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Learned Mastery in the Rat

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In a series of five experiments, we investigated the bidirectional effects of prior experience with both control or lack of control over shock on subsequent shock-motivated activity and escape learning. Rats were tested with inescapable shock rather than escapable shock as is used in typical helplessness experiments. Naive rats initially shuttled frequently during shock but decreased activity as testing continued. Pretraining with inescapable shock reduced shuttle responding throughout testing. Unexpectedly, rats which first learned to lever press to escape shock continued unabated shuttling through 200 trials of 10-sec duration inescapable shocks (Experiment 1). These bidirectional effects were replicated using a shuttle escape response for pretreatment and lever pressing as the test response. During two uninterrupted 1000-sec duration inescapable shocks (Experiment 2), escape rats continued to lever press through the 2000-sec of shock. In the third experiment, escapable shock facilitated and inescapable shock hindered later learning when the escape contingency was degraded by a 3-sec delay of shock termination. The fourth and fifth experiments demonstrated that (1) this associative facilitation effect is not simply due to an increase in active responding by escape animals (Experiment 4), and (2) no associative facilitation is observed if the contingency is not initially degraded by a 3-sec delay (Experiment 5). Taken together, these results are the first demonstration of bidirectional effects of control on aversively motivated behavior in animals. In addition to typical helplessness effects, a "mastery" phenomenon is observed. This mastery induced by experience with escape learning is characterized by (1) a motivational effect: persistent general active behavior in the face of inescapable shock, and (2) an associative effect: facilitation in learning degraded response–shock contingencies. These are the opposite of helplessness effects, operationally and descriptively, and may be opposite in process as well.

Both dogs and rats which first experience inescapable electric shock later show shock escape deficits in a different environment (e.g., Maier, Albin, & Testa, 1973, Overmier & Seligman, 1967; Seligman & Maier,

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1967). These animals often fail to make active responses and have difficulty learning to escape shock. In contrast, animals which are first exposed to escapable shock later learn to escape in a new situation just as well as do naive unshocked animals. These deficits observed after inescapable shock experience, but not shock per se, are termed "helplessness" effects. This phenomenon occurs under a wide variety of conditions and in several species including man (see Maier & Seligman, 1976; Maier, Seligman, & Solomon, 1969; Seligman, 1975).

Several explanations have been offered for helplessness effects. The most comprehensive and developed interpretation is the Learned Helplessness Theory (Maier & Seligman, 1976), which states that exposure to uncontrollable aversive events leads to the expectation of "nothing I do matters." This cognitive expectation is presumed to cause two basic behavioral effects; (1) decreased motivation to initiate escape responses (Maier *et al.*, 1973; Seligman & Beagley, 1975; Seligman & Maier, 1967) and (2) decreased ability to associate responses and outcomes (Maier & Testa, 1975).

While at least 100 animal studies employing the triadic design (an escape, yoked, and naive group) have investigated helplessness effects, there has been no systematic attempt to examine its converse, i.e., "mastery" effects which come about from first learning to control an outcome. Almost universally (see Seligman & Beagley, 1975, Experiment 1, for a notable exception), the escape group is not statistically better in escape than is the naive group. Escape pretraining is not a neutral condition, however, if an animal has first learned to escape shock, it appears to be "immune" to the helplessness effects associated with inescapable shock (Seligman & Maier, 1967; Seligman, Rosellini, & Kozak, 1975; Hannum, Rosellini, & Seligman, 1976; Maier & Jackson, 1977; Williams & Maier, 1977).

Why does immunization work? One strong possibility is that animals which first receive escapable shock do not perceive the lack of contingency between responses and shock termination. If passivity during shock reflects an expectation of lack of control over shock termination, then animals previously trained to escape should continue to respond actively during inescapable shock. If this is so, the technique for finding mastery effects becomes obvious: test with inescapable, rather than escapable shock.

Results consistent with this prediction have been reported with dogs (Seligman & Maier, 1967) and rats (Testa, Juraska, & Maier, 1974). In Experiment 1, we directly tested this prediction by pretraining rats with escapable, yoked inescapable, or no shock, and later testing with inescapable shock in a shuttle box. If helplessness and mastery effects are present, we would expect the yoked group to make fewer initial shuttle crossings and the escape group to shuttle more than the naive group.

EXPERIMENT 1

Method

Subjects. Subjects were 18 male Sprague–Dawley rats obtained from Holtzman Company, Madison, Wisconsin. The animals were 100–120 days old at the start of the experiment and were individually housed under a 12-hr light/dark cycle with food and water freely available. Rats were nonsystemically assigned to one of three pretreatment conditions: escape, yoked, and naive (n = 6 per group).

