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Reinforcing effect of aggressive behaviors preparatory to fighting in mice

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Four groups of adult male mice were run in a T-maze for 20 days. Group 1 received 15 days of fight training prior to acquisition. In the maze, Group 1 chose between provocation by a dangled victim of aggressive behaviors short of biting attack and exploring an empty goalbox. Mice in Group 1 occasionally managed to bite. As a control for partial reinforcement, Group 2 was yoked to Group 1 and given an equal number of bites. Group 3 did not receive fight training but otherwise was treated the same as Group 1. Group 4 served as a control for the possible reinforcing effect of sensory cues. The results suggest that elicitation of aggressive arousal can serve as a reinforcer, and this effect was greater for more experienced fighters.

Adult male house mice can be reinforced for instrumental learning by the opportunity to engage in successful biting attacks upon submissive conspecifics. This fact has been demonstrated in both discrete-trial (Legrand, 1970; Tellegen & Horn, 1972; Tellegen, Horn, & Legrand, 1969) and continuous-trial (Conner, 1974) learning situations. Therefore, it can be argued that aggression functions as a primary motivation in mice. In comparison to the traditionally studied motivations, aggression may be most like sex because of the social rituals commonly displayed during confrontations with the goal objects. That is, the behaviors usually considered as the terminal consummatory acts of aggression and sex are often preceded by readily observable species-specific social interactions. For example, the biting attacks of mice may be preceded by tail rattling, piloerection, and mincing steps. Both aggression and sex may include investigation of the other mouse, nosing, and grooming in preparation for the more dramatic consummatory responses of fighting or copulation. The mice may be considered in a state of aggressive or sexual arousal during the performance of these preparatory behaviors.

The present experiment was designed to explore further the similarities between aggressive and sexual motivations. Sheffield, Wulff, and Backer (1951) and Whalen (1961) found that male rats could be reinforced in T-mazes by the opportunity to mount or gain intromission with receptive females even though they were not permitted to ejaculate. The hypothesis of the present experiment is that male mice can be reinforced in a T-maze by the opportunity to engage in aggressive behaviors which are preparatory to biting attacks even though they are not permitted to bite.

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METHOD

Subjects

Forty male mice of the RF/J strain were purchased from the Jackson Laboratory at approximately 35 days of age. These albino mice were chosen as subjects because this strain reached the highest level of T-maze performance for aggression of the three strains studied by Tellegen and Horn (1972). The subjects were housed individually in 17.8 x 29.2 x 12.7 cm clear-plastic breeding boxes with wire-mesh tops. Ten male mice of the C57BL/6J strain were purchased at approximately the same age. The black mice were housed in groups of five and used as victims throughout the experiment. No victim ever showed aggressive behaviors toward a subject mouse.

Fight Testing and Training

When the subjects were approximately 90 days old, a victim drawn randomly from the pool of victims was placed in each subject's box for 10 min or until a fight occurred. A fight was allowed to continue for 5 sec before the victim was removed. If a subject did not attack spontaneously, a victim was dangled by its tail and bumped gently into the hindquarters of the subject for 1 min in an attempt to provoke the subject into biting. This procedure was administered once a day until a subject had attacked a victim on 5 days, at which point the testing for aggressiveness stopped. After 15 days, all subjects had met the criterion of five attacks and were considered equally aggressive. The subjects were then divided randomly into four equal groups.

Groups 1 and 2 were given an additional fighting experience of 1 min of fight training with dangled victim mice each day for 15 days. Fight training made these mice highly aggressive. On the last 5 days of fight training, the mice in Groups 1 and 2 were rated for the quickness and vigor of their attacks and then rank ordered within groups on the basis of aggressiveness. Groups 3 and 4 did not receive fight training.

Maze Procedure

The T-maze was constructed of wood and was 15.2 cm high and 15.2 cm wide throughout. It was covered with hinged wire-mesh sections and painted black. The startbox was 19.1 cm long. Raising a guillotine door allowed a subject mouse to leave the startbox and enter the choice compartment, which was 7.6 cm long. The door was closed behind the subject to prevent retracing. On the infrequent occasions when a mouse would not leave the startbox within 60 sec, it was gently forced out. The goalboxes were 30.5 cm long. Sliding partitions closed off the 10.2 cm furtherest from the choice point in order to conceal

the victims. When a subject entered the goalbox, a guillotine door was lowered behind it before the partition was raised to reveal the presence or absence of a victim. Every subject explored the maze for 2 min on Days 14 and 15 of fight training for Groups 1 and 2.

