CONDITIONED-REFLEX ELECTROENCEPHALOGRAPHIC CHANGES IN MAN AT VARIOUS STAGES OF THE FORMATION OF THE CONDITIONED CONNECTION

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Several authors [9, 10, 11] consider that the reticular formation of the brain plays a leading role in the mechanism of formation of conditioned-reflex connections and that the connection is joined in the subcortical formations. Other authors [1, 7, 8] consider that different functional structures of the brain take part in the formation of the conditioned reflex, stressing the importance, not so much of the horizontal cortico-cortical connections, as of the vertical connections between the cortex and the subcortical formations. In recent years the hypothesis has been put forward by several authorities that the site of formation of the connection may be variable [2, 3, 6]. The results of an earlier investigation [4] showed that during tactile stimulation of the hand, local changes in the dominant activity may be recorded on the EEG in man in the postcentral region of the hemisphere, contralateral to the stimulated limb.

In the present investigation we studied the dynamics of the conditioned-reflex changes in the EEG during formation of a conditioned connection (a combination of an acoustic stimulus with tactile stimulation of the hand) in order to compare the extent of the participation of different functional structures of the brain in this process.

EXPERIMENTAL METHOD

Investigations were carried out on 18 healthy persons with a marked Rolandic and α-rhythm. Bipolar recordings of the EEG were made on a 15-channel ink-writing electroencephalograph from the region of projection of the postcentral gyri of both hemispheres—the specific projection region of the unconditioned (tactile) stimulus. Since the purpose of the analysis of the results obtained was not merely to study the form of the electrographic changes, but more specifically to examine their degree in different parts of the hemispheres (including parts not directly associated with the applied stimuli), the EEG was also recorded from the occipital region of the hemisphere contralateral to the stimulated hand.

The conditioned stimulus was acoustic—a group of three sounds, with a total duration of 3 sec, 500 cps, 58 dB) and the unconditioned stimulus—tactile stimulation of the right hand. Before the formation of the conditioned reflex began, in most subjects the effect of 3-5 isolated applications of the tactile stimulus was investigated. Under these circumstances changes were observed which, initially, were recorded bilaterally, and later, with continued presentation of the tactile stimulus, became increasingly concentrated in the contralateral hemisphere. The orienting reaction to the acoustic stimulus was subsequently extinguished. These reactions were always conspicuous in both hemispheres and were usually extinguished only after 5-15 presentations of the stimulus. The investigations were carried out frequently on each patient (for 8-12 experimental days), either daily or allowing intervals of 1-2 days between the investigations.

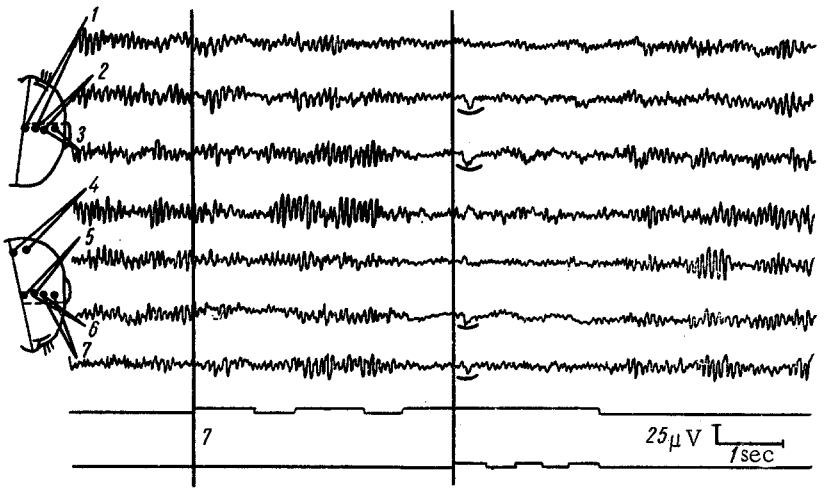

Fig. 1. Conditioned-reflex generalized changes in the EEG of a healthy person in the early stages of formation of a temporary connection. Two bottom lines—marker of acoustic (2nd line from the bottom) and tactile (bottom line) stimuli. The number by them is the serial number of the combinations. Vertical continuous lines—beginning of acoustic and tactile stimulation. Horizontal strokes below the curves—local changes.

EXPERIMENTAL RESULTS

The investigations showed that the region of conditioned-reflex changes in the EEG in man changes its localization at different stages of formation of the conditioned connection. In the first stages of this process the conditioned-reflex reactions of the EEG were generalized in character and took the form of depression of the original rhythm in all regions. As the number of combinations increased, the conditioned generalized changes in electrical activity were displaced towards the moment of application of the tactile reinforcement and their duration was shortened.

It may be seen from Fig. 1 that at the 7th combination of the acoustic with the tactile stimulus, a conditioned-reflex generalized depression of the original rhythm developed at the end of the acoustic stimulation but before the beginning of tactile stimulation.

Another feature to attract attention was the nonspecific response recorded in the postcentral regions of both hemispheres during application of the tactile stimulus, described in the literature as the response from the vertex.

