

## THE EFFECTS OF AMYGDALECTOMY ON LOCOMOTOR ACTIVITY IN MONKEYS<sup>1</sup>

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The present investigation was designed to examine the role of the amygdaloid complex in locomotor activity. Available data based upon lesion techniques appear to lead to conflicting conclusions. Anand and Brobeck (1952) reported a sustained drop in daily running activity of rats after lesions were placed stereotaxically within the amygdaloid complex. Such a decrease, however, has not been found in primates or carnivores. Removal of the anterior temporal lobes in the monkey, including the amygdala and other basomedial structures of the rhinencephalon, was said to have no effect upon ambulatory activity in the home cage (Blum, Chow, & Pribram, 1950). Pribram and Bagshaw (1953), on the other hand, reported hyperactivity in monkeys with similarly situated frontotemporal ablations, and they attributed the increase to the frontal involvement. But observations made on amygdalec- tomized cats have also prompted reports of hyperactivity (Morgane & Kosman, 1957; Schreiner & Kling, 1953).

In the present experiment, the locomotor activity of normal and brain-damaged monkeys was studied over a period of time in a relatively unfamiliar environment under two conditions of visual stimulation.

### METHOD

#### *Subjects*

The Ss were eight preadolescent rhesus monkeys that had been tested on problems of food preference and taste discrimination. Four Ss (AM 351, 352, 395, 400) received bilateral resections of the amygdaloid complex and adjacent anteromedial temporal cortex, while the others (357, 390, 399, 509) received an equivalent sham operation. The surgical and histological procedures have been summarized previously (Schwartzbaum, 1960). The lesions, as reconstructed

anatomically, conform in general to the ones contained in that report. A detailed description of the anatomical findings will appear in a subsequent report. Body weights of the Ss at the beginning of the experiment ranged from 4.8 to 6.3 lb.

#### *Apparatus*

The activity apparatus<sup>2</sup> was an eight-sided cage with a flat top and bottom, made of heavy wire mesh and angle iron. Opposing side walls of the cage were spaced 36 in. apart. The cage was 24 in. high and stood 26½ in. off the floor. A battery of lights was mounted about the test chamber. These included a red 25-w. bulb suspended 12 in. above the center of the cage and a pair each of yellow (60-w.) and blue (75-w.) bulbs mounted at diagonally opposite ends of the cage. They were arranged on alternate sides, 8 in. away from the cage.

The activity recorder utilized a stabilized capacitive effect. Four metal plates (aluminum cafeteria trays) were attached by insulated supports to alternate side walls of the cage adjacent to the lights. The circuit was designed so that if a monkey approached a plate, it decreased the negative voltage applied to the grid of a thyratron. Conduction in the plate circuit of the thyratron actuated a relay whose contacts were connected to an impulse shortener. Each approach to a metal plate, therefore, yielded a single count which was then registered on an electrical counter.<sup>3</sup>

#### *Procedure*

The Ss were moved to new quarters within the laboratory three days prior to the initiation of activity testing. This was done to minimize the influence of previous test procedures. They were individually caged and maintained on a 24-hr. deprivation cycle with a daily food ration of 10 Purina laboratory chow pellets and one-quarter of an orange. The feedings were given in the late afternoon.

The activity tests were carried out in a sound-insulated, windowless room. A ventilation system maintained room temperature at approximately 80°F., and provided a uniform background noise. Pre-operatively each S received a daily test of activity for five consecutive days. The tests were conducted during the mornings at some fixed time for each animal, spaced

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<sup>3</sup> Details of the circuit may be obtained by writing to the authors.

far apart from the time of feeding. The *S* was transported to the test room in a carrying cage, weighed, and then placed in the activity chamber. For a period of about 15 sec. before the start of the session, the only source of illumination in the room was a shielded 74-w. bulb. Each activity session lasted 56 min. and was divided into alternate periods of constant illumination and varied illumination. Each period of illumination was 7 min. in duration, which allowed four replications of each condition per session. The sequence always began with the constant illumination.

