EFFECT OF STEADY CURRENT STIMULATION OF CEREBRAL CORTEX ON MOTOR ACTIVITY OF STOMACH

(UDC 612.337-063:612.825.014.424)

Yu. A. Grinshtein

Pedagogic Institute, Borisoglebsk
Presented by Active Member AMN SSSR V. V. Parin
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 59, No. 1, pp. 15-19, January, 1965
Original article submitted August 13, 1963

The problem of cortical control of interoceptive reflexes has been the subject of many investigations [7, 8, 9] in which conditioned reflex methods were used.

Another method of studying the influence of the cortex on these reflexes is to produce changes in the state of the cortex by direct stimulation and study resultant changes in the reflexes. Bekhterev and Mislavskii [4] have already shown that direct electrical stimulation of the cortex has an effect on the motor functions of stomach and intestine.

Cortical excitation may manifest itself either as rapid, discrete oscillations of potential or as longer, slower waves. The latter are thought by Rusinov [20] to reflect Vvedenskii's "stationary excitation." It has been shown in Rusinov's laboratory that long changes in potential on the surface of the cortex develop during the elaboration of conditioned reflexes and also as a result of cerebral trauma. Action of a steady current on the cerebral cortex is known to produce similar potentials. A focus with all the properties of a dominant focus is formed; the changes developing are similar to those occurring during the creation of a temporary connection. A steady current affects the cortex much in the same way as certain pharmacological substances [5].

In this investigation the cerebral cortex was stimulated directly with steady current and any associated changes in gastric movements elicited by mechanoreceptor stimulation were observed.

METHOD

Dogs with fistulas of the fundal part of the stomach were used. A silver electrode in an insulated plug was fixed in the cavity of the skull 12-20 days before the experiments. The stomach was washed out with warm water immediately before an experiment. A rubber balloon, introduced into the stomach, served to record movements induced by stretching of its walls; it was filled with water (150-300 ml) and connected to a Marey tambour. The intragastric pressure was measured with a water manometer in some experiments.

The animals were last fed 20 h before an experiment as it has been observed that interoceptive reflexes in the digestive tract differ in satiated and hungry animals [14]. Conditions were standardized by the emptying of the stomach prior to introduction of the balloon. It was also intended to exclude structural changes in cortical cells, which have been observed after 48 h starvation [15].

The cerebral cortex was stimulated with steady current in 56 experiments on 4 dogs. The point electrode was located over the parietal cortex and the 2nd electrode, measuring 10 × 15 cm was applied to the skin in the cervico-occipital region. The positions of the implanted electrodes were determined exactly after death. The action of steady current on the cortex continued for periods of from 60-120 sec in the various experiments. The experiments on each dog extended over periods of from 2-4 months.

A special experiment in which it was hoped to determine the mechanism responsible for the contractions observed was carried out on one dog. In order to obtain evidence that these were not "hunger" contractions, the dog's

