INFLUENCE OF ELECTROMAGNETIC FIELDS ON THE ELECTRICAL ACTIVITY OF RABBIT CEREBRAL CORTEX

M. N. Livanov, A. B. Tsypin, Yu. G. Grigor'ev, V. G. Khrushchev, S. M. Stepanov, and V. M. Anan'ev (Moscow)

Reported at the Conference on Problems of the Electrophysiology of the Central Nervous System, Moscow, 1958
(Presented by Active Member AMN SSSR V.V. Parin)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny Vol. 49, No. 5, pp. 63-67, May, 1960
Original article submitted June 25, 1959

The problem of the effects of electromagnetic fields (EMF) on biological materials is very interesting, since, thanks to the development of technology, humans are increasingly subjected to the influence of such phenomena. In addition, the study of the effects on organisms of weak electromagnetic and magnetic fields is of general biological interest.

The literature contains reports on the sensitivity of various organic systems to electromagnetic fields, particularly on the sensitivity of the nervous system [1, 2, 4, 5, 6, 7].

While studying the effects of x-rays on the central nervous system of the rabbit, we discovered the following facts. In control studies in which the tube emitted neither heat nor x-rays, but with the high voltages maintained, we discovered that the electroencephalogram (EEG) of the rabbit was distinctly modified. Obviously, there could be only two causes underlying these changes: First, the effect of sound produced by the transformer or resulting from unstable leaks; second, the effect of electromagnetic oscillations produced when the tube and input cable were under high voltage.

Complete surgical bilateral exclusion of hearing did not abolish the observed effect. In addition, during "simulated" conditions which reproduced the setting without high voltage, the electrical activity of the brain was completely unaffected. Consequently, our first hypothesis could not explain the recorded phenomena. There remained the second possibility, i.e., the influence of electromagnetic fields. In connection with this, further experiments were directed to the study of the effect of EMF on the central nervous system.

METHODS AND RESULTS

During the experiments animals were placed in a shielded room. The high-voltage transformer was placed outside the room, but the single cable leading from the apparatus was inside the room at a distance of approximately 1 m from the animal. Apparently, the source of EMF was the high-voltage cable from the transformer. The cable had its own capacitance of 50 $\mu\mu$f. In addition, the apparatus had various "parasitic" capacitances shunting the casing of the high-voltage transformer, the high-voltage kenotron, etc. High-frequency oscillations could therefore result from these capacitances and leak along the high-voltage elements, particularly along the cable insulation. All our attempts, however, to determine the parameters of these oscillations (frequency, amplitude, etc.) were not crowned with success.

EMF was produced for various intervals from 8-15 sec. In order to record accurately the onset and termination of EMF, one channel of the oscillograph was connected across a resistance in parallel with the primary winding of the transformer. Biological potentials were recorded with an AC amplifier and another oscillograph channel.

Experiments were conducted on 98 rabbits. Using bipolar electrodes (interelectrode distance approximately 0.5 cm), potentials were led off from the parietal or visual area of the cortex through a trephined cranial opening 1 cm in diameter.

Reaction of the central nervous system to EMF was recorded in 84 out of 98 rabbits. Nearly all cases developed distinct depression of cortical potentials with amplitude reduction of 2-4 times. Intensification of electrical activity, indicated by the appearance of high-amplitude high-frequency oscillations, was recorded in only three animals.

The reaction of the cortex occurred immediately after the onset of EMF, in most cases during the first second (Fig. 1).

Depression of cortical activity usually lasted 2-8 sec, but in some animals it was more prolonged, lasting throughout the EMF interval or even beyond it (Fig. 1).

Frequency changes were observed in all animals. EEG frequency analysis (Bernstein-Livanov method [3]) showed that these changes usually involved the spectral range 1.3-8 cps (Fig. 2).

In order to examine precisely the relations between EMF parameters and reaction of the central nervous system, we set up experiments involving changes in EMF intensity. Both alternating and monotonic intensity

