two different mechanisms have been proposed to account for how such treatment interferes with subsequent escape/avoidance behavior. One has argued that the primary consequence of exposure to inescapable aversive events is reduced activity. Two views have emerged concerning how activity may be reduced by inescapable shock treatment. One position holds that inactivity occurs because exposure to the inescapable stressor, typically electric shock, depletes neurochemicals necessary for movement (Anisman, 1975; Anisman, Grimmer, Irwin, Remington, & Sklar, 1979; Weiss, Glazer, & Pohorecky, 1976). Alterna-

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tively, some have favored the position that inactivity is learned as a motor response to shock, either because it hurts more to move than to hold still (Bracewell & Black, 1974), because shocks accidentally terminate soon after a diminution on activity (Glazer & Weiss, 1976a, 1976b), or for more complex reasons (Levis, 1976). Regardless of the means whereby activity is putatively reduced, the common thread of all these arguments is that escape/avoidance learning suffers because inescapable shock results in a simple performance deficit.

The second view has been called the learned helplessness hypothesis. It proposes that organisms exposed to inescapable aversive events learn that the onset and termination of these events are independent of behavior. Interference with subsequent escape/avoidance acquisition occurs because the learning of the independence between responding and shock termination is said to reduce the organism’s incentive to attempt to escape and to interfere with the organism’s propensity to associate its behavior with shock termination should escape responses occur.

A recent series of studies from our laboratory seems to indicate that exposure to inescapable shock produces both activity and associative deficits (Jackson, Alexander, & Maier, 1979a; Jackson, Maier, & Rapaport, 1978; Maier & Jackson, 1979). The major evidence which suggested an activity decrement following exposure to inescapable shock came from an experiment reported by Jackson et al. (1978) (for other evidence see Anisman, Decantanzaro, & Remington, 1978). The purpose of that study was to determine whether exposure to inescapable shock produces an activity decrement that is reflected in the nonassociatively based suppression of those behaviors involved in shuttle escape performance. Since crossing in the shuttlebox is required for escape, the measure of activity used was unconditioned shuttlebox crossings in the absence of an escape contingency. Subjects were tested in a shuttlebox 24 hr after inescapable shock or control treatment. However, crossing the shuttlebox had no effect on shock. Shocks in the shuttlebox were inescapable and simply remained for a fixed period of time. The result was that inescapably shocked subjects crossed the shuttlebox in the presence of shock less frequently than did controls. That is, they were less active. Jackson et al. (1978) went on to show that increasing the intensity of shock used in the shuttlebox eliminated both the decrement in unconditioned shuttlebox crossing and the failure to learn to escape in a shuttlebox when escape was possible. When high test shock intensities were employed, previously inescapably shocked subjects were as active as controls when the shuttlebox shocks were inescapable (Expt 2) and performed shuttlebox escape as well as controls when shock was escapable (Expt 1). The same variable that eliminated the movement deficit also eliminated the shuttlebox escape learning deficit. These data suggest that exposure to inescapable shock produces an activity decrement and that
this decrement is responsible for the poor shuttlebox escape performance of inescapably shocked subjects.

Although these data indicate that exposure to inescapable shock does suppress activity, Jackson et al. (1979a) and Maier and Jackson (1979) have recently reported that inescapable shock also has true associative consequences. Shuttlebox or lever press escape tasks are not well suited for studying such associative effects. There are three reasons for this: (1) activity levels may largely determine performance (Jackson et al., 1978), (2) activity is completely confounded with learning, and (3) inescapably shocked animals frequently fail to respond and therefore do not encounter the escape contingency as frequently as do controls. To circumvent these problems, Jackson et al. (1979a) used a small Y-maze in which rats were required to choose between response alternatives to escape. Choice tasks such as this one have often been used to ascertain whether some manipulation affects learning or merely motivation/activity. The usual argument (e.g., Barrett, Leith, & Ray, 1971; Bryan & Spear, 1976) is that level of motivation and activity should affect the speed of responding but not the accuracy of responding. In any case, Jackson and Maier measured both the speed and the accuracy of responding in a Y-maze choice escape task and found the two to be uncorrelated under their conditions. Further, by careful selection of task parameters, the nonresponding problem associated with shuttle and lever press escape was also circumvented. Under these conditions, inescapably shocked animals were still slower to learn to choose a correct response from two alternatives than were controls.

Jackson and Maier have begun to explore the characteristics of both the activity and the associative deficit. One characteristic of the activity deficit is that it is eliminated by using strong shock. Since there is no reason to suppose that this manipulation should affect associative deficits Jackson et al. examined the effects of increased test shock intensity on Y-maze escape learning. Unlike the outcome with shuttle escape, strong shock did not improve the poor choice accuracy learning of inescapably shocked rats.