Apparatus. Pretraining and testing were carried out in two identical shuttleboxes 47.0 cm long, 20.4 cm wide, and 19.7 cm high. The walls were constructed of stainless steel with a ceiling of clear acrylic plastic. The floor consisted of stainless steel grid bars 0.4 cm in diameter, 1.9 cm apart. The chamber was divided into two identical sections by a 0.64-cm metal divider with a rounded archway 7.8 cm high and 5.8 cm wide cut out of the bottom. This allowed rats free access to both sides of the chamber. During pretreatment, this archway was blocked by a 0.95-cm thick plywood mount which had a bar-press lever (Ralph Gerbrands Model #G6-312) mounted 4.0 cm from the grid floor. The chambers were illuminated by a 7.5-W bulb mounted on the inside of a sound-attenuating shell which enclosed the chamber. A 0.6-mA electric shock was delivered through the grid floor and sides of the shuttleboxes by a constant current shock source consisting of a 600-V ac transformer and a limiting resistor. Shock was scrambled by a Hoffman and Flesher (1962) relay circuit scrambler. During the test phase, the mounted lever was removed, permitting the rats free access to both sides of the chamber.

Procedure. During pretraining, each rat in the escape group received 4 days of shock escape training in which each lever press (FR-1) terminated shock presentations on Days 1 and 2, and every second lever press (FR-2) terminated shock on Days 3 and 4. Each animal in the yoked group was paired with an escape animal such that both animals received the same intensity and duration of shock. Daily sessions consisted of 50 trials programmed to occur on a variable time (VT) schedule with a mean intershock interval of 60 sec and a range of 10–110 sec. If the escape subject failed to respond, shock was automatically terminated after 60 sec. The naive group received no preexposure to shock and was merely given an equivalent amount of handling during pretreatment. Testing with inescapable shock began 24 hr after the last pretreatment session and consisted of 4 days of 50 trials of 10-sec duration shock (0.6 mA) delivered in the shuttlebox with the mounted lever removed. These shocks were also administered on a VT-60-sec schedule (range 10–110 sec). Responses during shock were recorded when the subject crossed to the other side of the shuttlebox, approximately 18 cm from the archway barrier, thus activating a microswitch. Background white noise (76 dB) was present throughout pretraining and testing.

A rejection criterion of $p < .05$ is adopted for all statistical tests.

Results and Discussion

The escape group learned to escape shock by lever pressing during pretreatment and all subjects were escaping with short latencies (2–5 sec) by the end of training. The results of interest demonstrate dramatic mastery effects. The escape group *continued to respond without diminution* during the course of the 2000 sec of inescapable shock, whereas both the yoked and naive groups decreased responding over days. These results are summarized in Fig. 1. A 3 × 4 (groups × days) mixed design analysis of variance revealed a significant main effect for groups $F(2, 15) = 10.06$; a significant effect for days $F(3, 45) = 10.60$; and a significant groups × days interaction $F(6, 45) = 2.90$. Post hoc comparisons using Neuman–Keul's procedure on simple main effects revealed that on Day 1, the escape (E) and naive (N) groups did not reliably differ but each of these groups made significantly more responses than the yoked (Y) group. On each subsequent day, however, the N and Y groups did not reliably differ, but each group was less active than the E group. As Fig. 1 reveals, and post hoc within group comparisons confirm, the N and Y groups reliably decreased responding during the course of testing.

Why should the escape group continue to actively respond over the course of 4 days of inescapable shock? Three possibilities are apparent: (1) the lever press escape training may have reinforced specific movements consistent with the shuttle response, (2) escape training may reinforce active responding in general, or (3) the escape rats may have "superstitiously" associated shuttle responding with shock termination.

A priori, it can be argued that a particular response tendency can either compete or facilitate performance of a new response. Opponents of the Learned Helplessness interpretation have argued that the rats which receive inescapable shock learn to be passive and this response

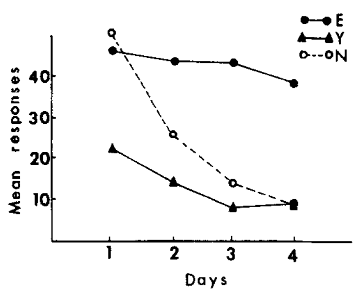

FIG. 1. Mean shuttle responses across days of 50 trials of 10-sec duration inescapable shocks (E = Escape Group, Y = Yoked Group, and N = Naive Group).

