CHANGES IN THE ELECTROENCEPHALOGRAM OF THE RABBIT IN A CONSTANT MAGNETIC FIELD

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Many investigations have been made of the effect of a constant magnetic field (CMF) on plants and animals at different levels of the scale of evolution [7]. Some workers consider that the CMF has no biological action, even when some form of effect is observed during its application; this effect is attributed to the e.m.f. produced at the moment of appearance and disappearance of the field [1, 4]. However, it has recently been found that the threshold of appearance of phosphene in response to the application of a CMF is determined by the product of the intensity of the CMF and the duration of its impulse [3]; these investigations have the defect that no objective control was provided.

In the present investigation the changes in the electroencephalogram (EEG) evoked in a CMF, which were described earlier by Yu. A. Kholodov [5] and by Becker [6], were studied and an attempt was made, by using this criterion, to analyze the role of the e.m.f. of induction in the observed reaction.

EXPERIMENTAL METHOD

Experiments were carried out on 20 rabbits. The EEG was recorded by a monopolar technique using needle electrodes implanted into the brain (6 animals) or inserted into the bone (14 animals) over the sensorimotor and optic areas of the cerebral cortex. The EEG was recorded on an "Ediswan" ink-writing electroencephalograph. An electromagnet with poles 22 cm in diameter and 16 cm apart produced a uniform CMF with an intensity of 300 Oe. The rabbit's head was placed between the poles. The electromagnet was switched on for 1 min, 20 sec, and 1.5 sec. The EEG was recorded for 1 min before the electromagnet was switched on, during the action of the CMF, and one or several minutes after its action had ceased. In some experiments the EEG was recorded continuously. The intervals between periods of exposure to the CMF were 5-10 min in duration.

EXPERIMENTAL RESULTS

In experiments on six rabbits (604 exposures) the character of the electroencephalographic reaction to the CMF was studied. The following criteria were used for the analysis of the EEG: the number of areas with increased or diminished amplitude relative to a mean for the experiment, the number of spindles, the number of pointed waves, of separate slow waves (with a frequency of 3 cps or less), and of groups of slow waves. For the statistical analysis the alternative variance [10] was used, obtained by dividing the EEG tracing into equal intervals (3-5 sec) and recording the presence or absence of the criteria listed above.

As a result of the statistical analysis it was found that only the number of spindles showed a significant increase. For the sensorimotor area the value of P was less than 0.0005 both during and after exposure. For the occipital region, in which spindles also were occasionally recorded, during exposure the differences were significant ($P < 0.05$), but after the electromagnet had been switched off they were not significant. The other criteria, apart from the number of areas with lowered amplitude, showed only a tendency to increase.

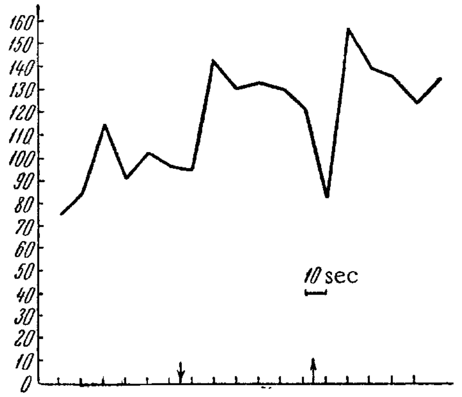

Fig. 1. Change in number of spindles of EEG of the sensorimotor area of the right hemisphere caused by a constant magnetic field (604 exposures). Along the axis of ordinates—absolute number of spindles per 10-second cut; along the axis of abscissas—time (in seconds). The arrows indicate switching the electromagnet on and off.

Consequently, to detect the electroencephalographic reaction of the rabbit to the CMF all that was necessary was to examine the changes in the number of spindles in the sensorimotor region. The changes in the number of spindles caused by the CMF are shown in Fig. 1. An example of the electroencephalographic reaction to the CMF is given in Fig. 2.

An increase in the number of spindles was not observed during every exposure to the CMF. The reliability of the reaction (the ratio between the number of reactions and the total number of exposures, in percent) was 51.99%. In control recordings (260 exposures) changes in the EEG similar to the reactions were observed in 21.57% of cases. Comparison of the reliability of the reactions with the results of the control experiments showed that the difference was significant (P = 0.0005). Changes in the EEG appeared 21.53 ±2.22 sec after switching the electromagnet on and 17.59 ± 2.26 sec after switching it off.