The fact that the same variable had such different effects on shuttle and Y-maze escape learning led Jackson et al. to suggest that the factors which underly the deficits in the two situations might be different and, perhaps, independent of one another. The possibility that exposure to inescapable shock affects more than one process and that the shuttlebox escape deficits are subserved by a different set of factors than are Y-maze choice learning deficits could be further substantiated by showing that performances on the two tasks are differentially affected by a variety of manipulations. As noted above, test shock intensity has already been investigated. The passage of time is another obvious candidate for study. Jackson et al. (1979a) have previously demonstrated that a Y-maze choice escape learn-
ing deficit occurs even if 7 days intervene between inescapable shock and testing. Such durability through time is just what would be expected of an associative effect. However, the inescapable shock produced shuttlebox learning deficit has sometimes been reported to be quite transitory and to dissipate within 48 hr (Glazer & Weiss, 1976a; Overmier & Seligman, 1967; Weiss et al., 1976), although this is not always the case (Glazer & Weiss, 1976a; Seligman & Groves, 1970; Kelsey, 1977; Seligman, Rosellini, & Kozak, 1975). Glazer and Weiss argued that dissipation in time occurs after high shock intensities but not after weaker shocks, and Seligman and Groves have indicated that the amount of exposure to inescapable shock is a critical factor.

The first experiment to be reported examined whether the shuttlebox escape learning deficit dissipates in time when the parameters routinely used in our laboratory are employed.

EXPERIMENT 1

This experiment asked whether the shuttlebox escape learning deficit which follows exposure to inescapable shock will persist over a 7-day interval. Shock parameters identical to those used by Jackson et al. (1979a) in which Y-maze choice learning deficits were shown to persist for at least 7 days were used. Rats were first given inescapable shock in a restraining tube and then given our standard shuttlebox escape learning test either 24, 48, or 168 hr later.¹ This test entails five single crossing (FR-1) escape training trials followed by 25 trials in which two crossings (FR-2) are required to terminate shock (see Maier, Albin, & Testa, 1973, and Maier & Jackson, 1977, for a rationale for this procedure). A control group was merely restrained in the tube and tested 24 hr later. Control groups tested at 48 and 168 hr were not necessary since the restraint used here has no effect on shuttlebox performance (e.g., Maier et al., 1973).

Method

Subjects. Forty male albino rats obtained from the Holtzman suppliers of Madison, Wisconsin, served. The animals were 90–100 days old at the start of the experiment. They were maintained on a 12-hr light–dark cycle and had food and water continuously available in the home cages.

Apparatus. Inescapable shocks or restraint occurred in four Plexiglas

¹ An escape-yoked-naive triadic design was not used. There were two reasons. First, it has already been shown that the shuttlebox escape learning deficit which occurs under exactly the conditions used here is a function of the controllability of the shock and does not follow exposure to escapable shock (e.g., Maier & Jackson, 1977). Given that the effect has already been shown to be specific to inescapable shock, the inescapable-restrained paradigm is preferable. It allows better control over shock durations and thus produces less variable data. Second, Jackson et al. (1979) used the inescapable-restrained design and the logic of our studies requires that the identical shock parameters be used here.
restraining tubes which were 23.4 cm in length, and 7.0 cm in diameter. The rat's tail extended from the rear of the tube and was taped to a plexiglas rod. Unscrambled shocks were delivered by four shock sources through electrodes attached to the rat's tail with tape and augmented with electrode paste. The restraining tubes were located in four separate sound attenuating chambers.

Escape training was carried out in four two-way shuttleboxes which measured 34.5 x 20.5 x 19.5 cm (L x W x D). The floors consisted of stainless-steel grids 0.35 cm in diameter which were spaced 1 cm apart. The boxes were divided into two compartments of equal size by a metal sheet which spanned the width of the box from floor to ceiling. An archway 5.5 cm high and 5.5 cm wide was cut from the center of the metal sheet. Thus the rats could cross from one side of the shuttlebox to the other only by passing through this archway. Both inescapable shocks and shocks to the grid floor were delivered by four independent constant current shockers. During escape training, scrambled 0.6-mA shocks were delivered across the grid floor of the shuttleboxes.

Procedure. The rats were randomly assigned to one of four groups (n = 10/group). On the first day of the experiment all rats were placed in the restraining tubes. Three of the groups (P) received 80 inescapable 1.0-mA, 5-sec tail shocks through electrodes fixed directly to the tail. The shocks were delivered on a variable time 60-sec schedule (range of 5–200 sec). The fourth group was merely restrained (R) in the tubes for an equivalent amount of time. Twenty-four hours later one of the preshocked groups (P24) and the restrained group (R24) received shuttlebox escape/avoidance training. Escape training was given 48 (P48) and 168 hr (P168) after inescapable shock exposure in the remaining two preshocked groups. The procedure used for shuttlebox escape training was the same in all four groups. Trials were presented on a variable time 60-sec schedule (range 5–200 sec). At the beginning of a trial a 1000-Hz tone was sounded which raised the background noise level from approximately 70 to 75 db (re 2000 dyn/cm²). If a response did not occur within 5 sec a 0.6-mA shock was applied, and the tone and shock terminated whenever a response occurred. The trial terminated automatically if no response had occurred within 35 sec of the onset of the tone. During the first five trials, shock could be escaped or avoided if the animal simply ran from one side of the shuttlebox to the other (FR-1). During the next 25 trials, shock could only be escaped or avoided if the animal crossed the shuttlebox twice (FR-2), i.e., the rats were required to cross from one side of the box to the other and then return in order to escape. Latency to terminate the trial was recorded to the nearest 0.1 sec. The data from each of the three experiments to be reported were analyzed using repeated measures analyses of variance followed by Newman–Keuls multiple comparisons. α was set at 0.05 in all cases.
Results and Discussion

