BIOCHEMISTRY AND BIOPHYSICS

THE EFFECT OF A PULSED SUPER-HIGH FREQUENCY (SHF) ELECTROMAGNETIC FIELD ON THE HIGHER NERVOUS ACTIVITY OF DOGS

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The effect of an alternating electromagnetic field on the higher nervous activity is a question that has repeatedly attracted the attention of research workers. The study of conditioned reflexes in animals exposed to a super-high frequency field has been carried out, for instance, by N. S. Kharchenko [6], D. Ia. Glezer [1], N. N. Livshits [3] and T. N. Promtova [5].

However the function of the higher divisions of the central nervous system has evidently not been studied in super-high frequency field conditions (centimeter and millimeter wave-bands); in experiments carried out on a single dog by V. A. Alekseev, he was unable to obtain any conclusive results.

Meanwhile the problem of the effect of an SHF field on the cerebral cortex is one of great interest, since microwaves are being used more and more widely in technology and medicine. In addition, persons working with microwave generators are particularly prone to complain of quickly becoming tired and sleepy.

The aim of the present investigation was to determine the changes in the higher nervous activity of dogs during single and prolonged exposure to an SHF field of varying intensity.

EXPERIMENTAL METHODS

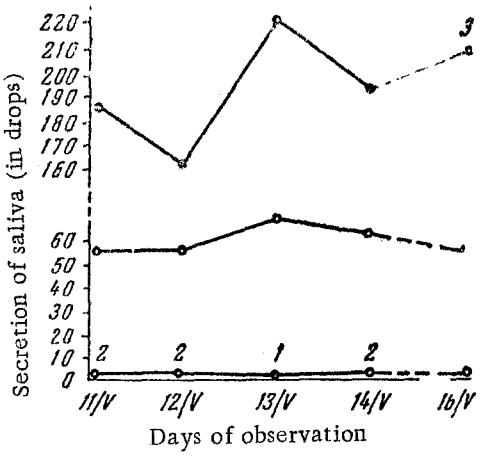
Experiments were carried out on 7 dogs by the classical food-saliva method of I. P. Pavlov. The secretion of saliva in 5 dogs was recorded by means of S. V. Zhevlakov's funnel, improved by us in conjunction with Iu. P. D'iakov. By means of a relay, this funnel enabled the number of drops of saliva to be recorded on paper. In the two remaining dogs the secretion of saliva was recorded on a Ganike-Kupalov scale.

The dogs Jim, Ryzhik and Dick were used first in the experiment; Jack, Trezor, Bel'chik and Orlik had been used earlier to study the interaction of extero- and interoceptive conditioned reflexes. In each dog a stereotype was established and consolidated (see Tables 1 and 2), and the type of its nervous activity determined.

The experiments began with accustoming the animals to the irradiation apparatus. The need for this was due to the fact that the noise of the SHF field generator was quite loud and could have an effect on the conditioned reflexes.

After extinction of the orientational reactions we set about irradiating the animals. For this purpose the dog was placed with the right or left side of its body in front of the SHF field emitter. The distance between the emitter and the animal was varied. The time of action did not exceed 2 hours.

On terminating the irradiation the dog was let out and allowed to walk about for 10-15 minutes, and only after this was it placed in a sound-proof chamber where, in the usual routine, the conditioned reflexes were investigated, always at the same time. From 4-12 days later the irradiation procedure was repeated. In this way the effect of various numbers of exposures was ascertained.



Changes in the secretion of saliva in the dog Trezor in response to a negative (1) and a positive (2) stimulus. Total volume of saliva in 40 seconds with food reinforcement of each signal (3).

In 2 dogs, in addition, the effects of a large number of exposures were studied. For this purpose the animals were exposed daily for over 50 days to the action of the SHF field. Measurements of the intensity of the SHF field at the points where the dogs were placed were made by physicist Iu. P. D'iakov.

EXPERIMENTAL RESULTS

Single exposures. The first experiments already showed that a weak SHF field, causing no signs of heating of the animals (raised temperature, increased rate of respiration, etc.), leads to obvious changes in higher nervous activity. The character of these changes depends on the intensity of the SHF field, the duration of irradiation and the type of nervous system possessed by the animal.

For instance, immediately after irradiation for one hour, and particularly for 2 hours, at a field intensity of about 0.005 w/cm^2, an increase in the secretion of saliva was often observed to positive conditioned stimuli, with relative stability of differentiation. The latent period of the conditioned reflexes was shortened in the majority of cases. As an example may be cited the results of one of the experiments on the dog Trezor (strong, balanced, mobile type of nervous activity). In the figure are shown curves of total secretion of saliva in response to positive (curve 2) and negative (curve 1) stimuli. Curve 3 shows the total volume of saliva in response to food reinforcement of each signal (for 40 seconds). Table 1 gives a detailed picture of the same experiment, showing the results for each stimulus separately.

