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BITING ATTACK BY RATS IN RESPONSE TO AVERSIVE SHOCK[1]

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Paired rats are known to behave aggressively when given painful electric shocks. The present study developed a procedure whereby individual rats given shocks might bite an inanimate target object. Unavoidable shock was delivered to the rat while it was restrained in a position close to, and facing a target object. Biting of the target was recorded automatically. Shock caused the rat to bite metal, wood, or rubber targets. Biting was most frequent immediately after shock and decreased as a direct function of time since the shock. Almost every shock produced biting and the behavior continued as long as the shocks were delivered. Biting ceased within and between sessions when shocks were discontinued. These results show how the pain-aggression relation can be studied objectively with rats.

Rats engage in aggressive posturing, and occasionally in biting, when they are given painful shock (O'Kelly and Steckle, 1939; Ulrich and Azrin, 1962). The shocked rat stands upright with its mouth opened and teeth bared, and strikes or slaps the attacked rat, but only infrequently bites it. A major problem in studying this aggression is the reliance on subjective evaluation of which postures and movements are aggressive. The failure to observe consistent biting by rats in response to shock raises the question of whether the postures and movements of shocked rats can be properly described as aggressive. One can appeal to postural similarities exhibited by rats in other aggressive episodes (Barnett, 1963), but such evidence seems inconclusive without the terminal response of biting. Unlike other animals, such as the monkey (Azrin, Hutchinson, and Sallery, 1964), the shocked rat usually does not attack a stuffed model or object (Ulrich and Azrin, 1962). Consequently, it has not been possible to attach a transducer to a target object to obtain automatic recordings. The present investigation sought to determine whether shock produced biting attack by rats and, if so, to devise automatic methods of measuring it.

A situation was arranged in which biting attack would be likely to occur in response to shock. Several factors discovered in previous studies of shock-elicited attack were combined: (1) an inanimate object was used as the target to eliminate the uncontrolled effects of counteraggression by a live target (Azrin *et al.*, 1964); (2) the rat was forced to face the target (Hutchinson, Azrin, and Hake, 1966) and was close to it (Ulrich and Azrin, 1962); (3) the shock was intense (Ulrich and Azrin, 1962; Azrin, Ulrich, Hutchinson, and Norman, 1964); and (4) the shock was delivered through surface electrodes and was unavoidable and inescapable (Azrin, Hutchinson, and Hake, 1967).

METHOD

The development of an appropriate target was the most difficult aspect of the present procedure. Ideally, the target should be such that the rat would not have a high level of biting it when not shocked, but would bite it when shocked; the transducer on the target should give an output signal whenever biting occurred, but no activity except biting should produce an output signal; the biting should be recorded continuously and automatically, yet the target should not be easily destroyed by continued biting.

Many devised targets failed to satisfy those criteria. One type was a pneumatic tube such

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as developed for recording biting attack by monkeys (Hutchinson *et al.*, 1966) in which the bite was recorded as a pressure change in the tube. The problem in extending this technique to rats was that a rat's sharp teeth rapidly punctured the tube; this problem could not be solved by self-sealing types of tubes, different tube materials, or blunting of the teeth.

Previous investigators have recorded the biting of rats by providing a block of wood which the rat could gnaw (Roberts and Carey, 1965; Welker and King, 1962). Unfortunately, that method did not permit a continuous recording of biting; the biting was indirectly measured by weighing the wood before and after a session and calculating how much had been removed (Welker and King, 1962).

Three types of target were developed in an attempt to satisfy the criteria outlined above; one made of metal, another of wood, and the third of rubber.

Figure 1 shows a schematic representation of the general apparatus. The main features were a rigid tube for restraining the rat so that it faced the target and minimized other movements, tail electrodes for delivering unavoidable shock to the rat, and a target object.

The restraining tube was a Plexiglas tube 9-in. long and 2.5-in. inside diameter. A Plexiglas floor was fiitted into the tube to provide footing; otherwise the rats tended to twist around in the tube. The bottom of the tube was fastened to a flat board which rested on the floor of the enclosure containing the apparatus. A brace above the tube (not shown) held it in a fixed position. The tube was long enough to extend past the full length of the rat, making it difficult for the rat to bite at its edges. The outer surface of the plastic tube was painted so that the rat's field of view was restricted to the target at the open end of the tube.