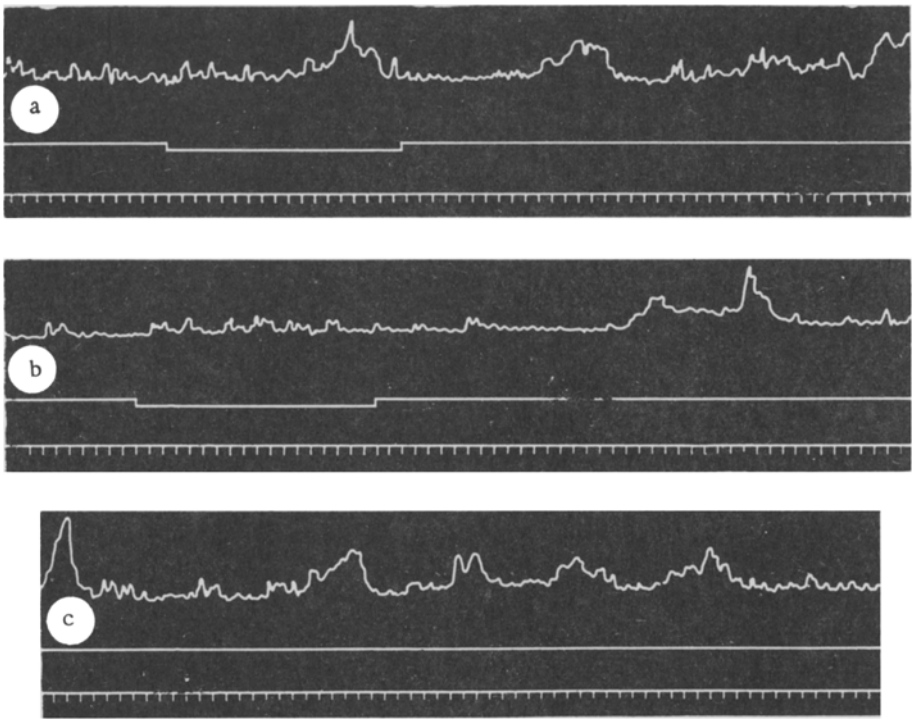

Fig. 1. Intensification of gastric contractions on anodal stimulation of the cortex. a) Current strength 1 mA, duration of stimulation 1 min 30 sec; b) current strength 2.5 mA, duration of stimulation 1 min 30 sec; c) motor activity of stomach 15 min after anodal galvanization of cerebral cortex (continuation of kymogram b. Tracings from top to bottom: stomach movements, stimulation, time (5 sec).

stomach was washed out with warm water and the periodic contractions developing every 2-2.5 h were recorded by means of a small balloon. These gastric movements lasted 20-25 min and resembled classical "hunger" contractions. A large rubber balloon was then introduced into the stomach through the fistulous opening in one of the periods of "rest" and 200 ml water was then introduced into the balloon. This elicited vigorous gastric contractions which continued for 3 h.

RESULTS

Moderate stretching of the stomach walls by the balloon induced active contractions of its musculature (4 to 6 contractions per min) soon after the commencement of stimulation. These contractions continued actively for 3-4 h and at some time during this period the cortex was stimulated.

The effect of stimulation depended on its polarity. When stimulation was effected with the anode of a steady current, the amplitude of the gastric contractions was increased in 63% of experiments (Fig. 1), reduced in 4% and unchanged in 33%. The effect began after a latent period of up to 5 min. The change in the motor activity of the stomach persisted for a considerable time and, in some instances, normal conditions had not been restored on the following day.

Cathodal stimulation of the cortex with steady current inhibited gastric movements in a considerable proportion of experiments (Fig. 2); increased motor activity was observed in only 9%. The latent period of the effect was from 5 sec to several minutes. The after-effect was of shorter duration than in the case of anodal stimulation, but in some instances gastric motor function did not become normal again for several hours.

Kurtsin [13] expresses the opinion that the motor activity induced in the stomach by stimulation of its mechanoreceptors is an interoceptive reflex. The results obtained in these experiments were therefore tentatively compared with observations made in investigations dealing with other interoceptive reflexes. There is agreement between our findings and those of Kovaleva [10] who noted inhibition of interoceptive reflex changes in blood pressure and respiration by cathodal galvanic stimulation of the cortex.

