Evoked Potentials as Indicator of Possible Involvement of Ventromedial Hypothalamus and Lateral Nucleus of the Amygdala in the Formation of Feeding behavior

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Electrical stimulation of the ventromedial hypothalamus in cats leads to the appearance of an additional component in the structure of evoked potentials of the amygdala lateral nucleus; this component disappears after discontinuation of food reinforcement (suppression of the conditioned reflex). It was concluded that the lateral nucleus of the amygdala and ventrolateral hypothalamus, the structures belonging to the system of defense behavior, can change their congenital characteristics depending on the situation, when involved in the feeding behavior system.

Key Words: *amygdala; evoked potentials; conditioned reflex*

The development of conditioned reflexes in response to direct electrical stimulation of subcortical nuclei and to adequate distant stimuli is accompanied by the appearance or intensification of delayed components of evoked potentials (EP) in the brain cortex. It is most typical of the sensorimotor cortex during the development of motor food-procuring conditioned reflexes. For example, during the formation of food-procuring reflex in cats in response to low-frequency stimulation of the specific thalamic nuclei (ventrolateral or ventroposterolateral) or of the hypothalamic lateral nucleus the main component of EP in the sensorimotor cortex is followed by delayed components strictly correlating with the characteristics of motor manifestation of this conditioned reflex. Similar changes in EP were observed in the cortical sensorimotor area during the formation of conditioned reflex in response to low-frequency electrical stimulation of the external geniculate body and ventromedial hypothalamus (VMH). Though the presence of direct anatomical projections from these nuclei into the sensorimotor cortex is disputable and EP in response to their stimulation are poorly expressed, the development of conditioned reflex leads not only to appreciable intensification of the main EP components, but also to the appearance of clear-cut delayed components in these structures. Hence, the delayed components of evoked responses in the brain cortex can be considered as an indicator of the formation and manifestation of conditioned reflex. The problem is whether these delayed components are characteristic of the hemispheric cortex alone or they can emerge during reflex development in the cerebral subcortical structures as well. Delayed components might serve as universal indicators of involvement of specific anatomical structures in a certain conditioned reflex.

In order to solve this problem, electrical stimulation of deep structures of the brain was used as conditioned stimulus. This experimental situation made it possible to investigate EP during conditioned reflex absolutely unique for the animal, which is very difficult in experiments with adequate (distal) stimulants, because the animal might have a history of individual experience of conditioned reflexes to these stimuli.

We investigated the dynamics of EP in the amygdaloid lateral nucleus (ALN) during food-procuring

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reflex in response to electrical stimulation of VMH directly (anatomically) connected with ALN and belonging to the defense behavior system.

MATERIALS AND METHODS

The study was carried out on 4 adult cats. Nichrome (0.3 mm) bipolar electrodes were implanted (under nembutal narcosis, 35 mg/kg) into the left ALN and VMH (according to stereotaxic coordinates). An indifferent electrode was fixed in the cranial bone above the frontal sinuses. One week after surgery EP in ALN in response to low-frequency (4 Hz) stimulation of VMH were recorded. Stimulation was carried out with rectangular 0.2-msec pulses (stimulation amplitude 3-6 V in different animals, which is the threshold value for evoking potentials). EP were recorded in a monopolar mode over 2-3 experimental days (10-15 in each experiment), 12 realizations were averaged and photographed from the oscillograph monitor in 4 experimental series: before the development of conditioned reflex, during its formation, suppression, and recovery.

The appearance of a conditioned reflex (turning to the feeder in response to a conditioned stimulus) was recorded using an ink writer with a special pickup fixed on the animal head. After basal registration of EP in several experiments the cats were trained to get meat from the feeder with the fore limb. Then food-procuring reflex to electrical stimulation of VMH (with the above parameters) was trained. Conditioned stimulation at 4 Hz lasted for 3 sec; during the third second the feeder with meat appeared, and the cat got meat with its right paw. A total of 20-25 combinations (stimulation+feeder) were offered during each experimental day; averaged (from 12 realizations) EP in ALN in response to each 3-sec conditioned stimulation of VMH were recorded. After the conditioned reflex was fixed, it was chronically suppressed, and then restored. After experiments the animals were sacrificed and electrode location was verified morphologically (Fig. 1). Before conditioning the type of behavioral reaction to high frequency (80-100 Hz) electrostimulation of VMH and ALN was evaluated. The stimulation of VMH caused a characteristic reaction of false rage, stimulation of LNA induced passive defense fear reaction.