Later in the course of formation of the conditioned connection a gradual contraction of the region of conditioned-reflex changes in the EEG was observed. The manifestations of conditioned depression were no longer generalized in character in the EEG, but were limited to the postcentral regions of both hemispheres, and often were combined with a reaction of a different type in the EEG—a nonspecific response. In Fig. 2 the conditioned-reflex contraction of the dominant rhythm is confined to the postcentral regions of both hemispheres and does not extend to the posterior regions. Meanwhile, against the background of this bilateral depression, after application of the 3rd acoustic stimulus the development of a clearly defined conditioned-reflex nonspecific response was observed, recorded in the postcentral regions of both hemispheres. A noteworthy feature was the difference in the localization of the potential arising in response to the conditioned and unconditioned stimuli. In the first case the response was seen mainly in the recordings made from the sagittal electrode, while in the second case it was recorded mainly parasagittally, and its amplitude was larger in the contralateral hemisphere.

With a further increase in the number of combinations the conditioned reactions of the EEG became more and more localized in character (Fig. 3, A, B).

Figure 3, A shows the appearance of a well defined conditioned localized depression of electrical activity in the postcentral region of the "active" hemisphere, contralateral to the stimulated limb, taking place twice: in the interval between the first and second acoustic stimuli of the group, and after application of the third stimulus (in this particular combination the tactile reinforcement was deliberately withdrawn to reveal the reaction to "time").

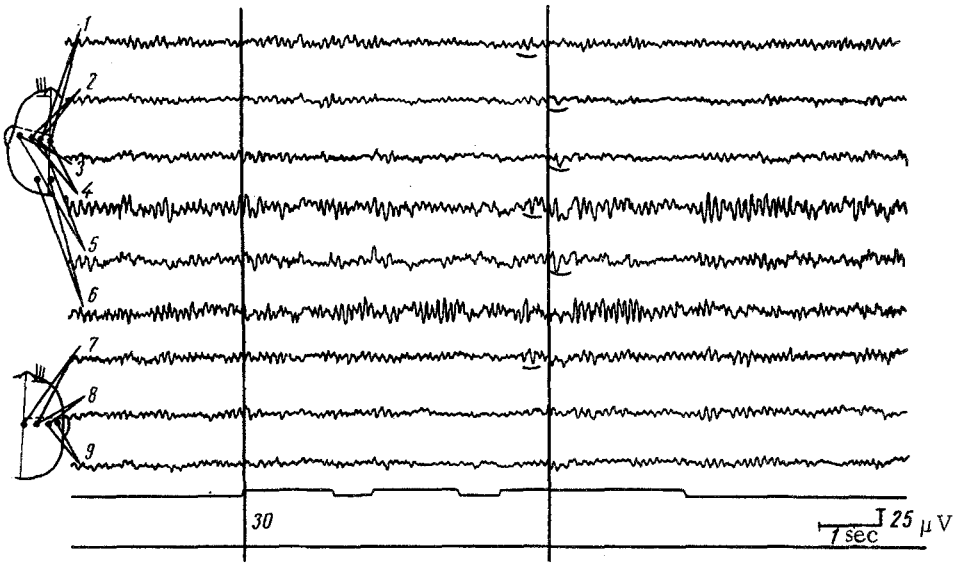

Fig. 2. Conditioned-reflex changes (decrease in electrical activity) and nonspecific response in postcentral regions. Legend the same as in Fig. 1.

The dynamics of the changes in the process of formation of the conditioned connection was similar also in respect of the nonspecific response. Whereas in the initial stages of formation of the connection the nonspecific response as a rule was clearly seen in both hemispheres (Fig. 2), subsequently, in the course of repeated combinations of the acoustic and tactile stimuli, like the changes in the dominant rhythm, it began to appear in an increasingly localized area. At symmetrical points of the postcentral regions (with the same distance between electrodes and all other conditions of recording identical) obvious asymmetry of the hemispheres was observed in the nonspecific response, which was dominant in the contralateral hemisphere.

In some cases the nonspecific response arising to the conditioned acoustic stimulus, like the conditioned-reflex depression of the dominant rhythm, was limited to the postcentral region of the "active," contralateral hemisphere, and it was followed by the gradual disappearance of these reactions as the conditioned connection became consolidated.

It is clear from Fig. 3, B that at the 93rd application of the conditioned acoustic stimulus (in the absence of tactile stimulation) a clearly defined nonspecific response was recorded in the postcentral region of the contralateral hemisphere in the form of a sharp-pointed peak. Similar changes were also observed in the after-effect of stimulation.

A well defined localized depression of the original rhythm was observed in 13 of 18 patients. In 5 persons with an ill defined Rolandic rhythm, no localized depression could be detected. The conditioned-reflex reactions of the EEG were recorded in the postcentral regions of both hemispheres, but in these cases, too, they were more marked in the contralateral hemisphere. Another form of EEG changes which has been described, the vertex potential, was observed in 14 of 18 patients. Clear asymmetry of the responses in the two hemispheres was observed in 11 cases. In three subjects the potentials arising in response to application of the tactile stimulus were always bilateral, and equally marked in both hemispheres, evidently as a result of the particular type of functional state of the cerebral cortex of these patients – a state of increased tendency towards drowsiness.

