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AGGRESSION AND TIMIDITY: RESPONSES TO NOVELTY IN FERAL NORWAY RATS[1]

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Wild rats were reared under various conditions and tested for amount of aggression exhibited toward human handlers, conspecifics, and mice, and for timidity. Additional animals were amygdalectomized and tested as above. The results were: (*a*) Rearing wild rats with albino foster mothers had no effect on performance on any test; (*b*) rearing wild rats with periodic human handling reduced aggression to humans but did not affect other measures; (*c*) rearing wild rats with mice reduced aggression toward mice but did not affect other measures; (*d*) members of an established colony did not fight among themselves but attacked unfamiliar wild rats; and (*e*) amygdalectomy reduced aggression and timidity in wild rats. The results were discussed in terms of the role of stimulus novelty in eliciting aggression and timidity.

Comparison of the behavior of the wild and albino domesticated strains of Norway rat reveals the considerable behavioral modifications which have occurred in the course of 100 yr. or more of breeding in captivity. Most marked among these behavioral modifications is the reduction in aggressiveness or savageness to be seen in domesticated rats when compared with their feral conspecifics. This difference in level of aggression can be observed in the response of these two strains of rats to human handlers, to their fellow rats, and to other small animals such as mice.

The wild rat's aversion to handling and its aggressiveness toward human handlers are clearly demonstrated when a handler attempts to remove an individual feral animal from its home cage (Stone, 1932; Yerkes, 1913). Wild rats treated in this fashion show extreme resistance to capture, considerable ferocity toward the capturing agent, and marked emotional arousal during capture. The albino domesticated rat is, by contrast, extremely easy to capture and handle, rarely exhibits aggression toward human handlers, and seldom exhibits extreme emotional behavior as a result of handling (Richter, 1949; Stone, 1932).

Differences between albino domesticated and wild rats with respect to intraspecific aggression are observable when adult male domesticated and feral rats are introduced into cages containing established colonies of others of their own strain. The "established" wild rats exhibit considerable aggression in such situations, and their attacks usually result in the death of the intruder (Barnett, Eaton, & McCallum, 1960). Fighting among albino domesticated rats under similar conditions is, by comparison, rather mild and resembles the harmless wrestling of immature wild rats, rather than the fighting of mature feral males (Barnett, 1963).

The domesticated rat is, in a similar way, far less savage and aggressive toward mice than its feral counterpart. The percentage of mouse killers is much higher among wild rats (70%; Karli, 1956) than among albino domesticated rats (4%; author's observation).

A second major behavioral disparity between wild and domesticated rats is to be found in their degree of timidity or shyness. The domesticated albino rat is an inquisi-

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tive animal, and, if some novel object is placed in an environment with which it is familiar, the albino rat will approach and explore it (Berlyne, 1950). Wild rats are, on the contrary, very timid animals and show a strong tendency to avoid any novel object in an otherwise constant environment with which they are thoroughly familiar, and exhibit extreme hesitancy in approaching such an object should it be necessary to do so (Barnett, 1956, 1958a, 1963; Chitty, 1954). This timidity response is a curious behavioral phenomenon in that no particular stimulus situation elicits or releases it. Any given object can either produce avoidance or fail to produce it simply as a function of its novelty.

These two differences in the behavior of the wild and domesticated strains of *Rattus norvegicus* were first described in the literature early in the twentieth century (Yerkes, 1913). However, little progress has been made in their study beyond the cataloguing of their existence and the exploration of some of the parameters relevant to them. The purpose of the research reported here is to demonstrate that these two major differences in the behavior of wild and domesticated rats, their degree of aggressiveness, and of timidity, have a common underlying basis. In the following series of experiments, evidence is presented supporting the hypothesis that the timidity and savageness which characterize wild-rat behavior are two different manifestations of the wild rats' response to novelty.

Of course, novelty avoidance and aggressive behaviors differ tremendously in their topology, and the question arises immediately as to the significance of any apparent similarities between them. Scott and Fredericson (1951), in their discussion of interactions between organisms, view "escape behavior" and "defense" behavior as similar in function in that they serve to maintain the integrity of the organism in the face of certain types of external threat. Although these authors do not concern themselves with interactions between an organism and an inanimate object, both avoidance and aggressive behaviors may be presumed to serve a parallel function in this case. The evidence presented here indicates that the similarity between these two behavior patterns, timidity and aggression, is not solely functional in nature.

In the present study, it will be demonstrated that both timidity and aggression in the wild rat are dependent for their elicitation on the presence of a novel-stimulus situation and for their realization on the functioning of a common subcortical area.

The first series of experiments demonstrates that stimulus novelty is a necessary condition for the occurrence of aggressive behavior as it is for timidity behavior.

