ATTACK, AVOIDANCE, AND ESCAPE REACTIONS TO AVERSIVE SHOCK¹

N. H. AZRIN, R. R. HUTCHINSON,² AND D. F. HAKE

ANNA STATE HOSPITAL

Aversive stimuli are known to produce the behaviors of both escape and attack. The interaction between these two basic reactions was studied with rats and monkeys using many shock-escape and shock-avoidance procedures. All procedures produced attack if a target was present, the attacks occurring shortly after shock delivery. The number of attacks during escape or avoidance was a direct function of the number and duration of shocks received. Consequently, any aspect of the procedure that produced many shocks also produced many attacks such as initial acquisition, extinction, or an increase of the response requirement for escape. The escape tendency acquired prepotency over the tendency to attack since successful escape eliminated attack behavior. The attack tendency retarded escape behavior only during acquisition when the preoccupation with attack precluded the opportunity to learn the escape response. This mutual interference of escape and attack was eliminated when the attack and avoidance tendencies were combined by using biting attack as the shock-avoidance response. The result was unusually rapid conditioning of the biting-attack response. These interactions indicate that both the attack and escape tendency should be considered whenever aversive stimulation is delivered.

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When a response terminates a stimulus and the probability of that response increases, the stimulus may be defined as aversive and the process designated as escape conditioning (Keller and Schoenfeld, 1950). Reinforcement

by escape can occur when the aversive stimulation is terminated (Dinsmoor and Winograd, 1958; Kaplan, 1956; Harrison and Abelson, 1959), postponed (Sidman, 1953), or reduced in intensity (Weiss and Laties, 1959; Campbell, 1955). Escape conditioning is usually conducted in an environment free of extraneous stimulus objects or events that interfere with the escape responses. Certainly no other subject is allowed in the experimental chamber.

Aversive stimuli are now known to have a second major effect: they elicit attack against a nearby animal (Ulrich and Azrin, 1962). In studies of elicited attack, strict precautions are typically taken to prevent escape from the aversive stimulus (Azrin, Hutchinson, and Sallery, 1964). Also, unlike studies of escape conditioning, another animal or object must be present with the experimental animal to serve as the target. Consequently, previous studies of shock escape and shock-elicited attack have used such different procedures that there has been no opportunity to determine the relationship between these two reactions.

Several types of interaction seem possible between the escape and attack reactions. The simplest possibility, of course, is that of no interaction, each of the reactions being independent of the other. One possible interaction

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²Now at Western Michigan University.

is that the frequent scheduling of shock, as in the continuous avoidance procedure of Sidman (1953), would establish a "general aggressive motivation" that would result in such frequent attacks against a target that the avoidance performance would be reduced. Conversely, the avoidance performance might be the dominant reaction and eliminate any attack behavior by reducing the shocks that would have otherwise produced attack.

A first step in studying the relation between attack and escape has been made in two studies (Ulrich and Craine, 1964; Ulrich, Stachnik, Brierton, and Mabry, 1966) in which the avoidance performance of paired rats was compared to that of single rats. The paired rats showed a reduction of avoidance responses. The present series of experiments used several types of shock escape and avoidance procedures to investigate further the relation between these two reactions. In a non-technical sense, the question posed here is the relation between fight and flight reactions to aversive stimulation.

EXPERIMENT IA: ACQUISITION OF A SHOCK-ESCAPE RESPONSE OF RATS

The present study investigated whether the attack reaction would interfere with the acquisition of escape behavior. The method for evaluating interference was to compare the speed of acquisition of escape behavior in the usual situation, where no target was present, with the speed of acquisition when a target was present. If the two reactions are independent, no difference should result. But if the reactions are interdependent, the escape reaction should be facilitated or retarded. In order to produce a high level of attack, a procedure was used in which shocks could not be avoided, only terminated. The target was arranged in such a way that the attack and escape reactions were fairly incompatible upon a given shock delivery, thereby simplifying analysis of the attack-avoidance interactions.

Method

Thirty Holtzman Sprague-Dawley rats, 120 to 130 days of age and experimentally naive, were individually housed with food and water always available.

Apparatus. The experimental chamber was 9 by 12 by 9-in. high and was located within a sound-attenuating and ventilated enclosure that contained a large one-way window. Foot-shock was delivered through the grid floor of the chamber from an Applegate constant current stimulator set at 2.0 ma. A scrambling circuit (Hoffman and Fleshler, 1962) ensured that the polarity of each of the floor grids was being continuously changed. The escape response consisted of the depression of a lever (Lehigh Valley Electronics) by 20 g or more of force. The lever was located near one corner of the chamber (see scale drawing in Fig. 1) 2 in. above the grid floor. The target rat was secured to the diagonally opposite corner by a harness, attached to the chamber wall, which maintained the rat in an upright posture. This harness arrangement prevented the target rat from activating the response lever and from interfering with the movements of the unrestrained experimental rat. The target rat was insulated from the shock by a small plastic floor-plate. The distance between the target rat and the lever was about 11 in., sufficient to make it difficult for the experimental rat to react to the target rat and still terminate the shock by lever-pressing.

Procedure. The 30 rats were assigned on a random basis into one group of 20 rats (social condition) or to a second group of 10 rats (individual condition). The 20 rats in the social condition were divided further on a random basis into 10 pairs, one rat in each pair selected for escape conditioning and the other as the target.

Fig. 1. Schematic of chamber for studying escape and attack. The chamber was 12 in. by 9 in.

Five hundred shocks were delivered 10 sec apart to the rats during a single session. Each shock presentation had a maximum duration of 1.0 sec but could be terminated sooner by a single lever-press (escape response). The shock could not be avoided; the lever-presses were ineffective if they occurred during the interval between shock deliveries. For the 10 rats in the "individual" procedure, no other rat was present in the chamber during escape conditioning. In the "social" condition, only the 10 unrestrained rats were conditioned; a target rat was present in the chamber but did not have access to the response lever.

