INFLUENCE OF THE AMYGDALA ON BACKGROUND ACTIVITY OF CORTICAL NEURONS

V. A. Makarov

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Stimulation of the basolateral nuclei of the amygdala in most cases causes no change in the background activity of cortical neurons in the sensomotor area. The latent period of response of neurons responding to stimulation of the amygdala averages 25-30 msec. The facts indicate indirect influences of the amygdala, mediated through subcortical structures, rather than direct effects on cortical unit activity in the sensomotor area.

The initial component of any functional system is the stage of afferent synthesis, at which all information reaching the brain is integrated [1]. A vital role in this process is played by structures of the limbic system which, together with the hypothalamus, determine the state of motivation of the organism [9, 13]. However, the concrete mechanisms of participation of the limbic structures and, in particular, of the amygdala, in integrative activity of the brain has been inadequately studied. Data in the literature on the functional and morphological connections of the amygdala with the cortex are contradictory. According to some workers [12, 15], the amygdala has direct connections with the cortex. Others consider that the amygdala has no direct connections, or that it is directly connected only with certain parts of the cerebral cortex [10].

The object of this investigation was to study the character of effects of the amygdala on cortical neurons in the sensomotor area.

EXPERIMENTAL METHOD

Acute experiments were carried out on unanesthetized cats immobilized with listhenon and maintained on artificial respiration. The basolateral portion of the amygdala was stimulated by regular pulses (1-5 V, 100/sec, 0.5 msec). Cortical unit activity was recorded extracellularly by single-channel glass microelectrodes (tip diameter 1-2 μ, resistance 2-10 MΩ). Unit activity was recorded on a dual-beam CRO (Disa Electronic).

EXPERIMENTAL RESULTS AND DISCUSSION

Activity of 97 cortical neurons in the sensomotor area was studied. The mean level of background activity of these neurons was 5-10/sec. Activity of 43.3% of neurons tested was within this frequency range, and 29.9% possessed activity of up to 5/sec. Only 8.3% of the total number of cortical neurons tested had activity of high frequency, over 20/sec. The structure of the background activity was extremely varied. In most cases it consisted of single spikes at irregular intervals, but in some cases the spikes were fairly regular, and in a third group of neurons the spikes were mostly grouped in volleys.

The results showed that most (55.5%) of the cortical neurons studied did not change their activity in response to stimulation of the amygdala. Analysis of responses of neurons which responded to stimulation of the amygdala showed no special features, and there was no definite predominance of any particular type of response, whether facilitation or inhibition, which were comparatively evenly distributed (22.8 and 21.7% respectively).

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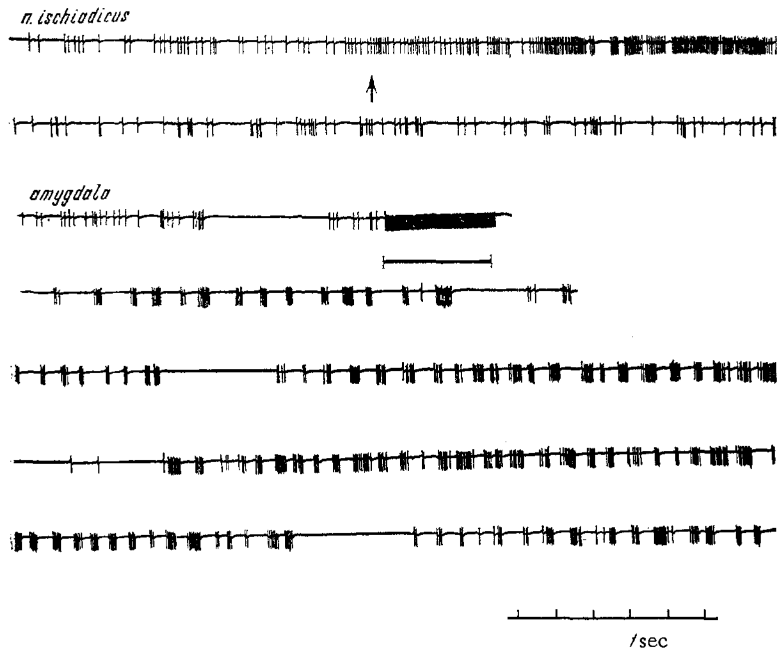

Fig. 1. Changes in structure of background activity of a cortical neuron after stimulation of the amygdala. Response of the same neuron to stimulation of the sciatic nerve is shown for comparison.