Avoidance responses did not occur at any point during training. Thus the task can be viewed as signaled escape. Figure 1 presents the latency to escape across blocks of five trials. As inspection would suggest there were no group differences during FR-1 training \([F(3,36) = 1.09]\). However, substantial group differences emerged during FR-2 trials. Relative to Group R24, preshock interfered with escape learning when it occurred 24 hr after inescapable shock (Group P24) but had no effect when escape training occurred 48 or 168 hr later (Groups P48 and P168). Statistical analyses confirmed these impressions. A \(4 \times 5\) repeated measures analysis of variance performed on the mean latency to escape during FR-2 trials revealed a substantial Groups effect \([F(3,36) = 4.02]\). Subsequent Newman–Keuls comparisons indicated that Group P24 was slower to escape than were any of the other three groups, which did not differ from each other.

These data indicate that the shuttlebox escape learning deficit dissipates within 48 hr of exposure to the identical inescapable shock procedure which produces a Y-maze choice accuracy escape learning deficit even after 168 hr. This provides further support for the contention that the shuttlebox and Y-maze inescapable shock effects are mediated by different processes. The results obtained by Jackson et al. (1979a) and in the present experiment form a pattern which suggests that exposure to ines-

![Figure 1](image-url)  
**Fig. 1.** Mean latency to escape shock across blocks of five shuttlebox escape trials. Rats received preshock 24 (P24), 48 (P48), or 168 (P168) hr prior to shuttle escape training. Group R was restrained 24 hr prior to testing.
capable shock has at least two different consequences. The fact that one consequence seems durable and the other transient is consistent with the notion that one of the two consequences is associative (durable), whereas the other reflects an activity deficit (transient). Finally, the data are consistent with the view that the effects of inescapable shock on shuttling are mediated by the activity factor and the effects on Y-maze choice by the associative factor. However, the data do not offer strong proof for these latter speculations, they are merely consistent with them. Strong support is only provided for the contention that the Y-maze and shuttlebox reflect different processes, not for what these processes are. Experiments 2 and 3 explore this issue further.

EXPERIMENT 2

The idea that the poor shuttlebox escape learning following inescapable shock is produced by a decreased level of activity requires that both shuttlebox learning and unconditioned activity covary. Thus, Experiment 2 investigated whether unconditioned shuttlebox crossings would vary with the passage of time in a manner similar to that which Experiment 1 found to be true for shuttlebox escape learning. Rats were exposed to inescapable shocks as in Experiment 1 and then tested in a shuttlebox either 24, 48, or 168 hr later. A control group was only restrained and was tested 24 hr later. However, the shocks in the shuttlebox were inescapable and of fixed duration. Shuttlebox crossings were recorded. These inescapable shock trials were preceded by five FR-1 escape trials. This was done because the shuttlebox learning deficit is evidenced in FR-2 trials which follow five FR-1 trials. Since the question is whether this learning deficit is produced by a decreased tendency to cross that is not a reflection of a reduced propensity to learn the contingency, the no-contingency trials had to be preceded by the same five FR-1 trials. This means that we are not examining "pure" unconditioned activity, but rather the tendency to shuttle in the absence of a contingency after having experienced five FR-1 escape trials. We will refer to this as unconditioned activity, but the reader should keep this qualification in mind. It might be noted that this procedure is preferable to more fine-grained activity measurement because the factor of interest is the rat's unlearned tendency to expose itself to the FR-2 shuttlebox escape contingency if one were in effect. Measures such as stabilimeter activity could not tell one whether any obtained differences would be sufficient to produce differences in shuttling. They would also not tell us if the differences would be present after five FR-1 trials.

Method

Subjects. Thirty-two rats of the same sex, strain and age as used in Experiment 1 served.
Apparatus. The apparatus was the same as used in Experiment 1.

Procedure. The subjects were divided into four groups (n = 8/group). Three of the groups, P24, P48, and P168 received inescapable shock while the fourth group was restrained as described in Experiment 1. The testing procedure in the shuttlebox was similar to that used in Experiment 1. A 1000-Hz tone preceded shock and terminated with shock at the end of the trial. Since we wished to ascertain whether FR-2 escape performance in Experiment 1 reflected variation in activity, it was necessary that the procedure used here parallel that used in Experiment 1. Thus, all animals first received five FR-1 escape trials as described in Experiment 1. This was done because the FR-2 trials which revealed poor escape performance in Experiment 1 were preceded by five FR-1 trials. Following these trials all rats received 25 trials in which there was no contingency between crossing and shock termination. The tone and shock automatically terminated 35 sec after the onset of the tone. Crossing had no effect on shock. The number of crosses each animal made on each trial was recorded.

