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AFFERENT IMPULSES FROM SKIN RECEPTORS IN RESPONSE TO A JET OF AIR

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UDC 612.794

The colliding impulse method was used to investigate afferent impulsation in different types of fibers of the cutaneous nerves innervating the hairy skin on the medial surface of a cat's paw. It was shown that a change in the intensity of the acting stimulus caused a change in the structure of the afferent flow. An increase in the strength of the jet of air caused an increase in the number of active fibers and in the frequency of the afferent impulsation and it led to the excitation of other types of fibers also.
KEY WORDS: cutaneous nerve; nerve fibers; stimulation of the skin; afferent impulsation.

The morphological and physiological properties of single skin receptors have now been studied detail [7-9]. The coding of information on stimulation is known to take place in them through changes in the frequency of impulsation [10-12]. Under natural conditions of excitation, however, many receptors of different types are excited simultaneously. Differentiation of the quality and intensity of the acting stimulus in this case is carried out through a code of nervous impulses travelling along the collection of nerve fibers with different conduction velocity and with different frequencies of impulses in the volley [18].

It is difficult to form any sufficiently true impression of the afferent flow from responses of single receptors, for, in the first place, when single fibers are tested the thickest of them are involuntarily chosen [8, 15] and, second, when fibers are separated from the nerve trunk the integrity of the ionic barrier surrounding the excitable membrane is disturbed. This leads to changes in the characteristics of the afferent responses [5]. The activity of a single receptor, moreover, depends not only on the parameters of the acting stimulus, but also on the influence of neighboring excited receptors on it [2, 13]. Ultimately all these factors modify the character of the global response of the receptors. To assess the afferent flow carrying information about stimulation correctly, it is essential to do more than analyze the activity of single nerve fibers.

In the course of the present investigation the method of recording from a whole nerve trunk was used. Changes in the afferent flow in the saphenous nerve were investigated during stimulation of the hairy skin by jets of air of different intensities.

EXPERIMENTAL METHOD

Experiments were carried out on 25 cats anesthetized with hexobarbital (250 mg/kg body weight, intramuscularly).

To determine the frequency spectrum of afferent impulsation and the distribution of the relative number of afferent fibers conducting impulses of particular frequencies, a modified colliding impulse method [4] was used.

For this purpose stimulating electrodes were applied in the region of the groin to a dissected length of the saphenous nerve, the central end of which was divided. The nerve was stimulated by square pulses whose

Department of Biocybernetics, Research Institute of Applied Mathematics and Cybernetics, N. I. Lobachevskii Gor'kii University. (Presented by Academician V. N. Chernigovskii.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 82, No. 9, pp. 1030-1032, September, 1976. Original article submitted January 9, 1976.

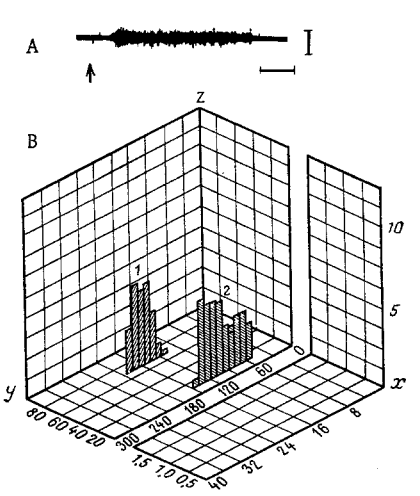

Fig. 1

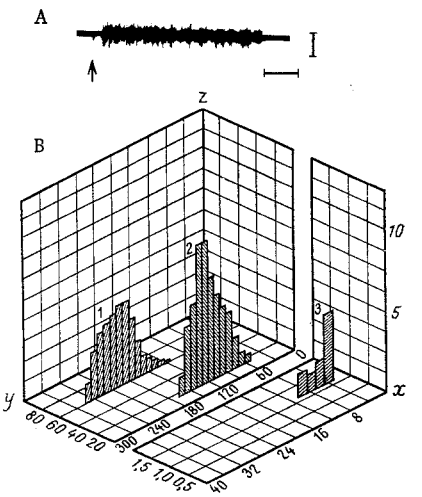

Fig. 2

Fig. 1. Characteristics of afferent impulsation in cutaneous nerve during action of a jet of air with a strength of 20 mg/cm^2 on hairy skin. A) Combined afferent flow obtained by action of jet of air with strength 20 mg/cm^2 on hairy skin. Calibration 200 msec, 50 μV; arrow marks beginning of action of jet; B) histograms of distribution of number of active fibers with respect to frequency of afferent impulses and conduction velocities: 1) in Aβ fibers; 2) in Aδ fibers; axes: X) conduction velocity (in m/sec), Y) frequency of afferent impulses (per second), Z) number of active fibers (in %).

