SYMPATHETIC INFLUENCES ON THE ACTIVITY OF THE CEREBRAL CORTEX

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We now know that all forms of cortical activation are associated with ascending generalized influences from the reticular formations of the brain stem, the thalamus, and other subcortical structures [16, 14, 3].

Some writers, however, on the basis of experimental stimulation and division of the sympathetic nerves, have postulated the existence of an additional trophic, activating influence of the higher sympathetic centers on the cerebral cortex [11, 8]. It is usually accepted that sympathetic influences proceed from the higher sympathetic centers of the cerebrum and cerebellum into the spinal cord, and along the rami communicantes to the sympathetic trunk, where they relay in the superior cervical ganglion and return to the brain along the carotid nerve. The carotid nerve forms the carotid plexus and ramifies along the course of the branches of the internal carotid artery, and in this way gives the brain tissue a sympathetic innervation.

The influence of the cervical sympathetic nerves on the cerebral cortex has been studied both by using the classical conditioned-reflex method [5] and by means of electroencephalography [1], although no agreement has been reached concerning the character of this influence, or even of its actual existence. If convincing evidence of its existence were obtained, it would probably necessitate a reexamination of many aspects of our views on the mechanisms of activation. We were interested in the application of certain new tests in order to solve the problems of the activating influence of the sympathetic nerves on the cerebral cortex.

In the present study, acute experiments were performed on rabbits under nembutal anesthesia (40 mg/kg) and investigations were made of the action of division and stimulation of the cervical sympathetic nerves below the superior cervical ganglion on the components of the induced potentials, on the EEG, and on certain autonomic indices: the respiration, blood pressure, and electrocardiogram.

EXPERIMENTAL METHOD

The undivided sympathetic trunk or its cranial end was stimulated by means of rectangular electrical impulses of duration 0.2-1.0 millisec, voltage 3-12 V, and frequency 20-30 cps. According to Larrabee and Posternak [15], the transmission of these frequencies in the superior cervical sympathetic ganglion is depressed hardly at all as a result of the resorptive action of nembutal. The effect of dilatation of the pupil was used as a control.

The induced potentials in the sensomotor region of the cortex in response to stimulation of the sciatic nerve (0.5-1.0 millisec, 5-10 V) were recorded from its surface by silver ball electrodes; the same electrodes were used to record the EEG. Respiration was recorded pneumographically, and the blood pressure in the femoral artery by means of the "Barovar" electromanometer. For recording the electrocardiogram needle electrodes were implanted into the fore-paws of the rabbit. The sympathetic and sciatic nerves were stimulated by means of a "Physiovar" electronic neurostimulator. The EEG and all the autonomic indices were recorded by means of an "Alvar" ink-recording 17-channel polygraph, and the induced potentials on a universal four-channel "Biophase 2-4" apparatus made by the same firm. In the experiments we used 13 rabbits weighing from 2 to 3.5 kg.

In an anesthetized rabbit the cervical sympathetic nerve was dissected and placed on special buried electrodes; the rabbit's head was fixed in a stereotaxic apparatus.

EXPERIMENTAL RESULTS

The background pattern of the cortical electrical activity was usually one of "synchronization," i.e., slow waves with more or less well marked bursts of spikes. The respiration rate varied with the depth of anesthesia. It usually amounted to 32-40 respiratory movements per minute, but in deep anesthesia it sometimes fell to 12. The arterial pressure in the femoral artery ranged between 70 and 80 mm Hg. The heart rate was 220-240 beats per minute.

