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COMPETITIVE FIGHTING IN THE RAT[1]

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Competitive fighting was obtained in pairs of like-sexed laboratory rats by placing a single piece of food into the food hopper following 48 hr. of food deprivation. The fighting was characterized by offensive sideways posture, full aggressive posture, and bite and kick attack. Tests were conducted at 110-120 days of age on pairs of animals that had been housed together since weaning. Fighting was more frequent in pairs consisting of nonlittermates than in pairs of littermates, and it was equally frequent in male and female pairings. Probability of fighting was enhanced by prior experience with food deprivation, and attack was most often initiated by the heavier animal of the pair.

Several types of fighting have been distinguished in laboratory experiments on rats. In defensive fighting, such as one observes when foot shock is administered to a pair of rats in a small compartment, the rats stand in an upright posture and spar with the forepaws against each other. In offensive fighting, such as one observes when one male is allowed to intrude into the home territory of another male, the home rat engages in sterotyped threat or attack behavior. The threat behavior, called the offensive sideways posture, consists of a sideways prancing movement towards the other animal. The attack behavior begins with the full aggressive posture, in which the attacker orients itself at a right angle across the back of the opponent, and the behavior may proceed to a bite and kick attack, in which the attacker bites its opponent on the opposite flank and simultaneously kicks with its hind legs. In a previous publication, these 2 types of fighting were shown to be under the control of 2 different areas or pathways in the hypothalamus (Adams, 1971).

In experiments on mice a third type of fighting has been reported in addition to the 2 described above. Fredericson (1950) distinguished what he called "competitive fighting" from "spontaneous fighting" in the mouse. Fredericson's spontaneous fighting, which occurs primarily in males (Fredericson, 1952), appears to correspond to the description of territorial fighting in rats. Competitive fighting is also offensive and involves the same postures and mode of attack as territorial fighting, but it is as frequently observed in female as in male mice, and it is obtained by competition of animals for an incentive object, such as food, when they are in a state of deprivation. The 2 types of fighting may also be differentiated by destruction of the olfactory bulbs, which abolishes territorial fighting and does not affect competitive fighting (Rowe & Edwards, 1971).

Whereas there have been many studies on defensive fighting and territorial fighting in the rat and mouse, there have been few studies on competitive fighting in rodents other than those of Fredericson on the mouse (1950, 1952). The methods of Fredericson, which produced competitive fighting in a high percentage of cases and with high test-retest reliability, have not been adapted for use with laboratory rats. Other methods have been used with laboratory rats to obtain fighting that may correspond to competitive fighting, however. Gallup (1965) obtained fighting in female rats when they were run in a straight alley and the accustomed food reward was withheld. Thompson and Bloom (1966) and Davis and Donenfeld (1967) obtained fighting in rats during extinction or partial extinction of food-

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motivated bar pressing. Grossman and Grossman (1970) obtained fighting in pairs of food-deprived female rats when they were run from opposite ends of a narrow tube that had led without obstruction to a food reward in previous trials.

Fredericson's (1950, 1952) methods required little training of experimental animals; he simply placed a single piece of food into the cage of 2 hungry mice. This method was easily employed to investigate the various behavioral parameters that effect the likelihood of fighting in mice. By contrast, methods used previously in rats have required pretest training in bar pressing or runway behavior, and they have not been used to investigate relevant behavioral parameters.

The present study was designed to obtain competitive fighting in rats using methods similar to those used by Fredericson in mice, to attempt a replication of the major findings in mice on the behavioral parameters of competitive fighting, and to explore other parameters that had been found to be relevant in preliminary research on rats.

Behavioral parameters explored in the present study included the role of sex differences to check the finding of Fredericson (1950) in mice that competitive fighting is equally likely in both male and female pairs. The role of prior food deprivation was assessed here in order to replicate the finding in mice that early experience with deprivation and competition enhances fighting when animals are tested later as adults (Fredericson, 1951). In order to test Fredericson's hypothesis that the effect in mice is specific to early experience, the prior deprivation experiences were given at several different stages of development. In addition to these parameters, another was investigated in order to replicate an effect that had been seen in preliminary work with rats: pairs formed at weaning from nonlittermates fought more than pairs formed from littermates even though all pairs of animals were housed together for many months before they were tested as adults. Preliminary work had also suggested that fighting was more likely to be shown by the heavier rat of a pair; therefore, the weights of individual animals were correlated with their aggressive behavior.

