ELECTROPHYSIOLOGICAL INVESTIGATION OF THE EFFECT OF SHORT PERIODS OF WEIGHTLESSNESS AND OVERLOADING

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Only a few investigations of changes in the bioelectrical activity of the central nervous system in the conditions of weighlessness have been published [7, 10].

The present paper describes the results of a study of the changes in the electrical activity of various parts of the brain on animals exposed for short periods to weightlessness and overloading.

EXPERIMENTAL METHOD

Conditions of weightlessness were created during the flight of an airplane on a parabolic trajectory. The duration of each period of weightlessness was 25-30 sec. Each period of weightlessness was preceded by a period of overloading (1.8-2 g) lasting 12-15 sec; the period of weightlessness was followed by a similar overloading lasting 10-12 sec. In individual cases, for control purposes, periods of weightlessness were created without the preceding or the succeeding overloading, and in this case the duration of weightlessness was approximately half that in the other series.

Experiments were carried out on 2 cats and 1 rabbit with permanently implanted surface and buried electrodes. The surface electrodes were steel needles fixed with phosphate cement into the cranial bones over the corresponding part of the cortex; the interelectrode distance was 2-3 mm. The buried bipolar electrodes were inserted into the subcortical structures by means of a stereotaxic apparatus. The electrodes were made of Nichrome wire insulated with enamel (diameter of section $50\,\mu$) housed in a glass capillary tube with an external diameter of 0.3-0.4 mm. The biopotentials were detected by unipolar and bipolar techniques and, after amplification with a single-channel AC amplifier, were recorded on a loop oscillograph.

During the experiment the animal was kept in a screened cage in a fixed position. The experiments were performed mainly on unanesthetized animals, and only in occasional experiments were the cats lightly anesthetized with Nembutal. The electrical activity was recorded in the following areas of the cortex: the anterior portion of the suprasylvian and ectosylvian gyrus, regarded as the zone of cortical projection of the vestibular analyzer [3, 14], and in the optic, auditory, and orbital zone (projection of the IX nerve and the chorda tympani). In the subcortical structures the electrical activity was recorded in the antero-lateral portion of the hypothalamus, and the medial and lateral geniculate bodies.

EXPERIMENTAL RESULTS AND DISCUSSION

Most of the results were obtained on cats, because the higher degree of differentiation of their cerebral cortex made it possible to localize the required zone more accurately. This is particularly true of the cortical projection of vestibular function, the localization of which in the rabbit's cortex could not be determined.

Frequency-amplitude analysis of the electroencephalogram showed that the degree of the changes taking place following transient exposure to weightlessness and overloading differed from one zone to another. The most characteristic and marked changes were observed in the cortical projection area of vestibular function, in the anterior part of the suprasylvian and ectosylvian gyrus. The character of the changes in the electrical activity in this zone of the cortex was as follows. With the beginning of overloading, preceding the period of weightlessness, marked desynchronization of the rhythm of the electrocorticogram (ECoG) was observed, and as a rule this persisted until the onset of weightlessness. This is clearly seen from the examples of oscillograms given in Fig. 1, A-C, and Fig. 2.

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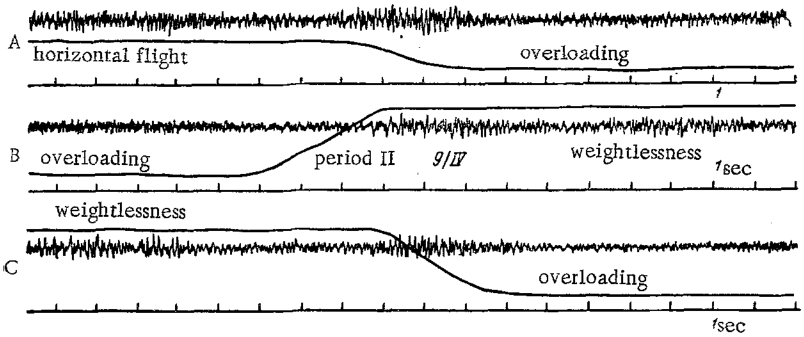

Fig. 1. Changes in the electrocorticogram of the vestibular zone of the cortex during changes in gravitation.

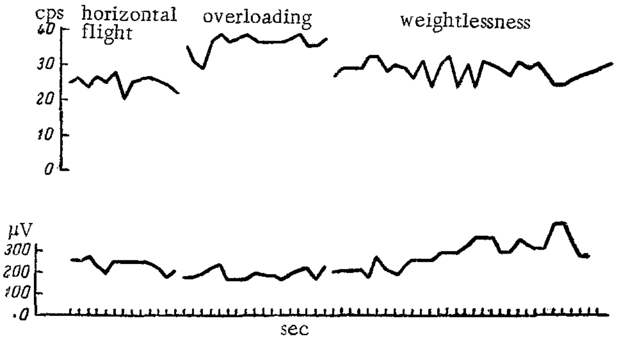

Fig. 2. Graph showing the changes in the frequency (above) and amplitude (below) characteristics of the electrocorticogram of the vestibular zone during changes in gravitation. Abscissa—time (in sec); ordinate—frequency (in cps on the upper graph) and amplitude (in μV; on the lower graph).

With the onset of weightlessness, after the first few seconds the amplitude of the waves increased and the frequency characteristic of the ECoG showed an appreciable shift toward the slow waves. The changes in electrical activity in the period of weightlessness were characterized by instability of the rhythm of the ECoG and by the presence of mixed waves. In the period from 25 to 30 sec the α-like waves were replaced several times by a fast, low-amplitude rhythm, and vice versa. Nevertheless, in the first 2-3 sec the slower waves of high amplitude were predominant, while toward the end of the period the amplitude fell and the rhythm became somewhat faster. The character of the changes in the ECoG during overloading following a period of weightlessness was similar to that observed during the preceding overloading.