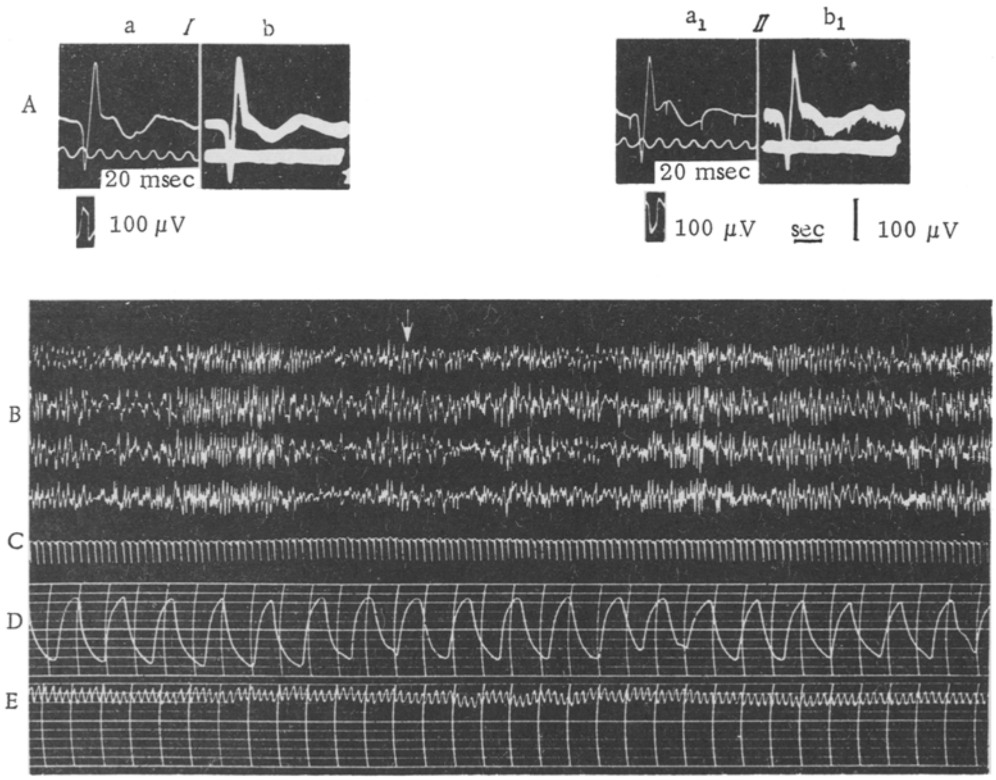

Fig. 1. Simultaneous recording of the induced potentials, EEG, ECG, respiration, and blood pressure before and during stimulation of the undivided right sympathetic trunk. Significance of the curves from above down: A—induced potentials in the right sensomotor cortex in response to single stimuli applied to the left sciatic nerve before (I) and after (II) stimulation of the right sympathetic trunk (artifacts of stimulation can be seen; a, a_1—a single induced potential; b, b_1—10 induced potentials, taken by the method of superimposition; B—EEG: unipolar leads from the right (channels 1 and 2) and left (channels 3 and 4) of the sensomotor cortex. The beginning of stimulation of the sympathetic trunk is indicated by an arrow; C—ECG; D—respiration; E—blood pressure in the femoral artery.

The single stimuli which, when applied to the sciatic nerve (3 per minute), elicited responses in the sensomotor cortex, did not alter the background. The latent period of the induced potentials in the focus of maximal activity was usually 20-25 millisec; the duration of the primary response also was 20 millisec and its amplitude 200-300 μV; the duration and amplitude of the positive and negative phases of the primary response were approximately equal in most experiments. The secondary response, with a duration of 50-70 millisec and an amplitude of 50-100 μV, followed immediately after the primary, or after an interval of 5-10 millisec.

After the background pattern had been established, in eight experiments the undivided sympathetic trunk was stimulated unilaterally. In order to avoid stimulation of the surrounding tissues, which caused desynchronization of the cortical activity in some of the experiments of Holmqvist and co-workers [13], the electrodes were insulated everywhere except at the parts on which the nerve lay. The sympathetic trunk was stimulated for 5-30 min; all the indices were recorded every 3-5 min during stimulation and for 20-30 min thereafter. In five experiments the sympathetic trunk was first divided. In this case the EEG, the induced potentials, and the autonomic indices were recorded before the operation and during the 30 min thereafter; subsequently the cranial end of the trunk was stimulated. In many experiments stimulation was applied more than once, at intervals of 1-1½ h.

Neither division nor stimulation of the cervical sympathetic nerve affected the duration or amplitude of the induced potentials; the EEG, respiration, and blood pressure all remained unchanged (Figs. 1, 2 and 3). In two ex-