tendency competes with actively responding during testing (Bracewell & Black, 1974; Levis, 1976). An analogous argument can be made here. Since the escape subjects were trained to press the lever near the barrier, it can be argued that those animals would be biased toward shuttle responding once the barrier was removed. Observations of the escape subjects during testing, however, suggest that lever press training did not simply bias the subjects to perform the shuttle response. Initially, the lever press response appeared to *compete with* the shuttle response, as subjects would stand on their hind legs and appear to search for the now-absent lever. While it is true that escape subjects tended to bias their responses toward the now-absent barrier, this bias initially inhibited the performance of shuttle responding relative to naive rats. These observations are supported by an analysis of shuttle responding during the first day of testing. As Fig. 2 reveals, the escape group shuttled *less frequently* than the naive group during the first block of 10 trials on the 1st day of testing. An analysis of variance on just Day 1 reveals a significant groups × blocks interaction $F(8, 60) = 5.77$. An analysis of simple main effects on the first block reveals a reliable groups effect $F(2,75) = 10.01$. Post hoc comparisons reveal no reliable differences between the escape and yoked groups, but each of these groups reliably differed from the naive group. Inspection of Fig. 2 shows that the escape group increased shuttle responding during the second block. This suggests that the bar-press pretreatment actually competed with shuttle responding, and this competing response bias extinguished during testing. It appears that the specific S–R association formed during pretreatment did not predispose the escape rats to shuttle.

If the escape pretrained rats were initially not biased toward making the shuttle response, then one is left with two alternative explanations for the persistent active responding. Since response–outcome expectations are presumed to affect both motivational and associative variables (Maier & Seligman, 1976), active responding may have continued either because the motivation to actively respond persisted despite the lack of response–

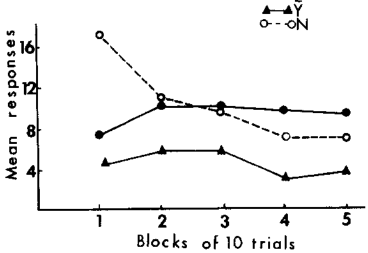

FIG. 2. Mean shuttle responses across blocks of 10 trials of 10-sec duration inescapable shocks for Day 1.

reinforcer contingency (motivational persistence), or the rats were predisposed to see adventitious response–outcome relationships during the inescapable test shocks ("illusion of control"), or both. These two possibilities are confounded in Experiment 1. In the subsequent experiments presented here, the "mastery" effect is found to be a function of both an increased motivation to actively respond and an increased sensitivity to response contingencies.

In summary, (1) both the escape and yoked groups initially made fewer shuttle responses than the naive group, but (2) as testing continued, the escape group persisted in their shuttle responding, while the naive and yoked groups became relatively inactive. This is the first systematic demonstration that prior experience with both control and lack of control can influence subsequent behavior in opposite directions. Just as helplessness experiments have demonstrated that animals which experience inescapable shock are strikingly passive when confronted with escapable shock, the phenomenon reported here shows experience with escapable shock makes rats strikingly more persistent in active responding when confronted with later inescapable shock.

EXPERIMENT 2

The first experiment demonstrated that shock-escape pretraining increases active responding during inescapable shock, but confounded motivational and associative variables as possible explanations. One can minimize potential superstitious conditioning in two general ways: (1) limit the possibility of adventitious associations during testing, and (2) ensure all rats are equally set to perceive response–outcome contingencies.

Testa, Juraska, and Maier (1974) used the latter approach to test motivational persistence. They pretrained one group of rats to escape shock in a wheel-turn apparatus, a yoked group received inescapable shock, and a naive group received no pretreatment. All animals were then tested in a shuttlebox. After administering 30 FR-1 escape/avoidance trials, all subjects were given 20 extinction trials of 30 sec inescapable shock. During extinction, the yoked group made fewer responses than both the escape and naive groups, and in addition, the escape group performed marginally more shuttle responses than did the naive group. However, as the authors point out, this procedure may not have eliminated associative factors. Although the groups did not differ behaviorally during acquisition, we cannot rule out asymptotic differences in the associative strength formed during the 30 conditioning trials. Therefore, it is important to demonstrate that persistence occurs when one eliminates the possibility of adventitious associations occurring during test sessions. This can be accomplished by presenting shock continuously; hence, there are no shock terminations to superstitiously reinforce active responding. Experiment 2 was designed to assess if motivational persistence unconfounded by associative factors, contributes to the "mastery" effect. In addition, the second experiment tests the generality of the mastery effect using a different test response (i.e., bar press).

Method

Subjects. The subjects were 18 male Sprague–Dawley rats as in Experiment 1.