It can be seen from the results given that on the day of irradiation (May 13) the total volume of saliva in response to positive conditioned signals was increased by 24% (from 54 to 67 drops); on the next day the secretion of saliva was also somewhat raised (61 drops), and on the 4th day it was almost back to its normal level. This increase in the effect took place in response to the action of exteroceptive conditioned stimuli; an interoceptive positive signal [inflation of a rubber balloon in the rectum at the rate of once per second (balloon +)] caused the same volume of saliva both before and after irradiation — 11 drops. Differentiation to a metronome (60 beats per minute; M_{60}) and to the balloon [inflation of the same balloon at a rate of once in 5 seconds (balloon —)] was not disturbed. Unconditioned reflexes were increased immediately after irradiation by 37% in comparison with the basic level.

In Jack, Orlik and especially Bel'chik — dogs with an unbalanced type of nervous activity — phasic phenomena were observed in addition. These were expressed as an increase in the secretion of saliva, mainly on account of weak stimuli, which took place immediately after irradiation for 1-2 hours in a weak SHF field (intensity about 0.005 w/cm^2), and for this reason the volume of saliva in response to the positive signals was evened out. Differentiation either was improved if it was incomplete, or was inhibited if it was absolute (experiment by Z. P. Sukhova).

In the dog Dick (strong, balanced, mobile type) and Jim (weak type) under the same conditions of irradiation most commonly an opposite picture was observed: suppression of salivatory reactions to positive signals and inhibition of differentiation.

It must be emphasized that the effects of irradiation with an SHF field of low intensity depend largely on the initial functional condition of the cerebral cortex. In cases where the excitation of the cortex was lowered, obvious stimulating effects appeared. Where, on the other hand, the cortical activity was high, depression of the reactions to the positive signals and inhibition of differentiation took place. As an example we may quote the result of Z. P. Svetlova's experiment on the dog Ryzhik (weak type). In this dog, after prolonged working with the same stereotype of stimuli, drowsiness appeared when it was placed in the chamber, and the animal reacted hardly at all to conditioned and unconditioned signals.

TABLE 1

Results of Experiments to Investigate the Changes in the Higher Nervous Activity of the Dog "Trezor" When Irradiated in an SHF Field

Stereotype	Initial level				Irradiation for 1 hour		After irradiation			
	11/V 1955		12/V 1955		13/V 1955		14/V 1955		16/V 1955	
	latent period (in seconds)	conditioned reflex secretion of saliva (in drops during 20 seconds	latent period (in seconds)	conditioned reflex secretion of saliva (in drops during 20 seconds	latent period (in seconds)	conditioned reflex secretion of saliva (in drops during 20 seconds	latent period (in seconds)	conditioned reflex secretion of saliva (in drops during 20 seconds	latent period (in seconds)	conditioned reflex secretion of saliva (in drops during 20 seconds)
M_{120}	3	12	3	10	3	15	4	11	5	11
Balloon	4	11	3	11	4	11	3	10	3	11
Bell	2	11	2	11	2	13	3	14	8	10
Light	3	6	5	5	4	8	5	8	4	8
M_{60}	6	2	12	1	13	1	5	1	14	2
Balloon	—	0	16	1	—	0	15	1	—	0
Light	8	5	4	5	8	7	3	7	4	6
Bell	5	9	3	12	3	13	4	11	6	9
Total (in response to positive signals)	—	54	—	54	—	67	—	61	—	55

TABLE 2

Results of Experiments to Investigate the Changes in the Higher Nervous Activity of the Dog "Ryzhik" When Irradiated in an SHF Field

Stereotype	Initial level				Irradiation for 1 hour		After irradiation	
	7/VI 1957 г.		11/VI 1957 г.		12/VI 1957 г.		13/VI 1957 г.	
	latent period (in seconds)	conditioned reflex secretion of saliva (in drops) during 20 seconds	latent period (in seconds)	conditioned reflex secretion of saliva (in drops) during 20 seconds	latent period (in seconds)	conditioned reflex secretion of saliva (in drops) during 20 seconds	latent period (in seconds)	conditioned reflex secretion of saliva (in drops) during 20 seconds
Bell	5	2	—	0	3	12	12	6
M_{120}	—	0	—	0	6	5	6	2
M_{60}	—	0	—	0	—	0	—	0
Light	—	0	—	0	—	0	—	0
Bell	—	0	13	1	—	0	—	0

It is shown in Table 2 that on a background of sharp inhibition, irradiation with a weak SHF field completely restored the reactions to the two first stimuli. After the application of differentiation to one stimulus, disinhibition did not take place.