The electrode arrangement was identical to that described previously for an apparatus for avoidance conditioning (Azrin, Hopwood, and Powell, 1967). Briefly, the rat's tail was fastened to the tail rod with a double layer of adhesive tape which held the rat in position. Shock was delivered through the two electrodes that rested on the tail.

The first target was the wood rod shown in Fig. 1. The general principle underlying this target was that a pulling motion accompanied biting because of the restrained, and relatively fixed position of the rat. The wood rod was 3-in. long, 5/16-in. diameter, 1 in. from the floor and was located where the rat could bite it by extending its body. Because of this slight body extension, the rod was pulled toward the rat during a bite. The force of the pull was transmitted to the target holder through the target sleeve to the switch contacts, the movement of which provided an electrical signal to the recording apparatus for the duration of the bite (see Fig. 1). The rat could pull the wood rod only with its teeth because its paws were too small to grasp the rod and the limited space in the tube prevented the rat from standing on its hind legs; consequently the rat's forepaws could not be easily used to manipulate the rod. Movements of the paws or head against the rod constituted a push rather than a pull. Lateral forces on the rod were absorbed by the target sleeve. The rod could be rotated easily and continuously within the target sleeve because of the swivel, which was taken from fishing leader equipment. This possibility of rotary movement appeared to lead to greater attack than a perfectly rigid rod. The rod could be pulled forward about

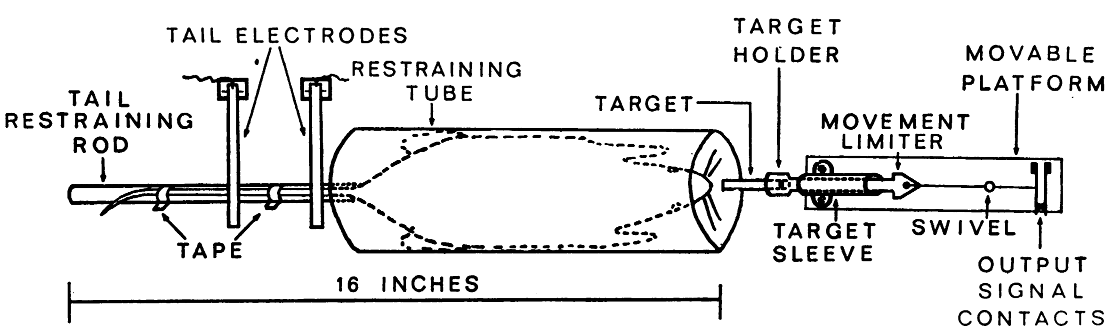

Fig. 1. Principal features of the electrode assembly (left portion of drawing), the restraining apparatus (center), and target apparatus (right portion). The target rod was either wood or rubber. Top view.

3/16 in. before the movement limiter hit the target sleeve. The output signal contacts pulled the target back after biting had ceased. The contacts signalled biting when the rod was pulled 1/32 in. with a force of 7 g or more. The wood rod was covered with thin rubber tubing which retarded destruction of the wood during extended biting. The wood was white pine unless otherwise indicated.

The second target was a rubber rod mounted in the target holder of Fig. 1 in the same way as the wood target. The rubber target was constructed of two concentric tubes of rubber with a thin aluminum rod 1/8-in. diameter in the center of the inner tube to provide rigidity. The overall diameter was 7/16 in. All other features of the rubber target apparatus were identical to that of the wood target apparatus shown in Fig. 1.