Fig. 2. Characteristics of afferent impulsation in cutaneous nerve during action of jet of air with strength of 42 mg/cm^2 on hairy skin. B: 3) In C-fibers. Remainder of legend as in Fig. 1.

TABLE 1. Characteristics of Afferent Impulsation during Stimulation by Jets of Air of Different Intensity

Strength of jet of air applied (in mg/cm^2)	Type of active fibers	Number of active fibers (in %)	Frequency of impulses in volley (per second)	
			minimal	maximal
16—20	Aβ	15—41	15—90	160—230
	Aδ	13—60	25—60	80—140
37—42	Aβ	20—80	20—120	240—300
	Aδ	40—68	40—80	100—160
	C	7—20	5—11	

amplitude and duration were chosen to be optimal for excitation of Aβ, Aδ, and C fibers. The recording electrodes were placed on a branch of the saphenous nerve innervating the skin of the medial surface of the paw.

To analyze the afferent flow in the Aβ fibers the distance between the stimulating and recording electrodes was maximal and ranged in different experiments from 140 to 176 mm; to analyze the afferent flow in the Aδ and C fibers the distance ranged from 44 to 100 mm.

A jet of air from a turbo-fan was used to stimulate the receptors. By means of a special shutter mechanism the jet of air could be applied for 1 sec to the entire receptive field. The strength of the jet of air on the hairy skin varied from 20-16 mg/cm^2 (weak action) to 40-37 mg/cm^2 (strong action) and its direction relative to the surface of the hairy skin was the same in all the experiments.

Stimulation of the nerve was synchronized with stimulation of the receptive field. The interval between receptor stimulations was from 3 to 5 min. Combined activity of the nerve fibers and action potentials of the nerve were recorded from the screen of an oscilloscope. The afferent frequency spectrum in the Aβ, Aδ, and C fibers was judged from changes in the amplitude of evoked potentials after collision of orthodromic and antidromic impulses [4].

EXPERIMENTAL RESULTS

The action of the jet of air on the skin of the medial surface of the paw evoked activity in the saphenous nerve fibers. The total afferent flow differed depending on the intensity of the stimulus (Figs. 1A and 2A). To determine the nature of this difference the colliding impulse method was used. Histograms plotted from the experimental results showed the characteristics of the afferent flow with respect to the number and type of active fibers and the frequencies of impulses in the volley.

A jet of air with a strength of 16-20 mg/cm^2 evoked activity in Aβ fibers with a velocity of 50-96 m/sec and in Aδ fibers with a velocity of 16-33 m/sec (Fig. 1B).

An increase in the strength of the jet of air to 37-42 mg/cm^2 changed the character of the afferent impulsation. During stimulation of this kind not only myelinated A fibers but also unmyelinated C fibers with a conduction velocity of 1-1.3 m/sec were active (Fig. 2B); the number of active Aβ and Aδ fibers and the frequency of impulses travelling along them were both increased (Table 1). A change in the intensity of the stimulus applied thus led to a change in the global picture of the afferent impulsation.

Unfortunately the results do not reflect all the changes taking place in the nerve trunk, for the measurements were made only for the modal group of nerve fibers. The whole spectrum of excited fibers participated in the formation of the structure of the afferent flow [6], but changes taking place in the modal groups describe the general picture sufficiently clearly.

The results are in agreement with those obtained by workers who used other methods. A change in the frequency of the flow of impulses with a change in the intensity of stimulation was shown previously in experiments on single receptor units [8, 14, 15, 17]. During mechanical stimulation of the skin, depending on the intensity of stimulation the frequency of impulses in the Aβ fibers varied from 300-400 to 600-700 per second and in Aδ fibers from 200-250 to 400-500 per second [8, 15]. The frequencies of activity obtained in the present experiments were numerically smaller (Table 1). The differences in the values of the frequencies can be explained both by certain limitations of the method used in the present case [1, 3] and by differences in the method of stimulation of the receptors.

Some workers consider that with a change in the intensity of a stimulus the number and type of active fibers must also change [15, 16]. The present experiments showed that with an increase in the strength of the jet of air the number of active fibers increased and the spectrum of conduction velocities was broadened through the spread of excitation to fibers of other types.

It can accordingly be concluded from these results that the coding of information on the intensity of stimulation takes place through changes in the structure of the afferent volley.

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