Experiment 1

Rasmussen (1938) demonstrated that it is possible to rear wild rats in such a way that they become almost as easy to handle as their albino domesticated conspecifics. He raised three wild rats under conditions differing in a number of ways from those experienced by feral rats reared in the wild. He found that these wild rats handled by the experimenter for considerable periods, reared by albino foster mothers, with albino littermates, and with considerable exposure to humans at a distance became quite amenable to human handling. However, the conditions under which Rasmussen reared each of his animals were not sufficiently clearly described, and the number of animals used was too small to establish which of the rearing conditions employed were necessary or sufficient to produce the observed reduction in savageness.

Farris and Yeakel (1945) and Stone (1932) found that young wild rats handled before weaning could thereafter be handled without difficulty. However, neither of these authors reported any systematic attempt to ascertain the effects of other types of early experience (being reared by an albino foster mother, for example) on the aggressive responses of wild rats toward handlers.

In the first experiment, wild-rat pups were systematically reared under a variety of conditions to establish those early experiences sufficient to reduce the wild rat's tendency to react savagely toward human handlers.

Method

Subjects. The subjects were 33 second- and third-generation laboratory-bred wild rats, the direct descendants of rats trapped on the wharves of Philadelphia. Successive generations of stock wild rats were bred and their offspring reared to weaning in the cage described in the *method* section of Experiment 4.

Procedure. Individual litters of laboratory-bred wild rats were divided into experimental groups at 3 days of age and reared for 20 days in groups of four or more pups under one of a variety of conditions. The factors varied during rearing were (*a*) the type of mother rearing, either domesticated albino or wild; (*b*) the type of littermates with which the pups were reared, either domesticated albinos or wild; (*c*) the degree of exposure which the pups received to humans at a distance, either the minimal exposure necessary for the maintenance of the animals or considerable exposure in a room where people were constantly coming and going; (*d*) the amount of human handling received by the wild-rat pups, either no handling at all or 2 min. of handling per day from the time the pups were 10 days of age until they were 23 days of age.

Handled animals were removed from their cages one at a time and held lightly by the tail in the left hand of the experimenter. They were lightly stroked with the left thumb.

Practical difficulties encountered in breeding wild rats in the laboratory precluded rearing pups under all 16 possible conditions. Pups were assigned to conditions, as the experiment proceeded, so as to maximize information gained from each new litter used in the experiment.

At 23 days of age, all the wild-rat pups were tested during a 1-min. period of handling. During this test period they were rated on a 0-½-1 scale in six categories of behavior: (*a*) the difficulty experienced by the experimenter in capturing the pup for testing in the absence of the mother; (*b*) the intensity of escape attempts exhibited by the pup during testing; (*c*) the amount of vocalization emitted by the pups during testing; (*d*) the amount of biting directed toward the restraining hand during the testing period; (*e*) the amount of urination; and (*f*) the amount of defecation. An animal that was extremely difficult to handle thus received a score of 6 while a tame one received a score of 0.

TABLE 1

TEST SCORES OF INDIVIDUAL HANDLED AND UNHANDLED WILD RATS AT 23 DAYS OF AGE

Amount of experience	Wild reared		Albino reared	
	Wild littermate	Albino littermate	Wild littermate	Albino littermate
Handled				
Experience		0, 0	0, 0, 0, 0, 0	0, 0
No experience	0, 0, 0, 1			0, 0
Not handled				
Experience			3, 3, 3, 4	4, 4
No experience	3, 3.5, 4, 4, 4.5, 6	4, 4.5	4, 4.5	3.5, 4

Results

The data recorded from all 33 rats during the 1-min. period of testing at 23 days of age are summarized in Table 1. Each entry represents the total score awarded to a single rat pup during the 1-min. testing period. The rearing conditions for the animals whose datum is presented in any cell are described by the intersection of the row and column headings defining that cell.

The rats whose scores are presented in the upper half of Table 1 are those which were handled by the experimenter, while the rats whose scores are presented in the lower half of Table 1 are those which were not handled by the experimenter during rearing.

It is apparent from the data that only those rats that had been handled by the experimenter showed any measurable diminution in savageness on the day of testing when compared with rats reared under the most naturalistic conditions used (animals whose scores are presented in the lower left-hand corner of Table 1). Rats handled daily by the experimenter, even those reared with a wild mother and wild littermates, became tame and docile in their response to human handling, while wild rats reared without daily handling, regardless of other conditions of rearing, were extremely difficult to capture and handle on the day of testing.

EXPERIMENT 2

Experiment 1 demonstrated that experience of human handling is sufficient to reduce markedly the wild rats' aggressiveness toward human handlers. Experiment 2 was designed to investigate the generality

of this taming by examining its effect on the mouse-killing behavior and intraspecific aggression of wild rats and by ascertaining the effects of handling on the timidity response of wild rats.

Method

Subjects. The subjects were four litters of fourth-generation laboratory-bred wild rats, 21 animals in all.