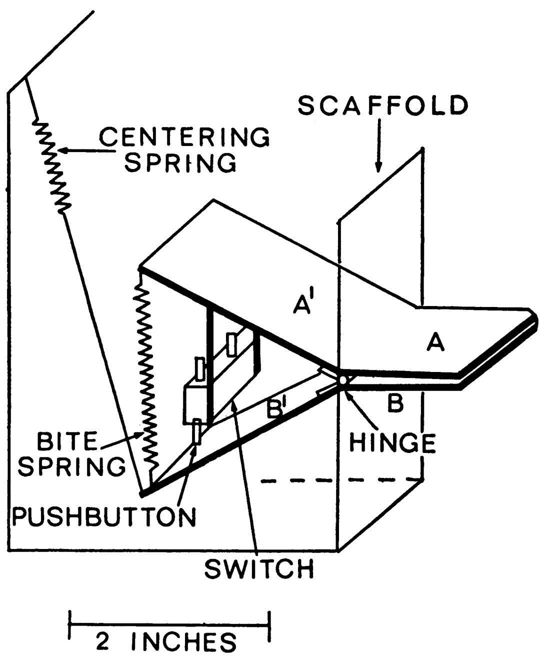

Fig. 2. Metal target used to record biting by rats. The leading edge (far right) of metal plates, A and B, faced the rat. Compression of the metal plates by a bite produced by an output signal from the switch. Side view.

Figure 2 shows the metal target which consisted of two sheets of steel, A and B, which when squeezed together by a bite closed the microswitch contacts by releasing the pressure of the bottom plate, B, that was otherwise exerted by the bite spring against the pushbutton. The metal plates were 1-in. wide, 1/16-in. thick and separated by 3/64-in. air space at the edge facing the rat. The metal plates rotated on the scaffold so that a blow from either above or below would not cause compression. The plates pressed together only when a force was exerted simultaneously from above and below. The centering spring was attached to the lower plate by a nylon cord and returned the plates to the normal horizontal position following an upward blow. Gravity restored the plates to the normal position following a downward blow. Closure of the switch contacts provided a measure of the number of bites. One hundred and twenty grams of compressive force were required on Plates A and B to activate the switch contacts. Variations of this force requirement could be made by changing the tension of the bite spring. If the force was set too low, however, the inertia of the system resulted in an output signal upon a sudden blow. The leading edge of the metal target was in the position indicated for the leading edge of the target rod in Fig. 1.

Procedure

The positioning of the rat with respect to the target was a critical feature, especially for the wood and rubber targets. During the first session the experimenter waited until the rat stopped moving about. The front of the target was then positioned about 1/2 in. from the nose of the rat. The further the target was from the rat, the less likely it seemed that the rat would bite, but the more likely that the bites would be accompanied by the pulling motion necessary to activate the recording switch on the wood and rubber target assembly.

Each shock delivery had a 200-msec duration at an intensity of 5.0 ma. The shock source was an Applegate constant current stimulator. The electrodes and the tail of the rat were cleaned and coated with electrode paste before each session. Ink marks on the rat's tail assured the same positioning of the rat in the electrode assembly during repeated sessions.

The subjects were 27 naive male Long Evans rats between 90 and 120 days of age. All rats were maintained under a free-feeding regime in the individual living cages. Twelve rats were studied with the metal target, 12 with the wood, and three with the rubber.

The 12 rats in the metal target condition were given daily sessions of 60-min duration without any shocks until fewer than 10 bites occurred in each of two successive sessions. Six rats satisfied this criterion of a low operant level of biting within three sessions; the other six required four sessions. During two additional 60-min sessions, shock was delivered every 10 sec during the 20-min period in the middle of the session. The initial 20-min period of no shock was a redetermination of the baseline level of biting, whereas the terminal 20-min period without shock could reveal any enduring effects of the preceding shock period on the biting behavior.

For the wood target condition, the 12 rats were given daily sessions of 60-min duration without shocks until less than 50 sec of biting occurred on each of two successive sessions. Six rats satisfied this criterion within three sessions. Since the pre-shock level of biting was higher for the other six rats, hard hickory wood was substituted for the soft pine for these rats, all of which then satisfied the criterion within three additional sessions. Then, five daily sessions of 60-min duration were given in which shock was presented according to the same ABA design used for the metal target rats: within each session a 20-min period without shock was followed by a 20-min period during which the rat was shocked every 15 sec, which was followed by another 20-min period without shock.

The three rats studied with the rubber target were given daily sessions of 3.5-hr duration. Sessions without shock were given until the rats bit for less than 100 sec on each of two consecutive sessions. Ten sessions were then given during which shock was delivered every 30 sec. A third period of five sessions without shocks was then given.