RESULTS

Low-frequency electrical stimulation of VMH in awaken cats under conditions of free behavior caused clear-cut EP in the ALN, the main component of these EP being high-amplitude positive deviation (Fig. 2, *a*, *1*). Two-fold increase of the stimulating current led to a proportional increase of all EP phases, causing no additional oscillations (Fig. 2, *a*, *2*).

The development of the food-procuring reflex to electrical stimulation of VMH was difficult: the reflex started to form only after 80-100 combinations of the signal with the reinforcement and manifested by turning of animal head to the feeder in response to conditioned stimulus. EP in ALN remained unchanged during several more sessions. An additional oscillation in EP structure, presenting as splitting of the ascending phase of positive wave, started to develop only after 200-300 combinations. The latent period of the peak of additional positive wave was 70-80 msec, that of the subsequent negative wave about 100 msec (Fig. 2, *a*, *3*). As the conditioned reflex fixed and specia-

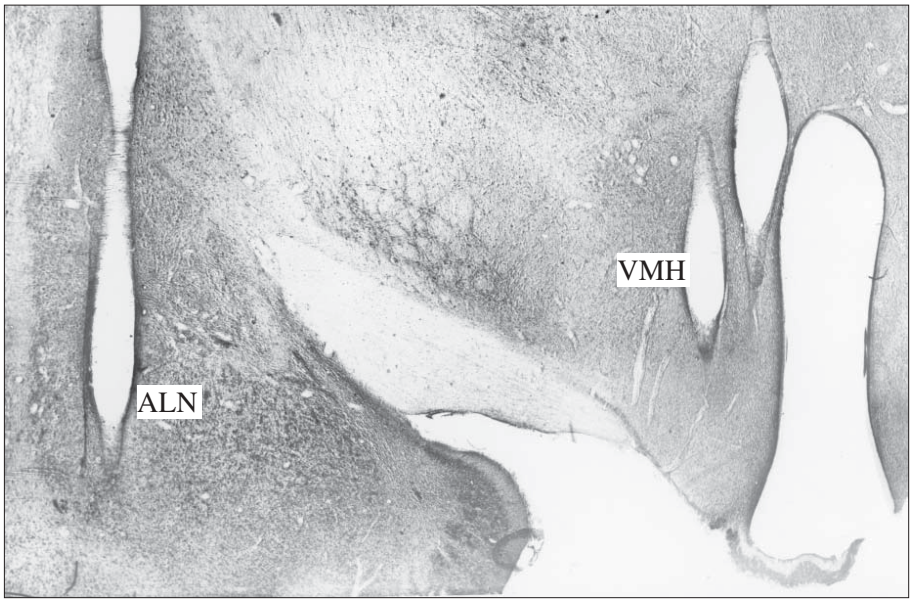

Fig. 1. Location of electrodes in the amygdaloid lateral nucleus (ALN) and ventromedial nucleus of the hypothalamus (VMH).