Rearing. Litters of wild rats, reared with wild mothers and siblings, were divided into experimental and control groups at 10 days of age. The experimental animals were handled for 2 min. per day until they were 3 mo. of age, while the controls were not handled at all. The two groups were treated in an identical fashion in all other respects. Handled rats continued to be extremely easy to pick up and handle throughout the experiment and would even submit to considerable pain, i.e., tail pinching or paw twisting, without biting the experimenter, attempting to escape, or emitting aggressive vocalizations.

Experimental procedure: Mouse killing. At 23 days of age the animals in both groups were weaned and transferred to small individual hanging cages, where they were maintained on Purina rat chow and water ad lib until they were 90 days of age. On Day 90 a single adult female albino mouse was introduced into each wild rat's cage. Twenty-four hours later the experimenter ascertained the condition of each test mouse. A third group of 10 wild rats, reared by two albino foster mothers and treated identically to the unhandled wild-reared group in all other respects, were similarly tested for mouse killing.

Experimental procedure: Timidity. Ten male animals, 5 from each of the two wild-reared groups, were then transferred to large individual experimental cages[3] and placed on a 5 hr/day feeding schedule, eating Purina rat chow pellets from a metal container placed against the back wall of their cages. Water was constantly available to both groups.

Twenty days after being placed in the experimental cages and on the new feeding regimen, the two groups of animals were tested for timidity. The handled experimental group continued to be handled throughout the experiment. (*a*) *Timidity Test 1:* On Day 1 the food cups of both the handled experimental rats and their unhandled controls were changed from metal to glass, and the food cups moved from the back wall of the cage to the front. The food in the cups was changed from the Purina rat chow to a starch-based powdered diet (Diet 4, Rozin, 1967). The experimenter measured the rats' intake on the day of the change and on succeeding days. (*b*) *Timidity Test 2:* Twenty days following the original change in feeding conditions, the experimenter began to measure latency to first ingestion of food following placement of the food cups in each rat's cage at the beginning of the 5-hr. feeding period. Following the establishment of a base-line latency to first ingestion of food, a metal plate, 5 × 5 in., was placed beneath each animal's food cup when it was introduced into its cage on Day 25. The plate was left in this position throughout the 5-hr. feeding period and removed at its conclusion. It was reintroduced on succeeding days. The experimenter continued to measure time to first ingestion of food to the conclusion of this testing period 3 days later.

Experimental procedure: Intraspecies aggression. All 21 animals in both the handled and unhandled wild-reared groups were placed on an ad-lib diet of Purina rat chow pellets and left undisturbed for a 1-wk. period in large experimental cages (see Footnote 3). Each rat was then tested for its aggressiveness toward a 3-mo.-old test wild rat of the same sex introduced into the animal's home cage. The experimenter recorded the number and intensity of all encounters during a 1-hr. period.

TABLE 2

NUMBER OF WILD RATS KILLING MICE DURING A 24-HR. TEST PERIOD

Group	*n*	% killing
Handled wild reared	12	67
Unhandled wild reared	9	77
Unhandled albino reared	10	70

Results

Mouse killing. Table 2 shows the number of wild-reared wild rats, both handled experimentals and unhandled controls, and of albino-reared nonhandled wild rats which killed a mouse within the 24 hr. following the mouse's introduction into the rat's cage. It is apparent that handling, which produces a tremendous decrement in the aggressiveness of wild rats toward human handlers, leaves the wild rats' aggressive response toward mice relatively unaffected. It is also evident that rearing wild rats with an albino foster mother does not appreciably affect mouse-killing behavior.

Timidity Test 1. As seen in Figure 1,

[3] Experimental cages (custom made by Norwich Wire Works, Norwich, Connecticut) were 18 × 17 × 12 in. Attached externally to one 12 × 17 in. end of the cage was a small nesting box, 6 × 8 × 6 in., connected to the main cage by a 4-in.-long tunnel, 2¾ × 2¾ in., in cross section. Food cups were always placed at the opposite end of the large enclosure from the nesting box and held in place by wires.

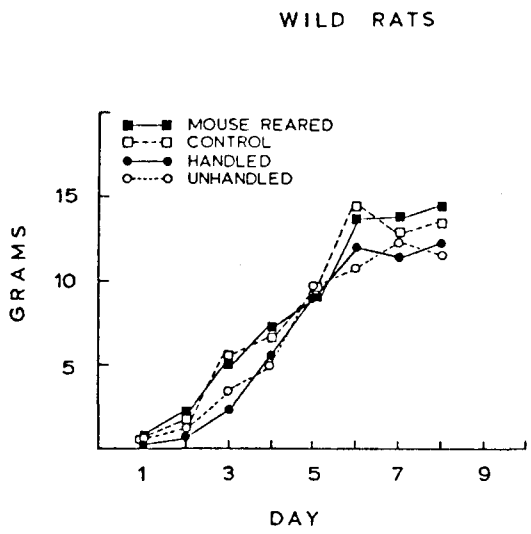

FIG. 1. Timidity Test 1: Mean grams of new food eaten by wild rats on a 5 hr. per day feeding schedule following a change in feeding conditions.

both groups of animals in the experiment showed a decided avoidance of the novel food on the first 2 days of its presentation. Neither group reached an asymptotic level of food intake during the first 6 days of exposure to the new feeding conditions. Most important, there was no difference observed in degree of novelty avoidance in the handled experimental group and its unhandled control on this measure.