An observer recorded, by pressing a micro-switch, each attack on a target rat. Attack was defined in the same manner as in our previous studies (Azrin, Ulrich, Hutchinson, and Norman, 1964) with rats: striking at the target rat while in an upright position with the head thrust forward, the mouth opened, and the teeth easily visible. Since this attack occurred only for a fraction of a second and immediately after a given shock delivery, only one attack response was recorded for a single shock regardless of the duration of the attack (Ulrich and Azrin, 1962). Two independent observers were used during part of the study; agreement exceeded 95%. Shocks were programmed, and the escape response was recorded, automatically by means of switching circuits.

Results

Figure 2 shows that the average rate of acquisition of the escape response was more rapid for the group of rats conditioned alone. Analysis of the data for the individual rats revealed little overlap between the two groups. Using an arbitrary criterion of 25 escape responses out of 50 consecutive shock deliveries as a rough indication of escape conditioning, only one of the 10 subjects in the social group reached the criterion of conditioning within 150 shocks, whereas nine out of 10 subjects in the individual group did. Using Fisher's Exact Probability Test (Siegel, 1956), the number of escape responses during the first 150 shocks was statistically greater for the rats that were conditioned alone ($p < 0.005$). Four of the rats in the social condition did not learn to escape. They made only infrequent contact with the response lever by "accidentally" brushing against it with the tail or body.

Figure 3 presents the probability of escape (solid line) and the probability of attack (dotted line) for the six rats in the social condition that had learned to escape. The figure shows that an inverse relation existed for each of the six subjects between the probability of escape responses and the probability of attack. During the first block of 100 shocks, the probability of attack was usually 0.70 or greater, whereas the probability of escape responses was usually less than 0.10. As the training continued, the probability of attack decreased, whereas the probability of escape increased.

For each of the other four rats not shown in Fig. 3, the escape responses remained at a low probability of less than 0.10 throughout the session, whereas attack remained at a high probability of 0.70 or greater. These four rats spent the major portion of the session near the target rat and facing away from the response lever, a position that appeared to preclude the opportunity to learn to escape the shock.

In order to determine whether the escape responses would displace the attack reaction once the escape response was learned, one of the four non-learners (S-41) was given a second

Fig. 2. Acquisition of the escape response (lever-press). The probability of escape was calculated by dividing the number of shocks that the rat terminated by the number of shocks delivered. This probability of escape was calculated for successive groups of 100 shock deliveries or trials. Each data point is the averaged performance of 10 rats. The solid curve is for the rats that were alone in the experimental chamber. The dotted curve is for the rats that were paired with a restrained target rat.

session of 500 shocks, but without the target rat present. Within 200 shocks, the rat was escaping more than 90% of the shocks. When the target rat was later reintroduced with S-41 in a subsequent session (see Exp. IIB), the escape response predominated, and the attack reaction was reduced to near zero. These results indicate that the initial failure of the non-learners to escape appeared to result from the competing attack reaction. Once the escape response was acquired, the attack reaction was displaced.

EXPERIMENT IB: NUMBER OF RESPONSES REQUIRED FOR SUCCESSFUL ESCAPE

The inverse relationship between escape and attack suggests that the acquisition of the escape response displaced the attack reaction. Yet, no definitive statement is possible since the relationship is correlational; one response was compared with another response as a function of the lapse of time. An attempt was made, therefore, to manipulate experimen-

tally a presumed cause of one of the responses, namely, the possibility that escape was reinforced by shock termination. With respect to the present procedure, one method of reducing the possibility of escape reinforcement would be to increase the number of lever-presses required to terminate the 1-sec shock presentation. For example, if 10, rather than one, lever-presses were required to terminate the shock, no escape reinforcement could occur, since 10 responses could not be emitted before the shock terminated automatically 1-sec after its onset. Similarly, if three responses were required, the shock could be terminated by a rapid response burst, but the duration for which the shock was shortened would necessarily be less than if only a single response were required. An experiment was conducted in which the extent of escape reinforcement was reduced by increasing the number of responses required to terminate the 1.0-sec shock delivery. The present study also determined whether the escape performance, once it was acquired, would be affected by the attack reaction. As in the previous study, the influences of the attack reaction were investigated by comparing escape performance when a target was present with the performance when it was absent. This design permitted evaluation of the influence of the attack reaction on escape performance at the various escape requirements.

Method

Four of the 10 experimental rats used in the "social" procedure of Exp. 1 served as subjects. All four had shown considerable escape conditioning; three during the first session of escape training, the fourth (S-41) during the second session.

The apparatus was the same as in the previous experiment: a target rat was restrained in the corner diagonally opposite to the response lever. The shocks of 1.0-sec duration were delivered 10 sec apart during each session. For the first 200 shocks, a single response on the lever terminated the shock. By the end of the 200 shocks, each of the subjects was consistently making an escape response to the shock. The response requirement was then increased by one response after every 100 shocks; two responses were required for escape after 200 shocks, three after 300 shocks, four after 400 shocks, etc. until the escape responses

Fig. 3. Probability of escape (solid line) and of attack (dashed line) for each of six rats that were given escape conditioning in the presence of a restrained target rat. Each data point represents the proportion of shocks that resulted in attack, or escape.

reached a near-zero level. This procedure was followed within each session for four consecutive sessions, one session per day. On Days 1 and 4, the experimental rat was present alone in the chamber. On Days 2 and 3, the target rat was also present.

