SPONTANEOUS LOCOMOTOR ACTIVITY AND FOOD AND WATER INTAKE IN RATS WITH MEDIAL AMYGDALA LESIONS

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Abstract. Locomotor activity was studied with the method of electromagnetic activity meters, before and after operation in rats bilaterally lesioned in medial amygdala, and in a sham-operated control. Two activity tests were performed daily. In the first test spontaneous activity was recorded for a 30 min period without access to food or water. The second test measured 12 h of nocturnal activity with full access to food and water. Bilateral destruction of the medial amygdala resulted in an increase of locomotor activity in the 30 min test and a decrease in locomotor activity in the 12 h test. Postoperative decrease in food and water intake and body weight were only transient. These results point to a participation of the medial amygdala in the complex mechanisms of locomotor activity and alimentary motivation.

INTRODUCTION

The role of the medial amygdala in the alimentary behavior of rats was the subject of our previous papers. It was shown that unconditioned food and water intake in the home cage were only transiently decreased after bilateral medial amygdala lesions, whereas instrumental reactions, especially those reinforced by water, were greatly impaired (18, 19). The question arises whether these disturbances in the performance of instrumental alimentary reactions were the consequence of decrease of the level of the alimentary drive, or were caused by a diminution in the general locomotor activity of the lesioned rats.

The results of other authors concerning the effects of amygdala...
lesions on spontaneous activity in the rat are not homogenous. Anand and Brobeck (1) have found a longlasting decrease in the general activity of rats tested in open field, while in the experiments of other authors lesions of the amygdala produced an increase of locomotor activity (2, 17, 25, 27). In all these studies lesions were rather extensive and might involve the amygdalar system with opposite physiological functions.

In dogs, dorsomedial amygdala lesions result in a longlasting aphagia and adipsia (8, 9, 10, 13), loss of body weight (12, 13, 14), disturbances of instrumental alimentary behavior (9, 10, 11, 15), hypodynamia and a decrease of general locomotor mobility (12, 13, 14). This last symptom was not however a subject of special studies and all remaining symptoms were attributed by the author to the emotional-motivational changes.

The purpose of the present study was to examine the effects of lesions restricted to the medial amygdala in rats on spontaneous locomotor activity, measuring this type of behavior by means of electromagnetic activity cage (31). We intended to check whether the formerly observed decrease of instrumental performance after medial amygdala lesions was caused by a decrease of general motor activity. It seemed also desirable to separate the motor activity connected with food intake and the locomotor activity independent of alimentary motivation. Thus, two different tests of locomotor activity were performed.

MATERIAL AND METHODS

Material. Eleven naive hooded rats 3–4 mo old, weighing 270–340 g at the beginning of the experiment, were used. The animals were randomly divided into a lesioned group (AMe) consisting of 5 subjects and a control group (C) composed of 6 subjects. All animals were individually housed in their home cages throughout the experiment.

Apparatus. The home cages were constructed of nontransparent material 2 mm thick and had the shape of an inverted, truncated pyramid 18 cm high, with a 28 × 46 cm ceiling and a 22 × 40 cm base. The ceiling was of wire grid with a hollow for food pellets and a water bottle.

The home cages of both groups were put on electromagnetic activity meters of the Am— 1 type (31), each having six independent solenoids. All movements leading to or from any of the coils tuned in a resonance circuit, the output of which was standardized to square waves and recorded on a cumulative recorder. For calculation and elaboration the experimental data were calculated in millimeters from cumulative curves. More detailed description of this device will be presented in Korczyński and Turewicz (in preparation). Housing was in a naturally
lighted room, separated from the recording apparatus. Measurements began 15 days before operation and were continued for 15 postoperative days without registration on the day of operation.

**Procedure.** Locomotor activity. Test 1. Before each test the rats were weighed, food and water intake was recorded and the cages were cleaned. The test began daily at 3.00 p.m. Locomotor activity was measured for 30 min without access to food and water. Following this test the food and water ad lib. were given in the home cages. **Test 2.** Locomotor activity was recorded for the period of 12 h. The test was performed starting at 8.00 p.m. in the same home cages as test 1, but with full access to food and water.