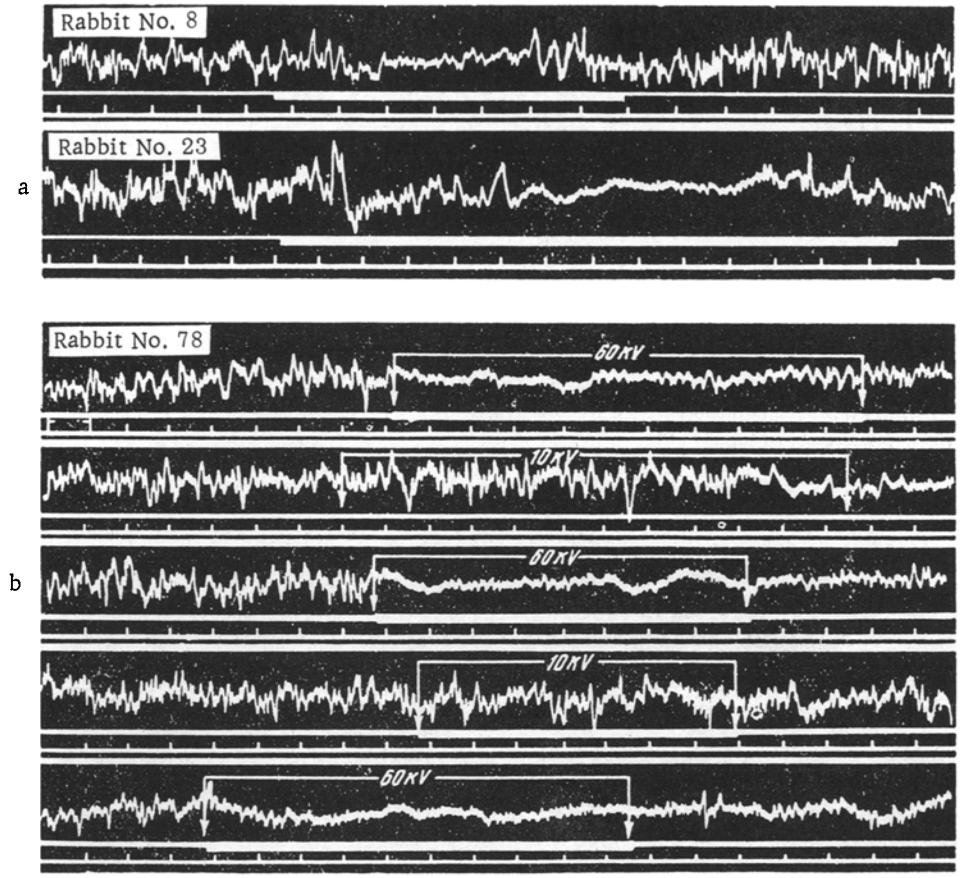

Fig. 1. a) Rabbits Nos. 8 and 23: Changes in electrical activity of the brain during the action of EMF; b) rabbit No. 78 : relation of changes in brain potentials to alternating physical parameters of EMF (10 and 60 kv). Second and third channels mark onset and termination of EMF (thickened lines) and time (1 sec).

sequences were used. Output transformer values were 10, 20, 40, 50, and 60 kv. It was found that changes became more distinct with increased voltages (Fig. 1b).

Experiments involving changes in the distance between the animal and the cable (which was the source of EMF), showed that at 2 m reaction was either absent or very weak; if the animal was placed closer to the cable, reaction intensity of EMF in turn increased the reaction of the central nervous system.

In order to determine the significance of the onset time of EMF from the moment the apparatus was switched on, we conducted experiments with intensity gradually increasing from 0-60 kv in the course of 2-3 sec. It was found that even in this case the reaction was completely maintained. Consequently, EMF is effective throughout the time the transformer is in operation.

We thus obtained experimental evidence concerning the nature of the changes in electrical activity of the cerebral cortex under the influence of EMF. The following facts support the idea that these changes are biological reactions of the brain: First, the reaction, as a rule, had a latent period of 1-2 sec, and sometimes even more; second, during prolonged action of EMF the initial abrupt change in the EEG was in most cases followed by a return to the original state; third, in narcotized animals the reaction, which was formerly distinctly observed, was absent; fourth, control experiments, conducted with dead rabbits, showed that the oscillograph record was not changed when the EMF was switched on. Thus, it is apparent that all the above descriptions are of biological reactions.

In order to examine the primary anatomical locus of the EMF effect, we set up experiments involving exclusion of certain analyzers. This revealed that simultaneous section of the optic nerves, exclusion of olfaction, and also destruction of the vestibular apparatus and hearing did not abolish the EMF effect. Consequently, input to the analyzers obviously does not play an essential role in the response to EMF. However, the possibility that other receptor systems are affected is not excluded.

It is very probable that EMF exerts an immediate influence on the brain. The following fact supports this hypothesis. When potentials were led across bone, i.e., when the cranium was not opened, the EEG changes were much weaker and were not always observed. Actually, these experiments do not exclude the possibility that the

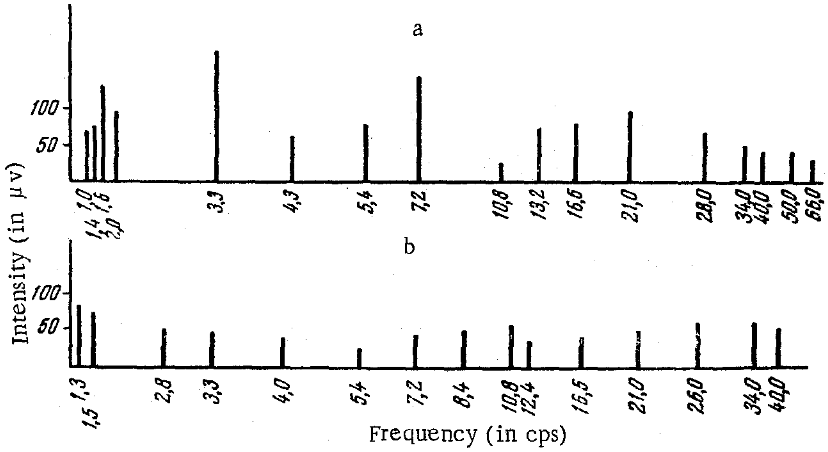

Fig. 2. Analysis of EEG of rabbit exposed to action of EMF. a) Before action; b) during action.