Results

Figure 4 shows, for each of the four subjects, the probability of attack and the probability of successful escape as a function of the number of lever-presses required for successful escape. Successful escape refers to the termination of the shock by the required number of lever-presses. Successful escape, rather than number of lever-presses, is presented; the number of lever-presses per shock can be roughly approximated by multiplying the response requirement by the probability of successful escapes. For all subjects, when the requirement for escape was low (FR 1) the

probability of successful escape (solid line) was 0.98 or more. This consistency of escape exceeds the level seen during the initial session (Fig. 2) at the same response requirement and probably reflected the additional escape training provided by this experiment. At this same response requirement of FR 1, the probability of attack (broken line) was less than 0.02, confirming the finding in Fig. 3 that little or no attack occurred when only one response was required for escape. The figure shows that as the response requirement for escape was increased, the probability of successful escape decreased to near-zero, whereas the probability of attack increased to 0.70 or more. For each subject, the attack reaction increased as the escape response decreased. When the shocks could no longer be successfully terminated at FR 5 and FR 6, attack predominated.

Figure 4 also compares the escape performance of the rats when alone in the chamber (solid line) on Days 1 and 4, with the performance when paired with the target rat on Days 2 and 3 (dotted line). At the lower response requirement, successful escape occurred on almost every shock whether or not the target rat was present. Similarly, no difference was observed at the higher response requirements, where almost no successful escape occurred. At intermediate response requirements, however, the presence of the target rat interfered with escape responding to a slight degree for two rats (S-30, S-35) and to a larger degree for the other two.

Fig. 4. Probability of escape and attack during escape conditioning under different fixed-ratio (FR) escape requirements for each of four rats. The "FR escape requirement" designates the number of lever-presses required to terminate a shock. The solid curve is for the escape responses of the rat when it was alone in the experimental chamber. The broken curves are for the escape (dotted curve) and attack (dashed curve) responses of the same rat when a restrained target rat was present in the chamber. Each data point is the average of two sessions. Probability is calculated as the proportion of shocks on which an escape (or attack) response occurred.

Discussion

The delivery of shock had two distinctive effects: (1) the probability of the escape response increased, and (2) unconditioned attack was elicited if a target was present. The dominant reaction was escape: attack did not occur when the rats escaped successfully. Attack occurred only when successful escape was absent: during the initial period of escape conditioning, and when the response requirement for escape was too high. The reason why the escape reaction was dominant may be derived from the previous finding (Azrin *et al.*, 1964) that the probability of attack is a direct function of shock duration. Since escape responses necessarily decrease the duration of shock, attack would necessarily decrease once escape occurred. In the present study, the average duration of shock presentation was less

than 0.1 sec for all subjects during the second day of conditioning. The probability of attack at that time was 0.02, a value which corresponds roughly to the low probability of attack obtained by Azrin *et al.* (1964) at similarly brief shock durations. It would seem that escape behavior displaced shock-elicited attack by reducing the duration of the shocks received by the subject.

The findings also indicate that once attack is elicited it may interfere with escape behavior, the clearest evidence being the delayed acquisition of the lever-pressing response. The preoccupation of the rat with the target appeared to prevent the occurrence of the incidental contacts with the response lever which were essential for acquisition to occur. Observation revealed that the rat often maintained a "preparatory" posture facing the target between shock deliveries instead of moving about the chamber. It appears, therefore, that attack behavior, once it is initiated, may lead to an incidental and often temporary interference with escape because of spatial factors. This general statement also describes the second instance in which the emergence of attack behavior reduced the probability of escape. When the escape requirement was increased in Exp. IB, the escape response was somewhat less probable in the presence of a target. Again, gross observation indicated that the interference was attributable to spatial factors. Once a shock of sufficient duration to produce attack had been received, the rat often remained facing the target in an upright posture until the subsequent shock was delivered, at which time there was little opportunity to press the response lever. The attack reaction seemed to interfere with escape primarily as a result of the spatial and temporal incompatibility between the two reactions.

EXPERIMENT IIA: ATTACK AGAINST AN INANIMATE TARGET BY A MONKEY DURING CONTINUOUS AVOIDANCE

This study analyzed further the relation between attack and escape by changing the nature of the target, the schedule of shock presentation, the species, and the response requirement. Monkeys, instead of rats were used as the subjects, an inanimate object, instead of a live animal as the target, an avoid-

ance procedure instead of escape, electrode shock instead of the relatively uncontrolled footshock, and an objective method of recording attack instead of the observer's interpretive judgments. Also, the present procedure allowed the attack response and the conditioned response to occur in rapid succession, whereas the two responses were, by design, mutually exclusive in the previous procedure.

Method

The subjects were two male, squirrel monkeys that were experimentally naive at the start of the study. Food and water were continuously available in their living cages.

Apparatus. An apparatus described by Hake and Azrin (1963) was used in which the monkey was loosely restrained in a seated position. A response lever (Lehigh Valley Model No. 1352) was located on the lower left of the wall that faced the monkey. A device for automatically measuring attack was located in the center of the same wall. This device has been described in detail (Hutchinson, Azrin, and Hake, 1966) and consisted of a rubber tube that could be bitten; the resulting change of pneumatic pressure yielded an automatic record of the number of bites by means of a pressure transducer. The response lever was approximately 5 in. from the center of the rubber tube and allowed the monkey to bite and lever-press simultaneously or in rapid succession. A force of 25 g was required to depress the response lever. The initial press on the lever defined an avoidance response. Successive responses required successive releases and presses. Electric shock was delivered to the shaved tail of the monkey by surface electrodes from the 150 v output of a transformer and through a 10,000 ohm series resistor that stabilized the current flow. The shock was 100 msec in duration and was delivered according to the procedure described by Sidman (1953) for studying continuous avoidance behavior. If the monkey did not press the lever, the shock was delivered every 30 sec. Each lever-press postponed shock for 30 sec.

The restraining chair was located within an illuminated, sound-attenuating, and ventilated enclosure. White noise within the chamber masked sounds originating outside. The bites on the bite apparatus and the presses on the lever were recorded automatically in an adjoining room.