Timidity Test 2. As seen in Figure 2, the two groups of rats in this experiment both showed a marked increase in latency to first ingestion of food following introduction of a novel object beneath the animals' feeding cups. The handled rats showed a slightly greater, though nonsignificant, increase in latency on the day of testing. (Of the six longest latencies to first ingestion of food, three were shown by handled animals and three by unhandled controls, and of the six shortest latencies, three were shown by handled animals and three by unhandled controls.) Timidity again remained unaffected by handling procedures.

Intraspecies aggression. Table 3 shows the number and intensity of aggressive attacks directed toward intruders of the same sex by resident male and female rats in both the handled experimental and unhandled control groups.

It is clear that there was no major decrement in intraspecies aggression as a result of handling. The average total number of fights for males was roughly the same (4.6 for handled males and 4.3 for unhandled controls), and the ratio of violent to moderate and mild fights was similar for the two groups. In the same way, the fighting scores for females in the handled and unhandled groups were quite similar. Gentling by a human handler does not produce any marked change in the intraspecies aggression of the wild rat.

Discussion

The results of the first two experiments are quite clear. First, wild rats reared without human handling behave in an aggressive fashion toward human handlers. This tendency toward savageness may be overcome by handling the animals daily from an early age. Other types of early experience fail appreciably to reduce this tend-

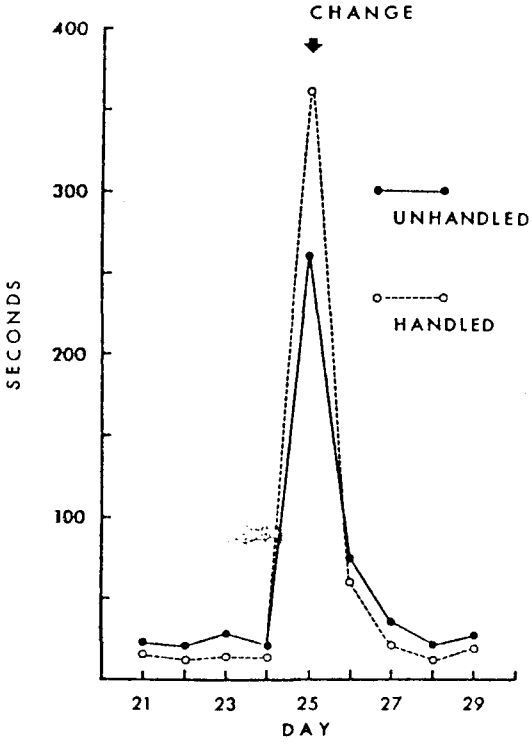

FIG. 2. Timidity Test 2: Mean latency to first ingestion of food by wild rats on a 5 hr. per day feeding schedule.

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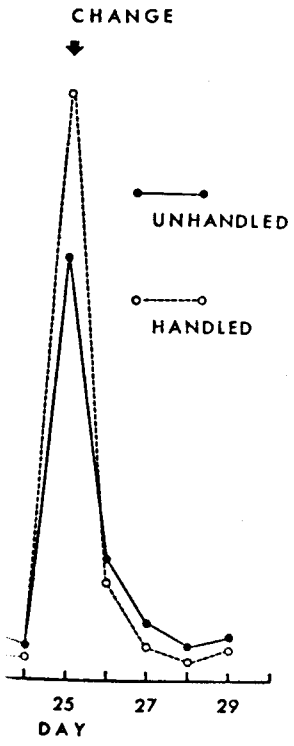

2: Mean latency to first
d rats on a 5 hr. per day

TABLE 3

MEAN NUMBER AND TYPE OF AGGRESSIVE ENCOUNTERS BETWEEN WILD-REARED WILD RATS OF THE SAME SEX DURING A 1-HR. TEST PERIOD

Rats	Male-male					Female-female				
	n	Violent	Moderate	Mild	Total	*n*	Violent	Moderate	Mild	Total
Handled	5	2.4	1.4	.8	4.6	5	1.4	.8	.8	3.0
Unhandled	6	2.3	1.2	.8	4.3	5	1.6	.6	.6	2.8

ency to savageness. In addition, the data presented indicate that the handling of wild rats, which so markedly reduces their aggressiveness toward human handlers, leaves their aggressiveness toward mice and toward conspecifics unchanged and leaves their level of timidity unaffected. The effects of human handling thus appear to be quite specific. Human handling does not reduce the general aggressiveness or timidity of wild rats, but simply reduces aggressiveness in the specific situation which has been made familiar to the handled rats. The results of this first group of experiments support the hypothesis that stimulus novelty is a necessary condition for aggressive behavior in wild rats, as it is for timidity, by demonstrating first, that habituation to handling is a necessary condition for reducing aggressive behavior toward humans; and second, that this handling leaves much of the other distinctive behavior of wild rats unaffected.