Results and Discussion

There were no differences in the latency to respond during FR-1 trials \[F(3,28) < 1.0\]. The mean latency to escape on these trials was 8.2 sec in Group R and was 9.0, 9.2, and 8.2 sec in Groups P24, P48, and P168, respectively. Figure 2 presents the mean number of trials on which two or more crosses occurred as a function of trials. This measure is important because it can be taken as an index of the unlearned likelihood that animals would have completed an FR-2 escape response had such a

![Graph showing the mean number of trials with two or more crosses across blocks of five trials.](image-url)
contingency been in effect. Examination of Fig. 2 reveals that preshocked animals tested 24 hr after inescapable shock were less likely to cross two or more times than were restrained controls. However, 48 or 168 hr after inescapable shock there was no obvious deficit. These impressions were statistically confirmed by a $4 \times 5$ repeated measures analysis of variance. The Group effect was reliable [$F(3,28) = 6.148$] whereas the Trials and Group $\times$ Trials factors were not. Finally, Newman–Keuls comparisons revealed that Group P24 crossed less frequently than did Group P48, Group P168, or Group R24, which did not differ. Thus, using crossing as an index of activity, it is clear that activity deficits dissipate within 48 hr following inescapable shock just as escape learning deficits do.

Several aspects of these data should be emphasized. First, our activity index, the number of trials with two or more crosses, represents a measure of exactly those behaviors which would fulfill an FR-2 escape requirement had one been present. Crossing two or more times in the presence of shock appears to be a rather high probability act in Groups R24, P48, and P168. Approximately 64% of the trials in these groups had enough crossing to ensure that the animals would have escaped within 35 sec (our usual maximum trial duration) had escape been possible. Since these behaviors occurred at high levels despite the fact that crossing was not reinforced, the present data suggest that crossing the shuttlebox two or more times may not strongly depend upon associative factors under the present circumstances. Rather, completing two or more crosses may largely depend on the animals' general activity in the presence of shock. This reasoning suggests that inescapable shock may interfere with FR-2 shuttlebox escape learning by reducing activity. The data obtained in Experiments 1 and 2 are consistent with this argument. Activity, as measured in Experiment 2, mirrored the escape learning effects observed in Experiment 1. In Experiment 2, inescapably shocked rats crossed as frequently in the presence of inescapable shock as did unshocked controls 48 and 168 hr after inescapable shock. These groups also acquired FR-2 escape responses in Experiment 1. Only the group tested 24 hr after inescapable shock crossed less frequently than did controls and this group alone showed deficits in FR-2 escape in Experiment 1. Thus deficits in crossing two or more times dissipated in exactly the same manner as did the escape deficits reported in Experiment 1. This pattern of results would be expected if the activity effect is involved in the mediation of the shuttlebox escape deficit.

**EXPERIMENT 2A**

The shuttlebox escape deficits that are observed 24 hr after exposure to shock are determined by the escapability of those shocks (cf. Maier & Jackson, 1977). Rats that were first able to escape shock by turning a wheel with their paws did not later respond slowly in FR-2 shuttlebox
escape training, whereas rats which received yoked inescapable shocks were slow to learn. Thus the argument that the escape deficits observed 24 hr after inescapable shock exposure are completely or partly produced by reduced activity requires that the reduced activity at this time point be a function of the inescapability of the pretreatment shocks.

Experiment 2A examined this question. Rats received either escapable shock in a small wheel turn box, yoked inescapable shock, or no shock. Twenty-four hours later all subjects were given a shuttlebox unconditioned crossing test identical to that used in Experiment 2.

Methods

Subjects. The subjects were 24 rats of the same sex, strain, and age as in Experiments 1 and 2.

Apparatus. The initial treatment was given in three Plexiglas wheelturn boxes modeled after those used by Weiss, Stone, and Harrell (1970). The walls of the apparatus were made of clear Plexiglas and the floors were made of Masonite. The chambers were 11.4 cm wide and 17.8 cm high. The tops of the chambers were 7.6 cm deep and the bottoms were 17.8 cm deep. Thus the end walls were at an angle and the top fit across the rat's back in such a way that the rat could not turn around in the chamber. A 6.4-cm-diameter grooved Plexiglas wheel was located in the front of each chamber and extended 1.5 cm into the chamber. The force required to turn the wheel was roughly 50 g and was sufficient to prevent spinning of the wheel. The rat's tail extended through a hole in the rear of each apparatus and was taped to a Plexiglas rod. Each chamber was enclosed in a sound-attenuating chamber illuminated by a 7.5-W bulb.