Method

Subjects and Maintenance Conditions

The subjects were 60 male and 60 female DA agouti rats, born and raised under controlled conditions in the laboratory. The DA agouti strain has been highly inbred through continuous systematic brother–sister matings for over 30 generations, 5 of which occurred in our laboratory since the original stock was purchased from the Yale University School of Medicine.

Subjects were weaned at 25 days of age, earclipped for identification, and housed as like-sexed pairs in 25 × 42 cm. steel mesh cages. An equal number of random pairings were made between animals of the same litter (littermate pairing) and animals of different litters (nonlittermate pairing). Subjects were provided with continuous ad-lib Purina Laboratory Chow and water with the exception of scheduled experimental deprivation periods as described below. Feeding hoppers were situated on the outside of the cage; food could be obtained by a rat only by extending its muzzle and paws through the wire mesh of the front of the cage. This arrangement restricted feeding to the area in front of the feeding hopper and prevented the exclusive possession of food by one animal. A controlled diurnal light cycle was used, providing artificial illumination from midnight until noon. Test animals were not subjected to human handling.

Experimental Design

The 60 pairs of animals were subdivided orthogonally by sex and littermate/nonlittermate pairings, there being 15 pairs in each of the 4 possible groups. Each group was further subdivided in terms of prior deprivation experience into the following subgroups: 3 pairs with no prior deprivation experience; 3 pairs with one prior deprivation experience 12 hr. in duration; 3 pairs with one prior deprivation experience 24 hr. in duration; 3 pairs with 5 prior deprivation experiences 12 hr. in duration; and 3 pairs with 5 prior deprivation experiences 24 hr. in duration. Each subgroup with any prior deprivation experience was further subdivided into 1 pair with deprivation beginning at 30 days of age, 1 pair with deprivation beginning at 60 days, and 1 pair with deprivation beginning at 90 days. In summary, the design was balanced in such a way that the data from animals in any one experimental treatment could be compared with data from another set of animals that were identical in terms of all other experimental treatments except the one under consideration.

Deprivation Procedure

Deprivation consisted of removal of all lab chow from the feeding hopper and from the tray beneath the cage at the beginning of the dark cycle. Water was always available. At the end of each specified deprivation period, all food was returned to the feeding hopper. Unlimited ad-lib feeding was allowed for 48 hr. between deprivation periods when more than one period was scheduled.

Testing Procedure

Subject pairs, aged 110–120 days, were tested for competitive fighting in their home cages during the mid-afternoon under red light illumination. Prior to testing animals had been deprived of food for 48 hr. Testing was begun by placing a single pellet of lab chow into the feed hopper located on the front of the cage. Due to the limited space in front of the hopper, only one animal at a time could gain access to the food pellet. In most cases, each animal jostled with its cagemate for position at the hopper, and in some cases, attack then occurred. Observations were made by a single observer for a standard 10 min., with a 10-min. extension to determine fighting persistence in those cases when fighting occurred. Each pair was tested only once. The weight of each animal was recorded following testing.

Behavioral Scoring

Identification and scoring of fighting behavior were based on the description by Grant and Mackintosh (1963) of stereotyped postures and acts in the rat and the description by Banks (1962) of the bite and kick attack in the mouse. Attack was defined as the appearance of any of the offensive postures or acts: offensive sideways posture, full aggressive posture, and the bite and kick attack. Boxing and upright posture were observed only as defensive responses by an animal following an attack by its cagemate, and they were not considered as an indicator of competitive fighting.

Results

Competitive fighting was obtained from 29 of the 60 pairs of rats tested. One animal of each pair attacked in 24 of these cases, and both animals attacked in 5 others, making a total of 34 individual rats that attacked out of a possible 120. Of the 34 attacking rats, 82% showed offensive sideways posture, 72% showed full aggressive posture, and 41% showed bite and kick attack. The mean latency of attack was 6.9 min. after food was introduced. Attacks persisted during an average of 2.3 min. of the 10 min. that followed the initial attack.[4]

[4] There were no systematic significant differences in mean latency of attack or mean persistence of attack as a function of any of the experimental treatments or correlations.

Both littermate/nonlittermate pairing and prior deprivation affected the probability of competitive fighting. Significantly more nonlittermate pairs engaged in fighting than did their littermate equivalents ($\chi^2 = 6.68$, $df = 1, p < .01$). Significantly more pairs of animals with 5 24-hr. prior deprivations engaged in fighting than did pairs of animals with less or no deprivation ($\chi^2 = 5.72$, $df = 1, p < .05$). There was fighting in 83% of the pairs with 5 24-hr. prior deprivation experiences, whereas in the other 4 groups with different amounts of prior deprivation experience there was no correlation of fighting probability with amount of deprivation (33% for 1 and 5 12-hr. prior deprivation groups, 42% for 1 24-hr. prior deprivation group, and 50% for the group with no prior deprivation).