The most marked reaction as regards the difference in the number of spindles before, during, and after exposure was observed when there were from 4 to 7 spindles per minute in the background EEG. If less or more (up to 13) were present, the effect either could not be detected or was slight.

To establish the role of the magnitude of the e.m.f. of induction, arising at the moment of switching the electromagnet on and off, in the reaction of the EEG to the CMF, the field was applied by switching the electromagnet on and off gradually through a rheostat (over a period of 2 sec) and suddenly with a tumbler switch. Direct measurements showed that the e.m.f. of induction arising when the electromagnet was switched on was 5 times greater, and when it was switched off—10 times greater when the tumbler switch was used than when the rheostat was used for this purpose. In three rabbits the CMF was applied 300 times, for 1 min each time, with the electromagnet switched on and off by the rheostat, and 110 times using the tumbler switch. The results of these experiments are given in the table. They show that the reaction was more intensive in the series of experiments in which the rheostat was not used.

Since it was observed that the same rabbits, on different days of the experiment, gave reactions of different intensity to the CMF, it was decided to carry out experiments in which the animals were exposed to a CMF switched on and off alternately by means of the rheostat and the tumbler switch.

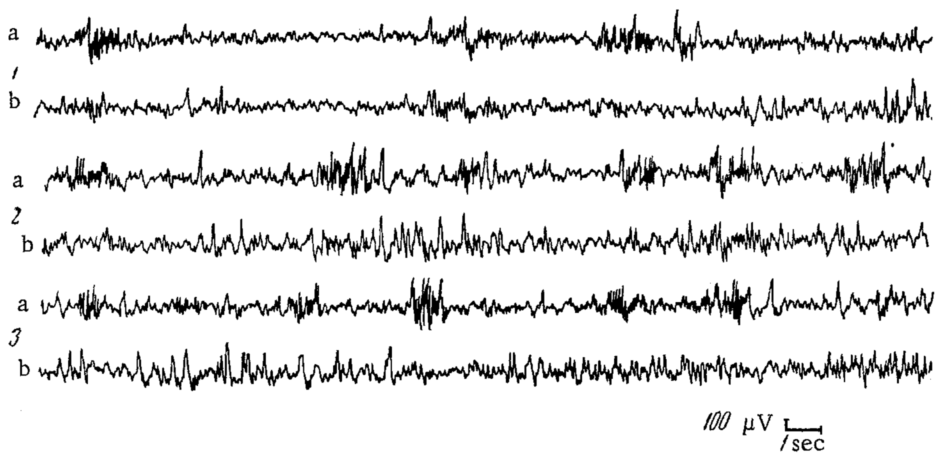

Fig. 2. Changes in EEG of a rabbit caused by a constant magnetic field. 1) Background; 2) during exposure; 3) after switching electromagnet off; a) EEG of sensorimotor area; b) of occipital region.

Results of Analysis of Number of Spindles in Experiments When the Electromagnet Was Switched On and Off through a Rheostat and a Tumbler Switch (1 min of background, 1 min of exposure, and 1 min after switching field off)

Series of expt	Switching procedure	Number of exposures	Back-ground	During exposure			After exposure		
			no. of spin-dles	no. of spin-dles	in-crease in %	P	no. of spin-dles	in-crease in %	P
I	Through rheostat	300	498	653	31,1	<0,025	609	22,3	<0,05
	By tumbler switch	110	36	108	200	<0,0005	79	119,5	<0,05
II	Through rheostat	150	182	281	54,4	<0,05	290	59,3	<0,001
	By tumbler switch	150	219	304	38,8	<0,05	306	39,7	<0,05

Note. The experiments of series I were performed on different days, and in series II the exposures were alternated on the same day.