During acquisition, every subject mouse was given three free-choice trials each day. Every free-choice trial was followed by a forced-choice trial, in which the goalbox door lowered on the free-choice trial remained closed and the subject could enter only the opposite goalbox. A randomly drawn victim was placed in each goalbox compartment at the beginning of each trial, thus providing equivalent cues for a subject at the choice point. A trial began with the lifting of the startbox door as soon as a subject was placed in the box. If a subject from Group 1 made a "correct" choice on a free-choice trial, the goalbox door was lowered behind it, the victim was lifted from the goalbox compartment, and the partition was raised. For 10 sec the experimenter attempted to elicit aggressive behaviors by bumping the subject's hindquarters with the dangled victim. The bait was withdrawn before the subject could bite it. Following the dangling manipulation, the subject explored the goalbox for 5 sec and then was returned to its box. If a subject in Group 1 chose the "incorrect" goalbox, the victim was removed before the partition was raised and the subject was given 15 sec in the empty goalbox. The procedure for forced-choice trials was identical to that for free-choice trials, except that subjects could not demonstrate their preferences. For a random half of each group the right arm of the maze was designated as "correct," and the left arm was "correct" for the remaining half. The order in which the groups were run, as well as the order of mice within groups, was randomized for each day.

Pilot work had shown that fight-trained subjects occasionally managed to bite dangled victims despite the efforts of the experimenter. Because biting attacks have been demonstrated to function as reinforcers for fight-trained mice on a 50% partial reinforcement schedule (Legrand, 1970), the occasional bites might have been sufficient for maze learning. This possibility could cloud an analysis of the reinforcing effects of the preparatory behaviors alone. Therefore, Group 2 served as yoked controls for Group 1 in order to determine whether acquisition could occur on an identical schedule of biting attacks but without the dangling manipulation. Subjects in Groups 1 and 2 were paired on the basis of their ranked aggressiveness. When a subject in Group 1 managed to bite a victim, its yoked counterpart in Group 2 was teased with a dangled victim on the equivalent trial in the same manner as was used with Group 1, except that the dangling was allowed to culminate in a biting attack. On all other trials, the victims were removed, the partitions were raised, and the mice of Group 2 explored empty goalboxes unmolested. Group 2 began acquisition 1 day later than Group 1, which permitted both yoking of biting attacks and randomization of the order of the daily running of the groups. In every other respect, the two groups were treated identically.

The mice of Group 3 did not receive 15 days of fight training, but otherwise were treated in the same manner as Group 1. The comparison of Groups 1 and 3 provided an opportunity to observe whether more extensive fighting experience would increase the reinforcing effect of the dangling manipulation for Group 1. The mice of Group 4 also were not fight trained and served as controls for the effects of various sensory cues provided by conspecifics. For this group, the goalbox compartment in the "correct" goalbox contained a victim held in a 4.5 x 4.5 x 8 cm wire-mesh cage. The victim was removed from the "incorrect" goalbox and subjects explored an empty chamber.

In summary, the extensively fight-trained mice in Group 1 were given a choice in the T-maze between aggressive provocation and exploration of an empty goalbox. Their fight-trained and yoked controls in Group 2 found both goalboxes empty unless a subject in Group 1 bit a victim, in which case its counterpart in Group 2 bit a victim on the equivalent trial. The relatively untrained mice in Group 3 received the same treatment as Group 1, and the relatively untrained mice in Group 4 chose between a caged victim and exploration of an empty goalbox.

The experimenter recorded the goalbox choice on free trials and whether a mouse from Group 1, 2, or 3 bit a victim during the dangling manipulation. A Standard electric timer started when the startbox door was raised and stopped when the goalbox door was lowered behind a subject for a measure of running time. A subject was transported to and from the maze on a wire-mesh carrier. Between trials it was returned to its home cage, placed next to the maze. The intertrial interval was approximately 15 sec. The table top, which served as the floor of the maze, was swabbed with a damp sponge between subjects to remove urine and boluses and smear odor trails. Studies of the attracting or repelling properties of mouse urine (e.g., Jones & Nowell, 1973) do not permit a clear prediction of urine's effect in a study of the incentive properties of aggression. Randomization of running orders and swabbing the maze must have confused odors, so any positive results in the present experiment occurred despite odors. Acquisition was continued for 20 days, at which point it appeared that the groups' performances were asymptotic.