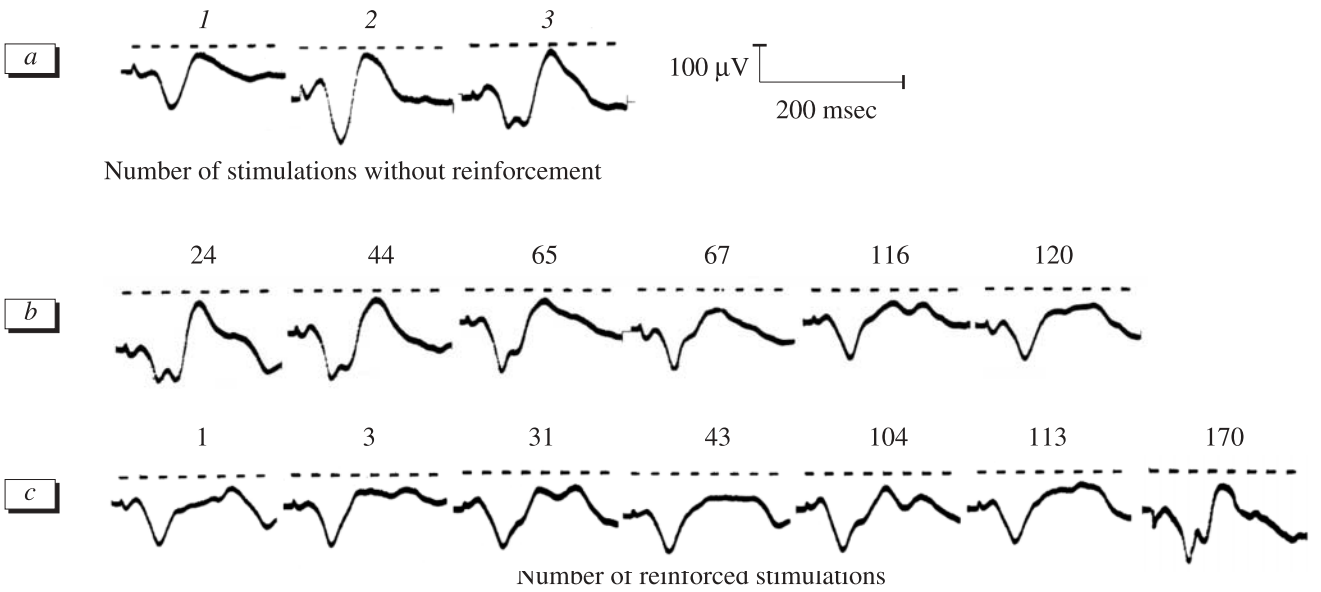

Fig. 2. Evoked potentials of the amygdaloid lateral nucleus in response to low-frequency electrical stimulation of the hypothalamic ventromedial nucleus. Averaged 12 realizations. Deviation of the ray down: positive oscillation. *a*) *1*, *2*: before the formation of conditioned reflex to stimulation with an amplitude of 3 V (*1*) and 6 V (*2*); *3*: after formation of conditioned reflex (combination 729); *b*) during suppression of conditioned reflex; *c*) during restoration of conditioned reflex.

lized, these newly formed additional components of EP became stable and were recorded in all cats in response to each conditioned stimulus. A specific feature of newly formed additional oscillations of ALN EP was that they did not strictly correlate with the motor manifestation of the reflex, as was observed in the sensorimotor cortex during the development of similar food-procuring conditioned reflex to stimulation of the specific thalamic and VMH nuclei. Additional components of ALN EP were more inert and were recorded even in cases, when the conditioned reflex did not manifest. This phenomenon was absent in studies of EP in the sensorimotor cortex: if the reflex did not manifest, no delayed components in EP cortical structure were recorded.

Conditioned reflex formed in response to electrical stimulation of VMH was suppressed slowly; deep suppression (10 failed manifestations of the reflex in succession) was attained within several experimental days, after 80-100 non-reinforced stimulations. The process of the reflex suppression was paralleled by characteristic changes in EP: after 60 non-reinforced stimulations the additional positive-negative components gradually decreased, but disappeared completely only during deep suppression after 100 non-reinforcement (Fig. 2, *b*). Suppressed conditioned reflex was rapidly restored (after 3-5 presentations) as concerned the behavior, but the restoration of ALN EP structure characteristic of a positive conditioned reflex was very slow, lagging far behind the restoration of the behavioral conditioned reaction: more than 100 combinations were needed again for restoration and stable emergence of additional positive-negative oscillations (Fig. 2, *c*). Additional components of the sensorimotor cortex EP, characteristic of a positive reflex, were restored rapidly and always in parallel with restoration of the behavioral reaction.

The detected differences in the time course of the sensorimotor cortex and ALN EP seem to reflect different functional significance of the studied brain structures in the formation and functioning of this conditioned reflex. If changes in the sensorimotor cortex EP, detected in our previous experiments on the development of the same food procuring reflex, could be explained by processes underlying the preparation and realization of the conditioned reflex motor act, the additional components of the amygdala EP can reflect the nonspecific processes of increase in the ALN stimulation associated with tuning to realization of the conditioned reflex act. Presumably, the additional components of EP can be a result of increased number of discharges of activated ALN neurons and increase of their synchronization as a result of involvement of this structure in the realization of conditioned reflex [1-4].

Our findings indicate that VMH belonging to the defense behavior system, when becoming the spot of signal stimulation of the food-procuring conditioned reflex, can modulate its congenital characteristics under conditions of a new situation. The same seems to be true about ALN, which is linked with VMH via direct anatomical bonds. The inertness of electrographic changes in the ALN during this process can be a result of this difficult restructuring, more time-con-

suming than the development of a simple conditioned reflex.

Hence, the development of a food procuring conditioned reflex is associated with the appearance and stable recording of delayed components in EP structure in the subcortical formation (ALN) and in the hemispheric cortex, which probably attests to the involvement of ALN in this conditioned reflex.

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