Shocks from three shock sources modified to yield unscrambled outputs were delivered to electrodes which were augmented with electrode paste and taped to the rat's tail.

Shuttlebox activity testing was conducted in the shuttlebox previously described. The only modification was the addition of a Plexiglas ceiling 10 cm above the grids. This addition was made because pilot experimentation revealed that wheel turn escape trained animals would often stand on their hindlegs and hang on the top of a side wall with their forepaw nails in the hinge between the top and side. The lower ceiling prevented this obvious unauthorized escape response.

Procedure. Each rat was assigned to either the Escape, Yoked, or Restrained group. The rats were run in triplets of Escape, Yoked, and Restrained subjects. The Escape subjects received one shock escape training session in a wheel turn box. The session contained 80 trials presented on a variable time schedule with a mean intertrial interval of 60 sec and a range of 30–120 sec. Shock terminated when the rat completed a one-quarter turn of the wheel beyond 0.8 sec following shock onset. Wheel turns during the first 0.8 sec of shock had no consequence. Shock
terminated after 30 sec if an escape response did not occur. Shock intensity for all rats began at 0.8 mA and was increased to 1.0 mA on Trial 20, to 1.3 mA on Trial 40, and to 1.6 mA on Trial 60. This was done because previous work revealed a deterioration of responding when shock intensity was constant.

Yoked subjects simply received the same duration and intensity shocks that their Escape partners produced. Shock began simultaneously for both subjects and terminated for both whenever the Escape rat responded. Restrained subjects were confined in a wheel turn box for an identical period of time but were not shocked.

Twenty-four hours later all subjects received a shuttlebox test session identical to that used in Experiment 2. Five FR-1 escape trials were followed by 25 trials of 30-sec inescapable shocks.

Results and Discussion

The escape subjects learned to escape shock by turning the wheel. Each had a shorter latency on the last 10 trials than on the first 10. Mean latencies were 8.6 sec on the first 10 trials and 2.1 sec on the last 10 trials.

The results of primary interest are shown in Fig. 3. It depicts the mean number of trials on which two or more crosses occurred as a function of trials, for each of the three groups. Analysis of variance revealed reliable effects of both Groups [$F(2,21) = 6.86$] and Trials [$F(4,84) = 24.93$]. The Subsequent Newman–Keuls comparisons indicated reliable differences

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Figure 3. Mean number of trials with two or more crosses across blocks of five trials. Rats received escapable shock (E), yoked inescapable shock (Y), or no shock (R) 24 hr prior to testing.
between Restrained and Yoked groups, and between Escape and Yoked groups. The difference between Restrained and Escape groups was not reliable.

This experiment indicates that at least part of the decrement in unconditioned shuttlebox crossing produced by exposure to inescapable shock is attributable to the inescapability of the shocks. Such a result has also been reported by Anisman et al. (1978). It is not clear whether the entire reduction in unconditioned shuttlebox crossings produced by exposure to inescapable shock was produced by the uncontrollability of the shock. The data revealed a large, albeit unreliable, difference between Restrained and Escape Groups. However, there was not even a slight activity difference between Escape and Restrained subjects on the first block of five trials, and it is at the beginning of testing when activity differences are likely to be most important in producing escape learning differences. It is then that learning of the response has not yet occurred and differential activity could produce differences in exposure to the escape contingency. It should be noted, however, that the possibility of the escape learning deficit being, at least in part, mediated by the activity deficit requires only that escapable and inescapable shock have a differential effect on activity, not that escapable shock have no effect at all. Such an escape-yoked difference was demonstrated.

EXPERIMENT 3

As already noted, the correspondence between activity level and escape learning supports the notion that reduced activity is involved in the mediation of the poor shuttlebox performance of inescapably shocked subjects. Maier and Jackson (1979) suggested that this reduced activity might be caused by an inescapable shock produced reduction in pain sensitivity. A number of studies had already noted that exposure to any of a variety of stressors, including electric shocks, produces an analgesic reaction which persists for between 1 and 2 hr (Bodnar, Kelly, & Glusman, 1978; Hayes, Bennett, Newlon & Mayer, 1976; Madden, Akil, Patrick, & Barchas, 1977). Jackson et al. (1979a), using hot plate and tail-flick tests, added demonstrations that such an analgesic reaction occurs even 24 hr after inescapable shock exposure if the subject is reexposed to shock. Jackson et al. also showed that this decrease in pain sensitivity only occurs if the initial shock is inescapable. Exposure to an equivalent amount of escapable shock did not result in a tendency to become analgesic 24 hr later. These data led Jackson et al. to propose that activity decrements in the presence of shock might occur because of this antinociceptive response. If shock hurts less the subject should move less. However, this idea requires that pain sensitivity changes should covary with changes in activity and shuttlebox learning. Thus the analgesic
reaction to inescapable shock exposure should have the same time course as do activity and learning in the shuttlebox.