There are several deficiencies in the experimental design which render the conclusions to be drawn from the data somewhat weaker than might be desired. First, the sample size is uniformly small. Second, the same animals are used successively for several tests resulting in nonindependence of the measures, given the author's conception of their import. Both these problems in design result from the difficulty in breeding and maintaining large numbers of wild rats in the laboratory. Third, there is some question as to the validity of the various measures of aggression and timidity used in the preceding experiment. It is, of course, possible that these particular measures are simply not sufficiently sensitive to detect changes in behavior which are of interest. However, as will be seen below, manipulations quite similar to those used in the present study can cause marked variation in the performance of wild rats on these same measures.

EXPERIMENT 3

Approximately 70% of wild rats will kill mice placed in their home cages for a 24-hr. period (Karli, 1956), while only 4% of albino domesticated rats exhibit mouse-killing behavior under identical circumstances (author's observation). Although the motivation underlying the mouse-killing behavior of wild rats is not known, it seems probable that it is an aggressive behavior pattern elicited by some as yet undefined constellation of external stimuli and part of the highly aggressive behavior generally exhibited by these organisms, rather than the result of a predator-prey relationship comprising part of the feeding behavior of the wild rat (Karli, 1956; Myer, 1964; Myer & White, 1965).

The hypothesis under investigation implies that stimulus novelty is a necessary condition for the occurrence of aggressive behavior. One would therefore predict that, if mouse killing is an aggressive behavior, wild rats which were thoroughly familiar with mice would not exhibit aggression toward them.

Kuo (1930) found that cats reared with rats never killed the rats with which they were reared and seldom killed other rats, while 50% of cats reared in isolation from rats killed them. In the present experiment, a similar procedure was carried out. Wild rats were reared with mice constantly present in their cages to determine whether or not familiarization with mice would inhibit the wild rats' tendency to kill mice. Rats raised with mice and their normally reared

controls were then tested to determine whether or not the experience of being raised with mice affected the amount of aggressiveness which the wild rats demonstrated toward conspecifics and toward human handlers. These animals were then tested to determine whether their timidity responses were affected by the experience of being reared with mice.

Method

Subjects. The subjects were four litters of fourth-generation laboratory-reared wild rats (22 animals) and 36 Charles River adult female albino mice.

Procedure. Four litters of wild rats were reared by their natural mothers for 21 days. The pups were then weaned and placed in individual cages where they were maintained on ad-lib food and water to the completion of the experiment. At 28 days of age, the 22 rats in the experiment were divided into experimental ($n = 14$) and control ($n = 8$) groups. A single albino mouse was placed in the home cage of each experimental rat and left there until the rats were 3 mo. of age. The control rats were left undisturbed for the same period.

When the rats reached 3 mo. of age, each mouse was removed from the cages of the experimental rats and immediately replaced with a second mouse. A mouse was also placed in the cage of each control rat. The experimenter recorded the number of mice surviving for 3 mo. in the cages of the experimental rats and the number of mice placed in the cages of experimental and control rats at 3 mo. of age surviving for a 24-hr. period.

Six animals (three male and three female) were then randomly selected from the experimental groups and six animals (three male and three female) from the control group. These animals were then tested for their aggressiveness toward humans and toward conspecifics and on two measures of novelty avoidance as described in the Method section of Experiment 2.

Results

Of 14 wild rats reared with mice, none killed the mouse with which it had been reared. One of the 14 experimental rats killed the mouse which was placed in its cage immediately following removal of the original cagemate. Five of the eight control animals killed the mouse introduced into their cages within 24 hr.

The rats in the experimental group (those raised with mice) showed no observable diminution of their aggressiveness toward human handlers at 3 mo. of age. When captured by the experimenter they screamed, bit, urinated, and made every attempt to escape from the hand imprisoning them. The behavior of these animals toward the experimenter was in no observable way different from that of their normally reared controls.

The rats raised with mice showed approximately the same level of aggressiveness toward conspecifics as did their normally reared controls. The average number of fights for the mouse-reared rats during a 1-hr. test period was 4.1 and for the controls 3.9.

Figure 1 shows the mean daily intake of the two groups following the change in feeding conditions in Timidity Test 1. There was no observable difference between the experimental and control groups. Similarly, animals in the two groups showed no differences in behavior on Timidity Test 2. The mean latency to first ingestion of food was 18.2 sec. for experimental rats and 18.5 for controls. The mean increase in latency following introduction of the metal plates was 197.5 sec. for experimentals and 206.7 sec. for controls.