RESULTS

The experimenter observed that bumping subjects in the hindquarters with dangled victims elicited from most subjects the commonly accepted signs of aggressive arousal such as tail rattling, piloerection, and mincing steps, as well as rapid spinning around and even leaping to try to catch a bite of the victims. As acquisition progressed, some of the more subtle signs disappeared for most subjects, while attempts to bite increased.

The course of T-maze acquisition is depicted in Figure 1. It can be noted that the mice were more likely to choose the "correct" goal on the second and third trials of each day than on the first. This "warm-up" effect was reported by Tellegen and Horn (1972), who ran mice to biting attacks under conditions very similar to those in the present study.

As a measure of the relative strengths of reinforcing events, two-tailed sign tests were performed on the number of "correct" choices by the groups on the third trials of the 20 days of acquisition. The elicitation of aggressive arousal by the dangling procedure led to more "correct" choices by Group 1 than can be accounted for by biting attacks alone, as shown by a comparison of Group 1 with its yoked control, Group 2 ($p < .002$). Moreover, aggressive arousal was more reinforcing for the highly experienced fighters of Group 1 than for the less experienced Group 3 ($p < .002$). The higher level of choice performance for Group 3 as compared to Group 4 ($p < .022$) suggests that the dangling manipulation provided more incentive than that offered by exposure to just the sensory cues of a conspecific.

Another measure of the reinforcement effect of aggression short of biting attack is that on 10 of the last 12 days of acquisition both Group 1 and Group 3 chose the "correct" goal on third trials at a level significantly above chance, whereas Groups 2 and 4 exceeded

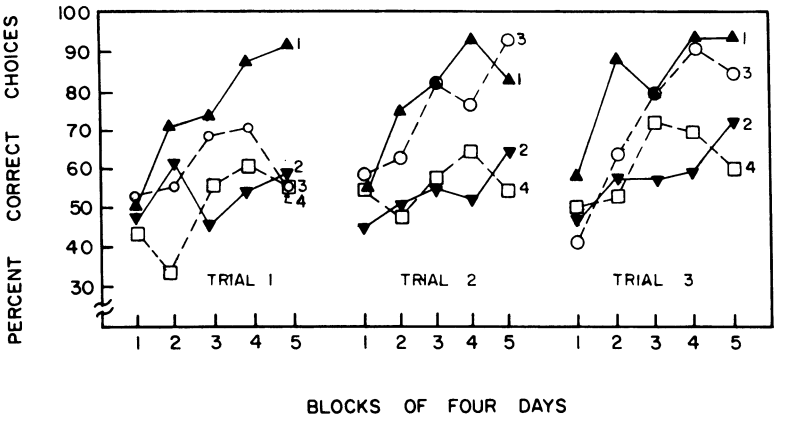

Figure 1. Percent correct choices on free-choice trials by the four groups on Trials 1, 2, and 3 in 4-day blocks of T-maze acquisition.

chance on the same trials on only 1 and 4 days, respectively [using the binomial approximation of the normal distribution, $z(10) \geq 1.90$, $p < .05$, for all cases].

Although the experimenter tried to elicit aggressive behaviors without allowing bites, the mice in Group 1 managed to bite dangled victims on 16% of their opportunities in the "correct" goalbox. The yoked controls in Group 2 were not always provoked into biting attacks on those trials on which they were to match Group 1 and, therefore, obtained bites on 13% of trials run to the "correct" goal. If biting attacks alone were the reinforcing mechanism in the T-maze, the significantly higher performance of Group 1 might be attributed to the 3% difference in reinforcements. However, the fact that Group 3 bit on only 7% of the opportunities, yet performed at a significantly higher level as compared to Group 2 ($p < .036$), suggests that aggressive arousal was a more important source of reinforcement than biting attacks in this study. The difference in performance between Groups 1 and 3 could be attributed to the difference in biting attacks or to another factor, such as secondary reinforcements developed through greater fighting experience or the reduction of fear associated with agonistic encounters.