Table 1

Effect of target availability on the performance of two monkeys during a continuous shock-avoidance procedure.

	Monkey 127		Monkey 196	
	Target	No Target	Target	No Target
Lever presses/min	12 $\pm$ 2	13 $\pm$ 3	31 $\pm$ 4	37 $\pm$ 2
Shocks/hr	1.5 $\pm$ 0.2	1.2 $\pm$ 0.8	0.8 $\pm$ 0.3	0.6 $\pm$ 0.2
No. of Sessions	41	39	15	8

For the first five days, the shock was disconnected to obtain an operant level of lever pressing and tube biting. The sessions were 3 hr in duration. During the next five days, the response lever was removed and the monkeys were given 60 shocks, delivered 30 sec apart, to determine whether biting attack would result. The lever was then replaced and the shock-avoidance procedure was in effect until the number of avoidance responses was fairly stable from day to day. The effect of the target tube on avoidance responses was evaluated by withdrawing it at intervals. For one monkey (M-127) the bite apparatus was successively absent for 7 days, present 11, absent 6, present 10, absent 9, present 17, absent 11, present 3, and finally absent for 6 days. For the second monkey, the bite apparatus

was present for 6 days, absent 8, and present 9. The avoidance sessions were conducted daily and were 8 hr in duration for one monkey and 5 hr for the other (M-196).

Results

When no shock was scheduled, both monkeys made fewer than eight bites per hour during the first session and fewer than one per hour thereafter. During sessions 5 to 10, when unavoidable shocks were delivered, one monkey averaged 690 bites per hour, the other averaged 1380.

Table 1 shows the mean number of lever-presses and shocks received after the lever-press response was conditioned. Both monkeys averaged fewer than two shocks per hour. The presence of the target did not discernibly

Fig. 5. Two cumulative response records of one monkey during continuous avoidance conditioning. The upper curve is for the lever-pressing avoidance responses; the lower one is for the biting responses. The two records were obtained concurrently. The short downward movement of the pen on both records designates the delivery of a brief shock.

change the rate at which the monkeys pressed the lever or the number of shocks they received.

Figure 5 shows two sample cumulative response records for one monkey, one of the lever-presses and the other of the bites. The records were taken concurrently. Lever-presses

were emitted at a rate sufficient to avoid most of the scheduled shocks. Biting was absent until the shocks were delivered, at which time the monkey immediately bit the tube several times in rapid succession. This general pattern of behavior was obtained in every session; both monkeys made over 97% of the bites within the 20-sec period after a shock. Almost every shock was followed by biting.

Figure 6 shows the relation between the number of shocks received and the number of bites per session for both monkeys. The figure shows that the number of bites was a direct function of the number of shocks received.

Discussion

The results confirm the findings of previous studies with monkeys using a ball (Azrin *et al.*, 1964) or a tube (Hutchinson *et al.*, 1966) as a target, that pain-shock produces attack. As in the previous studies, the attacks were made immediately after shock was delivered.

The previous studies of escape (Exp. I) had revealed that effective escape displaced attack between rats. The present results extended this finding in revealing that effective avoidance responding also displaced attack, in this instance by a monkey. Consequently, the displacement of attack in Exp. I would not appear to have been entirely a consequence of the incompatibility between the attack and lever-press response since the same displacement occurred here where the two responses could be made concurrently.

The attack reaction did not interfere with avoidance responses in the present study; there was no increase in shocks received and no decrease of lever-presses when the target tube was present. It appears that the occasional interference with escape performance in Exp. I was attributable to the incompatibility of the two reactions.

Biting during the shock-avoidance procedure occurred only upon shock delivery. Consequently, frequency of biting during the avoidance procedure was a direct function of the number of shocks received. The existence of attack during escape (Exp. IA and IB) or avoidance (the present experiment) conditioning seemed to depend entirely on whether shocks were actually received. The nature of the response requirement seemed to be important only insofar as it allowed different

Fig. 6. The number of bites per session as a function of the number of shocks received per session during shock-avoidance conditioning for each of two monkeys. Each data point is for one session. The line through the points is the line of best fit based on least squares. For the monkey in the lower graph several sessions were included from the period shortly after acquisition, whereas the data for the monkey in the top graph were taken after the avoidance performance was stable. Note the difference in scale between the two graphs.

durations (Exp. I) or numbers (the present experiment) of shocks to be delivered.

EXPERIMENT IIB: ATTACK DURING A SUSTAINED ESCAPE RESPONSE PROCEDURE

Experiments IA, IB, and IIA required repeated lever presses to eliminate or to reduce the shock. The present study examined further the role of the response requirement by requiring the response lever to be held down rather than pressed repeatedly as in Exp. IIA, which might have interfered with the biting. The response lever could be easily held down by the monkey while simultaneously biting the tube, thereby reducing further any physical incompatibility between the attack and escape reaction.

Method

Two male squirrel monkeys, both experimentally naive at the start of the study, were used.

Procedure. The apparatus was the same as used in Exp. II for conditioning shock avoidance of the monkey. One monkey was given 16 sessions and the other seven, the bite apparatus and response lever were in the experimental chamber but no shocks were delivered. Then, both monkeys were given one session during which the response lever was removed and a pulse train of shocks, 100 msec in duration, was delivered at a rate of 60 per min for

a total of 1000 shocks. The response lever was then replaced in the chamber and made effective; the pulse train of shocks was not delivered as long as the response lever was held down. As soon as the lever was released, the pulse train of shocks began. The escape response was then made ineffective in avoiding the shocks for several sessions and then effective again. For one of the monkeys, the response lever was disconnected and reconnected a second time. The bite apparatus was present in the chamber at all times. This design permitted evaluation of the biting responses to shock when the holding response was not effective, as well as when it was effective. At least five sessions were given under each condition.