Discussion

It is clear from the data that familiarizing wild rats with mice results in a strong inhibition of the wild rats' tendency to attack mice. Furthermore, the effect is quite specific. Habituation to mice does not affect the tendency of the wild rat to behave savagely toward humans or toward conspecifics and leaves its timidity response unaffected. The results serve to confirm the hypothesis under investigation by demonstrating that habituation to a mouse, a stimulus which normally elicits an aggressive mouse-killing response, leads to inhibition of mouse killing while leaving other aspects of the wild rats' behavior unaffected.

EXPERIMENT 4

Wild rats exhibit aggression not only toward humans and toward mice, but also toward their fellow wild rats. The conditions under which this intraspecific aggression occurs are of considerable interest

with respect to the hypothesis under investigation.

Lorenz (1966) has described the members of a small established colony of wild rats as "models of social virtue." Wild rats living under such conditions never bite one another and rarely exhibit milder forms of aggression toward one another. Barnett (1963) describes the occurrence of aggressive behavior in small artificially maintained established colonies as exceedingly unlikely, and Eibl-Eibesfeldt (1961) states that wild Norway rats living in the wild coexist peacefully in large packs.

There is, however, one type of situation in which aggressive behavior directed toward conspecifics is highly likely to occur. Should an unfamiliar wild rat be introduced into a previously established colony, the intruder is almost invariably attacked (Barnett, 1958b, 1963; Eibl-Eibesfeldt, 1961; Lorenz, 1966).

In addition, there exists in the literature one exception to the observation that wild rats living in an established colony are almost completely nonaggressive toward one another. This is in the case of large numbers of wild rats maintained in a very large enclosure. Calhoun (1962), using an enclosure of 10,000 sq. ft., reports considerable fighting in established colonies. However, as will be discussed later, the very large enclosure containing large numbers of wild rats may represent a special case.

The majority of the evidence available in the literature strongly implies the importance of stimulus novelty in the occurrence of intraspecific aggression in wild Norway rats. Wild rats live peacefully within an established group and attack only unfamiliar intruders.

In the present experiment, observation of an established breeding colony of wild rats was undertaken to establish the incidence of aggressive behavior. After this base line was determined, foreign wild rats were introduced into the colony one at a time to see if any increase in the level of aggression occurred.

Method

Subjects. The subjects were 14 third-generation laboratory-bred wild rats.

Procedure. Three male and four female wild rats were removed from their mothers at 28 days of age and placed in a large cage (6 × 3 × 1 ft.) with three externally attached nesting boxes. The floor of the cage was kept well covered with wood chips, and hay was provided whenever a female rat was observed to begin nest building. New litters were removed when they reached 23 days of age. The animals were left otherwise undisturbed for 6 mo. on a 12-hr. day/night cycle, with water available ad lib. and powdered food available in a single container 5 hr. per day. Background illumination was provided by three 25-w. red lights. A cloth blind was erected 3 ft. from the cage to allow the experimenter to observe the behavior of the animals within the enclosure without disturbing them.

After the experimenter had had ample opportunity to observe the behavior of the established colony, seven foreign wild rats (three adult male, two adult female, and two juvenile) were introduced into the colony individually at intervals of several days. The experimenter continued observation of the colony.

Results

During 70 hr. of observation over a period of 10 wk., during both the day and night cycle of illumination, the experimenter observed no aggressive behavior at all within the established colony, with the exception of female rats defending a nest site and pups from intruders. There was no competition or fighting of any kind over food, water, or females in estrus. The observer saw numerous examples of other behaviors: feeding, hoarding, drinking, copulation, nest building, delivery of young, retrieval of young, savaging of litters, etc. The only behavior pattern conspicuous by its absence in the established colony was aggression.

When a foreign wild rat was introduced into the colony, the behavior of the colony members changed dramatically. Each of the seven animals introduced into the colony by the experimenter was the recipient of vicious attacks. In every case the intruders were attacked by one or more of the residents and suffered repeated bites. During a period of 48 hr., two of the intruders (one adult male and one juvenile) died, the remaining five introduced animals became covered with lesions, especially on the tail and posterior portion of their bodies, lost weight rapidly, and would probably have died if not removed by the

experimenter. During the period while foreign rats were present in the colony, the colony members showed an increase in the amount of sniffing they directed toward one another, but they did not engage in aggressive behavior among themselves.

Discussion

The results of the foregoing study and of similar observations reported in the literature on the level of aggression in small established colonies of wild rats are in agreement. Aggressive behavior is rarely observed in these small established colonies. The response to intruders by members of the established colony is also well established. These intruders, which are identical in every respect, except for their familiarity to colony members, are almost invariably the recipients of savage attacks. Barnett (1963) has reported that only male rats are attacked when introduced into an established colony and that females and immature rats are left relatively undisturbed. The source of the discrepancy with Barnett's results in the present experiment is not known, though it is interesting to note that when intruders were placed into a pair of smaller cages (4 × 2 ft.), each containing only a single male and female, the aggression directed toward males was far greater than that directed toward females or juveniles. It is thus possible that low population density is a factor in producing the lower level of aggression toward nonmales reported by Barnett. However, it must be noted that even an extremely high population density (the author reared 12 wild rats in a cage, 1 × 2 × 1 ft., and saw no spontaneous aggression during 25 hr. of observation) does not itself produce aggression.

