STUDIES ON THE ELECTRICAL ACTIVITY IN THE AUDITORY AND MOTOR ANALYZERS OF THE HUMAN BRAIN CORTEX, DURING THE FORMATION OF A DEFENSIVE CONDITIONED MOTOR REFLEX

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The bioelectric potentials of the brain cortex are intimately related to the neurological processes arising during the formation of conditioned reflexes.

Numerous studies on brain biopotentials arising during the formation of conditioned reflexes in animals [2, 3, 5, 6, 7, 8, 10] and in man [1, 4, 9, 11] have been published.

It has been demonstrated by P. I. Shpilberg that the α-rhythm may be conditionally depressed by sound after a number of simultaneous light and sound stimulations. But sound alone, before the beginning of the light stimulus and after the end of the orientation reaction, did not produce any changes on the electroencephalogram.

I. S. Beritov and A. Vorobyev have shown that the increase or appearance of α-rhythms may be conditioned by sound when the latter is repeatedly made in conjunction with a black-out effect. After 8-10 such simultaneous stimuli, sound alone provoked the appearance of a definite α-rhythm.

After a number of simultaneous excitations with sub-threshold sound and light, V. A. Kozhevnikov and A. M. Maruseva detected a temporary connection by observing a depression of the α-rhythm in response to a sub-threshold sound stimulus.

V. E. Mayorchik and B. G. Spirin studied the variations in the electroencephalogram of man during a conditioned activity by using the ability of the cortex cells to increase the rhythm of their potentials in response to a rhythmic excitation. In these experiments, the conditioned excitation was reinforced by a rhythmic light stimulus. As a result, the cortical rhythm tended to approach the rhythm of the light blinking.

We studied the variations of the electrical activity in the auditory and motor regions of the brain cortex of a healthy, adult person, during the investigation of the mechanism of cortical processes and of the relationship between the primary and secondary signal systems.

The experiments were carried out according to the defensive-motor procedure.

EXPERIMENTAL METHODS

The brain currents were tapped with silver electrodes and led to a 4-channel amplifier, "4 UNCh-1" amplifying circuit (band width: 1 to 75 cycles). The electroencephalogram was recorded on an ink-writing apparatus, type "4-gr". The tapping of the biopotentials was monopolar, from the cortex of the left hemisphere, in the region of the auditory and motor analyzers. A 200-cycle sound generator was used to emit the positive conditioned sound stimulus, while the differential stimulus was emitted by a 100-cycle sound generator.