Hence, in the process of formation of a conditioned connection by the repeated application of a combination of acoustic and tactile (to the hand) stimuli, the dynamics of the conditioned-reflex changes in the EEG in man shows certain special features.

The region of the conditioned-reflex changes, especially of depression or intensification of the original rhythm, changes its location at different stages of formation of the connection. Initially the conditioned depression is generalized in character, but later it is confined to the postcentral regions of the two hemispheres. Subsequently it is manifested in the form of obvious asymmetry of the hemispheres, or locally in the postcentral region of the hemisphere contralateral to the stimulated hand, followed by its gradual disappearance as the conditioned connection is consolidated. The conditioned nonspecific response exhibits the same dynamic pattern.

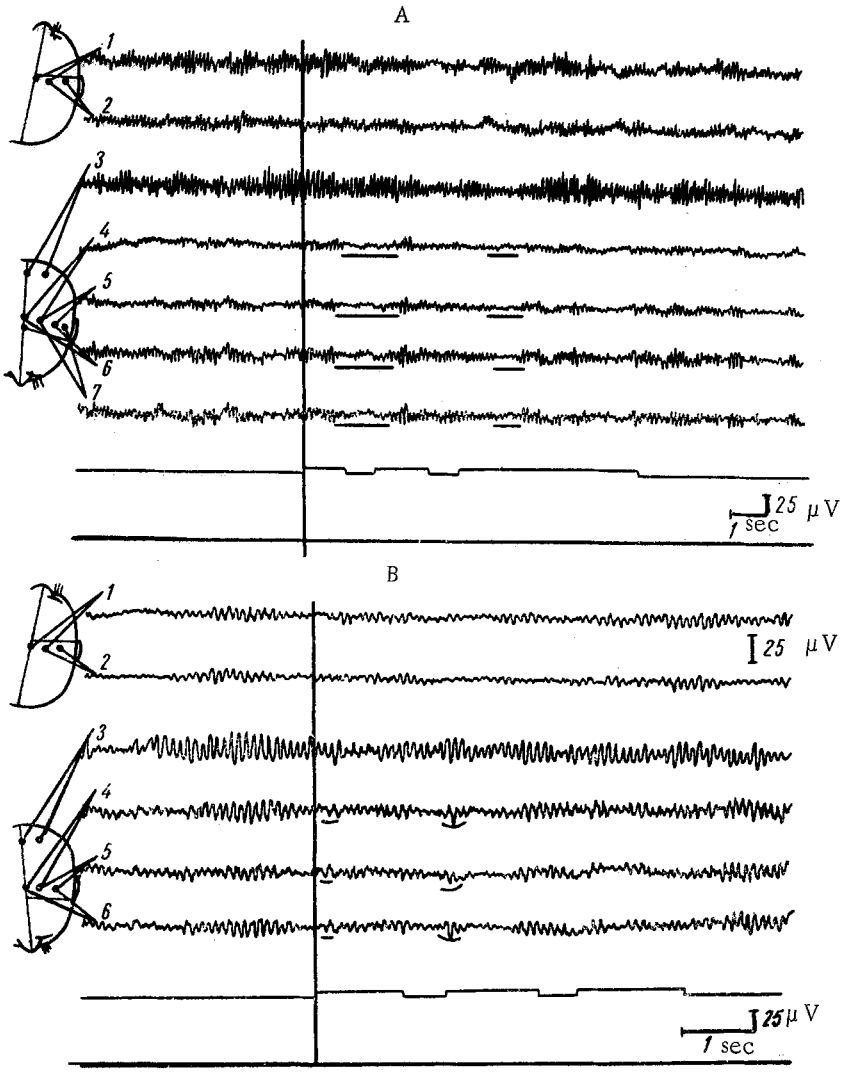

Fig. 3. Conditioned-reflex localized changes in the EEG of a healthy person in relatively late stages of formation of a temporary connection in the post-central region of the contralateral hemisphere. A) Localized depression; B) localized nonspecific response. Legend the same as in Fig. 1.

The following conclusion may be drawn from the relationship between the dynamics of the conditioned-reflex changes in the EEG and the stages of formation of the conditioned connection or the number of combination during each day of the experiment.

The reactions of the electrical activity described above (depression of the original rhythm, nonspecific response) are evidently adequate reflections of the changes in the functional state of the corresponding cortical structures arising at different stages of formation of the conditioned connection. The appearance of generalized or of relatively localized bilateral conditioned-reflex electrographic changes in the EEG in man in the early stages of formation of the conditioned connection is evidence of the considerable involvement of the nonspecific structures of the brain on this stage of the process of formation of the connection. In the later stage of formation of the conditioned connection, with the creation of a functional "active focus," processes in specific cortical projections begin to dominate. This is confirmed by the localized nature of the conditioned-reflex reactions of the EEG demonstrated in the post-central region of the hemisphere contralateral to the stimulated hand and by the asymmetrical character of their manifestations in the contralateral and ipsilateral hemispheres.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