The second area of uncertainty in the literature regards the absence of aggression in colonies of wild rats artificially confined in small areas and its prevalence in colonies confined in larger areas. It is possible that this difference in amount of aggression is the result of a difference in the social structure within the two sizes of enclosure. In the small enclosure territories are not established, and all colony members are constantly in contact with one another. In the large enclosure, the animals rapidly segregate themselves into territorial groups (Calhoun, 1962). The territoriality to be seen in larger enclosures must serve to isolate groups of animals from others so that all colony members are not familiar to one another, and hence the mutual familiarity which inhibits aggression does not exist between many pairs of colony members. One would thus expect to see small clans of animals living in relative peace but attacked by and attacking outsiders. Steiniger (in Calhoun, 1962) reports the observation of such mutually tolerant "in-groups" or "Rudels" within the larger colony, and Calhoun considers their occurrence likely. That Eibl-Eibesfeldt (1961) does not report high levels of intraspecies aggression in the wild may be due to the fact that spatial dispersion, which is prevented in artificial enclosures by the walls of the enclosure, greatly reduces contact between unfamiliar and, hence, antagonistic clans.

There is no question, however, that in small colonies where all the members are thoroughly familiar to one another, aggression is rare. It is only when novel, or unfamiliar, rats are placed in the enclosure that aggression is seen.

EXPERIMENT 5

The behavioral evidence presented in the preceding experiments offers considerable support for the hypothesis that stimulus novelty is a necessary condition for the release of aggressive behavior, as it is for timidity.

Of course, the fact that two behavior patterns are both released by similar stimulus conditions is not, in and of itself, sufficient to demonstrate that they are two manifestations of some single underlying process. More direct evidence of the existence of a common neural substrate underlying the two behavior patterns under discussion is needed. The present experiment provides such evidence.

Woods (1956) demonstrated that wild rats with bilateral lesions of the amygdala no longer attack human handlers, while re-

maining as alert and active as prior to operation. Karli (1956) showed that in 14 of 16 cases wild rats which were habitual mouse killers stopped killing mice following bilateral amygdalectomy. In addition, the author has found that when one amygdalectomized wild rat was introduced into the cage of another, they fought far less often and with greatly reduced ferocity than sham-operated controls treated in the same way. These observations indicate that amygdalectomy greatly reduces the amount of savageness or aggressiveness in the behavioral repertoire of wild rats. If savageness and timidity are two manifestations of the same basic response to novelty, then amygdalectomy should reduce timidity as well as aggression.

Method

Subjects. The subjects were 10 3-mo.-old male laboratory-bred fourth-generation wild rats, maintained on a diet of laboratory chow and water.

Procedure. Electrolytic lesions were made using a Scientific Prototype stereotaxic apparatus. Dental broaches, made of stainless steel, were used as electrodes, insulated with Dupont "Krylon" spray acrylic. A direct current of 2 ma. was used for 15 sec. for each lesion. In each of the five operated animals, two lesions were made on either side. Taking lambda as a reference point, the following coordinates were used: *anterior lesion:* 6 mm. rostral, 4 mm. lateral, 9 mm. deep; *posterior lesion:* 5 mm. rostral, 4.5 mm. lateral, 9 mm. deep. The five control animals were subjected to the same operative procedure, the only difference being that no current was passed from the indifferent electrode to the active one.

Following lesioning, each of the operated animals was assigned a yoked sham-operated control. Animals in each pair were treated as similarly as possible. All five of the operated animals stopped feeding themselves for a period of 5–17 days following lesioning. During this period they were tube fed a mixture of Metrecal and Kaopectate. Each yoked control received this Metrecal and Kaopectate diet for the same period of time as its partner, though it was not possible to tube feed the mixture to these yoked control animals because of their extreme savageness toward handlers.

After self-feeding resumed in the operated animals, they and their controls were returned to 95% of preoperative body weight on a diet of lab chow and water. All animals were then placed on a 5-hr/day feeding schedule, eating lab chow from a metal container placed against the back wall of their cages for 2 wk. During this 2-wk. period, the rats were tested for their savageness toward humans, toward mice, and toward conspecifics, as described in Experiment 2, and the two tests of timidity, (*a*) the changing of food cup, food cup location, and diet and (*b*) the placing of the metal plates beneath the food cups, were then conducted in the fashion described in Experiment 2.

Histology. Following completion of the experiment, all lesioned animals were sacrificed and perfused with saline and 10% formalin and their brains removed, sectioned, and stained with thionin. Histological study of the sectioned brains revealed symmetrical lesions destroying more or less completely the amygdala on both sides.