Besides in the vestibular zone of the cortex, similar although less marked changes were sometimes seen in the optic zone, especially during the action of overloading. The effect of overloading on the ECoG was more extensive, and it often produced changes where none were observed during weightlessness. For instance, in the orbital zone of the cortex a weak desynchronization of the rhythm was observed during overloading, whereas during weightlessness the pattern of the ECoG was almost indistinguishable from the curve recorded in the horizontal part of the flight.

At the moment of change from weightlessness to overloading, lasting, 1.0-1.5 sec, a burst of α-like waves, 2-3 sec in duration, regularly appeared (Fig. 1, C); similar bursts of α-waves were observed rather less frequently during the change from normal gravitation to overloading (Fig. 1, A). As mentioned above, the onset of weightlessness also was characterized by the appearance of high-amplitude α-waves. These intermediate states during changes in gravitation were thus characterized usually by the appearance of a burst of α-like waves, after which the characteristic picture of the particular form of gravitation developed: desynchronization during overloading and a mixed rhythm during weightlessness.

When the potentials were recorded from the subcortical centers, their electrical activity was found to be relatively resistant to the action of weightlessness and overloading. When changes in the electrical activity were found, they differed in character from the changes observed in the cerebral cortex. During the action of overloading, the number of slow waves of high amplitude increased slightly or a picture of mixed waves was observed, i.e., the desynchronization of the rhythm characteristic of the cortex was not observed here (Fig. 3). During weightlessness waves of high amplitude and a frequency of 11-16 cps predominated, and both the very fast and the slow waves were almost completely absent. The frequency of the biopotentials was somewhat higher than during horizontal flight and overloading. Hence, during the action of weightlessness, changes in activity were observed which differed from its changes in the cerebral cortex. A special feature of the reaction of the subcortical centers was that the changes described above did not

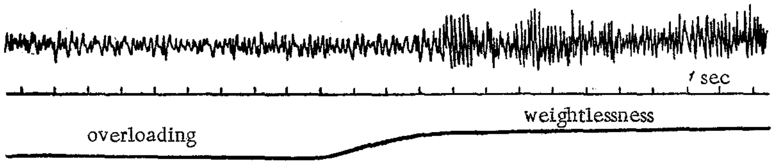

Fig. 3. Changes in electrical activity of the hypothalamus during the action of weightlessness.

appear immediately after the change in gravitation, but developed comparatively slowly, so that for the first 3-4 sec after the change in gravitation the pattern observed in the preceding period still continued.

All the changes in the cortical and subcortical bioelectrical activity were seen most clearly in the waking animal. In the experiments in which the animals were lightly anesthetized the character of the changes was the same, but they were less marked in degree. Comparison of the ordinary periods of weightlessness and the control periods (i.e., without the preceding or the succeeding overloading) showed that the changes in the EEG were similar in direction, although in the first case the changes in the EEG during weightlessness were more marked, thus showing that preceding overloading intensified the changes taking place during the transition from normal gravitation of once to weightlessness.

Data in the literature show that vestibular stimulation may give rise to considerable changes in the electrical activity of the brain. On the other hand, Grandpierre and co-workers [10], who investigated the character of the changes in the electrical activity of the cortex and the mesencephalic reticular formation of the rat's brain in conditions of weightlessness, found no changes in either the cortex or the reticular formation. In the present investigations, when the biopotentials of the subcortical centers were recorded, in many cases no marked or consistent changes could be observed in their basic rhythm, presumably on account of the greater inertia of the nervous processes in the subcortical centers. So far as the cortical electrical activity is concerned, its changes differed from on region to onother: the most marked changes were observed in the projection zone of vestibular function, and rather weaker changes in the optic zone, while the activity in the orbital zone was almost unchanged. Since the topographic differentiation of the cortex is much simpler in the rat than in the cat, and the localization of vestibular function in its cortex is unknown, in the investigations of Grandpierre cited above, the cortical potentials were evidently recorded from points unrelated to vestibular function. This could explain the difference between the results, as is confirmed by the findings obtained in the control experiments on the rabbits, when the regular pattern of changes in the ECoG in weightlessness described above for the cat was not found.

Information in the literature on the localization of vestibular function in the cortex is conflicting. Some authors localize it in the posterior portion of the suprasylvian gyrus [17], others in the anterior portion of the suprasylvian and ectosylvian gyrus [3, 14]. The results of the present experiments, indicating that the most marked changes in the ECoG during changes in gravitation are observed in the anterior portion of the suprasylvian and ectosylvian gyrus, provide further evidence in support of this latter point of view.

Besides the specific action on the vestibular apparatus, a change in gravitation may have a direct mechanical action on the brain tissue and an indirect action resulting from the disturbance of the hemodynamics. Both these may give rise to changes in the electrical activity of the brain. However, in this case the action of the change in gravitation would be manifested equally in the different parts of the cortex, which was not observed. The presence of identical changes in the optic zone of the cortex was evidently due to the intimate connections between the vestibular and optic analyzers.

Comparison of the ordinary and control investigations showed that the direction of the changes was the same in both cases, although their degree in weightlessness was much greater if preceded by overloading. This is evidently natural, because in both cases there was a reaction to a comparable change in gravitation—a decrease in one case from 1 go to 0, and in the other case from ~2 g to 0.

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