INVESTIGATION OF THE TRACE CHANGES IN THE ELECTROENCEPHALOGRAM IN MAN DURING THE FORMATION OF MOTOR CONDITIONED REFLEXES

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During the investigation of changes in the electrical activity of the cerebral cortex in the course of formation of a conditioned reflex, interest is due not only to the reactions during the action of the conditioned stimulus, but also to the changes observed subsequently. Pavlov [2] paid great attention to the relationships of induction: He wrote that "when a positive or inhibitory stimulus disturbs this equilibrium in the cortex, through that structure there passes what is apprently a wave with a crest – a positive process, and a wave with a trough- an inhibitory process, which gradually become flattened, i.e., irradiation of the processes takes place with the alternate participation of their mutual induction."

In the present communication we examine the trend of the changes in electrical activity in the motor region of the cerebral cortex in man during the formation of a conditioned motor reaction, and we study the after reactions in the electroencephalogram associated with these changes.

EXPERIMENTAL METHOD

Investigations were conducted on 20 healthy individuals aged from 20 to 35 years. We used the method of formation of motor conditioned reflexes on the basis of speech reinforcement in response to a complex sound stimulus consisting of three identical signals applied at uniform intervals. For differentiation we also used complex sound stimuli consisting of three signals: the first two signals were of the same tone as in the conditioned positive stimuli, but the third signal was of a different tone. The motor reactions were recorded by means of electromyograms (EMG). For this purpose electrodes shaped like cups, filled with paste, were glued to the right forearm over the flexor muscles. The electrodes for the electroencephalograms (EEG) were applied to the skin of the head in a chain from the frontal to the occipital region at a distance of 4-5 cm from each other and 3-5 cm from the midline.

The EEG (bipolar) and EMG were recorded on a multichannel ink-recording electroencephalo-graph. Analysis of the EEGs was undertaken by means of an eight-channel wave analyzer, made at the request of the Institute of Neurosurgery.

The subjects sat in a easy chair, with their eyes closed, in a darkened, screened, but not completely soundproof room.

EXPERIMENTAL RESULTS

Before the formation of the conditioned motor reflexes, the reaction of the electrical activity of the cortex in response to sound was first extinguished. Extinction of the generalized depression in the EEG in response to movement (clenching the fingers of the right hand) was carried out. It may be mentioned that with the first clenching movements generalized depression of the α-rhythm was observed. Subsequently depression was seen only in the sensomotor region, and was more conspicuous at the beginning of and after relaxation of the positive contraction of the muscles. During clenching the basic rhythm was recorded. The findings corresponded to those described in the literature.

The changes in the electrical activity of the motor region of the left hemisphere in the course of formation of a conditioned motor reflex followed a definite pattern. During the first applications of the conditioned stimuli, after the motor reaction in the sensomotor region of the left hemisphere depression was observed. A few seconds later the α-rhythm appeared. In some subjects β-waves appeared before the restoration of the α-rhythm. In a proportion of cases the α-rhythm was again depressed and subsequently restored for a second time.