Prolonged irradiation. During prolonged irradiation of dogs with a weak SHF field (intensity about 0.005 w/cm^2) changes arise in their higher nervous activity similar to those observed during single exposures. However under these new conditions fresh details appeared. In the dog Jack (strong, balanced, mobile type), for instance,

TABLE 3

Conditioned Reflex Secretion of Saliva in the Dog "Jack" (in drop)

Stereotype	Initial level	Exposure for 2 hours a day, 36 hours altogether																						After effects							Additional exposures, 70 hours altogether				
	2/VI	3/VI	4/VI	6/VI	7/VI	8/VI	9/VI	10/VI	11/VI	13/VI	14/VI	15/VI	16/VI	17/VI	18/VI	20/VI	21/VI	22/VI	23/VI	24/VI	25/VI	27/VI	28/VI	29/VI	30/VI	2/VII	5/VII	16/VIII	16/VIII	17/VIII	23/VIII
M_{120} . .	8	8	12	12	15	14	17	16	14	15	11	15	14	14	15	15	13	14	8	12	12	14	11	9	13	8	—	—	13	12	10
Light . .	5	5	8	10	9	13	14	12	13	13	12	10	10	15	12	12	11	8	9	9	11	10	10	9	8	9	—	—	6	6	6
Balloon+	8	8	9	9	14	13	14	16	14	14	11	12	12	14	14	13	10	10	8	12	8	11	11	10	9	8	—	—	8	8	8
Balloon	0	1	1	0	2	2	1	1	2	0	2	1	0	2	2	1	1	1	1	1	1	2	0	0	1	2	—	—	2	0	2
M_{60} . . .	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	—	—	0	0	0
M_{120} . . .	8	5	6	8	9	8	7	11	3	7	0	4	6	7	7	7	6	4	4	4	4	5	4	3	5	4	—	—	0	6	6
Light . .	3	6	7	7	12	11	6	8	10	10	7	7	11	11	11	10	9	9	8	7	7	8	7	7	8	7	—	—	4	5	6
Bell	10	10	11	10	13	14	15	12	14	15	13	11	12	14	12	13	13	10	13	12	13	13	13	12	10	12	—	—	10	8	9

in the course of the first 4-5 days, as irradiation was repeated (for 2 hours a day) a growth was observed in the conditioned reflex secretion of saliva from day to day (cumulation). Next, for several days the positive conditioned reflexes remained at a high level. Later on, as the exposures continued the magnitudes of the positive conditioned reflexes gradually fell to their original level, especially after an additional 35 day period of irradiation. Differentiation (M_{60} and balloon −) was disinhibited either not at all or only slightly.

From a comparison of the action of the conditioned stimuli separately it may be seen that, in the first place the secretion of saliva grew mainly on account of weak stimuli (Table 3). At the 4th-5th exposure, for instance, e.g. at the period when the effect of the irradiation has reached its peak, the secretion of saliva in response to the light stimulus was almost 3 times as great as that before irradiation; the secretion in response to M_{120} and to the balloon + was almost twice as great, and in response to the strongest stimulus − the bell − the increase in secretion of saliva was insignificant. As a result there was some approximation of the effects to weak and strong stimuli (equalizing phase). On some days paradoxical phenomena were observed. Such phasic effects were also observed on the last days of irradiation in the first series of experiments; however at the end of an additional 35 day period of irradiation there were no abnormalities in their strength relationships. In the second place, the secretion of saliva in response to an interoceptive stimulus (balloon +) did not increase on the 1st day, as in response to exteroceptive signals, but usually only on the 3rd and even on the 6th day. In the third place, in response to a positive stimulus M_{120}, following differentiation, the increase in the volume of saliva in the course of irradiation was far less than that to the same M_{120} when occupying a leading place in the stereotype. Starting with the 5th irradiation, the opposite picture could even be observed − depression of saliva secretion to this stimulus. This may clearly be seen from a comparison of the figures shown in Table 3 (compare M_{120} occupying first place in the stereotype).

Further, if some degree of disinhibition may be present, it was only observed in response to the first negative stimulus of a pair. The second differential signal (M_{60}) resulted in a zero reaction almost every day. Finally a shortening of the latent period of the conditioned reflexes could be observed, but only at the beginning of a large number of exposures.