Here rats were given inescapable shock or restraint as in Experiments 1 and 2. They were then given five FR-1 shuttlebox escape training trials followed by a tail-flick pain reactivity test. Again, five shuttlebox trials were given before the tail-flick test because such trials preceded the measurement of both the shuttlebox learning and unconditioned activity test. A test of whether pain sensitivity varies in the same manner as the shuttlebox behavior requires the use of the same procedure.

The tail-flick test is a standard procedure used to measure pain sensitivity (Dewey & Harris, 1975). A radiant heat source is focused on the rat's tail and the time taken to deflect the tail is measured. No movements of the organism as a whole are required, and the body of the rat is actually restrained. All that is required is a 5- to 7-mm deflection of the tail. This movement in response to heat appears to be largely a spinal reflex to painful stimulation (Dewey & Harris, 1975).

Method

Subjects. The subjects were 40 rats of the same sex, strain, and age as in Experiments 1 and 2.

Apparatus. Inescapable shock, restraint, and shuttlebox training were administered using the same apparatus as in Experiments 1 and 2. The tail-flick test device consisted of a 43.0 × 17.7 × 8.0-cm (L × W × H) metal box which supported a 7.4 × 3.0-cm (L × W) aluminum plate. A shallow groove was cut in this plate and the rat's tail was put in this slot during a trial. A photocell receiver was located in this groove. A General Electric 150-W projector spotlight was mounted above the plate which held the rat's tail. The distance between the lamp and the tail was adjustable. A condenser lens was located between the light source and the tail and served to focus the light. The position of the lens was fixed and its flat surface was located 6.5 cm above the aluminum plate. A 5- to 7-mm deflection of the tail activated the photocell and automatically terminated the trial.

Procedure. Three groups of rats (n = 10/group) were first given inescapable shock using exactly the same procedure as in Experiments 1 and 2. A fourth group was merely restrained (R). One of the inescapably shocked groups (P24) and the restrained group were tested 24 hr later. A second shocked group was tested 48 hr later (P48), and the last group was tested 168 hr later (P168).

It should be noted that Jackson, Maier, & Coon (1979a) have already shown that the analgesic reaction which occurs 24 hr after inescapable shock exposure is dependent on the inescapability of the shock. Escapable shock does not lead to the reaction. Also, tail-flicks do not occur in the absence of the heat stimulus for the trial durations here used. Thus controls that are tested without the heat stimulus are not necessary.
Testing consisted of five FR-1 shuttlebox escape training trials followed immediately by tail-flick testing. The shuttlebox training was exactly as before. Each subject received three tail-flick testing trials. The interval between trials was spent in the shuttlebox and was approximately 3 min. On a test trial an experimenter (unaware of group membership) held the rat in his/her hand and placed the rat's tail in the grooved metal plate. A switch activated the lamp and started a timer. The light beam was focused on a spot about halfway between the base and the tip of the tail. The distance between the heat lamp and the tail was initially adjusted to produce control group latencies in the range of 6–8 sec. Of course, once adjusted it remained the same for all subjects. A trial was automatically terminated if a tail flick had not occurred in 20 sec, and a 20-sec latency was recorded. This was necessary in order to prevent tissue damage to the tail.

Results and Discussion

The groups did not differ with regard to FR-1 shuttlebox latencies. The mean latency to escape across these five trials for group R was 7.88 sec, while for groups P24, 48, and 168 the latencies were 8.44, 8.66, and 8.78 sec, respectively. The between-groups factor of an analysis of variance on the FR-1 data did not approach significance. The tail-flick latencies are shown in Fig. 4. It is apparent that inescapably shocked subjects showed

![Fig. 4. Mean latency to flick the tail in the presence of radiant heat. Rats received preshock 24 (P24), 48 (P48), or 168 (P168) hr prior to testing. Group R was restrained and tested 24 hr later.](image)
increased tail-flick latencies to radiant heat when tested 24 hr later. This is a large effect, representing an approximately 60% increase from the control level. It is also clear that this reaction has a time course. It is greatly diminished if 48 hr intervene between preshock and testing and it is totally absent if 168 hr intervene. A repeated measures analysis of variance yielded a reliable groups effect \([F(3,36) = 11.92]\). Neither the trials factor nor the interaction of groups and trials approached significance. Newman–Keuls comparisons revealed a reliable difference between group P24 and Groups P168 and R, which did not differ from each other. P48 did not differ reliably from any of the other groups.

The present experiment thus confirms the finding reported by Maier and Jackson (1979) that inescapably shocked rats show increased tail-flick latencies to radiant heat when tested after reexposure to shock 24 hr later. The fact that the analgesic reaction produced by inescapable shock dissipated over the same time intervals as did the inescapable shock produced shuttlebox activity and learning decrements supports the notion that all three are related.

The tail-flick results suggest that inescapably shocked subjects have decreased reactivity to pain. However, there is no way to be certain that the tail-flick test is sensitive to only nociceptive changes. One might argue that the elevated latencies reflect something other than an analgesia. However, a number of points argue otherwise. First, the tail-flick test is the most common procedure used to assess nociceptive changes and seems to be generally sensitive to manipulations known to influence pain sensitivity (cf. Dewey & Harris, 1975).