Food and water intake. Once a day the total daily amount of food and water intake were measured and body weight was registered.

**Surgery.** Bilateral lesions of the amygdala were performed under Nembutal anesthesia (50 mg/kg i.p.) Unipolar wolfram electrodes 0.5 mm in diameter and insulated with enamel except for 0.3 mm at the tip, were placed stereotaxially using the König and Klippel (20) atlas coordinates: AP + 4.5, L ± 3.2, H — 3.0. Electrolytic lesions were made by passing 2 mA anodal current for 10 s with a rectal cathode completing the circuit. Full sham operations were performed in a control group of rats introducing the electrodes into the brain according to the same coordinates without passing the current.

**Histology.** Following 15 postoperative days, the experimental animals were sacrificed with a lethal dose of Nembutal. Each brain was removed, preserved in a 10% formalin solution and sectioned at 15 µm frontal slices with the cryostatic method. The slices were then stained using either the Klüver or the Nissl method. After the histological procedure was accomplished, the neuroanatomical verification was made by a microscopic examination of the morphological boundaries surrounding each lesion.

**Statistics.** The data collected during the 30 day-period of observations were divided into 3 preoperative and 3 postoperative blocks. Each block consisted of data covering a period of 5 days. The sums from these blocks were analyzed separately for each of the measured parameters using the A × B mixed design analysis of variance (21).

**RESULTS**

**Test 1.** Figure 1 (upper part) presents the mean locomotor activity of individual rats before and after medial amygdala lesions. It shows an increase of locomotor activity in all lesioned rats. Figure 2 (upper part) shows locomotor activity of both lesioned and control groups
Fig. 1. Locomotor activity of individual rats in AMe group before and after operation. Each bar represents mean value from 5 days of observation. Numbers below bars — symbols of individual rats.

expressed in percents. The rats of the AMe group exhibited a stable postoperative increase of activity, contrary to the animals of the C group where after an initial decrease of the level of activity in the first postoperative block of time, an increase was observed in the second block and than a return to preoperative level in the third block. An analysis of variance (A × B) mixed design (21) (Table I) revealed a postoperative statistically significant increase of locomotor activity only for the AMe group. On the other hand, changes in the particular postoperative periods of time and interaction were statistically significant
only for the C group. This indicates that in the C group a fast compensation of postoperative changes occurred, whereas in the AMe group the effect of operation was stable.

Fig. 2. Mean percent of locomotor activity in AMe and C groups before and after operation. 100% was calculated from the last 5 day blocks of registration before operation. Arrows — denote operation.

Test 2. Figure 1 (lower part) shows the mean values of locomotor activity in the 12 h test for lesioned rats. In comparison to preoperative level, the activity decreased in all the AMe rats except one No. 237, in which a temporary increase occurred in the second postoperative block. A comparison of the activite of the AMe and C rats is given in Fig. 2 (lower part). In the first postoperative block a decrease in noc-
Mean values of rats activity in AMe and C groups in 30 min test before and after operation.

Two-dimensional analysis of variance

<table>
<thead>
<tr>
<th>Groups</th>
<th>Before operation</th>
<th>After operation</th>
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<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Lesioned AMe</td>
<td>94.3</td>
<td>78.7</td>
</tr>
<tr>
<td>Controls C</td>
<td>98.7</td>
<td>94.4</td>
</tr>
</tbody>
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Source of variation | $df$ | Lesioned | Controls |
<table>
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<tr>
<td>Operation A</td>
<td>1/5</td>
<td>8.6920</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Blocks of time B</td>
<td>2/10</td>
<td>1.0436</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td>AB</td>
<td>2/10</td>
<td>3.3385</td>
<td>&lt; 1.0</td>
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Turnival activity is seen in the rats of both groups. However in the successive second and third postoperative blocks the AMe animals show a constant low level of activity while in the C-group animals the level of activity increased to the preoperative state. The analysis of variance (Table II) showed a statistically significant influence of operations in both groups AMe and C. However the postoperative restitution of locomotor activity was statistically significant only in rats of C group, in which the effect of sham operation in the first postoperative block and interaction between the two factors (operation and time) were statistically significant.