Apparatus. The pretraining apparati were the two shuttleboxes used in Experiment 1. The inescapable shock testing was carried out in two lever press boxes each 30 cm long, 20 cm wide, and 20 cm high. The boxes were constructed of two acrylic plastic sides (lengthwise) and two aluminum ends. A microswitch-operated lever (2.5 cm × 10.0 cm) was mounted 6.4 cm above the floor in one of the metallic sides. The floor was constructed of 0.32-cm stainless steel bars 1.9 cm apart. A Grason-Stadler shock generator (Model E6070B) supplied a 0.8-mA scrambled shock to the grid floor, metallic sides, and lever of the unit. The boxes were housed in a sound-attenuating chamber and 76-dB white noise was supplied to the room to mask extraneous noises. Programming and recording of experimental events was done automatically by relay and recording equipment located in an adjoining room.

Procedure. The rats were nonsystematically assigned to one of three groups: escape, yoked, and naive. Pretraining was conducted on 2 successive days. On Day 1, the escape groups received 50 FR-1 shock escape trials in which a single shuttle response terminated shock. On Day 2, the animals were required to shuttle twice to terminate shock (FR-2). Failure to terminate shock on either day resulted in 30 sec of shock. Yoked animals were paired with escape subjects and received identical shocks as their escape partner. Naive animals were merely placed in the shuttlebox for an equivalent amount of time without shock presentations. Shock was delivered on a VT 60-sec schedule (range, 10–110 sec). On Days 3 and 4, all animals were placed in the lever press boxes and, after a 5-min habituation period, received 1000 sec of continuous inescapable shock. Shock intensity during testing was 0.8 mA.

Results and Discussion

The data were analyzed by dividing each testing session into 100 ten-sec blocks. A response was recorded if the subject made at least one lever press during a 10-sec block. This measure of responding is a sensitive index of persistent coping attempts over time and is not biased by short bursts of multiple lever presses.

During pretraining, all escape subjects consistently escaped from shock with no subject failing to terminate shock on more than five trials. The results of interest, as presented in Fig. 3, demonstrate mastery effects once again. During testing, the escape group continued to lever press

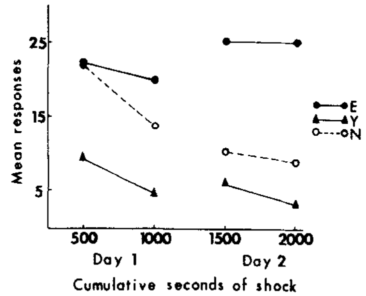

FIG. 3. Mean responses (10-sec blocks with one or more lever presses) as a function of 2 days of 1000-sec duration shocks in blocks of 500 sec.

over the course of 2000 sec of inescapable shock while the naive animals decreased responding to a level comparable to the yoked group. A 3 (groups) × 4 (blocks of 500 sec of shock) analysis of variance revealed a reliable groups effect, $F(3, 9) = 7.68$. Post hoc tests revealed that the escape group responded more than did the naive or yoked groups. The naive and yoked groups did not reliably differ. Within group comparisons revealed that only the naive group reliably decreased responding over trials.

In Experiment 1, there were no reliable differences between the escape and naive groups after the first day (500 sec of shock), while both groups were more active than the yoked group (see Fig. 1). A similar pattern emerged in this experiment; the escape and naive groups were initially identical in responding, but the naive group became less active over the course of testing.

We have demonstrated in two quite different experiments that shock initially motivates active responding in escape and naive rats to about the same level. Over the course of testing, however, shock apparently loses its ability to motivate active responding for naive animals. Yoked subjects are both initially less active and continue to be relatively passive as testing continues. Others state that the inactivity of yoked rats demonstrates the motivational deficit that is one of the characteristics of helplessness effects (Maier & Seligman, 1976), and we suggest the continued responding of escape rats demonstrates a converse effect (i.e., motivational persistence).

EXPERIMENT 3

The results of the previous two experiments demonstrate that experience with escapable shock increases active responding in new situations when shock is inescapable, and this effect is at least partially due to persistently high levels of responding motivated by shock. As previously suggested, a perceptual set to more easily associate responding and outcomes may also result from escape pretraining. While we have demonstrated persistence effects independent of associative effects, how does one demonstrate associative effects not confounded by performance or shock-motivated activity differences? To show an associative difference, we believe it is necessary to fulfill two criteria: (1) the groups respond at the same rate when no response contingency is present, and (2) rate differences emerge when there is an ambiguous response contingency, but are attenuated when the contingency is made salient.