After analyzing the material obtained we came to the conclusion that it was not possible to speak of

full restoration of conditioned reflex activity during continuing exposure to irradiation; only partial adaptation of the cerebral cortex to the action of the SHF field can be suggested.

In another dog, Jim, with a weak type of nervous activity, the changes in the conditioned reflexes were fluctuating in character: in the first 2 days of irradiation the volume of saliva secreted in response to a conditioned signal gradually fell, then grew for a few days, again fell and so on. Differentiation, which in this dog was incomplete, even improved during irradiation. However, as in the preceding dog, phasic changes were observed in this case also, with a gradual evening out of the conditioned reflex activity as the irradiation continued.

It must be pointed out that signs of adaptation were observed in the behavior of animals exposed to many repeated exposures to irradiation. These were shown by a certain restlessness of the dogs on the first days of irradiation only, after which, in spite of continuation of the exposures, this disappeared.

Thus a weak SHF field (intensity about 0.005 w/cm^2) when applied on single occasions or frequently, exerts mainly a stimulating effect on the conditioned reflex activity of animals. Of fundamental importance here are the number of exposures to irradiation, the original functional state of the animal and the type of its nervous activity.

Single intensive irradiation. An intensive SHF field (intensity about 0.1 w/cm^2), in contrast to a weak field, caused pronounced signs of heating of the animal (raised temperature, shortness of breath, salivation and so on). Under these circumstances the positive conditioned reflexes, especially in a dog of weak type, almost always were depressed, and differentiation was disinhibited. The latent period of the conditioned reflexes was usually lengthened. Phasic phenomena were seen even more commonly than with exposure to weak fields. Normalization of the conditioned reflex activity after single exposures of 2 hours to an intensive SHF field (intensity about 0.1 w/cm^2) appeared on the 4th-5th day. The unconditioned reflexes, on the other hand, were hardly changed or else increased.

The relationships described were shown quite clearly during irradiation both of the side from which the flow of saliva was drawn and of the opposite side.

Thus the direction of the changes during intensive irradiation was in the majority of cases opposite to that observed after exposure to weak fields.

The dependence of the effect of irradiation on the initial functional state of the animal was clearly evident during exposure to an intensive field also. In the same dog, Ryzhik, for instance, which as we have pointed out fell asleep in the chamber, the conditioned reflex activity was restored completely to normal by intensive irradiation: the positive conditioned reflexes were disinhibited and the animal began to take its food greedily.

Experiments with single exposures of dogs to irradiation show that a weak SHF field usually intensifies the excitatory process. Active inhibition is evidently more stable under these conditions.

Experiments with large numbers of exposures to irradiation indicate the possibility of adaptation of the cortex to the SHF field. However complete adaptation does not evidently take place to this stimulus, as shown by the phasic phenomena and the intensification of successive inhibition (a fall in secretion of saliva in response to M_{120} when applied after differentiation) during frequent exposures to irradiation. At the same time cumulation of the changes caused by irradiation obviously takes place.

An intensive SHF field, conversely, weakens both the excitatory and inhibitory processes, since it diminishes the magnitude of the conditioned reflex and disinhibits differentiation. These changes are most probably connected with the heating of the animal. A local thermal action of the SHF field on the salivary gland cannot, of course, be excluded; however this obviously has no essential significance, since if the area of the gland alone is irradiated the conditioned reflexes are unchanged.

It is more difficult to account for the action of the weak SHF field, in which neither the rectal not the subcutaneous temperatures are changed. Here either a specific thermal action (heating of only certain tissue structures) or a purely specific action of the electromagnetic waves may be postulated. In one way or another the changes in the higher nervous activity may follow along 3 lines: 1) on account of the direct penetration of electromagnetic waves into the brain; 2) reflexively, on account of stimulation of the receptor apparatus; 3) by a humoral-chemical route. This mechanism in respect of the SHF field has been suggested previously [2].

SUMMARY

The process of excitation is, as a rule, intensified in dogs on the background of relative stability on active inhibition in dogs submitted to a weak (pm about 0.005 wt per cm^2) SHF alternating power field for 2 hours (about 0.005 wt per cm^2).

Repeated numerous actions of such a field bring about development of phasic conditions. The phenomena of cumulation and partial adaptation to SHF field are observed. On the contrary, in high intensity of the action causing a thermal effect with SHF alternating power field (equal to about 0.1 wt/cm^2) a weakening of conditioned reflex reactions are observed with a disinhibition of differentiations.

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