Under the constant conditions of stimulation, the activity cage was illuminated continuously by the red bulb centered above the top of the cage. Under the varied conditions, the source of light shifted every 3 sec. in an unsystematic order among one of the five multicolored bulbs mounted about the cage. Since the yellow and blue bulbs were higher in wattage than the red bulb, the varied conditions of stimulation also involved an increased intensity of illumination.

The last preoperative activity test preceded the surgery by approximately 10 days. After a two-week recovery period from surgery, the *Ss* received a battery of discrimination tests utilizing food as a reward. The activity tests started approximately 12 weeks postoperatively. Exactly the same procedure was followed as before the operation, except that now the daily tests were extended for 12 consecutive days.

The experiment was run in the form of two partially overlapping replications, each comprising two normal and amygdalectomized monkeys. After the preoperative tests, some modifications were made in the recording equipment which affected the measurement of the activity. Meaningful comparisons between pre- and postoperative activity were, therefore, not possible. However, the pre-operative data were analyzed to determine whether or not the groups were matched properly. An analysis of variance failed to indicate any significant group differences, stimulation effects, or Group  $\times$  Stimulation interaction. In no case did *F* even approach significance at the .05 level. It may also be added that the groups did not differ significantly in the change of activity as measured before and initially after the operation.

## RESULTS

Figure 1 shows the mean activity count of each of the groups postoperatively under the two conditions of illumination. The results are plotted for successive blocks of sessions. An analysis of variance was performed on the repeated measurements obtained from the individual animals. It was designed to evaluate the variance in activity attributable to brain damage, stimulation conditions, repeated blocks of sessions, individual differences, and associated interactions. For each of the error terms used in this analysis, a check was made to determine whether or not the variances pooled across groups met the assumption of homogeneity. In no case was it found necessary

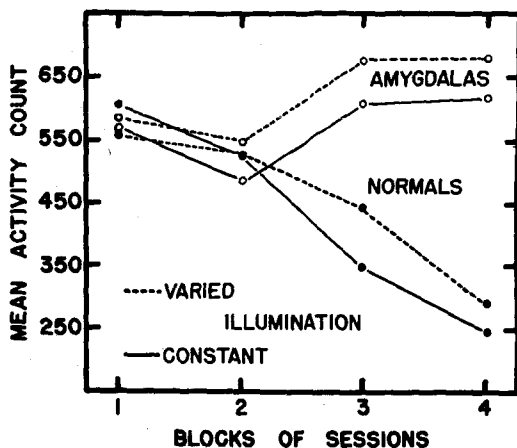


FIG. 1. Postoperative activity scores of normal and amygdalectomized monkeys for successive blocks of three sessions under conditions of constant illumination and more intense, varied illumination.

to reject this assumption, using a .05 criterion. Since departure of the distributions from normality was not deemed to be serious, no transformations of the data were made.

The results demonstrate clearly an effect of the lesion upon the adaptation of activity with repeated blocks of sessions. It can be seen that initially both groups showed nearly identical mean levels of activity under the two conditions of illumination. But with repeated tests, the activity count of the normal *Ss* decreased progressively to about 50% of the initial levels. By contrast, the amygdalectomized *Ss* remained active throughout the tests, evincing no decrement in performance. This difference between the groups occurred under both conditions of illumination and thus takes the form of an interaction between group and session. When tested against the variance for Individuals  $\times$  Sessions, the Group  $\times$  Session interaction was significant at the .01 level ( $F = 5.47$  for 3 and 18 *df*). The only departure from the trends described above occurred with one of the normal animals that initially had a very low activity count. Its performance showed little change over time.

The terminal increase in activity shown in Figure 1 for the amygdalectomized animals was not a reliable finding. A separate analysis of their data failed to indicate any significant changes in performance with the repeated tests ( $F = 2.46$  for 3 and 9 *df*).

As noted, there were no reliable effects of the lesion in relation to the conditions of illumina-

tion. Both groups showed a tendency to be more active under the varied and more intense illumination, especially during the last two blocks of sessions. But these differences were not significant statistically when compared with the individual differences in activity under the two conditions ( $F = 1.48$  for 1 and 6  $df$ ).