An analysis of variance was performed on the running times for all trials during the 20-day acquisition period. The results duplicated other studies of the running behavior of mice for aggression. The mice increased in speed across days [$F(1,39) = 14.23$, $p < .01$] [1] and from first to third trials ($F = 4.87$, $p < .05$). They ran faster to the "correct" arm of the maze than to the "incorrect" arm ($F = 5.57$, $p < .05$). There was a significant groups effect ($F = 6.79$, $p < .05$), but contrasts suggested that the differences in running speed between groups was not related to the manipulation of goal events that created differences in choice behaviors. Group 4 ran insignficantly faster than Group 1 ($F = .001$, $p > .05$), which ran significantly faster than Group 3 ($F = 4.69$, $p < .05$). The difference between Group 3 and the slowest group, Group 2, was not significant ($F = 2.59$, $p > .05$). The disagreement between choice and running speed measures in this experiment cannot be explained readily.

Groups 1 and 2 were ranked for aggressiveness before being paired and yoked. This was done in case aggressiveness is related to the reinforcing power of aggression. In order to check this hypothesis, Groups 3 and 4 were assessed for aggressiveness in the same manner as Groups 1 and 2 but following maze learning. The post hoc nature of this procedure must weaken the conclusions drawn. A two-tailed sign test revealed that the high-aggressive mice in Groups 1 and 3 chose the "correct" goal on third trials more often than the low-aggressive mice ($p < .058$). High-aggressive mice in all groups ran faster than low-aggressive mice ($F = 5.85$, $p < .05$). Thus, more aggressive mice may not only show greater vigor in fighting and running, but may also be more reinforced by aggressive arousal.

DISCUSSION

The results suggest that the elicitation of the species-specific aggressive behaviors which often precede biting attacks by mice can serve as a reinforcer for instrumental sequences. Groups 1 and 3 chose aggressive arousal more frequently than Group 2 chose a "lean" partial reinforcement schedule of bites or 4 chose a caged victim. Groups 1 and 3 displayed levels of preference comparable to those recorded by Tellegen and Horn (1972), who ran the same strain of mice to full biting attacks in the same maze. The fight-trained Group 1 showed a greater preference for aggressive arousal than did the untrained Group 3. The superior performance of Group 1 may be accounted for by its greater experience with the reinforcing effect of biting attacks or by the reduction of fear associated with aggression. This finding, perhaps, can be related also to both the fact that fight training makes mice very aggressive and to the tentative finding that mice rated high in aggressiveness in Groups 1 and 3 chose to run to aggressive arousal more frequently than did mice rated low.

Kelsey and Cassidy (1976) claim that demonstrations of the reinforcing properties of aggression are actually due to the reinforcing effects of nonaggressive social interactions with a conspe-

cific. Using ICR mice in a T-maze procedure similar to that employed in the present experiment, they pitted the opportunity to fight in one arm of the maze against exposure to a caged victim in the other arm. No preference for fighting was found. However, finding no preference for one incentive pitted against another need not lead to the conclusion that the two incentives represent the same motivation. In the present study, a between-groups rather than a within-groups design, aggressive arousal led to a higher level of choice behavior than did exposure to a caged victim. Furthermore, the mice in Group 4 displayed none of the agonistic behaviors, such as rattling or piloerection, shown by Groups 1 and 3. Although there is some overlap in the social behaviors of mice in aggressive, sexual, and neutral interactions, the present finding of different levels of appetitive behavior and different topographies of goal behaviors suggests that some degree of independence in motivations exists.

As is true for the motivation of sex, species-specific aggressive behaviors that stop short of what is usually considered consummatory behavior can be reinforcing by themselves. The present experiment may be allied to the investigations, beginning with Thompson (1963), of the reinforcing effect for fish of aggressive display toward mirror images, fish models, or conspecifics behind glass. Although researchers in this area usually have not permitted fish to actually fight, they have not discussed aggressive display as a behavior preparatory to fighting, but have treated it instead as a terminal consummatory act. Whether or not the studies of mice and fish can be directly compared, the present experiment represents the first demonstration in mammals of the reinforcing effect of the elicitation of behaviors preparatory to fighting.

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NOTE

1. This conservative estimate of the degrees of freedom applicable to correlated observations was used for all F statements (cf. Winer, 1962, p. 123).

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