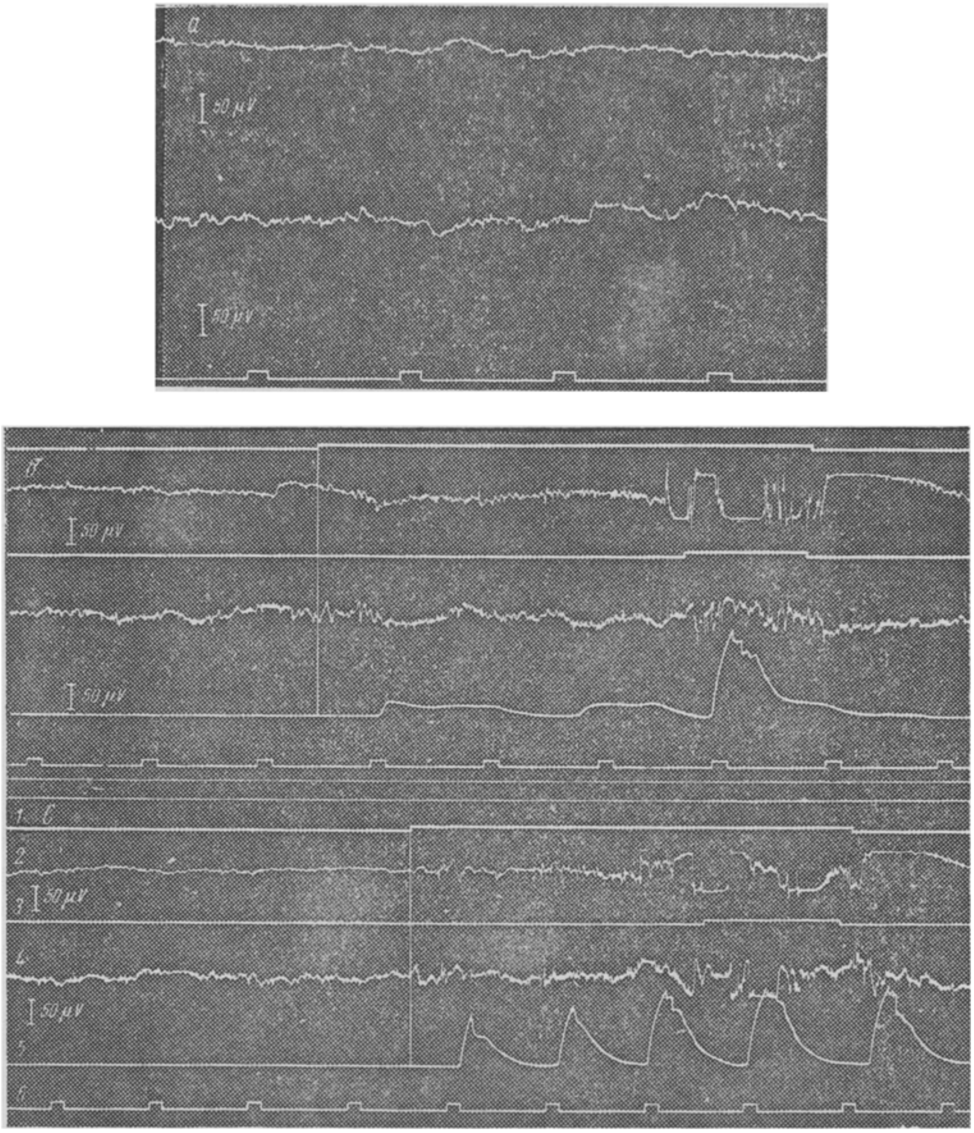

Fig. 1. Electrical activity in the region of the auditory and motor analyzers of the human brain cortex before the appearance of the defensive motor conditioned reflex (a), after 95-min.; (b) and 97-min.; (c) of conditioned stimulation (bell) and non-conditioned skin excitation (electrical).
Significance of curves (from top to bottom): a) electroencephalogram of the auditory analyzer region, electroencephalogram of the motor area; b) and c) beginning of bell signal, electroencephalogram of the auditory analyzer region (left hemisphere), beginning of electrical stimulus (electrical excitation of the skin of the right hand, electroencephalogram of the motor analyzer region (left hemisphere), recording of the movements of the right hand receiving the electrical excitation, time tracing (1 second).

The non-conditioned stimulus was introduced by direct current through a special metal plate supporting the right wrist of the subject. The conditioned and non-conditioned stimuli and the movements of the hand were registered simultaneously with the electroencephalogram.

Sixty-eight experiments were performed on 7 healthy males and females, 20 to 25 years old.

After the appearance of the positive conditioned reflex, the conditioned stimulus was replaced by a vocal signal. This made it possible to evaluate the interaction between the primary and the secondary signaling systems.

RESULTS

The obtained data show that the amplitude of the bioelectric potentials in the region of the auditory and motor analyzers increases during the formation of a defensive-motor conditioned reflex in response to a non-rhythmic excitation during the action of a conditioned stimulus. This points to an increase of the activity of the

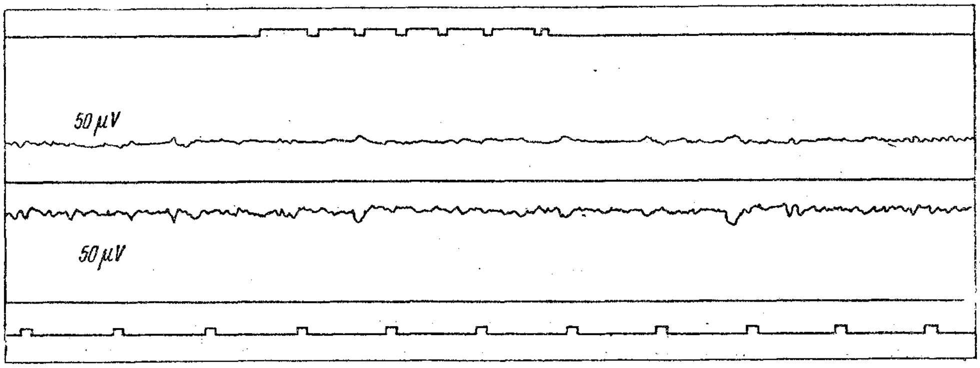

Fig. 2. Variations in the electrical activity in the region of the auditory and motor analyzers in the human brain cortex during differential excitation.
Significance of curves (from top to bottom): closing of the 100-cycle (differential) sound generator circuit; electroencephalogram of the auditory analyzer region (left hemisphere); closing of the electrical circuit; electroencephalogram of the motor analyzer region (left hemisphere); recording of the right hand movements; time tracing (1 second).