The daily food intake (Fig. 3, upper part) in rats of the AMe-group...
decreased only in the first postoperative block and returned to preoperative level in the second block. A decrease of food intake was statistically significant for the AMe-group (analysis of variance A×B mixed design \(P < 0.005\)) whereas in the C-group postoperative changes in food intake were not significant.

The daily water intake (Fig. 3, middle part) decreased in the first and second postoperative time blocks in all of the AMe-rats and returned
Fig. 4. Reconstructions of the lesions on the sections through areas of maximum tissue destructions in brains of individual animals in AMe group.

<table>
<thead>
<tr>
<th>Rats number</th>
<th>AMe n.</th>
<th>ACr n.</th>
<th>ABm n.</th>
<th>ACbl n.</th>
<th>AL n.</th>
<th>m. intercalata</th>
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<tr>
<td>234</td>
<td>L</td>
<td>R</td>
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<tr>
<td>239</td>
<td>L</td>
<td>R</td>
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<tr>
<td>240</td>
<td>L</td>
<td>R</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>243</td>
<td>L</td>
<td>R</td>
<td></td>
<td></td>
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</table>

TABLE III
Comparison of localization of lesions in particular nuclei of the amygdala in individual rats.

AMe, medial n.; ACr, cortical n.; ABm, basomedial n.; ABl, basolateral n.; ACbl, central n.; AL, lateral n.; m. intercalata, massa intercalata; V, ventral part; D, dorsal part; M, medial part; L, lateral part

to the preoperative level in the third block. The animals of the C-group also showed a decreased water intake in the first postoperative time block, but a full recovery occurred already in the second block. Analysis of variance (A × B mixed design 21) showed a statistically significant effect of the operation on water intake in the AMe-group (P < 0.001) and the C-group (P < 0.005). Changes in postoperative blocks
of time were also statistically significant for the AMe-group ($P < 0.001$) and for the C-group ($P < 0.001$) and interaction between these two factors occurred in both groups of rats (AMe $P < 0.001$ and C $P < 0.001$).

In both groups the postoperative inhibition in normal increase of body weight was observed (Fig. 3, lowest part). The analysis of variance however showed no statistically significant changes in postoperative body weight in neither group.

**Neuroanatomical verification.** Verification of the localization of lesions revealed a bilateral symmetrical damage, strictly limited to the medial parts of the amygdala in all the rats of the AMe-group. The dimensions and localizations of the amygdaloid lesions in individual rats are presented in Fig. 4 and Table III. Representative photograph of typical bilateral localization of medial amygdala lesions is shown in Fig. 5.

![Fig. 5. Typical bilateral localizations of lesions in medial parts of the amygdala in rat No. 239 of AMe group.](image)

**DISCUSSION**

The results of test 1 and test 2 were not uniform. In test 1, i.e., during 30 min of afternoon registration, general activity increased, whereas 12 h night activity (test 2) decreased. Thus, the data obtained in this experiment have not answered the question whether the decrease in instrumental performance observed in our earlier studies (18, 19) was caused by a decrease of general motor activity, as after AMe lesions. The increase of locomotor activity in 30 min afternoon test, in comparison with the decrease in 30 min daily test of instrumental performance (18, 19) eliminate the possibility that this last impairment was
produced by a general motor deficit as an effect of medial amygdala lesions. It is however well known that the efficient performance of instrumental reactions requires and adequate level of general arousal and that an excessive level of locomotor activity may disturb specific instrumental reactions. In our previous experiment (19) the rats were required to press each of the two separate levers for food and water respectively, situated on opposite sides of the cage. The hyperactive animals might have been unable to perform a sufficient number of presses on the two levers in such a relatively short period as a 30 min session, because they moved around the cage. On the other hand, it is known from Mabry and Campbell's (23) study that lesions of the amygdala increase the level of general locomotor activity but simultaneously attenuate a characteristic increase of locomotor activity induced by food deprivation, typically observed in normal animals. It should be noted that our rat's, lesioned in the medial amygdala in which instrumental reactions were elaborated (19) were in a chronic state of partial food and water deprivation. Thus the characteristic locomotor reactivity to food and water deprivation present in intact rats (5), which is necessary for a good performance of alimentary instrumental reactions, would be abolished after medial amygdala lesions. However, this last effect did not contradict the fact of an increase of locomotor activity in the 30 min test measured in activity meter in medial amygdala lesioned rats which were fully alimentated in the present study. It should be mentioned that the amygdala, apart from above hypothetized functional role in the locomotor reactivity to alimentary deprivation may be also involved in an opposite mechanism which serves to suppress feeding during satiation Fonberg et al. (16). These authors obtained a release of alimentary inhibition to duodenal glucose infusions after bilateral dorsomedial amygdala lesions in the rabbit.