#### DISCUSSION

The present findings indicate that, under certain conditions, removal of the amygdaloid complex can selectively affect the persistence of locomotor activity in monkeys by minimizing or retarding decrements that normally occur. This effect of the lesion points to a disturbance in the habituation of motor activity.

At the same time, it must also be emphasized that amygdectomy would not seem to increase the peak rate of activity. The activity levels of the brain-damaged animals were not significantly higher than those of the normal animals on the first few postoperative tests. Indeed, both groups displayed quite similar behavior on these tests.

The effects of the lesion differ in this respect from the form of hyperactivity associated with ablations of the frontal lobe. Although frontal lesions in the monkey also appear to impede the habituation of activity, in addition they elevate markedly the over-all level of activity in the presence of visual stimulation (French, 1959; French & Harlow, 1955). Moreover, the increase relates closely to the intensity of visual stimulation (Isaac & DeVito, 1958). Judging from the present findings, this relationship would not seem to hold for amygdaloid operates. Their activity was not differentially affected by increased stimulation, although a more extended range of conditions is required to check on this point. It may also be added that amygdalotomized monkeys do not exhibit the almost incessant pacing of the frontal operates. These considerations emphasize some of the distinctive features of the amygdaloid effects.

The most plausible interpretation of the present findings is in terms of differential response to the novelty of the test situation. This interpretation, like that of French and Harlow (1955), would suggest that novelty of the stimuli played a major part in eliciting activity in the test situation. The amygdal-

tomized monkeys may have persisted in their activity because of a failure to habituate to the novelty; there was no evidence of habituation during the limited preoperative tests. The interpretation is supported by the qualitative evidence, consistent with the findings of Blum et al. (1950), that in the more familiar surroundings of their home cages, the amygdalotomized monkeys did not differ grossly in activity from normal monkeys.

#### SUMMARY

Locomotor activity of normal and amygdalotomized monkeys was studied in a relatively unfamiliar test situation under two conditions of visual stimulation: constant illumination and more intense, varied illumination. Bilateral amygdectomy had no effect upon the peak rate of activity, but it reduced markedly the decrement found with repeated exposure to the test situation. This disturbance in habituation was independent of the conditions of illumination. It was assumed to relate to the novelty characteristics of the stimuli in the test situation.

#### REFERENCES

- ANAND, B. K., & BROBECK, J. R. Food intake and spontaneous activity of rats with lesions in the amygdaloid nuclei. *J. Neurophysiol.*, 1952, **15**, 421-430.
- BLUM, J. S., CHOW, K. L., & PRIBRAM, K. H. A behavioral analysis of the organization of the parieto-temporo-preoccipital cortex. *J. comp. Neurol.*, 1950, **93**, 53-100.
- FRENCH, G. M. Locomotor effects of regional ablations of frontal cortex in rhesus monkeys. *J. comp. physiol. Psychol.*, 1959, **52**, 18-24.
- FRENCH, G. M., & HARLOW, H. F. Locomotor reaction decrement in normal and brain-damaged rhesus monkeys. *J. comp. physiol. Psychol.*, 1955, **48**, 496-501.
- ISAAC, W., & DEVITO, J. L. Effect of sensory stimulation on the activity of normal and prefrontal-lobectomized monkeys. *J. comp. physiol. Psychol.*, 1958, **51**, 172-174.
- MORGANE, P. J., & KOSMAN, A. J. Alterations in feline behaviour following bilateral amygdectomy. *Nature*, 1957, **180**, 598-600.
- PRIBRAM, K. H., & BAGSHAW, M. Further analysis of the temporal lobe syndrome utilizing fronto-temporal ablations. *J. comp. Neurol.*, 1953, **99**, 347-375.
- SCHREINER, L., & KLING, A. Behavioral changes following rhinencephalic injury in the cat. *J. Neurophysiol.*, 1953, **6**, 643-659.
- SCHWARTZBAUM, J. S. Changes in reinforcing properties of stimuli following ablation of the amygdaloid complex in monkeys. *J. comp. physiol. Psychol.*, 1960, **53**, 388-395.

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