Results

All five of the operated wild rats became extremely tame and easy to handle following lesioning. It was, in fact, a relatively easy matter to tube feed these amygdalectomized animals. The sham-operated controls continued to be extremely savage and difficult to handle, and tube feeding them presented insurmountable difficulties.

All five mice placed in the cages of the operated animals survived unharmed for 24 hr., while three of the five placed in the cages of the sham-operated animals were killed during a 24-hr. period.

Of the five operated animals, only one exhibited any aggression toward an intruder placed in its cage during a 1-hr. period of observation, and this animal exhibited only relatively mild aggression (boxing) toward its opponent. Four of the five controls engaged in rather vicious

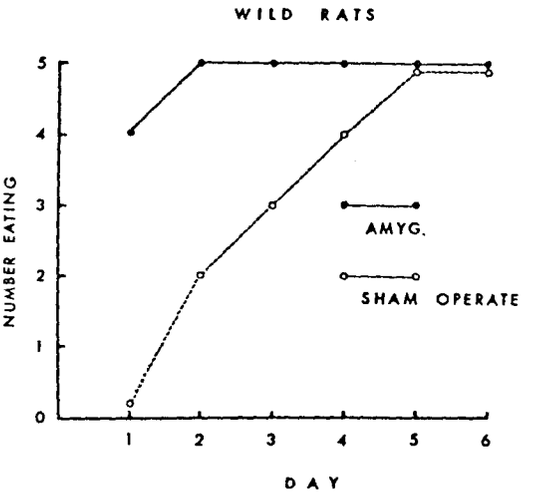

FIG. 3. Timidity Test 1: Number of rats eating any food at all following a change in feeding conditions.

TABLE 4
TIMIDITY TEST 2: LATENCY TO FIRST INGESTION OF FOOD BY WILD RATS WITH BRAIN LESIONS AND THEIR YOKED CONTROLS

Rat No.	Lesion			Control		
	Base line	Test	Δ	Base line	Test	Δ
1	6	44	38	11	106	95
2	7	31	24	14	62	48
3	12	60	48	10	475	465
4	18	125	107	60	265	205
5	40	61	21	5	170	165
M	16.6	64.0	47.6	20.0	215.6	195.6

fighting during the 1-hr. period during which intruders were present in their cages.

These results confirm the findings of Woods (1956) and Karli (1956) that amygdalectomy markedly reduces the aggressive behavior of wild rats.

The results of the first test of timidity are presented in Figure 3. Figure 3 shows the number of wild rats in the two groups, amygdalectomized and sham-operated controls, eating any food at all on the day of change in feeding conditions and on the days subsequent to the change. Four of the five rats in the operated group ate on the day of change itself, while none of the sham-operated rats did. All five of the operated rats were feeding by the day following the change in feeding conditions, while the most timid of the sham-operated rats did not begin to feed until 5 days after the change had been made.

The results of the second test of timidity are to be found in Table 4. Table 4 shows the change in latency to first ingestion of food from the day before the placing of the metal plates to the day of placing of the metal plates for the five amygdalectomized experimental rats and five yoked controls. In each pair the experimental animal showed a far smaller increase in latency than its yoked control. The mean increase in latency was four times as great for experimentals as for controls.

Discussion

The results are quite clear: Bilateral lesions of the amygdala which reduce the general level of aggressive behavior in wild rats also reduce the amount of timidity which wild rats demonstrate. These two behavior patterns, typical of the wild rat, are thus shown to have a common neural basis in the limbic system.

Timidity and aggression are similar not only in function and the stimulus situations which elicit them, but also in their dependence on the normal functioning of a common cortical area for their occurrence.

CONCLUSIONS

Wild rats differ behaviorally from their albino domesticated conspecifics in two major respects. First, wild rats are aggressive animals with respect to humans, mice, and their fellow rats, while domesticated albino rats are gentle and docile. Second, wild rats are timid and shy when faced with a novel object, while domesticated albino rats are curious and inquisitive in the same situation. The hypothesis under investigation in the present paper is that these two seemingly disparate behavior patterns, timidity and aggression, which differentiate the behavior of wild rats from that of domesticated albinos are actually two different manifestations of the wild rats' response to novelty. Two different types of experiments, one behavioral and one "physiological," are presented in support of the hypothesis.

The first group of experiments demonstrated that stimulus novelty is a necessary condition for eliciting aggression as it is for eliciting timidity. Wild rats familiar with humans through handling do not attack human handlers. Wild rats familiar with mice do not attack mice, and wild rats which are members of an established colony do not attack their familiar fellow colony members while behaving savagely toward foreign intruders. In each case, familiarity with a given class of stimuli (men, mice, or rats) leaves aggression toward other classes unaffected and does not affect the general level of timidity of the animals so treated. Familiar objects do not provoke aggression, while identical objects do, if they are novel, in just the same fashion that novel objects produce avoidance behavior, while identical familiar objects