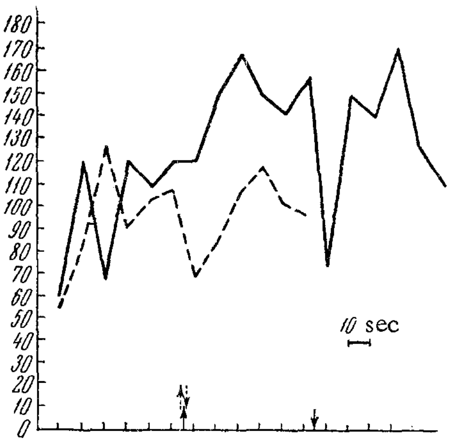

Fig. 3. Changes in the number of spindles evoked by a constant magnetic field with exposures of 1 min and 1.5 sec. Along the axis of ordinates—relative changes in the number of spindles (in %): along the axis of abscissas—time (in seconds). The arrows denote switching the electromagnet on and off.

Five rabbits were exposed 300 times in this way. The results of these experiments are likewise given in the table. In this case, in contrast to the preceding experiments, a more intensive reaction was observed when the rehostat was used.

No difference in the reliability and the latent period of the reaction was observed when the electromagnet was switched on and off through the rheostat and the tumbler switch ($P > 0.05$).

Evidently the five- or tenfold difference in the magnitude of the e.m.f. of induction had no significant influence on the observed reaction, at least with a field of the intensity used.

For further clarification of the influence of the e.m.f. of induction arising at the moment of switching the electromagnet on and off, experiments were carried out on four rabbits. The animals were exposed to the action of the CMF for periods of 1 min and 1.5 sec (150 exposures to each). The electromagnet was switched on and off by a tumbler switch. The two different exposures were alternated on the same days of the experiments. The results of an analysis of these experiments are given in Fig. 3. To facilitate the comparison of the two graphs, the mean number of spindles in 10 sec of background in each series was taken as 100. As Fig. 3 shows, a CMF with an exposure time of 1 min evoked the usual electroencephalographic reaction characteristic of this factor, while a CMF with an exposure time of 1.5 sec (the e.m.f. of induction was present but the CMF lasted for only 1.5 sec) did not produce an increase in the number of spindles; their number actually diminished immediately after exposure. As control experiments showed, switching the electromagnet on and off when disconnected from the power supply did not cause a decrease in the number of spindles. Some reduction in the number of spindles was nearly always observed immediately after switching the electromagnet off, and less frequently, immediately after switching it on. This decrease may be attributed to the effect of the e.m.f. of induction itself or to a weak reaction of the orienting type, or to both. The inconstancy of the reduction on the number of spindles when the electromagnet was switched on was probably associated with a reaction to the CMF or with the fact that, when the magnet was switched on, the magnitude of the e.m.f. of induction was smaller than when it was switched off.

The electroencephalographic reaction under investigation was thus, mainly at least, the result of the action of the CMF and not of the e.m.f. of induction at the moment of switching the electromagnet on and off.

In another series of experiments carried out on seven rabbits, exposures of 20 sec to the CMF were used (200 exposures). During exposure to the CMF for 20 sec only a very slight increase in the number of spindles took place; the reaction failed to develop further. After switching the CMF off practically no increase occurred in the number of spindles ($P > 0.5$), whereas in the case of three rabbits exposed 194 times to the CMF for a period of 1 min the reaction after switching the magnet off lasted approximately 2.5 min. Evidently the development of the reaction during and after exposure to the CMF is possible only if the duration of exposure is long enough.

The results of these experiments do not show directly whether the reaction after switching the electromagnet off is an after effect, and effect separate from the main reaction to switching off, or whether it is an independent reaction. However, it was noted that in cases when a reaction could be observed visually, the electroencephalographic reaction took place only during the exposure or only after switching the magnet off, and it appeared, moreover, after a definite, fairly constant, latent period. This is rather in favor of the second suggestion. The effect of switching off has been demonstrated for several analyzers [8], and in the eye it depends on the duration of illumination [9]. Although the reaction under investigation is one whose appearance and development are measured in magnitudes essentially different from those associated with specific stimuli, and although the question of whether any receptor for a CMF exists or not remains unsolved, the reaction of the animal organism to the CMF may nevertheless be compared with its reactions to other agents. Exposures to ionizing radiation (one type of electromagnetic field) in small doses also evokes an off-reaction [2].

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