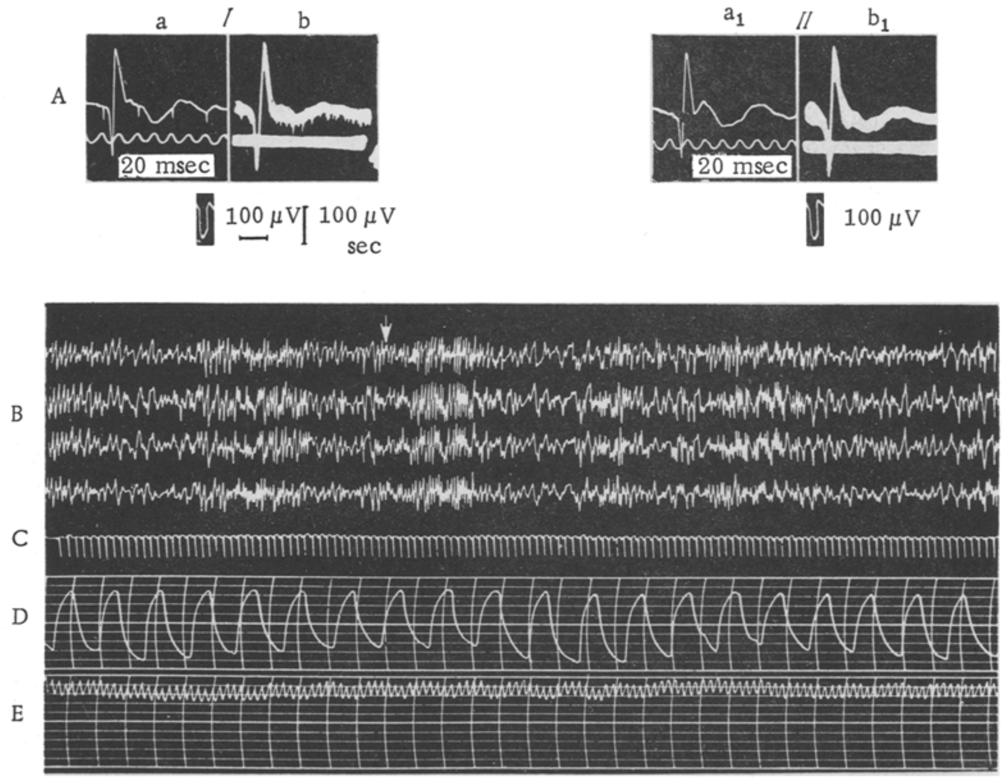

Fig. 2. The same indices as in Fig. 1, at the 18th min of stimulation of the undivided right sympathetic nerve and at the cessation of stimulation (↓). Legend as in Fig. 1.

periments in which the undivided sympathetic trunk was stimulated, at the moment of switching on the current extrasystoles were observed, probably due to an effect on the heart by the superior cardiac nerve, arising from the superior cervical sympathetic ganglion and not always present in rabbits. In the remaining 11 experiments there were no changes in the ECG.

In the face of the possibility that afferent fibers may be present in the composition of the cervical sympathetic nerve [9], we attempted to discover potentials in the cortex induced by single stimuli applied to the trunks (0.5-1 millisec; 5-30 V). We investigated the sensomotor, parietal, temporal, and occipital regions of both hemispheres, but found no responses. At the end of the experiment, in six cases we removed the superior cervical sympathetic ganglia, at first on one side and then on the other as well; these operations likewise had no effect.

Evidence in the literature on the influence of the cervical sympathetic nerves on the cerebral cortex is very conflicting. Ê. A. Asratyan [5], for instance, found the almost complete disappearance of positive reflexes after bilateral division of the cervical sympathetic trunks. G. N. Pribytkova and S. I. Gal'perin [10] observed no changes in the higher nervous activity of the experimental dogs after the same operation, while in M. S. Alekseeva's experiments [2] extirpations of the superior cervical ganglion unilaterally led to disappearance of conditioned defensive reflexes.

It should be mentioned that the magnitude of the conditioned reflexes in all these investigations was estimated by the number of drops of saliva flowing from the ducts of the salivary glands.

T. A. Dolzhenko [7], who observed an increase in the unconditioned and conditioned salivation on the side of the sympathectomy, saw one explanation of this effect in the abolition of the efferent influences of the cervical sympathetic nerve directly on the salivary gland, on which this nerve acts as an inhibitor.

The electrophysiological investigations of A. I. Karamyan [8] and T. N. Sollertinskaya [11] showed that after unilateral and bilateral sympathectomy the slow waves with a frequency of 3-6 cycles per second and a voltage of 70-100 μV in the EEG of the rabbit are replaced by a prolonged (lasting 2-3 months) background "desynchronization," which in the case of unilateral removal of the superior cervical ganglion takes place only in the ipsilateral hemisphere. During this period the EEG shows no reaction to sound or light. These writers observed no desynchronization during stimulation of the sympathetic nerves.