RESULTS

Figure 3 shows the mean number of bites for the 12 rats that had the metal target. The biting of the metal target was recorded in terms of the number of bites rather than bite duration, since each bite was fairly discrete and lasted less than 0.3 sec. Almost no biting occurred during the first 20 min of the session when no shocks were delivered. During the 20 min of shock delivery, about 20 bites were made during each 5-min period. When shock was discontinued during the last 20 min, biting ceased within 5 min. The results for each of the 12 rats resembled the averaged data of Fig. 3 in that every rat made more bites during the shock period than the non-shock periods in each of the two sessions. One rat bit only five times during the shock period; the other 11 made at least 20 bites. The mean number and average deviation of bites during the last 5 min of the three periods for all 12 rats were: pre-shock period, 0 ± 0; shock, 20 ± 18; and post-shock, 1 ± 1. For each rat, the number of bites during shock was at least 10 times as great as during the pre- or post-shock period (the rat that made only five bites during shock had made none during the pre- and post-shock periods). The mean number of bites was slightly less for the first session (97) than for the second (121).

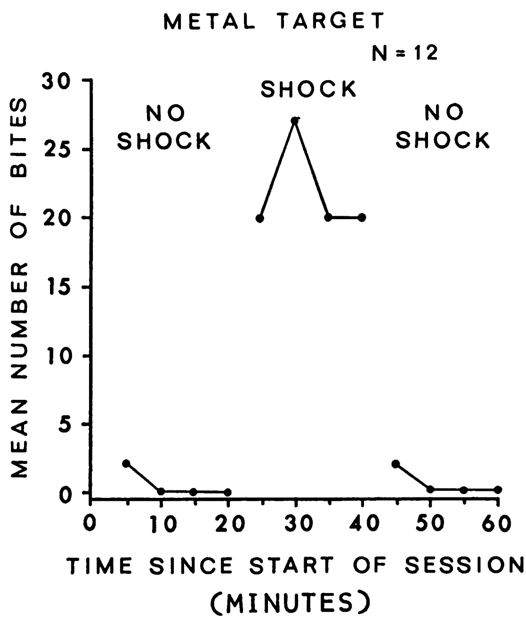

Fig. 3. Biting within sessions when shocks were delivered during the middle period of the session. Each data point is the average of two sessions for 12 rats of the number of bites per 5-min period within the sessions.

Figure 4 shows the mean duration of biting for the 12 rats that had the wood target. Some biting occurred at the start of the session but decreased to a near zero level within 20 min. The duration of biting increased when the shock was delivered, averaging about 90 sec of biting during each of the last three 5-min periods. Biting gradually decreased to a near zero level over the 20-min period when shock was discontinued. The data for the individual rats revealed a general correspondence with the averaged data of Fig. 4. Each of the 12 rats bit at least six times as much during the last 5 min of the shock period as during the last 5 min of the pre- or post-shock period. This relation applied during all five sessions. The mean duration and average deviation of biting for the last 5 min of each period was pre-shock, 1 ± 2; shock, 92.0 ± 50.0; post-shock, 7 ± 10 sec.

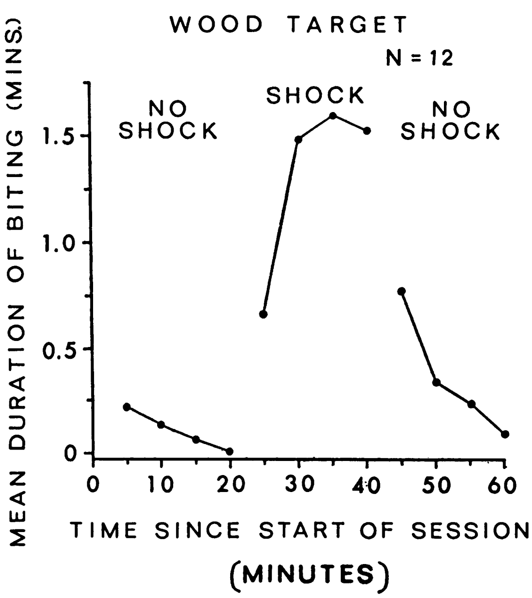

Fig. 4. Biting within sessions when shocks were delivered during the middle period of the session. Each data point is the average of five sessions for 12 rats of the duration of biting per 5-min period within the sessions.

