MECHANISM OF RECIPROCAL INTERACTION BETWEEN TACTILE RECEPTORS OF THE SKIN

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By an electrophysiological method of recording afferent activity of a cutaneous nerve evoked by pinpoint stimulation of the skin, results were obtained indicating the existence of reflex interaction between tactile receptors of symmetrical skin areas. Spinal neurons at the level of segment 8-9 and also efferent somatic and sympathetic pathways are involved in this interaction, and each of them is characterized by the specific nature of its final effect.

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We have previously shown [1] that interaction takes place between spatially separate skin receptors. Activity of the tactile receptors of an investigated area of skin is modified by mechanical stimulation (touching) applied to various parts of the body. These changes vary in direction depending on the point of application of stimulation to the skin. Reciprocal relationships were established between tactile receptors of areas of skin whose underlying muscles also bore reciprocal relationships to each other. Hence, according to our observations, motor reciprocity is supplemented by receptor reciprocity.

The object of the present investigation was to study the mechanism and pathways of interaction between tactile receptors of symmetrical skin areas.

EXPERIMENTAL METHOD

Experiments were carried out on curarized frogs (Rana temporaria). The index of tactile receptor activity was the responses recorded from the cutaneous branch of spinal nerve X (cutaneous branch of n. cruris medialis) to pinpoint subthreshold stimulation of the skin on the dorsal surface of the thigh. Changes in spike responses to adequate stimulation of tactile receptors of the symmetrical skin area for 60 sec were studied. Skin flaps measuring 100 mm^2 were detached from the underlying muscles, remaining only in nervous communication with the animal, the blood vessels having been divided.

In some experiments the tested area of skin was desympathized by devisceration of the animal, extirpation of the sympathetic chain, and careful division of the rami communicantes at the level of the lumbar sympathetic ganglia. In other experiments the sympathetic nerve chain remained intact and the dorsal and ventral roots of spinal nerves IX and X were divided on the side of testing. Electrical activity was recorded by means of a pair of silver electrodes on an "Alvar" myocathograph.

EXPERIMENTAL RESULTS AND DISCUSSION

The experiments showed the existence of a definite inhibitory interaction between the receptors of symmetrical skin areas, manifested by changes in both the frequency and duration of discharge from the investigated receptors.

The experimental results are shown in Fig. 1. By 10 sec after the beginning of stimulation of the symmetrical area the frequency of spikes in the response of the tested receptor fell by more than half, and the duration of discharge fell from 900 to 650 msec. Against the background of continued stimulation the response of the receptors recovered only very slightly. After cessation of stimulation, prolonged inhibition of

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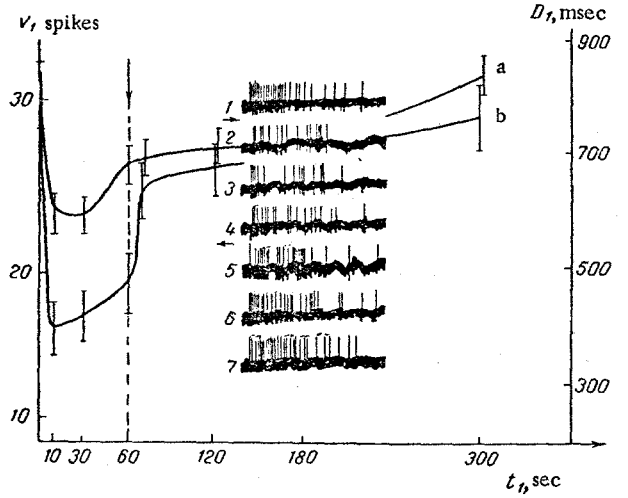

Fig. 1. Changes in frequency and duration of spike response of tactile receptors during mechanical stimulation of symmetrical skin flap. Ordinate: on the right, duration of response (in msec), on the left, frequency of spikes (in sec); abscissa: time (in sec). a) Dynamics of change in response duration; b) dynamics of change in spike frequency. On oscillogram: 1) initial response; 2-4) responses after 10, 30, and 60 sec during stimulation; 5-7) responses 60, 120, and 180 sec after stimulation.

the after-activity was observed. The response regained its initial level after 5-6 min. The duration of the receptor response was less affected by inhibition than the frequency of the spikes.