Several researchers have attempted to demonstrate associative deficits in inescapably shock rats. Maier and Testa (1975) first showed that all subjects can learn an easy FR-1 shuttle response, but the yoked group fails to learn an FR-1 response if a 3-sec delay is introduced between the response and shock offset. Since criterion 1 was not fulfilled, we cannot be certain that the yoked group was inferior at learning or merely became less active as testing continued. Indeed, when one examines their data, one is not so much impressed with faster learning on the part of the escape and naive groups, but rather the yoked group appears to be "giving up" faster. However, in a second series of experiments, Jackson, Maier, and Rappaport (1978) were closer to demonstrating an unconfounded associative deficit. They first showed that preshocked and naive animals do not differ in suppression of appetitive responding when no contingency exists between responding and signaled shock. If there is a response–shock contingency, the naive rats suppress appetitive responding to a greater extent, while the preshocked animals behave as if no response contingency exists. This experiment comes quite close to meeting both criteria. The best evidence to date, however, comes from a series of experiments by Jackson, Alexander, and Maier (1980). Using a Y-maze, yoked animals were slower to learn the correct response even when activity differences were factored out. Interestingly, in their second experiment, the escape group was superior (though not significantly so) to naive rats in acquiring the correct response. If the escape task is made sufficiently difficult it may be possible to reliably demonstrate differences between the naive and escape groups.

In the following experiment, we tested rats on a difficult escape task in which a single lever press terminated shock after a 3-sec delay. In this way, the motoric requirement to terminate shock was easy and not biased for the escape or naive groups; yet the contingency between responding and shock termination was ambiguous. If escape pretraining predisposes rats to see contingencies between their responses and shock termination, then the escape group should learn to lever press faster than the naive group.

Method

Subjects. The subjects were 24 male Sprague–Dawley rats, obtained from Holtzman Company at 90 days of age. The rats were individually housed for 7–17 days before the start of the experiment and placed on a 12-hr light/dark cycle with food and water continuously available. All experimental procedures were carried out during the light phase of the cycle.

Apparatus. Pretreatment was administered in two identical shuttle boxes as described in Experiment 1. Shock–escape testing was conducted in two identical lever boxes as described in Experiment 2. All apparati were housed in sound-attenuating chambers with white noise present during both phases of the experiment.

Procedure. The subjects were nonsystematically assigned to one of three groups ($n = 8$): an escape, yoked, and naive group. During pretraining, the escape group received 10 FR-1 trials followed by 50 FR-2 trials in the shuttlebox. Shocks were programmed to occur on a VT 60-sec schedule (10–110-sec range) with a maximum duration of 30 sec if the animal failed to respond. Yoked animals received an equivalent shock which terminated independently of their behavior. Naive animals were merely placed in the shuttlebox without shock presentations.

Approximately 24 hr after pretreatment, each animal received 20 shock escape trials in the lever press box. A 3-second delay was imposed between the FR-1 requirement and shock termination. If the subject failed to respond in 30 sec, shock was automatically terminated. Therefore, the maximum total duration of shock was 600 sec.

Results and Discussion

All latencies were submitted to a log transformation in order to stabilize the variability inherent in such data. The results are presented in Fig. 4, and show the escape group learned to escape faster than the naive group, while the yoked group failed to show any escape learning. A 3 × 4 (groups × blocks) repeated measures analysis of variance revealed a main effect for groups, $F(2, 21) = 7.22$; blocks of trials $F(3, 63) = 5.30$; and a significant groups × blocks interaction, $F(6, 63) = 4.87$. On the first block of five trials, post hoc comparisons on simple main effects reveal that there were no differences between the groups. By the second

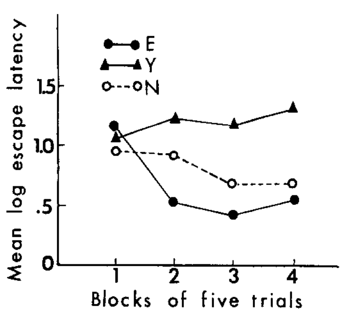

FIG. 4. Mean latency to escape shock in log seconds across blocks of five trials.

block of five trials, the escape group had already learned to escape as demonstrated by reliably shorter latencies relative to the first block of trials. In addition, escape subjects had reliably shorter escape latencies than did the naive and yoked groups, which themselves did not reliably differ between themselves or with respect to within group comparisons to Block 1. On the third and fourth blocks, the naive group had learned to escape, as demonstrated by reliable within group comparisons to Block 1, and there were no reliable differences between the escape and the naive groups. Both of these groups, however, had reliably shorter latencies than did the yoked group.