For one monkey, the sessions were 6 hr in duration and the shock intensity was 200 v; for the other, the sessions were 2 hr and the shock intensity was 100 v. If 1000 shocks were delivered, the session terminated automatically.

Results

During the initial session with no shock, about 20 bites per min were made by one monkey and 2 per min by the other. As was also found in the previous study (Exp. IIA), the biting gradually decreased or "adapted out" to a near-zero level (fewer than 0.1 bites per min) for both monkeys during the succeeding sessions without shock. During the single session of unavoidable shock, one mon-

Fig. 7. Performance of one monkey during escape conditioning in which a pulse train of shocks was delivered unless the monkey held the response lever down. The solid curve designates the percentage of time that the response lever was depressed. During periods of "no escape", holding the response lever down did not eliminate the pulse train of shock; during the periods of "escape", it did.

key averaged 47 bites per min, the other 36. These results confirm the finding of Exp. IIA that little or no biting occurs in the absence of shock, but that a high rate of biting occurs during unavoidable shock.

Figure 7 shows the duration of holding the lever and the rate of biting the tube during successive sessions of escape conditioning for one of the monkeys. Both monkeys learned the holding response rapidly; by the fourth day, both monkeys held the lever down for more than 99% of the session. The number of bites was high on the first day but decreased to fewer than 1.0 per min after the fourth day. When the holding response no longer terminated the shocks (no escape), the holding response gradually decreased. Within three days, the lever was depressed less than 15% of the session and the rate of biting increased. When the holding response was again made effective (escape), the duration of holding increased within two days to its previous high level, whereas the rate of biting decreased to its previous low level. For M-252 the second period of no escape again produced a high rate of biting and a decrease in holding; the second period of escape again decreased the rate of biting and increased the duration of holding.

Figure 8 shows a sample cumulative record of the biting response and a concurrent event recording of the holding response for one of the monkeys during the condition when the holding response terminated the shocks. It can be seen that biting occurred almost exclusively at the time that the monkey released the lever and allowed shocks to be delivered. The second monkey received fewer shocks (fewer than 1.0 per session) and made almost no bites; of the bites made, however, 70% occurred within 20 sec after the shock deliveries.

Discussion

The present results extend the findings of Exp. I and IIA that a shock-avoidance or shock-escape procedure produces attack only insofar as the escape or avoidance performance permits the delivery of the shocks. As in Exp. I, which used an escape procedure with rats, a reciprocal relation existed between the attack behavior and the escape response. Similarly, the present results extend the findings of Exp. I and IIA in revealing that the attack reaction (presence of a target) does not affect escape or avoidance responding even when the response is a static one, such as holding down a lever.

EXPERIMENT IIC: ATTACK DURING DISCRETE-TRIALS AVOIDANCE

This study attempted to determine the interaction between the attack and avoidance tendencies during classical avoidance with discrete trials. During discrete trials avoidance, a conditioned stimulus precedes each shock delivery and responses are effective only during the conditioned stimulus (see Bechterev, 1932 and recent review by Hoffman, 1966). Since the conditioned stimulus precedes each scheduled shock during discrete trials avoidance conditioning, it is possible that attack might result during that stimulus, rather than solely after shock delivery, as had been found in the previous experiments.

Method

The subjects were two male squirrel monkeys with previous histories of discriminated avoidance conditioning.

The apparatus was the same as used in Exp. IIA on continuous avoidance.

Fig. 8. Two records taken concurrently of the performance of one monkey during escape conditioning. The top record is a cumulative response record of the bites; the lower record is an event recording of the position of the escape lever. The short downward movements of the pen in the top record indicate the delivery of shocks.

Table 2

Effect of target availability on the performance of two monkeys during a classical avoidance procedure.

	Monkey 249		Monkey 153	
	Target	No Target	Target	No Target
Lever presses/min	3.2 ± 0.8	3.1 ± 0.6	3.3 ± 0.2	3.3 ± 0.2
Shocks/session	1.0 ± 1.5	1.0 ± 0.9	0.8 ± 0.9	1.1 ± 0.9
No. of Sessions	20	11	26	6

A shock was scheduled every 22 sec. A 2500 cps tone sounded for 2 sec before each shock and co-terminated with it. A lever-press during the tone terminated the tone; a lever-press in the absence of the tone had no effect. When lever pressing was stable from day-to-day, the target tube was made available for several days, removed for another block of days, and then reinstated. One monkey (M-249) received a total of 11 sessions with the target absent and 20 with it present; the second monkey had the tube present for 26 days and absent for six. The duration of each session was 8 hr for M-153 and 5 hr for M-249.

Results and Discussion

Table 2 shows that both monkeys averaged about one shock per session and pressed the lever about once every 20 sec. The number of lever-presses and the number of shocks for either monkey were not affected by the presence of the target.

Figure 9 shows a sample of the concurrent cumulative records of the bites and the lever-presses for each monkey. The lever-presses

Fig. 9. Performance of each of two monkeys during classical avoidance conditioning. Two concurrent cumulative response records are shown for each monkey. The upper record is for the lever-pressing responses, the lower for the bites. The short downward movement of the pen in all records indicates the delivery of a shock. The occurrence of the conditioned stimulus is not indicated.

were emitted at a low regular rate corresponding to the occurrence of the conditioned stimulus every 20 sec. For both monkeys, over 92% of the lever-presses were emitted during the conditioned stimulus but none of the bites occurred during the stimulus. Biting did not occur unless a shock was delivered, at which time a number of bites followed. As a consequence, the number of bites during a session was roughly proportional to the number of shocks received, as seen in Fig. 10. The number of bites was usually zero during the many sessions in which no shocks were received.

Fig. 10. The number of bites per session as a function of the number of shocks received per session during shock-avoidance conditioning for each of two monkeys. Each data point is for one session. The line through the points is the line of best fit based on least squares.