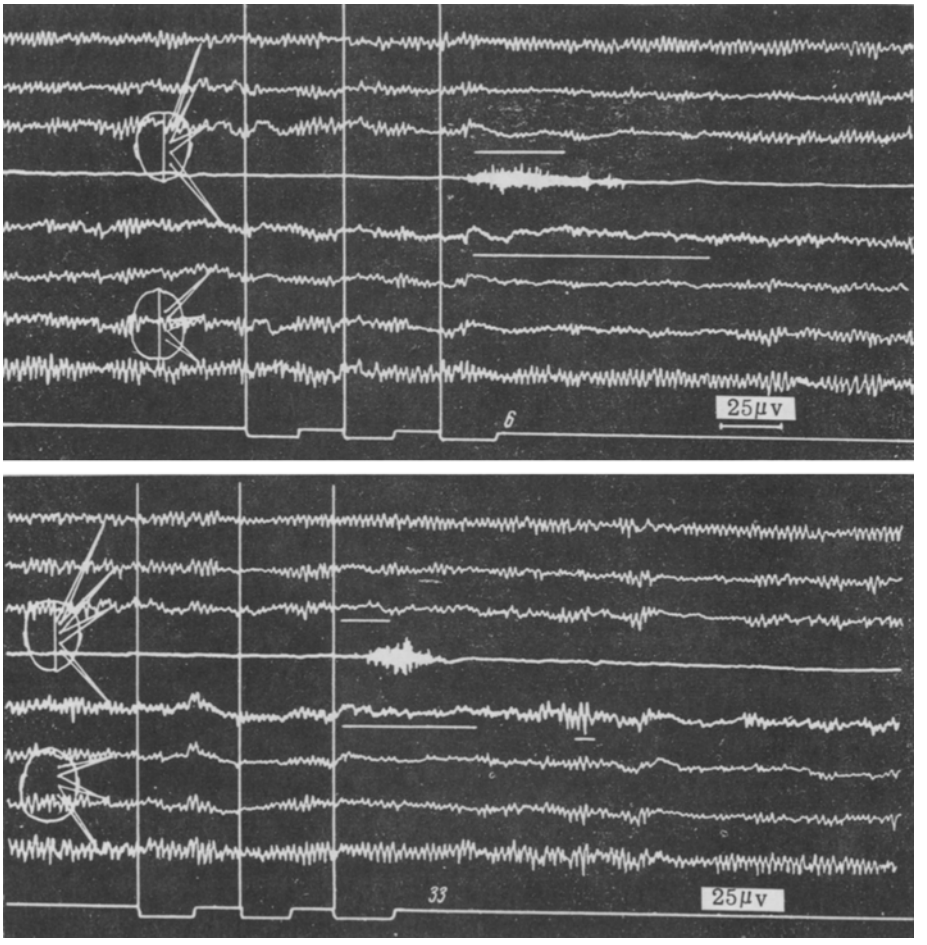
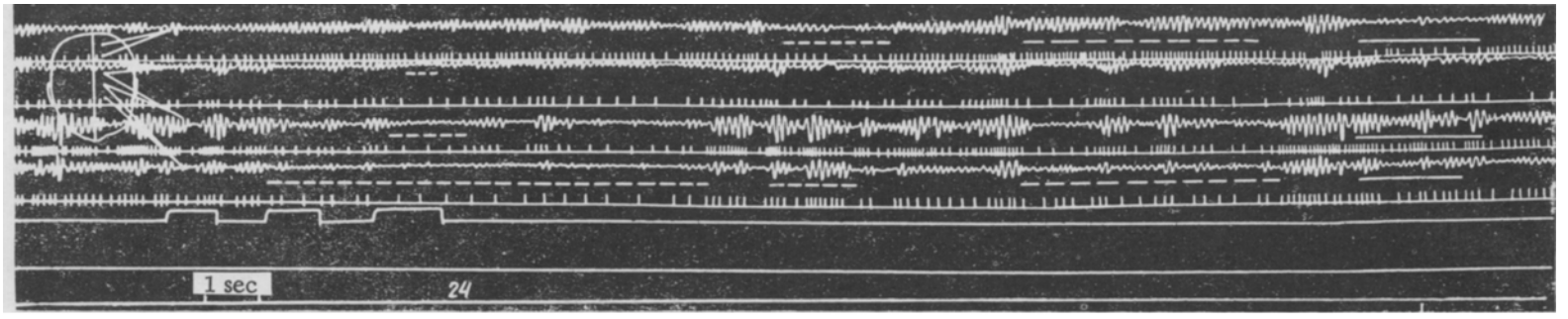


Fig. 1. Increase in the amplitude of the α-rhythm in the left sensomotor region in the after effect of the conditioned motor reaction (clenching the fingers of the right hand to make a fist) in the subject S. a) 6th combination. The reaction during the after effect is shown by restoration of the α-rhythm; b) 33rd combination. After clenching the fingers of the right hand a group of sharply pointed α-waves of exalted amplitude was recorded in the left sensomotor region. Fourth line from the top: EMG of the right forearm; depression of the bottom line – marker of the sound stimulus.

a



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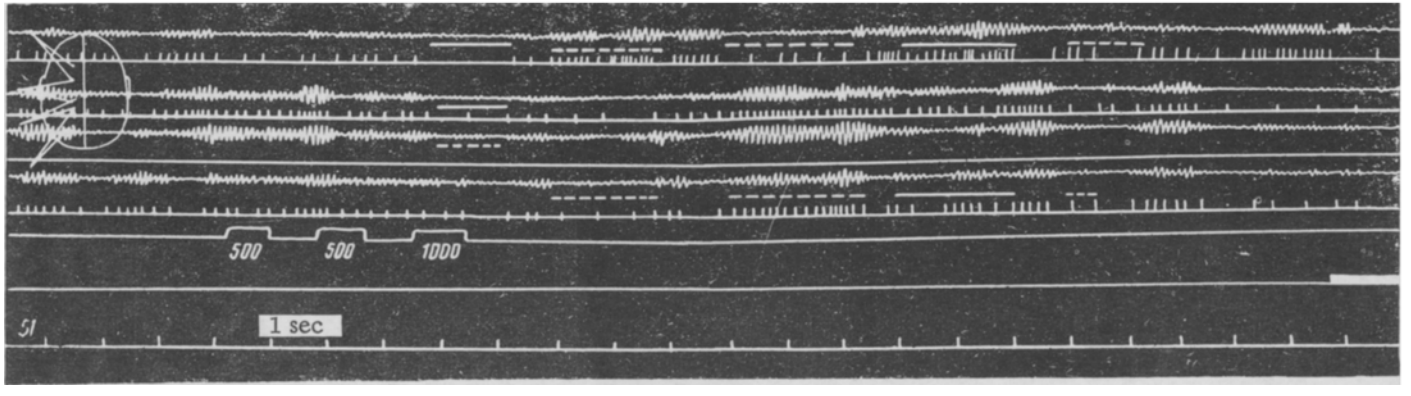