This is the first reported reliable difference between escape and naive groups in rate of learning a shock escape task. Why then did the groups significantly differ in this experiment while the groups do not typically differ in helplessness experiments? As previously mentioned, when one compares "learning curves" in a shuttlebox, one does not typically observe decreasing latencies on the part of the escape and naive groups (i.e., Maier, Albin, & Testa, 1973, although for an exception, see Brett, Burling, & Pavlik, 1981). These groups seem to merely persist in shuttle responding while the yoked group appears to "give up." Thus, the ability of the shock to motivate active responding appears to be the most important variable in the performance of the response. However, when one uses an escape task which is difficult to learn, as evidenced by slowly decreasing escape latencies, one does observe a faster rate of acquisition for the escape group (i.e., Goodkin, 1976).

In order to unambiguously conclude that the faster response acquisition of the escape group demonstrates an associative facilitation, we must show that the escape subjects are not especially predisposed to perform the escape response. The results of Experiment 2 demonstrate that over the first 500 sec of continuous inescapable shock, the escape and naive groups are equally likely to lever press when no escape contingency is present. Since the maximum amount of shock that rats could receive in the third experiment was 600 sec (20 trials × 30 sec), the results of Experiment 2 suggest that the escape rats were not biased to perform the lever press during testing. These results, however, are derived from one long continuous shock, and it is possible that interrupted shocks of the type presented in Experiment 3 would show that escape subjects are more likely to perform unconditioned lever presses.

EXPERIMENT 4

This experiment was designed to measure unconditioned lever presses using shock parameters identical to those used in Experiment 3. Therefore, 1 day after escapable, inescapable, or no shock experience, rats were placed in a lever press box and were yoked to a naive rat as it learned to lever press to escape shock. If prior escape experience biases rats to lever press, then the escape subjects should lever press more than naive rats as both groups receive yoked inescapable shock.

Method

Subjects. The subjects were 24 male Sprague-Dawley rats obtained from Holtzman Co. and maintained under a 12-hour light/dark cycle with food and water freely available. The subjects were individually housed for 10-20 days before the start of the experiment.

Apparatus and Procedure. The apparati for pretraining and testing were the same as those used in the previous experiment. The procedure during pretraining was also identical to that used in Experiment 3. During testing, one subject from each of the escape, yoked and naive group was given inescapable shock. The presentations of inescapable shock were determined by yoking each triad to a naive subject which received 20 shock escape trials. Escape training was identical to that used in the previous experiment after a lever press shock termination occurred after three seconds delay. Shock was automatically terminated if the subject failed to respond in 30-seconds.

Results and Discussion

The results presented in Table 1 show that the escape subjects were less likely to lever press during inescapable shock relative to naive rats. In fact, relative to naive unshocked rats, escape animals made reliably fewer total lever presses and had fewer trials in which at least one response occurred. An analysis of variance revealed significant group differences for responses: $F(2, 33) = 4.55$; and trials with at least one response, $F(2, 33) = 5.76$. Post hoc comparisons showed reliable group differences between the naive and escape groups for responses and a marginally significant difference for trials with at least one response ($p < .07$). The yoked subjects did not reliably differ from escape subjects on either measure, but were reliably less active than naive rats for both responses and trials with a response.

These results demonstrate that the escape rats are not more likely than are naive rats to contact the escape contingency. If the escape rats

TABLE 1
Mean Activity Scores during Inescapable Shock

Group	Responses	Trials with a response
Naive	21.33	8.00
Escape	11.58	5.25
Yoked	5.17	3.08

acquire the escape response *faster* than naive rats, but do not respond more when there is no contingency between responses and shock termination, then the superior performance of the escape group during escape learning must be due to the response contingency. These results strongly suggest that after escape training, rats are more sensitive to contingent relationships between their responses and shock termination. Hence, the escape rats quickly learn to escape shock in new situations even when the response–shock termination contingency is degraded by a 3-sec delay.

If the learning differences in Experiment 3 are due to an increased tendency to perceive response–reinforcer contingencies on the part of the escape animals, then it should be possible to attenuate these differences by presenting initial trials where the contingency is quite salient, thus leading all animals to easily perceive the response–reinforcer contingency.

EXPERIMENT 5

In the previous two experiments, we demonstrated that even over a range of shock where escape rats are not biased to come in contact with the escape contingency, we can still observe a faster rate of acquisition of a lever press response for the escape group. In this experiment, the learning conditions of the previous two experiments were replicated, except that the first five trials did not have a delay between responding and shock termination. By making the contingency more obvious during these initial trials, we expected that all subjects should have no difficulty bridging the 3-second delay, and no "mastery" effect should be shown.

Method

Subjects. The subjects were 24 male Sprague–Dawley rats obtained from Holtzman Company and maintained under a 12-hr light/dark cycle with food and water freely available. The subjects were individually housed for 10–20 days before the start of the experiment.