The next problem to discuss concerns the difference in the effects of medial amygdala lesions on locomotor activity in the 30 min afternoon test and in the 12 h nocturnal test. Mabry and Campbell (23) obtained an increase in locomotor activity after amygdala or stria terminalis lesions in a 22 h test registration in stabilimeter activity cages with full access to food and water i.e., their results were quite opposite to ours. It is possible that the procedural differences may account for the discrepancies between the results of Mabry and Campbell (23) and ours. In the 12 h nocturnal test, apart from spontaneous locomotor activity, alimentary locomotor activity was also measured. The latter activity is known to be regulated by light-dark cycle and is significantly greater in the dark period (3, 24, 26). Therefore it is possible that the decrease in nocturnal locomotor activity following medial amygdala lesions was
a result of a decrease in nocturnal alimentary activity due to a partial
displacement of circadian activity pattern. It is interesting to note that
lesions of ventromedial hypothalamus (strictly linked anatomically with
the medial amygdala by the stria terminalis (7) result in a reduction
of the control of alimentary activity patterns by the light-dark cycle (4).

On the other hand, the differences in the effects of medial amygdala
lesions in this experiment and in that of Mabry and Campbell (23)
might result from using different types of activity meter cages. In our
experiment the rectangular activity cage was more than two and a half
times longer than the cage in the quoted experiment (23). Differently
designed cages may measure different forms of locomotor activity, e.g.,
Strong (29) and Tapp (30) have experimentally differentiated two types
of activity measured by stabilimeter activity cage and activity wheel
respectively. While one type of activity (activity wheel) is sensitive to
to changes in the internal environment (hunger level), the activity measured
by stabilimeter cages appears to be related to external cues. Anato-
mically, Lynch (22) has implicated the lateral hypothalamus in the me-
diation of activity in wheel-activity cage and the inferior thalamic
peduncle in stabilimeter activity cage. In our experiment the electro-
magnetic reactangular activity cage was much larger than standard
stabilimeter cages and measured the movements in all directions. It is
therefore possible that in our experiment a larger distance for running
in a greater cage may reflect, to same degree, a different components
the complex behavior of locomotor activity than in a smaller cage.
Further research is indicated with the purpose to compare the role of
the amygdala in feeding and locomotor activity behaviors and to study
the activity measuring devices appropriate to reveal the particular me-
chanisms.

Coming back to the problem of the increase of locomotor activity
after lesions of medial amygdala: there are some experimental data
indicating to the important role of this structure in the complex mecha-
nisms of alimentary arousal of behavior. Turner (32) has reported that
medial amygdala lesions result in deficit reactivity to external cues.
The above results and those obtained by Sclafani et al. (28) showing
a prolonged latency to eat in a novel environment may indicate to the
role of the medial amygdala in the initial processes of recognizing
and/or utilizing the biological significance of cues from both the exter-
nal and internal environment. An increase in the 30 min test activity
could be interpreted as a support for Campbell and Sheffield's (6) hypo-
thesis that locomotor activity during alimentary deprivation is directed
towards obtaining more information from the external environment in
order to increase the probability of getting the food. In the 30 min test
the rats were placed in cages which were previously cleaned and partially eliminated from previous odors. The animals, therefore, found themselves in a sufficiently different environment, requiring reexploration. Therefore it is possible that deficits in the utilization of information from the external environment may have resulted in an increased exploratory activity during the first 30 min period after placing the rats in the somewhat novel environment. Thus the increase of locomotor activity might have had rather an exploratory character than an alimentary one. On the other hand, the decrease in 12 h night activity test with access to food and water might have revealed a decrease of alimentary motivation.

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