Second, the “other process” which might produce increased latencies is unlikely to be some sort of generalized movement deficit. It is not likely that such a deficit mediated the present results because only a very small deflection of the tail was required as a response. It is really not much more than a twitch. Moreover, general activity and tail-flick latencies have proved to be independently manipulable. For example, the analgesic effect of stress adapts with repeated exposure (e.g., Akil, Madden, Patrick, & Barchas, 1976) while the activity effect does not (Bodnar, Glusman, Spiaggia, Brutus, & Kelly, 1978).

Third, Jackson et al. (1979b) recognized the possibility that their “analgesia” results might be an artifact of tail-flick testing. Thus they examined the effects of inescapable shock on hot plate paw licking, another commonly used measure of pain sensitivity. The outcome was the same as with tail-flick testing. Of course, this test also requires movement. However, converging results of this sort using different testing procedures argue for a nociceptive change. Further research is needed to eliminate the possibility that some form of activity deficit mediates our measure of analgesia.
GENERAL DISCUSSION

The results of the present experiments can be easily summarized. Animals showed poor shuttlebox escape learning, reduced activity, and decreased pain reactivity when tested 24 hr following exposure to inescapable shock. However, none of these three consequences of exposure to inescapable shock were present if 48 or 168 hr were allowed to intervene between pretreatment and testing.

These results offer further support for the suggestions made by Jackson and Maier which were noted in the introduction to this paper. First, support is provided for the possibility that the poor performance in shuttlebox and Y-maze choice escape consequent upon inescapable shock exposure is produced by different processes. Jackson et al. (1979a) based this suggestion on the fact that manipulation of test shock intensity influenced the two tasks very differently. Jackson et al. also reported that the Y-maze learning deficit did not dissipate over a 168-hr interval. The present experiments revealed that the shuttlebox learning deficit dissipated over a 48-hr interval when the same parameters as in the Y-maze experiment were used. They provide another instance of a variable which has very different effects on the inescapable shock produced performance deficits in the shuttlebox and Y-maze, and thus suggest that exposure to inescapable shock has at least two different consequences for the organism.

Second, the present results support the notion that one of these consequences is a reduction in unconditioned movement in the presence of shock, and that this effect may participate in the mediation of the shuttlebox learning deficit. The data suggest this conclusion because both the shuttlebox learning deficit and shuttlebox unconditioned activity deficit produced by inescapable shock dissipated with the passage of time in similar fashion. Further, both effects are at least partly determined by the uncontrollability of the inescapable shocks. Finally, Jackson et al. (1978) showed that covariation between activity and escape performance also occurred when test shock intensity was manipulated. Thus activity and shuttle escape performance seem to be related. Of course, this does not mean that activity change is the sole cause of the shuttlebox learning deficit. It only means that it is probably involved. In addition, causation could be in either direction. However, it is much easier to envisage how the activity decrement could account for the learning deficit than is the converse. This is because there is no escape contingency to be learned in the unconditioned activity testing situation.

Third, Experiment 3 provided confirmation for the possibility that the activity deficit is at least partly produced by a decrease in pain reactivity produced by prior inescapable shock. The passage of time affected the inescapable shock produced analgesic reaction in the same fashion as it
did the inescapable shock produced inactivity. However, it should again be noted that the pain reactivity test response involved movement, and that differences on this measure could thus be either wholly or partly a product of activity effects. We find it easier to argue that decreases in pain reactivity as assessed by tail-flick latencies produce movement reductions than the converse, but further work will be needed to examine the causal relationship between inactivity and analgesia.

Although the present experiments do not resolve the question of what factors underlie the time course of inescapable shock produced changes in activity or shuttlebox performance, they do comment on several interesting possibilities. For example, one might argue that the diminution of shuttle escape and activity deficits with the passage of time reflects the progressive failure of subjects to retrieve or transfer what was learned during exposure to inescapable shock. Animals may have learned to be inactive during inescapable shock (Bracwell & Black, 1974; Glazer & Weiss, 1976a, 1976b; Levis, 1976) or have learned that behavior and outcome are independent (Maier & Seligman, 1976) but the FR-2 shuttle escape task may be unable to cause retrieval of this learning after 48 hr.

If it is the case that animals tested 48 or 168 hr following exposure to inescapable shock simply do not show as much transfer of their original learning, tasks involving relearning or recognition might be expected to provide a more sensitive index of this learning. Recognition tasks should tend to promote retrieval. Since it is during inescapable shock that rats are said to have acquired either the expectancy that behavior and outcome are unrelated or incompatible motor responses, it would be expected that exposure to inescapable shocks should provide the best circumstance for retrieval of this learning. Escape extinction presents subjects with inescapable shocks and therefore should promote recognition or relearning. Since Experiment 2 involved escape extinction, one might expect that preshhocked rats should have eventually come to cross less than restrained controls. However, there was no obvious indication that there was any effect of inescapable shock in Groups P48 or P168 even after 25 extinction trials. Thus Experiment 2 offers no support to the possibility that animals in Groups P48 and P168 failed to retrieve their prior learning.