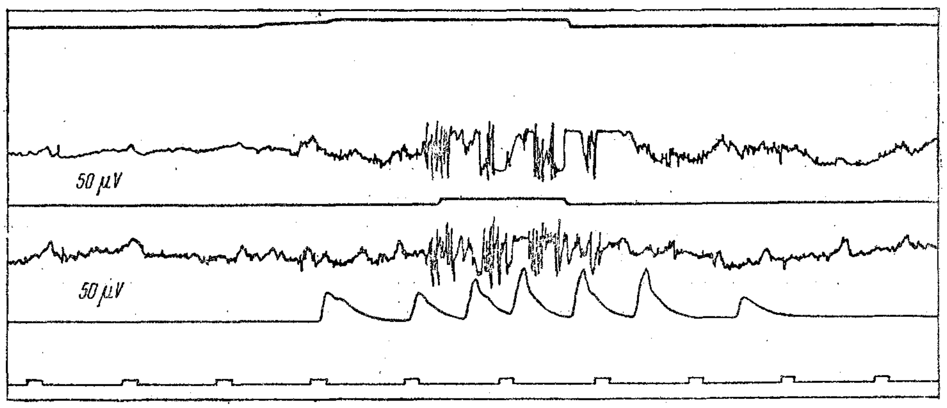

Fig. 3. Variations of the electrical activity in the region of the auditory and motor analyzers of the human brain cortex during the use of the word "bell" as the conditioned stimulus.
Significance of curves (from top to bottom): pronunciation time of the word "bell"; electroencephalogram of the auditory analyzer region (left hemisphere); closing of the electrical circuit (excitation of skin of right hand); electroencephalogram of the motor analyzer region (left hemisphere); recording of the right hand movement during electrical excitation; time tracing (1 second).

brain cortex cells during a conditioned excitation. A change in the biopotentials was observed before the appearance of the defensive motor reaction. The latter appeared in the majority of cases after 26 to 28 simultaneous excitations by the conditioned sound and the non-conditioned electrical stimuli.

This statement is illustrated by the oscillograms (Fig. 1).

It is clear from the obtained oscillograms that the electrical activity in the auditory and motor analyzer regions of the brain cortex has changed significantly in comparison to the background activity during the action of the bell-conditioned stimulus. A distinct increase in the amplitude of the bioelectric potentials may be observed (auditory region amplitude: 17.5 μV against 11.1 μV; motor region amplitude: 21.8 μV against 14.3 μV). As the conditioned reflex was strengthened, a great increase of the bioelectric potentials and of the motor reaction of the subject occurred during the action of the conditioned excitation (auditory region amplitude: 21.7 μV; motor region: 22.1 μV). After the appearance of the conditioned reflex to the bell and to the 200-cycle sound generator, a differential reflex to the 100-cycle sound generator was produced. The appearance of the latter reflex suppressed the increased electrical activity of the brain during the action of the conditioned stimulus. However, in some cases under these conditions the amplitude of the bioelectric potentials somewhat decreased (auditory region: to 9.4 μV; motor region: to 10.2 μV; Fig. 2), while during the positive conditioned reflex, the bioelectric potentials continued to increase.

In subsequent experiments the positive conditioned sound excitation was replaced by its verbal designation. After the production of the defensive motor conditioned reflex to the sound excitation (bell), the replacement of the latter by its verbal designation – the word "bell" – provoked both analogous changes in the auditory and motor analyzer regions of the brain cortex and a conditioned motor reaction. In a number of cases the word "bell" provoked a somewhat greater reaction than the conditioned sound excitation, i.e. both a greater increase of the bioelectric potentials and a more intensive motor reaction. Fig. 3 may be taken as an illustration. In response to the word "bell", the amplitude of the bioelectric potentials in the auditory and motor analyzer regions increased. This increase was greater than the one observed during the action of the direct conditioned stimulus – bell sound (amplitude in the auditory region: 23.7 μV; in the motor region: 26.3 μV). The conclusion is that the stimuli primarily aimed at the secondary signal system are responsible for the changes in the electrical activity of the auditory and motor analyzer regions of the human brain cortex.

These investigations demonstrate the variations of the electrical activity in the auditory and motor analyzer regions of the human brain cortex that occur during the formation of a defensive motor conditioned reflex to sound stimuli and during the replacement of the conditioned stimulus by its verbal designation.

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