The age at which deprivation occurred had no significant effect on fighting in those pairs with low prior deprivation experience, presumably because there was no deprivation effect at all. For pairs with high prior deprivation experience (5 24-hr. deprivations), there was a tendency towards more fighting among pairs that had been deprived at 60 or 90 days of age than among pairs that had been deprived at 30 days of age, the percentages being 100% and 100% vs. 50%, respectively. The number of pairs of animals in these categories was too small to test for significance, however.

The occurrence of fighting by both members of a pair tended to follow the same pattern as the overall data analyzed by pairs. Of the 5 cases in which both animals attacked, 3 were in pairs with high depri-

TABLE 1
Mean Body Weights of Animals as a Function of Fight Relationships

Group	Attacking	Defensive	Nonfighting	All animals
Males				
Littermates	297	290	287	289
Nonlittermates	257	236	250	252
M	277	263	269	271
Females				
Littermates	183	172	175	176
Nonlittermates	173	170	172	172
M	178	171	174	174

vation (expected by chance: 1.0), and 4 were in nonlittermate pairs (expected by chance: 2.5). Four of the 5 cases were in pairs with 60 or 90 day deprivation (expected by chance: 3.3).

There was no significant difference in occurrence of fighting between male and female pairs (14 pairs of males fought and 15 pairs of females fought).

Among pairs in which only one animal attacked, it was usually the heavier animal that was aggressive ($\chi^2 = 5.05$, $df = 1$, $p < .05$). Attacking males were an average of 14 gm heavier than their defending opponents, and the average weight difference for females was 7 gm. Table 1 displays the average body weight of attacking, defending, and nonfighting subjects in relation to sex and littermate/nonlittermate pairing. A t test of paired comparisons was applied to the body weight data for subject pairs in which one animal attacked. The mean weight of attacking rats was found to be significantly higher than the mean weight of their corresponding cagemates both in the case of male pairs ($t = 1.96$, $df = 12$, $p < .05$) and in the case of female pairs ($t = 1.86$, $df = 10$, $p < .05$).

Littermates weighed more than nonlittermates. The difference was significant by analysis of variance ($F = 49$, $df = 1/116$,

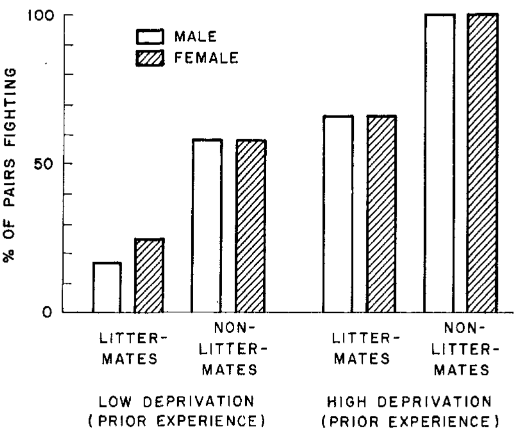

FIGURE 1. Percentage of pairs that engaged in competitive fighting as a function of sex and experimental treatments. (High deprivation refers to pairs that were given 5 24-hr. deprivations prior to testing. Low deprivation refers to all other deprivation treatments.)

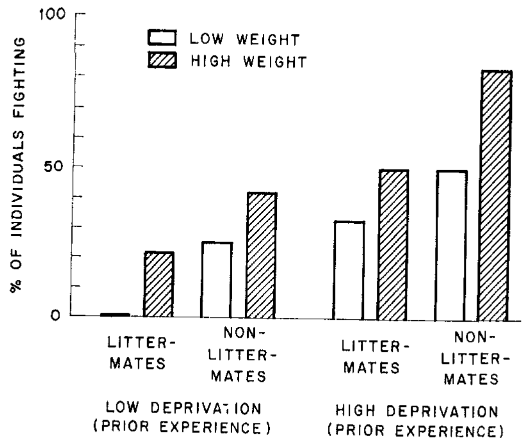

FIGURE 2. Percentage of individuals that displayed competitive fighting as a function of relative weight and experimental treatments. (High and low deprivation defined as in Figure 1.)

$p < .01$). The effect was much stronger among males than among females, as indicated by a significant interaction of the littermate/nonlittermate difference with sex difference ($F = 121$, $df = 1/116$, $p < .01$).