The results obtained during this discrete-trials avoidance procedure were parallel to those obtained during continuous avoidance in Exp. IIA. The very low rate of avoidance responding during this discrete-trials procedure makes it especially unlikely that the attack and avoidance responses were incompatible. The absence of attack during discrete-trials avoidance seems, therefore, to be a result of the absence of shocks received, as in Exp. IIA and IIB, and not of response incompatibility.

EXPERIMENT IID: SHOCK AVOIDANCE BY AN ATTACK RESPONSE

In the previous experiments, the attack reaction to shock was directed toward one object (a live rat or a rubber tube), whereas the escape or avoidance response was directed at a different object (a response lever). By using two different objects, the escape and attack reactions could be easily differentiated and their interactions analyzed. Interaction between the escape and attack reactions might also result from an inherent identity such as would occur if the attack response itself terminated shock deliveries.

This dual source of control is of special theoretical interest since it provides an opportunity to examine a response that occurs both as a conditioned operant and as an unconditioned response to the same stimulus of shock. The reaction is being operantly reinforced by the termination of shock as well as being elicited by its onset. Consequently, the escape tendency should be expected to strengthen, rather than compete with, the elicited reaction. This experiment attempted to condition an attack response by means of a shock-avoidance procedure. A similar attempt had been made in a previous study (Miller, 1948) that terminated the delivery of foot-shock to rats when they attacked each other. It was found that attack occurred after each shock. Unfortunately, the procedure did not permit evaluation of whether the attack was occurring as an escape reaction that had been learned or as an unconditioned reaction to the unavoidable, albeit escapable, shocks. To avoid this ambiguity of interpretation, a discrete-trials avoidance procedure was used in the present study wherein a conditioned stimulus

preceded the shocks. This procedure should make it possible to distinguish the unconditioned attack (which would occur immediately after shock and before the conditioned stimulus) from the conditioned attack (which should occur only during the conditioned stimulus).

Subjects. Two male squirrel monkeys, one experimentally naive at the start of the experiment, were used. The other monkey had no exposure to shock avoidance or escape but had been studied previously for several months in a procedure that delivered unavoidable shocks.

Apparatus. The same apparatus was used as in Exp. IIA, IIB, and IIC, except that no response lever was present. The shock intensity was 200 v.

Procedure. A discrete-trials avoidance procedure was used in which a shock was delivered every 5 sec during the sounding of the tone. If the monkey bit the tube during the tone presentation, the tone was terminated and did not sound again for 15 sec. The next shock was scheduled 5 sec after the tone onset. Consequently, the shocks were avoided when the monkey bit the tube during the tone. When the tone was not sounding, bites did not postpone the shocks. Sessions were conducted daily for several weeks. The session duration was 30 min for one monkey (M-198) and varied between 2 to 4 hr for the other (M-104).

A probe was conducted for both monkeys to determine the effects of avoidance extinction. During the first few trials of a single session, the bites terminated the conditioned stimulus as usual and the shock was thereby avoided. A number of trials was then given in which the bites did not terminate the conditioned stimulus. Instead, a single shock was delivered every 20 sec and was preceded by the conditioned stimulus, which was still 5 sec in duration. An additional series of trials was then given in which the bites were again effective.

Results and Discussion

Figure 11 shows cumulative records of the biting responses for both monkeys. The lower portion of the figure is for the monkey that was naive at the start of the experiment. The top curve of the lower figure shows that the monkey made a large number of bites (about

450 in 30 min) during the first session, almost all of them immediately after the shocks. Consequently, only one shock was usually received for each presentation of the conditioned stimulus. Few biting responses were made during the conditioned stimulus (avoidance responses) before the first scheduled shock of each conditioned stimulus presentation. This absence of avoidance responses is indicated by the regular spacing of the shocks on the curve. The middle curve shows that by the fifth day, after 2 hr of conditioning, almost all shocks were avoided. The bites were reduced in number, but occurred primarily during the conditioned stimulus. The lower curve for the tenth day shows that after 5 hr of conditioning, the bites were being made almost exclusively during the conditioned stimulus, as indicated by the single bite made at regular intervals of about 15 sec and the almost complete absence of shocks.

The upper portion of Fig. 11 is for the monkey that had a history of exposure to

unavoidable shocks, the last session of which is shown in the top curve. Shocks were being delivered at irregular intervals averaging 1 min apart; no conditioned stimulus was present. It can be seen that a number of bites was made immediately after each unavoidable shock. The middle curve is for the first day of avoidance conditioning. For about the first 15 shocks, the usual burst of bites was made immediately after shock delivery. Thereafter, the monkey bit the tube almost exclusively during the conditioned stimulus, thereby avoiding the shocks. Only one shock was received after the first 15 min of conditioning. On the second day, one shock was received at the very start of the session, after which the monkey avoided all scheduled shocks.

Gross observation indicated that the difference between monkeys in speed of acquisition was related to the degree to which the monkey struggled to escape from the chair. The experimentally naive monkey struggled vigorously during the first hour or so, whereas struggling seemed to have been absent (extinguished) for the monkey that had a prior history in the experimental chamber.

During the five months of avoidance conditioning, both monkeys averaged fewer than 1.0 shocks per hr and the latency of the biting response to the conditioned stimulus averaged less than 1.5 sec.

Figure 12 shows the rate of biting during the session in which the shocks were temporarily made unavoidable. When the shocks were avoidable at the start of the session, almost all bites were made during the conditioned stimulus. When the shocks were made unavoidable, the bites occurred at a higher rate in the absence of the conditioned stimulus than during it. When the shocks were again avoidable, reconditioning was almost immediate; the monkeys again began biting almost exclusively during the conditioned stimulus.