Apparatus and procedure. The apparati for pretraining and testing were the same as those used in the previous two experiments. The procedure was also identical except during testing all the subjects received five FR-1 trials *without* a delay followed by 15 FR-1 trials with a 3-sec delay between the response and shock termination.

Results and Discussion

All data were submitted to a log transformation in order to stabilize the variance inherent in such data. The results are presented in Fig. 5, and show that the escape and naive groups are virtually identical in performance of the shock escape task. The yoked group appears somewhat inferior to both of these groups when the delay is introduced. An analysis of variance over all four blocks of trials revealed no reliable groups

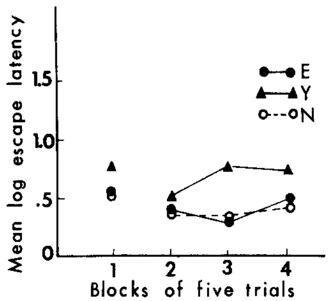

FIG. 5. Mean latency to escape shock in log seconds across blocks of five trials.

effect, $F(2, 21) = 1.69$. A separate analysis of variance for each block of five trials revealed no reliable groups effect on each of the first two blocks, $F < 1$. On the third block, however, the yoked animals appear to have difficulty maintaining escape responding (see Fig. 5), suggesting some inability to bridge the 3-sec delay even with the initial five no-delay trials. This block revealed a significant groups effect, $F(2, 21) = 4.04$. Post hoc comparisons showed no reliable differences between the escape and naive groups, but each of these groups reliably differed from the yoked group. On the fourth and final block, the statistical analysis just fails to reach significance levels $F(2, 21) = 2.87$, $< .05\ p < .10$. These results demonstrate that the escape and naive groups do not differ in escape learning if five trials without a delay are introduced before the delay trials, while the yoked group appears to have difficulty bridging the delay even with this procedure.

Taken together, the results of Experiments 3 and 4 show that prior exposure to escapable shock facilitates associations between responses and shock termination, but this effect is attenuated when the response contingency is salient. These results are also consistent with previous research (Baker, 1976; Maier, Albin, & Testa, 1973; Jackson, Maier, & Rapaport, 1978), suggesting associative interference in inescapably shocked animals. The criteria outlined above for the demonstration of an associative difference between the escape and naive groups have been met. There are no differences between the escape and naive groups in lever pressing when shock is presented noncontingently, but by manipulating the salience of the contingency we can separate these groups. Therefore, prior exposure to escapable shock facilitates acquisition of response–outcome associations, as well as produces increased motivation as measured by greater persistence during inescapable shock.

GENERAL DISCUSSION

The results of these five experiments demonstrate that prior experience with control over an aversive event leads to both increased persistence of shock-motivated responding and facilitation in learning response–outcome associations. These results are the opposite of the motivational and associative effects which are induced by uncontrollable events. Since experience with control or lack of control leads to opposite empirical results and represents converse operations, it suggests an opposite process is operating as well. To this point, we have assumed that inescapably shocked rats learn that shock termination is response independent, and this leads to an expectation of lack of control. It follows logically from the Learned Helplessness Theory that experience with controllable events should lead to an expectation of "there is something I can do to escape." In new situations, this expectation should: (1) increase motivation to find an escape response, and (2) increase ability to associate responses and outcomes. The findings of the present series of experiments are clearly consistent with this interpretation. However, alternative interpretations must also be considered.

Consider first the response initiation deficits of the yoked group and the persistent activity of escape subjects. The Learned Inactivity Theory states that during inescapable shock, inactivity is adventitiously paired with shock termination and through superstitious conditioning, response passivity becomes the dominant response during shock (Bracewell & Black, 1974; Levis, 1976; Weiss, Glazer, & Pohorecky, 1975). Likewise, it can be argued that activity is reinforced when given escape training, and this leads to increased active responding for the escape group. The Learned Activity/Inactivity theories do not seem to be satisfactory accounts of the data. In the first and fourth experiments, we observed that the escape group was initially *less* active than the naive group, suggesting that the pretreatment task actually *competed* with the test response. In the second experiment, we observed that the naive group became inactive over the course of continuous inescapable shock. This demonstrates that adventitious reinforcement of inactivity is not necessary to observe response initiation deficits. Although the escape and yoked animals experience the identical physical stressor, there must be some psychological factor which induces bidirectional effects on subsequent shock-motivated activity. This factor cannot be explained simply in terms of specific S–R associations. The results suggest, rather, two general types of organismic states which follow from both escapable and inescapable shock experience.