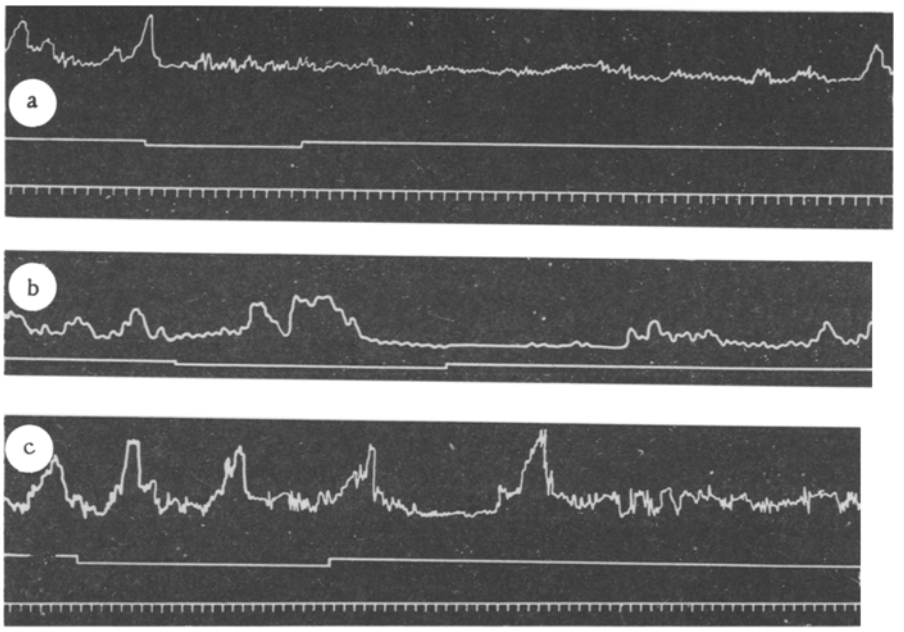

Fig. 2. Effect of cathodal stimulation of cortex on motor activity of stomach. a) Current strength 2.5 mA, duration of stimulation 60 sec; b) current strength 3 mA, duration of stimulation 2 min; c) current strength 4 mA, duration of stimulation 1 min 30 sec. Tracings from top to bottom: stomach movements, stimulation, time (5 sec in a and c; 1 sec in b).

Cathodal stimulation of the cortex inhibited gastric contractions in our experiments. Observations made by Blagodatova [5] would suggest that these cathodal effects may be of the type of "cathodal parabiosis." Such inhibition may be the result of overstimulation of cortical cells, already weakened by the cranial trauma inflicted at the time of operation, by the presence of the electrodes and by starvation prior to the experiment.

A different inhibition mechanism is also possible. A focus of stationary excitation, with the features of a dominant focus, may be produced in the cortical cells by the stimulation [18, 19]. According to Ukhtomskii [23], a dominant focus inhibits other reflexes.

The anode had an effect opposite to that of the cathode. Experiments carried out by Naumova [18] have shown that anelectrotonus increases the rate of potentials by creating a dominant focus in the cerebral cortex. It may be that the anode has the effect of restoring inhibited conductivity in the central nervous system just as at the periphery, as suggested by Rusinov [20]. The anode in our experiments may possibly have facilitated the conduction of impulses from cortex to lower centres capable of intensifying gastric contractions.

While in general the anode intensified and the cathode inhibited, in certain cases both poles produced the same effect. Similar observations have been made by Sokolova [21] and Naumova [18]. It must be remembered in this connection that the mere introduction of a balloon into the stomach alters the functional state of the cerebral cortex [2, 6, 12, 13, 16, 17, 22]. The presence of electrodes within the cavity of the skull may also modify the excitability of the cortical cells. This has been observed to affect higher nervous activity and to cause autonomic disturbances [11]. During the first 2 weeks, electrodes implanted in the cortex produce phasic changes in its excitability and may create a parabiotic [3] or a dominant focus [20].

These various considerations would apparently explain the well-known dissimilar forms of reaction to electrical stimulation. Further, the effects produced by concomitant factors (implanted electrode, presence of the balloon, hunger etc.) do not vitiate the conclusion that polarity of stimulation is of great significance, a conclusion which can justifiably be drawn from these experiments. The small percentage of contradictory results and the absence of any regular relationship between the results of stimulation and length of time between experiments or time since operation are, in our opinion, evidence in support of this. It may also be noted that our results are very similar to findings on the effects of electrical stimulation of the cerebral cortex in other animals [3, 10].