The present study used a discrete-trials avoidance procedure to permit independent evaluation of the avoidant and elicited functions of the attack. If a bite was made during the conditioned stimulus, the bite could be considered a discriminated avoidance response in the same manner as in Exp. IIC; if it was made immediately after shock in the absence of the conditioned stimulus, it could be considered elicited. Avoidance conditioning of the biting was evidenced by the transition

Fig. 11. Cumulative response curves for two monkeys during classical avoidance conditioning in which a bite served as the avoidance response. The short downward movements of the pen indicate the delivery of shock; the occurrence of the conditioned stimulus preceding each shock is not indicated. The lower graph is for a monkey that was experimentally naive at the start of conditioning; the upper graph is for a monkey that had a history of unavoidable shocks, the last session of which is represented in the top curve of the upper graph. The two lower curves in the upper graph show the first two sessions of avoidance conditioning.

Fig. 12. Rate of biting for each of two monkeys during a single session. During the period designated as "unavoidable shock" period in the middle of the session, the bites did not postpone the shocks. Rate of biting was calculated separately for the bites that occurred during the conditioned stimulus (solid circles) and those in its absence (open circles) by dividing the number of bites during (or in the absence of) the conditioned stimulus by the duration of conditioned stimulus presentation (or absence).

from the elicited to the avoidance pattern of biting during acquisition and *vice versa* during the unavoidable shock type of extinction. This design avoided the problems inherent in the shock-escape procedure (Miller, 1948) in which the escape and elicited reactions can not be easily differentiated, since both occur upon shock delivery.

The attack reaction has probably been an undetected factor in previous studies of shock avoidance and escape. For example, we have often noted that a rat or monkey will bite a projecting object in the experimental enclosure during the initial stages of shock-avoidance conditioning. While using a lever-press as the avoidance response, one incidental instance was continuously observed in which shock-induced biting seemed to facilitate acquisition. Shocks were being delivered

to a squirrel monkey through the floor grid of a Lehigh Valley monkey chamber during the first session of avoidance conditioning using the procedure developed by Sidman (1953). Each press on the projecting response lever postponed the shocks for 20 sec. The cumulative record of the lever presses in Fig. 13 shows that for about the first 20 min each shock resulted in a brief burst of lever-presses, apparently indicating that the lever-press was being conditioned. However, visual observation revealed that the lever movements were the result of the monkey biting the lever. This shock-induced biting, which is an unconditioned reaction, was seen to change into conditioned lever-pressing at the vertical arrow when the monkey began grasping the lever before biting it. Gradually, the manual grasping movements predominated and continued

throughout the intervals between shocks, whereas biting of the lever was observed only upon shock delivery. Visual observation of other monkeys and rats has revealed many similar instances in which biting was the initial reaction to the response lever during shock-avoidance conditioning.

Fig. 13. Cumulative response record of the lever depressions of a monkey during continuous shock avoidance. The short downward movements of the pen designate the delivery of a shock.

GENERAL DISCUSSION

Attack and escape-avoidance constitute two of the basic reactions to aversive shock. In analyzing their interactions, the present series of experiments showed that the escape-avoidance reaction was prepotent over the attack reaction, since attack resulted only if, and when, the escape or avoidance responses did not eliminate the shocks. The response requirement, be it a single lever-press as in Exp. IA, repeated lever-presses as in Exp. IB, IIA, and IIB, or holding as in Exp. IIC, was not important except insofar as it changed the frequency or duration of shock delivery. These results suggest a general rule: the amount of attack during a shock escape or avoidance procedures is determined by the frequency and duration of the shocks actually received under that procedure.

The present results suggest that the attack tendency may play an unsuspected but major role in the conditioning of some types of avoidance responses by bringing the animal in contact with the manipulandum being used for the avoidance response. Conversely, the escape tendency may play a major role in studies of pain-induced attack as evidenced by the need for shock scramblers (Ulrich and Azrin, 1962) and electrodes (Azrin *et al.*, 1964) to prevent escape reactions. Indeed, it appears that both tendencies must be considered when

either process is being analyzed, since both are reactions to aversive stimulation.

Shock avoidance and escape have often been described as producing fear, anxiety, stress, conflict, *etc.* Evidence for such states has been obtained, for example, by Brady's (1958) and Sawry and Weisz' (1956) finding that ulceration resulted from avoidable shock but not from unavoidable shock. If the escape and avoidance procedures produced continuous attack, strong evidence would exist that these emotional states were also factors in producing attack. Such a relation is implied in the supposition of a relationship between "frustration" and aggression (Dollard, Doob, Miller, Mowrer, and Sears, 1939). Yet, the present studies revealed that attack occurred only to the extent that shocks were delivered. The critical factor was the actual delivery of shock and not the avoidance schedule. It appears, therefore, that the emotional states associated with avoidance and escape have no discernible influence on attack behavior.

The presence of a target seemed to have little effect on shock avoidance or escape behavior once conditioning occurred and the shocks were no longer being received. Only during initial acquisition of the escape response, and at high escape requirements, was the escape or avoidance behavior reduced, the reduction being the apparent result of spatial or temporal incompatibility of the two behavioral reactions. It had been noted previously (Ulrich and Craine, 1964; Ulrich *et al.*, 1966) that the presence of a target rat produced an enduring reduction of avoidance responses of an experimental rat. Since the target rat was not restrained, it is possible that the reduction of avoidance responding in those studies was produced by physical interference by the target rat. The present results indicated that the presence of a restrained target rat produced no enduring interference with the escape responding once the rat had been conditioned to terminate the shock quickly, and no reduction of avoidance or escape responding of monkeys when an inanimate target was used that could not physically interfere with the avoiding animal. The presence of a target appears to interfere with shock avoidance or escape behavior only when (1) the avoidance behavior is not eliminating the shocks, and, (2) the avoidance and attack reactions are physically incompatible.