The inhibitory interaction between symmetrical areas is reflex in nature and disappears after destruction of the spinal cord. It cannot take place unless the spinal segments are intact at the level of entry of the afferent fibers from the tested skin areas.

Division of the postganglionic sympathetic pathways supplying the tested area of skin considerably weakened the effect of "symmetrical inhibition." This was shown by a reduction in its depth to 20-25% and a significant shortening of its duration, to 30 sec. Absence of after-activity also was characteristic (Fig. 2, II).

Division of the ventral and also the dorsal roots at the level of entry of pairs IX and X of spinal nerves, i.e., division of the somatic connections between the spinal cord and tested receptors, while leaving their sympathetic innervation intact, also modified the "sympathetic inhibition" effect. The onset of inhibition under these conditions was delayed and not until 30-60 sec after the beginning of stimulation of the symmetrical area was a maximum (40%) reached. A long after-activity was observed, so that the responses of the receptor did not return to their initial level until 5-6 min (Fig. 2, III).

The relationship between the somatic and sympathetic components in the "symmetrical inhibition" effect is shown graphically in Fig. 3. In the intact animal this effect took place as a result of complex interaction between influences spreading along sympathetic and efferent somatic pathways. Each of these pathways is responsible for particular parameters of "symmetrical inhibition." The efferent somatic pathways supply the rapid and brief component of "symmetrical inhibition," whereas sympathetic influences are brought in at a later stage and supply the slow component and the prolonged after-activity. The "symmetrical inhibition" effect in the intact animal is evidently not the simple arithmetical sum of the sympathetic and somatic influences, for in the intact animal the rapid component of "symmetrical inhibition" is deeper than in the desympathized animal: probably the sympathetic nervous system is able to stress or deepen somatic effects.

Analysis of the oscillograms presented in this paper shows that the recorded activity is activity of single fibers. In our investigations we were dealing with receptor–fiber units. The activity of such a unit was found to depend not only on the parameters of the adequate stimulus, but also on influences arriving from tactile receptors of the symmetrical area, provided that they also were subjected to adequate stimulation. This means that an interaction effected with the participation of spinal neurons takes place between the receptors of symmetrical skin areas. Research during recent years suggests that spinal internuncial neurons may take part in the mechanism of symmetrical interaction between skin receptors (4-6, 8, 9, 11, 13).

Afferent impulses reaching the spinal cord from receptors in different parts of the skin can evidently relay to sympathetic pathways via connections between the somatosensory and sympathetic elements of the spinal cord, as morphological studies have shown [3]. As the experiments with division of the ventral roots and desympathization showed, transmission of influences from the spinal cord to the skin receptors takes place with the participation of sympathetic and efferent somatic pathways, each characterized by the specific nature of its final effect. Whereas somatic influences are characterized by the short latency and the rapidity and brevity of the effect, sympathetic influences, on the contrary, give an effect which is relatively slow to develop, but which is of considerable duration and is followed by a prolonged after-activity.