Fig. 2. Reciprocal changes in the electrical activity in the sensomotor and occipital regions appearing in the process of formation of a conditioned motor reflex (the recording was made on the analyzer and integrator, and the frequency was deduced in the range of 8-12 per second). a) Subject S., 24th combination. The leads correspond to the scheme shown on the left. Under each curve is given the recording of the EEG on the integrator. Significance of the curves (from below upward): time marker (in seconds); marker of light stimulus; marker of sound stimulus (elevation of the line); b) subject Kh., seventh application of the differential stimulus. The leads correspond to the scheme illustrated. The markers of the stimuli are the same as in Fig. 2,a.

In response to further applications of the conditioned stimuli, an increase in the amplitude of the basic rhythm or the appearance of sharply pointed impulses was observed in the sensomotor region after the motor reaction. For instance, in the EEG of the subject S (Fig. 1,a,b), in response to the sixth combination of the conditioned stimulus, depression of the basic rhythm and its subsequent restoration were observed after clenching the fingers. In response to the 33rd combination sharply pointed impulses were observed after the motor reaction, but these were not found in the symmetrically opposite areas of the other hemisphere.

In some subjects during the motor reactions either local changes in the sensomotor region or a phenomenon which we called "a crater" were observed. The "crater" took the form of a depression of the basic rhythm, beginning first in the central regions and then spreading towards the occipital divisions. The rhythm was restored first in the posterior divisions, and took longer in the motor region. We suggest that the "crater" is the electrographic representation of irradiation of the excitation from the focus created in the course of formation of the conditioned motor reflex.

Immediately after these changes, during the after effect of the conditioned motor reaction "reciprocal" relationships were observed between the α-rhythms in the motor and occipital regions. While the basic rhythm was restored in the anterior divisions it was depressed in the posterior divisions, and, conversely, when the rhythm was depressed in the anterior divisions waves appeared or were strengthened in the posterior divisions. This can be demonstrated especially clearly when recording with the analyzer.

In the subject S. (Fig. 2,a) after the 24th combination it can be seen that when the rhythm in the sensomotor region reached its maximum amplitude, a decrease in its amplitude was found in the occipital region. Similar changes in the EEG were also observed during differentiation. For instance, in the subject Kh. (Fig. 2,a) during the seventh application of the differential stimulus, the tracing of the analyzer shows that the change in electrical activity in response to the third sound of the complex took the form of a "crater," immediately after which restoration of the wave rhythm took place with a reciprocal relationship between the anterior and posterior divisions.

We regard the development of these changes in the EEG as the result of the influence of the fluctuating state of after excitation in the motor region during the formation of a motor conditioned reflex. They evidently reflect the state of excitation in the dominant focus [3] created by accumulating after excitations, and are related to Pavlov's mutual induction. These changes are possibly close in their mechanism to the phenomena of perielectrotonus, observed by Vvedenskii [1] in a nerve-muscle preparation.

Taken as a whole, these investigations show that during the formation of conditioned motor reflexes in man, the following changes in the electrical activity of the cortex take place in the after effect. After the conditioned motor reaction, depression of the basic rhythm followed by its restoration may be observed in the sensomotor region. After subsequent applications of the conditioned signal the amplitude of the basic rhythm is increased or sharply pointed impulses appear. The latter are found only in the course of formation of the conditioned reflex.

A reciprocal relationship is seen between the changes in the electrical activity in the sensomotor and occipital regions. During restoration of the basic α-rhythm in the anterior divisions, there is a decrease in the α-rhythm in the posterior divisions, and vice versa. The reciprocal changes in the electrical activity in the sensomotor and occipital regions do not arise immediately after the beginning of formation of the conditioned reflexes, but after reinforcement of the conditioned motor reaction.

SUMMARY

A study was made of the EEG changes in healthy adults during elaboration of conditioned reactions. At the beginning of the conditioned motor reflexes elaboration there sets in a depression of the main rhythm in the EEG of the sensory motor area, following the conditioned motor reaction with its subsequent restoration. Later a rise of the amplitude of the main rhythm or the appearance of acute impulses is noted in this area. Trace reactions in the form of "reciprocal" changes of electric activity were observed in the sensory motor and occipital areas. During the restoration of the main rhythm in the anterior portions a reduction of the α-rhythm was seen in the occipital areas and vise-versa. These changes occurred after stabilization of the conditioned motor reaction.

LITERATURE CITED

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