The time course found here is more compatible with the notion that exposure to inescapable shock produces a change in some neurochemical process (e.g., Anisman, 1975; Anisman et al., 1978; Weiss et al., 1976), and that this change dissipates or recovers through time. The finding that rats perform as if they had never been exposed to inescapable shock 48 or 168 hr after exposure to inescapable shock might simply indicate that the neurochemical mechanisms responsible for active responding recover to normal or near normal levels by these times.

It should be stressed that such a notion is not inconsistent with the idea that inescapable shock leads to response-outcome independence learning,
and that such learning produces decreased incentive to respond and associative interference (i.e., the learned helplessness hypothesis). We have already noted that there is evidence to support the notion that inescapable shock has multiple effects, and that one of them is the sort of associative change required by the learned helplessness hypothesis. The Y-maze choice escape learning deficit does not show any of the phenomena which have suggested that the shuttlebox escape learning deficit is activity mediated. Here we simply suggest that one of the several effects of inescapable shock may be a neurochemical alteration which affects movement in the presence of shock, and that it is this particular consequence of inescapable shock which has the greatest impact on shuttlebox responding.

Although neurochemical changes may be involved, the present experiments do not indicate what the neurochemical change might be. Anisman (1975) has argued for the involvement of cholinergic mechanisms, while Weiss et al. (1976) have favored adrenergic involvement. However, both seem to suggest the view that these neurochemical alterations produce decreased movement in a direct fashion. That is, the neurochemicals affected are said to be associated with the organism's movement generation system. The results of Experiment 3 suggest that this might not be the case. Rather, pain sensitivity might be directly altered and produce decreased movement in the presence of shock as a secondary consequence. Cholinergic, adrenergic, and other mechanisms are all involved in the central modulation of pain sensitivity (e.g., Bodnar, Kelly, Steiner, & Glusman, 1978; Price, Hayes, Bennett, Wilcox, & Mayer, 1976), and so the analgesia possibility does not decide between neurochemical systems. It should be noted that there is increasing evidence for the psychological control of nociception (see Liebeskind & Paul, 1977, for a review), so the suggestion that experiencing the uncontrollability of aversive events leads to such changes is not without foundation. An interesting possibility is that the critical event might be an alteration in endorphins or enkephalins. These are naturally occurring opiates in the brain (Hughes, 1975; Hughes, Smith, Kosterlitz, Fothergill, Morgan, & Morris, 1975), and their release is known to produce an analgesic reaction (Jacquet & Marks, 1976). It is also known that their activity is increased by stress (Akil et al., 1976). Clearly, our experiments do not separate these biochemical possibilities since pain sensitivity and reactivity seem to be controlled by more than one biochemical system (Amir & Amit, 1978; Bodnar et al., 1978).

Finally, it should be noted that not all studies have found that interference with shuttlebox escape acquisition dissipates within 48 hr. The present experiments might aid in the understanding of the factors which

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3 We have replicated the time course experiment on two additional occasions. Thus there is no question that shuttle escape deficits dissipate over a 48-hr interval under the conditions used here.
determine whether or not such a time course emerges. We have already referred to prior work indicating two important factors: (1) the amount of inescapable shock (Seligman & Groves, 1970) and (2) the intensity of the inescapable shock (Glazer & Weiss, 1976a). The present results in combination with those reported by Jackson et al. (1979a) suggest the importance of a third factor. Jackson et al. found that performance on an escape task (the Y-maze) for which there was no correlation between performance and activity did not show a time course, whereas here we found that a time course did appear with regard to performance on a task in which performances did correlate with activity. The obvious implication is that tasks which are sensitive to the activity consequences of inescapable shock exposure will reveal a time course, and tasks which are sensitive to the associative consequences will not. This might help to explain why some laboratories (Experiment 1 here; Overmier & Seligman, 1967) find a time course in interference with escape learning in shuttleboxes, whereas others do not (Glazer & Weiss, 1976a; Kelsey, 1977). The shuttleboxes used in these studies differ in size, shape, the type of barrier which divides the box into two compartments, and the nature of the electric shock. Although shock in our shuttlebox seems to produce unlearned activity which is highly compatible with, if not identical to, the FR-2 shuttle escape response that is required, it may be that the above differences alter the extent to which elicited activity mimics the response to be learned. Thus it is possible that the test tasks used by Glazer and Weiss and Kelsey might have been more sensitive to associative effects than was our own, and therefore more likely to measure a long-lasting deficit in performance. The possibility that "trivial" factors such as the geometry or other details of the test apparatus are critical to the type of time course of interference revealed is distressing, but may be true nonetheless. This possibility would not be surprising if the appearance of a time course really depended on the extent to which performance on the task in question was determined by activity factors.

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