Attack might conceivably be a type of superstitious (Skinner, 1948) avoidance response to the shocks. If so, the attacks should be affected in the same way as the lever-presses that actually avoided the shocks. Yet, in the escape procedure with the rats in Exp. IA and IB, the two responses were mutually exclusive and never occurred at the same time. In the lever-press avoidance procedure of Exp. IIA and the lever-hold procedure of Exp. IIB, the response to the lever occurred almost continuously during the long intervals between shocks, whereas the attacks were few in number and occurred only after a shock delivery. Similarly, in the discrete-trials procedure of Exp. IIC, the lever-press avoidance responses were emitted only during the conditioned stimulus, whereas the bites were made in its absence. Even when the bites were given a history of shock avoidance in Exp. IID, they reverted to the elicited pattern once the shocks were made unavoidable. These results strongly indicate that the attack reaction is not a type of avoidance behavior.

According to the principles of respondent conditioning, bites might have been expected to occur during the conditioned stimulus that preceded each shock during Exp. IIC and IID. Yet, no bites occurred at that time. One cannot definitely conclude, however, from the avoidable-shock procedure of Exp. IIC that classical conditioning of bites does not occur, since the lever-pressing response usually terminated the conditioned stimulus, thereby eliminating the consistent pairing with the unconditioned stimulus that is necessary for respondent conditioning. Even when the shock was not avoidable, few bites occurred during the conditioned stimulus, as seen in Exp. IID. This failure to obtain respondent conditioning of biting is not explicable on the basis of the present study.

The avoidance and attack reactions tendencies need not be antagonistic. When an attack response was also given an avoidance function in Exp. IID, the attack was conditioned very rapidly. Both monkeys learned to bite much more quickly than has generally been true in this laboratory when a lever-press was used as the response. The reason for this rapid acquisition of biting appears to be that the biting responses were regularly elicited by the shocks from the very start of shock-avoidance conditioning, thereby providing a high level of

responding that is characteristically absent during initial lever-press conditioning. Consequently, the eliciting properties of the shock facilitated, rather than competed with, the acquisition of avoidance and escape.

A second distinctive feature of the biting-avoidance performance was the high resistance to extinction to unavoidable shocks. When the shocks were avoidable, bites occurred at a high rate during the conditioned stimulus; when shocks were unavoidable, the bites occurred at a high rate immediately after shock delivery. In contrast, lever-pressing responses have been found to decrease when the shocks are unavoidable; those that do occur are emitted primarily during the conditioned stimulus (Sidman, Herrnstein, and Conrad, 1957). It appears that attack reactions that serve an avoidance function are necessarily resistant to extinction, since attack will occur as an elicited reaction when shocks are unavoidable. Unlike an arbitrary response, attack responses should extinguish only when the shocks are discontinued, but not when the shocks are made unavoidable.

Many previous methods of avoidance conditioning have used a response that is not arbitrarily selected, *i.e.*, that bears an inherent relation to the unconditioned stimulus. Such procedures seem to include running as an avoidance response to shock in an activity wheel (Brogden, Lipman, and Culler, 1938; Sheffield, 1948), running in a circular grill (Mowrer, 1940; Gwinn, 1949), running down a runway (Seward and Raskin, 1960), jumping across a hurdle in a shuttle box (Solomon, Kamin, and Wynne, 1953), and jumping in the air (Mowrer and Lamoreaux, 1946; Mowrer and Viek, 1948). The above procedures have usually been used precisely because the inherent relation of the response to the unconditioned stimulus allows for rapid conditioning. This dual source of control has been described by Keller and Schoenfeld (1950) as operant-respondent overlap. One great danger in attempting to generalize the results of these procedures to other responses would be that other responses may not have the same type of elicited relation to the aversive stimulus. The present results suggest that acquisition period and effect of unavoidable aversive stimulation would be two aspects of conditioning that would vary greatly between arbitrary and elicited responses.

Several previous studies have noted that aggression can be increased by operant reinforcement. Many ethological studies have found that aggression is reinforced by possession of a territory (Tinbergen, 1951) or of a female by a male (see recent reviews by Lorenz, 1964, 1966; Fisher, 1964; Matthews, 1964; and Hall, 1964). Similarly, laboratory studies have shown that attack will be operantly reinforced if it results in the opportunity to drink (Ulrich, Johnston, Richardson, and Wolf, 1963), the delivery of intercranial stimulation (Stachnik, Ulrich, and Mabry, 1966), and food delivery (Reynolds, Catania, and Skinner, 1963). The results of Exp. IID demonstrated that attack can also be operantly reinforced by reducing aversive stimulation. It also demonstrated a method for studying this reinforcement process objectively and quantitatively over extended periods of time. In one sense, it is useful to consider attack as one more class of behaviors that can be understood and analyzed by the principles of operant reinforcement. During discriminated avoidance conditioning of the biting response, for example, the bites occurred primarily during the conditioned stimulus, as has been found previously using the lever-press response, as in Exp. IIC and by Sidman (1955) Ulrich, Holz, and Azrin (1964), and Azrin, Holz, Hake, and Ayllon (1963). In another sense, the search for a favorable consequence of all attack behavior may prove futile since unavoidable aversive stimulation is also a sufficient basis of attack, as seen from the attacks that resulted in each of the present experiments when unavoidable shock was used. Stated otherwise, attack is intrinsically reinforcing during aversive stimulation (see Azrin, Hutchinson, and McLaughlin, 1965).

We may speculate as to the extent to which attack serves an avoidance function in the natural environment as it was designed to do in Exp. IID. If one considers aggression as inflicting aversive stimulation, the aversive properties of an attack should then elicit counter-aggression which, if sufficiently severe, will also receive escape reinforcement from the reduction of further aversive attacks. According to this interpretation, counter-aggression can become a highly probable reaction to aggression because of the dual source of control: operant and elicited.

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