Reference may also be made to the histological and histochemical investigations of Aleksandrovskaya [1] in which it was shown that changes occurred in nerve cells and synapses at the tips of implanted electrodes. These changes were only very slight after 14 days and could no longer be observed after 15 months.

The prolonged after-effect produced by anodal stimulation of the cortex merits attention. A similar after-effect has been observed by Rusinov [20]. This phenomenon might possibly be explained by the peculiar "memory" of the cortical cell, discovered by Morell [24] in investigations on single neuron potentials in a segment of cortex in a state of anodal polarization.

SUMMARY

Experiments were performed on 4 dogs with gastric fistulae and electrodes implanted into the cranial cavity. The author studied the effect produced by the changes of the functional state of cerebral cortex under the effect of direct current on the gastric contractions, caused by stimulation of its mechanoceptors.

In stimulation of the cerebral cortex by direct current the contractions of the stomach changed in relation to the polarity of the stimulus. In the majority of experiments anode caused an increase of the amplitude of gastric contractions (63%). A reverse effect occurred in 4% of the experiments. The changed reflex persisted for a prolonged period of time after the termination of stimulation. In the greater number of the experiments the cathode reduced the motor function of the stomach.

LITERATURE CITED

1. M. M. Aleksandrovskaya, Zh. Vyssh. Nervn. Deyat. 4, 727 (1962).
2. P. T. Andrenko and N. V. Bratus, Fiziol. Zh. SSSR 2, 151 (1959).
3. N. I. Arlashchenko and G. M. Erdman, Fiziol. Zh. SSSR 1, 22 (1957).
4. V. Bekhterev and N. Mislavskii, Med. Obozr. Sprimona 33: 2, 185 (1890).
5. E. T. Blagodatova, Fiziol. Zh. SSSR 8, 948 (1960).
6. I. A. Bulygin, Byull. Éksp. Biol. 29: 1, 26 (1950).
7. K. M. Bykov, Arkh. Biol. Nauk. 54: 5, 3 (1939).
8. K. M. Bykov, Cerebral Cortex and Viscera [in Russian], Moscow and Leningrad (1944).
9. K. M. Bykov and I. T. Kurtsin, Corticovisceral Theory of the Pathogenesis of Ulcer [in Russian], Moscow (1952).
10. G. A. Kovaleva, In: Physiology of Interoception, Moscow and Leningrad 1 (1959), p. 255.
11. A. B. Kogan, Electrophysiological Examination of the Central Mechanisms of some Compound Reflexes. Moscow (1949).
12. I. Kurtsin, Fiziol. Zh. SSSR 25: 6, 885 (1938).
13. I. T. Kurtsin, Gastric mechanoreceptors and Functioning of the Digestive Apparatus, Moscow and Leningrad(1952).
14. N. A. Lapshin, In: Experimental Biology and Medicine. Moscow (1952), 2, p. 9.
15. S. V. Levin, Byull Éksp. Biol. 4, 36 (1952).
16. P. O. Makarov, Byull. Éksp. Biol. 26: 8, 113 (1948).
17. N. A. Moiseeva, Sci. Papers of Inst. Physiol. Moscow and Leningrad (1952), Vol. 1, p. 93.
18. T. S. Naumova, Fiziol. Zh. SSSR 4, 361 (1956).
19. L. A. Novikova, V. S. Rusinov, and A. F. Semiokhina, Zh. Vyssh. Nervn. Deyat 6, 844 (1952).
20. V. S. Rusinov, Zh. Vyssh. Nervn. Deyat. 5, 776 (1961).
21. M. E. V. Sokolova, Mechanisms of Diencephalic Influence on Motor Apparatus and Cardiovascular System [in Russian], Dissertation. Leningrad (1951).
22. E. S. Tolmasskaya, Byull. Éksp. Biol. 26: 12, 413 (1948).
23. A. A. Ukhtomskii, Russk. Fiziol. Zh. 6: 1-3, 31 (1923).
24. F. Morell, Fiziol. Zh. SSSR 3, 251 (1962).