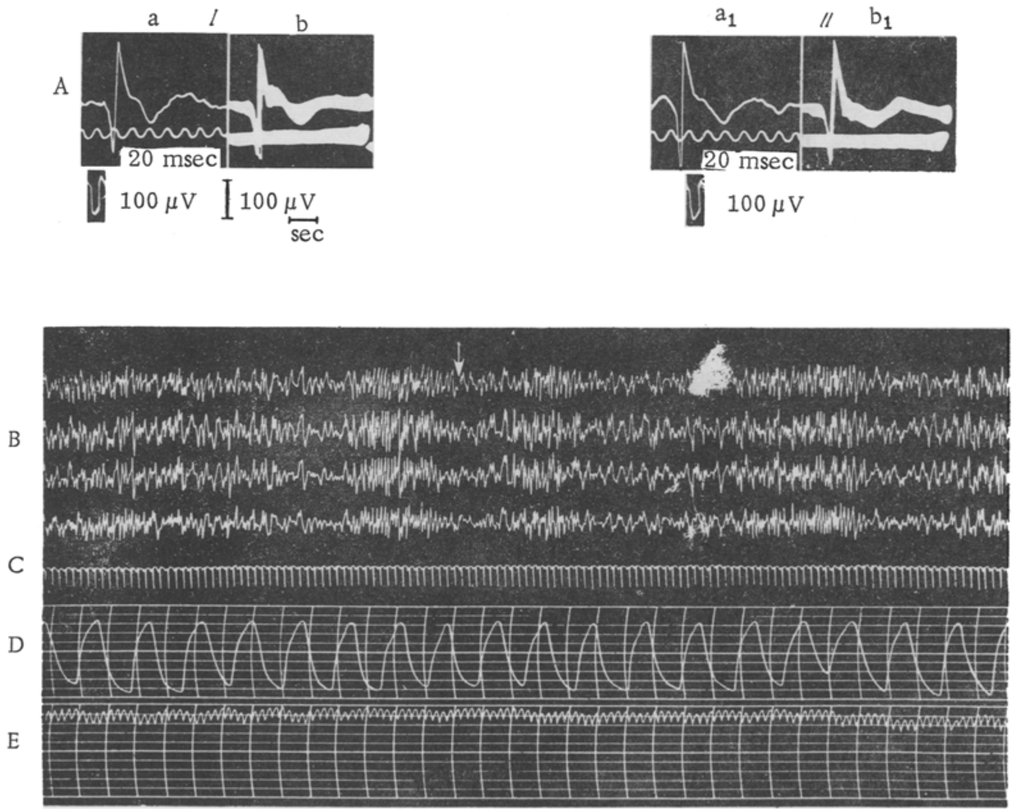

Fig. 3. The same indices as in Fig. 1 after division (↓) of both sympathetic trunks. Legend as in Fig. 1.

A. M. Aleksanyan and R. S. Arutyunyan [1] obtained directly opposite results: during stimulation they obtained "desynchronization," but after extirpation (unilateral or bilateral) of the ganglia they found "an increase in the number of slow waves, accompanied by an increase in their amplitude." The reactions to exteroceptive stimuli were unchanged. Holmqvist, Ingvar, and Siesjö, working with cats, observed no changes in the EEG either after division or after stimulation of the cervical sympathetic nerves [13].

In our previous research [12], we found in chronic experiments that unilateral sympathectomy causes no changes in the EEG of either the contra- or ipsilateral hemisphere in the rabbit. A special frequency analysis showed that there was no difference between the reactions of the contra- and ipsilateral hemispheres to light and sound.

The results of the present investigation are in some agreement with the reports in the literature. Wang T'ai-an and M. G. Belekhova [6], for instance, showed that "stimulation of the sympathetic nerve in the neck, unilaterally, has no action or only an insignificant effect on the primary responses in the auditory cortex caused by stimulation of the medial geniculate body." Judging by the indices we used, the excitability of the respiratory and vasomotor centers is also not under the influence of the sympathetic trunk, which is in agreement with I. P. Anokhina's experimental results [4].

Our experiments thus did not confirm the suggestion, made in the literature, that the cervical sympathetic nerves have a direct efferent influence on the cerebral cortex.

SUMMARY

Acute experiments were staged on rabbits under nembutal anesthesia. Stimulation and section or cervical sympathetic nerves had no effect on the evolved potentials in the sensory-motor cortex in response to stimulation of the sciatic nerve. EEG, the rate of cardiac contractions, respiration and blood pressure also remained unchanged.

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