Biting was maintained throughout the five-day period. The mean duration of biting increased about 50% from the first to the third session, but remained fairly constant during the last three sessions. Visual observation of the rats indicated much struggling during the first two or three days of shock, which may account for the lower level of biting at that time. No rat was ever observed to eat the wood rod.

Figure 5 shows the mean duration of bites per day for each of the three rats that had the rubber target. The duration of biting increased when the shocks were given for 10 days and decreased when shocks were discontinued for five days. For each rat, the duration of attack increased during the first few sessions but showed no consistent increase after five ses-

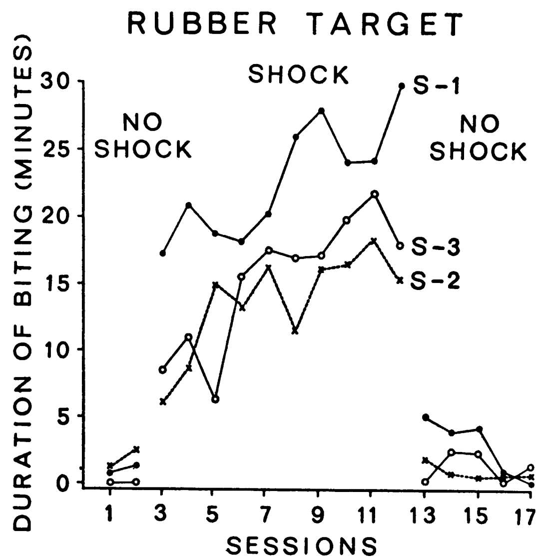

Fig. 5. The duration of biting the rubber target for each of three rats for 17 consecutive sessions. Shock was delivered during Sessions 3 to 12.

sions. As was true of the wood target, the rats did not eat the rubber target.

Figure 6 shows how the biting of the rubber target was distributed between shocks. A high level of biting occurred immediately after shock delivery then decreased to near zero by the end of 30 sec when the next shock occurred. This inverse relation between biting

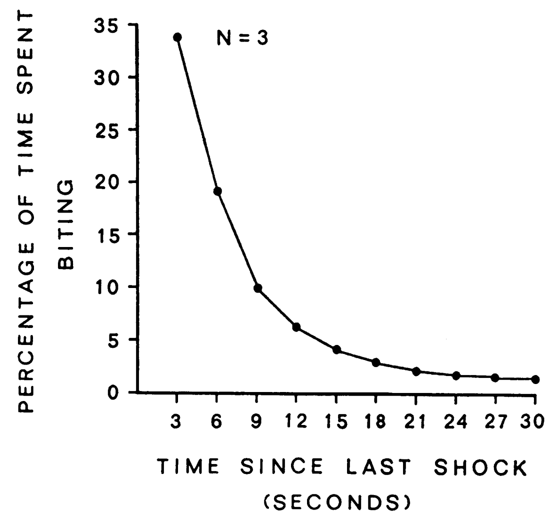

Fig. 6. Biting of the rubber target as a function of time since shock delivery. Each data point is the mean of the last five sessions of shock presentation of three rats. Shock was delivered every 30 sec. Each point shows the mean percentage of time that the rats were biting during each of the ten 3-sec intervals between shocks.

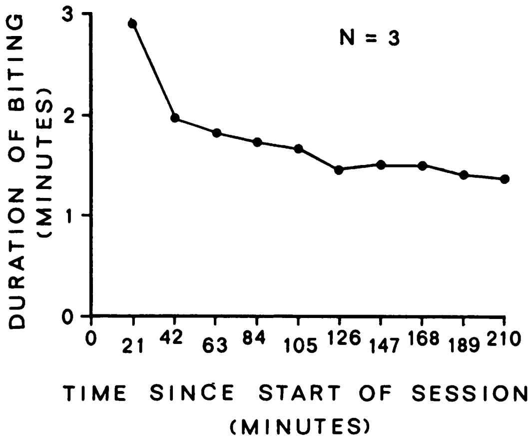

Fig. 7. Within-session changes in biting of the rubber target. The data points are the mean duration of biting for the 10 successive 21-min periods that constituted the 210-min session. The data are averages of three rats for the last five sessions in which shock was delivered.

and time since shock was obtained for all three rats after the first two sessions of shock delivery. The relation was ambiguous for two of the rats during the first two sessions.