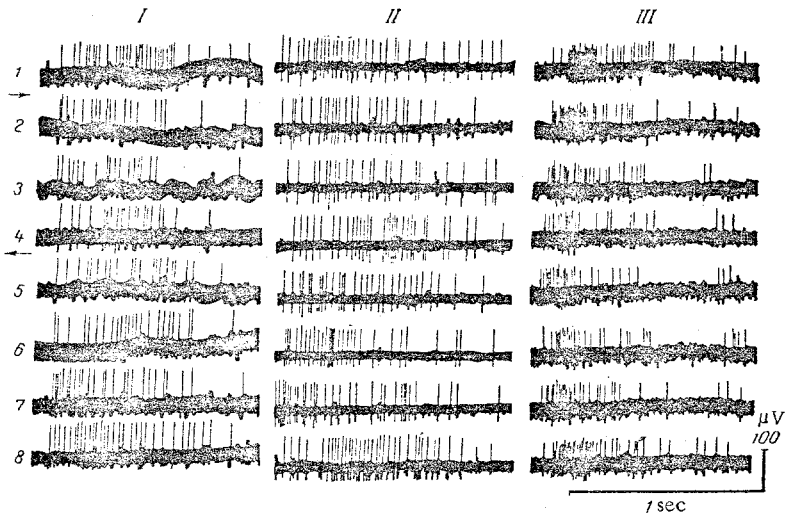

Fig. 2. Changes in responses of tactile receptors during stimulation of symmetrical skin area in an intact animal (I), a desympathized animal (II), and an animal with divided ventral roots but with an intact sympathetic chain (III). 1) Initial response; 2-4) after stimulation for 10, 30, and 60 sec; 5-7) 30, 60, 180, and 300 sec after stimulation.

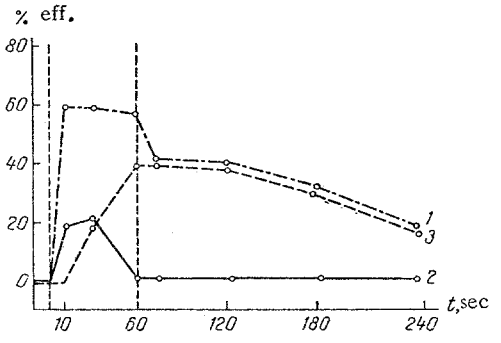

Fig. 3. Relationship between sympathetic and somatic influences in the "symmetrical inhibition" effect. Ordinate: depth of effect (in percent), abscissa: time (in sec). 1) Intact animal; 2) desympathized; 3) animal with divided ventral roots, but with intact sympathetic nerve chain. Arrows denote beginning and end of stimulation.

A number of workers using different methods have described the important role of the sympathetic nervous system in regulation of activity of the mechanoreceptors of the skin [7, 12]. Fuxe and Nilsson [10], moreover, showed that the sympathetic influences may be the result of direct action of the sympathetic mediator on the receptor endings.

In our experiments on intact animals regulation of the activity of the tactile receptors appeared to be a complex process of interaction between somatic and sympathetic influences on the final link, the receptor. Examples of such interaction may also be seen with other receptors, particularly those of taste [2].

It would be interesting to study the nature of the somatic fibers and their central cells taking part in regulation of tactile skin receptors.

LITERATURE CITED

1. T. M. Dmitrieva and A. I. Esakov, Dokl. Akad. Nauk SSSR, 171, No. 2, 490 (1966).
2. A. I. Esakov, S. É. Margolis, and G. Yu. Yur'eva, Nauchn. Dokl. Vyssh. Shkoly. Biol. Nauki, No. 4, 92 (1966).
3. A. L. Mikeladze, Arkh. Anat., Gistol. Émbriol., No. 5, 3 (1965).
4. V. I. Saf'yants, Fiziol. Zh. SSSR, No. 1, 34 (1966).
5. C. J. Armett, J. A. B. Gray, and L. F. Palmer, J. Physiol. (Lond.), 156, 611 (1961).
6. C. J. Armett, J. A. B. Gray, R. W. Hunsperger, et al. J. Physiol. (London), 164, 395 (1962).
7. K. E. Chernetski, J. Neurophysiol., 27, 3 (1964).
8. J. C. Eccles, P. G. Kostyuk, and R. F. Schmidt, J. Physiol. (London), 161, 237 (1962).
9. R. M. Eccles, B. Holmquist, and P. E. Woorhoeve, Acta Physiol. Scand., 62, 469 (1964).
10. K. Fuxe and B. Y. Nilsson, Experientia (Basel), 21, 641 (1965).
11. G. H. Kolmodin and S. R. Skoglund, Acta Physiol. Scand., 50, 337 (1960).
12. W. R. Loewenstein, Fed. Proc., 14, 94 (1955).
13. P. D. Wall and J. R. Cronly-Dillon, Arch. Neurol. (Chicago), 2, 365 (1960).