These states can be characterized by implied cognitive expectations and/or in terms of biochemical changes. While the Learned Helplessness Theory has assumed that cognitive expectations cause helplessness effects, biochemical mechanisms for these effects have been proposed. Weiss and his associates have proposed the Norepinephrine Depletion Theory, which suggests that stress leads to a transient depletion of brain norepinephrine which causes a motor activation deficiency (Weiss, Stone, & Harrell, 1970; Weiss, Glazer & Pohorecky, 1975). Similarly, Anisman

(1975) has proposed that stress termination induces a cholinergic rebound in yoked rats, and this imbalance in the catecholamine–cholinergic systems causes an activity deficit. While these theories can explain why a single prolonged shock leads to decreased activity, there is no adequate explanation for the performance of the escape group. Given that yoked rats may experience more stress than their escape partners (Weiss, 1971a, 1971b), it is reasonable that inescapable shock should lead to a greater activity deficit. Escape pretraining, however, should be more stressful than no shock experience, thereby producing a modest decrease in norepinephrine; hence, the escape group should be less active during testing than the naive group. Contrary to this expectation, we observed that escape animals continue to persist in active responding, while the naive group gradually decreased activity. These results suggest that escape pretreatment somehow "immunizes" rats to the disruptive effects of inescapable shock. It is obvious that the emotional stress mechanism is not adequate to explain how control over shock termination can influence catecholamines. The most perplexing finding for the stress mechanism is that after escape training, brain norepinephrine levels actually *increase* relative to naive unshocked animals (Weiss *et al.*, 1970).

A second biochemical theory has recently been proposed by Maier and Jackson (1979). They suggest that stress-induced analgesia may attenuate shock-motivated activity. Again, we have no mechanism to explain why the escape group should not show this analgesia effect when they are tested with inescapable shock.

The Learned Helplessness Theory has proposed that the expectation of control or lack of control modulates shock-motivated active responding. While this cognitive interpretation appears to be the most parsimonious explanation for the motivational persistence effect, even this approach may not completely describe the data, since it does not take into account the emotional reaction to inescapable shock. Our observations of the rats during testing suggest that active responding was accompanied by signs of emotional arousal and the escape subjects appeared to remain visibly aroused throughout inescapable shock, while the naive and yoked groups became less visibly aroused and passively "accepted" shock. If the escape rats expect to control shock, being placed in a situation where control is no longer available may increase arousal and frustration. This effect was demonstrated by Stroebel (1969), who trained monkeys to control shocks, aversive lights, noise, and ambient temperature. When the controlling lever was placed just out of reach with no other stressors present, the subjects became quite emotionally upset as evidenced by disrupted circadian rhythms, irregular brain temperature, and bizarre compulsive behaviors. It is reasonable to speculate that during testing with inescapable shock escape rats were motivated to escape not only the aversive shock but the frustrating effects of having lost control over shock termination.

Despite our several attempted explanations, we do not have a complete understanding of the unabated responding in the escape group during 2000 sec of inescapable shock. All interpretations predict that with sufficient experience with inescapable shock, active responding would decrease to the same low levels exhibited by the yoked and naive animals.

Escape animals not only show increased motivational persistence, but appear set to associate responding and outcomes during testing. How can associative facilitation be explained? This effect can be explained in terms of learned relevance/irrelevance. Since shock termination was contingent on some response, we can assume the proprioceptive stimuli associated with responding became a reliable predictor of shock termination. This procedure may increase the salience of proprioceptive stimuli from responding or even the salience of response–relief contingencies themselves (MacIntosh, 1973). If escape subjects learn to attend to responses or to the contingency between its responses and shock termination, then escape learning should be facilitated. This effect should be most obvious when the escape contingency is obscured by a delay procedure as in Experiment 3. Conversely, we suggest that rats which receive inescapable shock learn their responses are irrelevant with respect to shock termination and come to pay less attention to responding or to escape contingencies. This should interfere with the acquisition of future response–outcome associations, and may explain the associative aspect of helplessness deficits. Recent evidence in both classical and instrumental learning paradigms demonstrate that it is difficult to establish an association between two events if the organism has had prior experience with these events presented randomly (Baker, 1976; Jackson, *et al.*, 1978; Maier & Jackson, 1979; Jackson, Alexander, and Maier 1980; Maier, *et al.*, 1979; and Alloy & Ehrman, 1981). Clearly, further research investigating the possibility of learned relevance is mandated.

In summary, we have demonstrated the existence of a phenomenon which appears to be the converse of helplessness effects. Following escapable shock, we find (1) a motivational increase—persistent active responding in the face of inescapable shock, and (2) an associative facilitation—increased ability to associate responding and shock termination. We suggest that the converse process of learned helplessness—a general expectation of control over shock—is the most parsimonious explanation for this phenomenon.

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