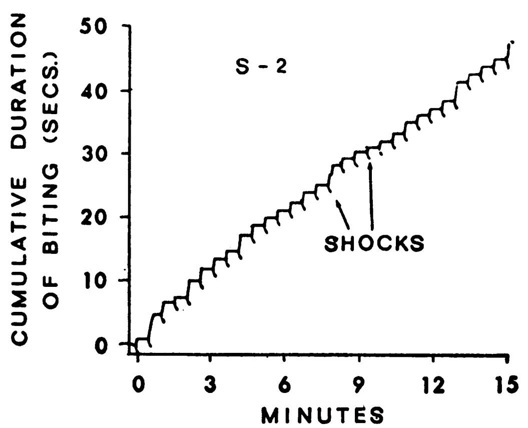

Fig. 8. Sample cumulative record of the duration of biting a rubber target by one rat. The recorder pen moved upward one step for each 0.1 sec of biting. Each of the short oblique pips designates a shock. The sample record was taken from the last session of exposure to shock.

Figure 7 shows the intrasession changes in biting during the last five days of shock delivery. Biting was highest at the start and then decreased slightly during the remainder of the 3.5-hr session. For each rat and for each session the duration of biting was greatest during the first 20 min of the session.

The moment-to-moment record of biting can be seen from Fig. 8, which presents a sample record of the cumulative duration of biting by one rat during the last hour of the tenth shock session. This record is characteristic of every session in that virtually every shock produced biting, the biting occurred immediately upon shock delivery, and the biting stopped abruptly in advance of the next shock. During the last eight sessions of shock delivery, 100% of the shocks produced biting by S-1, 96% by S-2, and 94% by S-3. Most of the failures to bite occurred during the first two sessions when much struggling and random movement resulted from the shocks.

DISCUSSION

The results reveal that shock produced biting attack by rats. This biting attack was not unique to a particular type of target; the rats attacked a wood, rubber, and metal target. Nor was the attack unique to a given target configuration, since the metal target differed in size and shape from the wood and rubber ones. The biting attacks recorded were not part of a general high level of biting as indicated by the absence, or reduced level of biting during the periods without shock that were provided within and between sessions. Virtually all rats attacked in response to shock. The effect of the shocks was reversible for all three targets and for each subject in that biting decreased or ceased when the shocks were discontinued.

The changes in biting over time were studied most extensively for the rubber target procedure. These results revealed that the attacks occurred immediately upon each shock delivery and decreased as a function of time since the shock. This temporal pattern corresponds with the visual observation of shock-elicited attack between two live rats (Ulrich and Azrin, 1962) and between two live monkeys (Azrin, Hutchinson, and Hake, 1963). The correspondence of temporal patterning supports the interpretation that the biting attack discovered here, and the previously observed aggressive attacks between live animals, are parallel instances of a pain-aggression relationship.

The present procedures will allow more extensive study of the pain-aggression relation in the rat, a convenient and widely available laboratory subject, without the need for subjective recording of the aggression. Each of the three methods of recording biting attack had the desirable characteristic of providing an automatic and objective recording of bites, but each method had advantages and disadvantages compared to the others. For durability, the metal target was superior to the rubber, which was in turn superior to the wood target. The metal target was virtually indestructible and the rubber withstood continuous attack for the 3.5-hr sessions, at least. The wood targets were not durable; even the very hard hickory wood was partly chewed away by some rats by the end of the 20-min period of shock delivery. For eliciting biting, the wood target was superior to the rubber, which was in turn superior to the metal target. Although exact comparisons cannot be made between targets because of the different method of recording and such procedural differences as shock frequency, the average duration for which the rats bit the targets was about 30% of the available time for the wood, and 15% for the rubber; the rats averaged only four bites per minute on the metal target. The stability of the shock-induced biting was not evaluated extensively with the metal target because of the severe limitation in the amount of attack, nor with the wood target because of its easy destructibility. The suitability of one of these rat bitometers will depend on how important it is to a particular study to achieve durability of the target and a large amount of biting. The rubber target seemed a reasonable compromise.

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