It will be noted that 36.6% of neurons responded to stimulation of the amygdala by a change in the configuration of their discharges, without changing their frequency characteristics. In this case the unit activity as a rule took the form of volleys, in which 5, 6, or more spikes were grouped together into short, high-frequency volleys, with short intervals between the spikes in each volley. The intervals between the volleys were very variable (Fig. 1). The latent periods of the unit responses also varied considerably, with a mean value of 25-30 msec.

Analysis of unit activity layer by layer revealed a marked difference in the distribution of responding neurons depending on the depth of recordings. The overwhelming majority of neurons responding by changes in spike activity to stimulation of the amygdala were located in the deep layers of the cortex (IV-V).

The results showing that many cortical neurons do not respond to stimulation of the amygdala, and demonstrating the relatively long latent period of the unit responses to impulses from the amygdala, suggest that the pathway of these impulses from the amygdala to the cortex must be interrupted by many synapses.

The probable explanation of the larger number of reactive neurons in the deep layers of the cortex is that there are in general relatively few cells in the superficial layers [2], or they were inhibited by the operative trauma [14]. However data in the literature [3, 4] suggest that the reason was not entirely the experimental conditions, and that it also had a functional significance.

It must be noted, in particular, that in most cases stimulation of the amygdala did not affect the frequency characteristics of the cortical neurons but modified the structure of their background activity. Although the physiological significance of this fact is not yet completely understood, the hypothesis [7] that neurons of this type are included in reverberating circuits, in which the circulation of impulses takes place, can be accepted. According to Shumilina [6], the reverberation of excitation is one of the mechanisms of nervous activity and it facilitates the active selection and analysis of information during orientating and investigatory responses. The results of the present experiments suggest that the ascending influence of the amygdala on the cortex is indirect, through other subcortical structures, rather than direct.

After comparing these results with those of previous investigations [5] and with other data published in the literature [8, 11], the writer considers that the effects of the amygdala on the cerebral cortex are mediated through the mesencephalic reticular formation, through which afferent impulses of different modalities reach the cortex, where the final integration of nervous processes preceding the formation of the behavioral act as a whole, i.e., reaching a decision and putting it subsequently into effect, takes place. This may be the way in which the amygdala participates in the integration of excitation at the stage of afferent synthesis, an "essential and universal stage in the formation of any behavioral act" [1].

LITERATURE CITED

1. P. K. Anokhin, Biology and Neurophysiology of the Conditioned Reflex [in Russian], Moscow (1968).
2. N. N. Vasilevskii, Zh. Vyssh. Nervn. Deyat., No. 3, 529 (1965).
3. A. B. Kogan, in: Current Problems in Electrophysiology of the Central Nervous System [in Russian], Moscow (1967), p. 138.
4. K. M. Kullanda, in: The Integrative Activity of the Brain [in Russian], Moscow (1967), p. 49.
5. V. A. Makarov, in: Abstracts of Proceedings of the 22nd Conference on Problems in Higher Nervous Activity [in Russian], Ryazan' (1969), p. 157.
6. A. I. Shumilina, in: Integrative Activity of the Nervous System under Normal and Pathological Conditions [in Russian], Moscow (1968), p. 276.
7. A. Fessard, in: Theory of Communication in Sensory System [Russian translation], Moscow (1964), p. 81.
8. J. French, R. Hernandez-Peon, and R. Livingston, J. Neurophysiol., 8, 74 (1955).
9. J. Holmes and J. Beckman, J. Physiol. Behavior, 4, 563 (1969).
10. B. Kaada, Acta Physiol. Scand., 23, Suppl. 83, 1 (1951).
11. A. Kreindler and M. Steriade, Electroenceph. Clin. Neurophysiol., 15, 732 (1963).
12. W. Nauta, in: Mechanisms of the Whole Brain [Russian translation], Moscow (1963), p. 182.
13. J. W. Papez, Arch. Neurol. Psychiat., 38, 725 (1937).
14. E. Ramon-Moliner, J. Comp. Neurol., 117, 43 (1961).
15. F. Valverde, Progr. Brain Res., 24, 469 (1961).