The probability of fighting in a pair of rats ranged from 21% to 100%, depending upon the behavioral parameters employed. As illustrated in Figure 1, at the low end, only 21% of the pairs fought in the category of low deprivation and littermates. At the high end, 100% of the pairs fought in the category of high deprivation and nonlittermates. The data were also highly regular when each individual of a pair was analyzed separately as illustrated in Figure 2. At the low end, none of the individuals attacked in the category of low-weight, low-deprivation littermate. At the high end, 83% of the individuals attacked in the category of high-weight, high-deprivation nonlittermate.

DISCUSSION

This study demonstrates that competitive fighting, previously elicited in mice by giving 1 piece of food to 2 food-deprived cagemates, can also be elicited in similar fashion from laboratory rats. The postures of the attacking animal have been found to be similar to those reported in territorial fighting by rats and unlike those in defensive fighting such as observed in response to footshock in a small enclosure. Unlike territorial fighting, however, competitive fighting in rats is seen to be as frequent in females as in males and is readily elicited in animals that are familiar with each other. It should probably be distinguished from territorial and defensive fighting as an equally distinct and important form of aggressive behavior.

The competitive fighting of rats is similar in most respects to that observed by Fredericson (1950, 1952) in mice. It can be elicited in a high proportion of cases and is equally likely in both males and females. Furthermore, competitive fighting may be obtained in several inbred strains of rats, including the ACI Irish inbred strain as well as the DA agouti (D. B. Adams, manuscript in preparation), and has been observed in similar test situations in outbred hooded rats (Adams unpublished observations 1970).

There are some differences between the competitive fighting of rats and that reported in mice, however. Fredericson (1951) found competitive fighting by the mice that were deprived at 29 days of age, whereas in the present study no fighting was observed when food was restored to 30-day-old animals that were given experience with food deprivation. Fredericson (1951) administered prior deprivation at only one age, from 29 to 34 days, and when he obtained increased fighting in these mice as adults (Fredericson, 1951), he concluded that early experience was important for adult behavior. He did not test the effects of prior deprivation experience at other ages. Our results indicate that in the rat prior deprivation experience is effective at any age and that it may be more effective at later ages than as early as 30 days old.

The effect of littermate vs nonlittermate pairings on the competitive fighting of adults has not been described previously. The mechanisms by which pairings at age 25 days can continue to influence the behavior of animals tested at 110 days of age is not clear. As far as is known there are no previous studies that have distinguished these 2 types of early pairings and demonstrated their effects on adult behavior. The finding does, however, find some theoretical basis in the work of Hamilton (1971) on kin selection and its effects on the evolution of aggressive behavior. Hamilton has predicted that "within species, fights will be most damaging when combatants: (a) differ most in heritable characteristics perceptible to the opponent, (b) derive from distant regions or from different subpopulations" (p. 77). The difference between littermates and nonlittermates should probably be considered as subpopulation or regional differences rather than genetic differences, since all of the rats in this study were derived by brother–sister matings from a highly inbred population. A critical test, however, would require a cross-fostering study.

Weight differentials for winners and losers of fights are similar to those reported by Calhoun (1962) in his study of fighting among wild rats in an outdoor pen. Like Calhoun, we found that winners weighed more than nonfighting animals of the same age and losers weighed less than nonfighting animals of the same age. Our data do not indicate which came first, the dominance relationship or the weight differential. Data from a study by Bronson and Eleftheriou (1964) suggest a possible explanation, however. They found that mice exposed to defeat develop a syndrome that includes increased adrenal weight and plasma corticosterone levels, and decreased body and seminal vesicle weight. It is possible that the pairs of animals in this study had already engaged in fights with each other during the weeks and months prior to testing, that one animal had become dominant, and that the other animal had developed the syndrome including weight loss. If so, then one could explain both the attack by the heavier animal and the relatively low weight of the partner as the result of prior fighting episodes. It could also explain why nonlittermates weighed less than littermates if one assumes that there was more fighting among nonlittermates than among littermates not only during the test, but also during the months prior to testing.

This study demonstrates that competitive fighting is under the close control of easily manipulated behavioral parameters. By varying prior deprivation experience and littermate/nonlittermate pairings it is possible to vary systematically the probability of competitive fighting by a pair of rats, and with the proper choice of parameters, it is possible to obtain fighting in all cases. It is also possible to predict, by weight differences, which animal of previously paired subjects will probably be the attacker. Because competitive fighting is reliable, easily elicited, and under such precise parametric control, it has distinct advantages over other procedures that have been used in the study of aggression, and it should prove of value in assessment of the effects of brain lesions, drugs, and early experience.

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