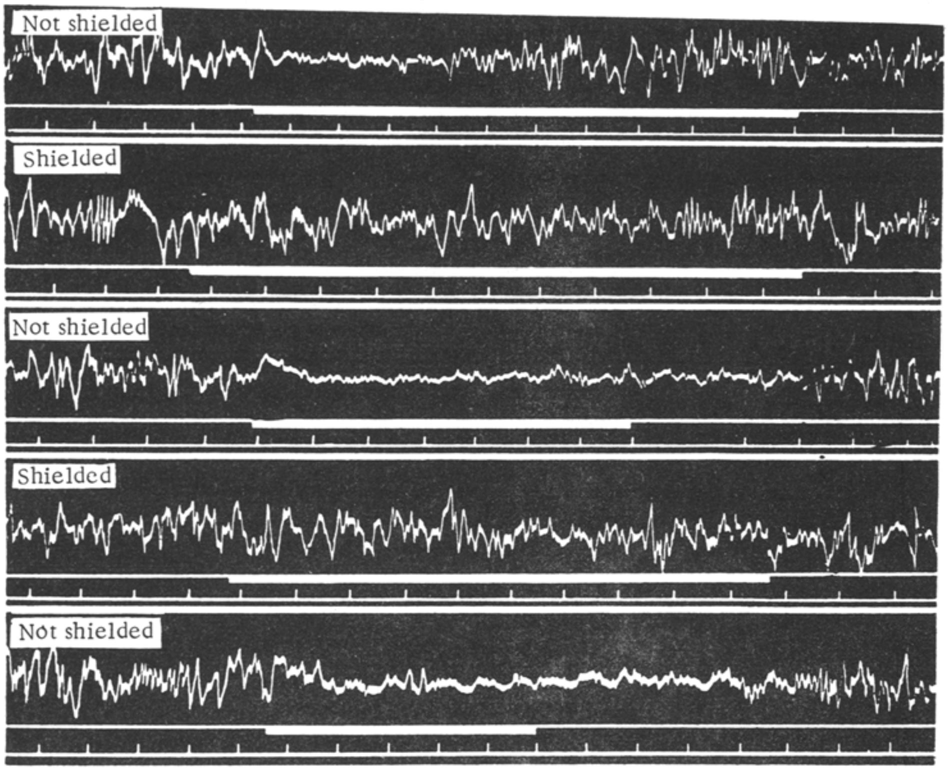

Fig. 3. Influence of shielding the animal on the effect of EMF. Alternate action of EMF with and without shield (rabbit No. 84). Time channels same as in Fig. 1.

increased sensitivity of the brain to EMF results from an augmentation of excitability of neural tissue following trephination.

In addition, it was assumed that the EMF influence on the central nervous system might possibly be due to a direct action of EMF on the recording electrodes; this condition would also cause direct stimulation of the brain. Specifically designed experiments, however, completely excluded this possibility. These experiments, in which the recording electrodes were shunted to ground by condensers of various capacitances (up to 1μf), showed that under such conditions the effects of EMF were maintained. In addition, it was found that placing the rabbit in a shield consisting of an iron box with walls 3.5 mm thick abolished the observed effect, regardless of the fact that the recording leads passed through and outside the shield (Fig. 3). Consequently, the EMF in our experiments directly affected the animals and altered the activity of the central nervous system, resulting in distinct changes in the electrical activity of the brain.

SUMMARY

The effect of electromagnetic fields on the bioelectric activity of cerebral cortex was investigated on 98 rabbits. As established, the electromagnetic field provokes signal changes in the electroencephalogram. Increased intensity of the magnetic field raises the reaction of the cerebral cortex. Exclusion of various receptor fields (of hearing, vision, smell, vestibular apparatus) had no effect on the reaction of the brain to the action of the electromagnetic field. This led to a suggestion on the possibility of direct action of electromagnetic fields on the brain .

LITERATURE CITED

1. V. Ya. Danilevskii, Studies on the Physiological Effects of Electric Fields [in Russian] (Kharkov,1900).
2. L. L. Vasil'ev, Russk. Fiziol. Zhurn. 3 , 4 (1921).
3. M. N. Livanov, Trudy Inst. Mozga. Nos. 3-4 (Moscow, 1938), p. 487.
4. F. P. Petrov, Abstracts of Reports of the Fourth All-Union Congress of Physiology [in Russian] (Kharkov, 1930) p. 179.
5. F. P. Petrov, Trudy Inst. Fiziol. im. I. P. Pavlova 1 (Leningrad, 1952), p. 369.
6. E. V. Selivanova and G. M. Erdman, Biofizika 1, 412 (1956).
7. Yu. A. Kholodov, Physiological Analysis of the Effects of Magnetic Fields on Animals (Author's abstract of Master's Thesis) [in Russian] (Moscow, 1958).