COMPARATIVE CHARACTERISTICS OF FUNCTIONS OF THE SKIN THERMORECEPTORS AND MECHANORECEPTORS DURING CHANGES IN THE AMBIENT TEMPERATURE

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UDC 612.79.014.43

Responses of the skin thermoreceptors and mechanoreceptors, biopotentials of which had unequal amplitude and responded differently to changes in the ambient temperature, were studied separately in 11 rabbits. The combined activity of the thermoreceptors that responded by an increase in the discharge frequency to cooling of the skin, and of the mechanoreceptors whose discharge frequency decreased with a decrease in the ambient temperature, evidently plays an essential role in maintenance of the temperature homeostasis of the organism.

KEY WORDS: thermoreception; mechanoreception; action of temperature factors.

Most electrophysiological investigations of skin temperature reception so far undertaken have resulted in the description of different properties of single thermoreceptors. Data on changes in their discharge frequency have been obtained chiefly in response to very rapid changes in skin temperature [6, 7, 9]. In their earlier investigations, Dodt, Hensel, and Zotterman [4, 5, 10] describe the presence of a response of both thermo- and mechanoreceptors (stimulated by pressure from a thermistor) in the lingual nerve of cats in response to stepwise changes of temperature. The effect of temperature on the change in spike activity of mechanoreceptors of the wall of the veins and the cutaneous nerves has been demonstrated by Minut-Sorokhtina [1-3].

The most complete characteristics of function of the cat skin thermo- and mechanoreceptors was given by Witt and Hensel [11]. However, insufficient attention has so far been paid in the literature to the comparative characteristics of operation of these two groups of receptors. Obviously to determine the role of these two types of receptors in thermoregulation it is necessary to investigate and compare their response during continuous physiological changes of temperature within the range from 5 to 40°C.

EXPERIMENTAL METHOD

Altogether 60 nerve branches were investigated in 20 experiments on 11 chinchilla rabbits weighing 3.0-3.5 kg. In the anesthetized animal (100 mg amobarbital, intraperitoneally) two or three branches 100-200 μ in diameter, innervating the dorsum of the nose, were separated from the infraorbital nerve under the microscope (12.5 × 1.0). The nerve was divided. Its peripheral end was placed in a special chamber measuring 5 × 10 mm on platinum electrodes. The wound was closed. The experiments were carried out in a special microclimatic chamber in which a temperature drop of between 5 and 40°C could be created; the skin temperature of the animal's nose changed under those circumstances from 22 to 35°C at the rate of 0.1-0.2°/min. Standard pulses from the output of a UBP1-01 amplifier were loaded to the input of a type ISS-3 counting rate meter (intensimeter). The output of the intensimeter was connected to a type ÉPP-09 multichannel potentiometer. A continuous graphic record of the skin temperature of the region investigated, the temperature in the microclimatic chamber, and the spike frequency from the nerve was made on the

Laboratory of Temperature Regulation, I. P. Pavlov Institute of Physiology, Academy of Sciences of the USSR, Leningrad. (Presented by Academician V. N. Chernigovskii.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 78, No. 10, pp. 11-14, October, 1974. Original article submitted December 11, 1973.

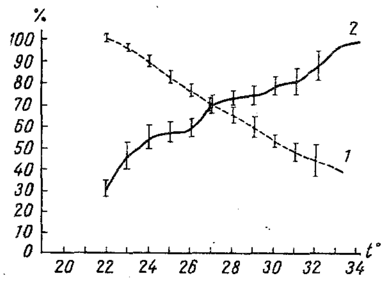

Fig. 1

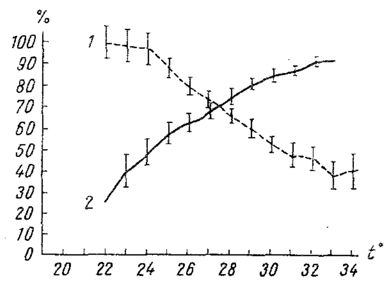

Fig. 2

Fig. 1. Changes in firing rate of thermo- (1) and mechanoreceptors (2) during cooling (mean results of all experiments). Here and in Fig. 2: abscissa, skin temperature on dorsum of rabbit's nose (in deg.); ordinate, change in % relative to maximal rise.

Fig. 2. Change in firing rate of thermo- (1) and mechanoreceptors (2) during warming (mean results of all experiments).

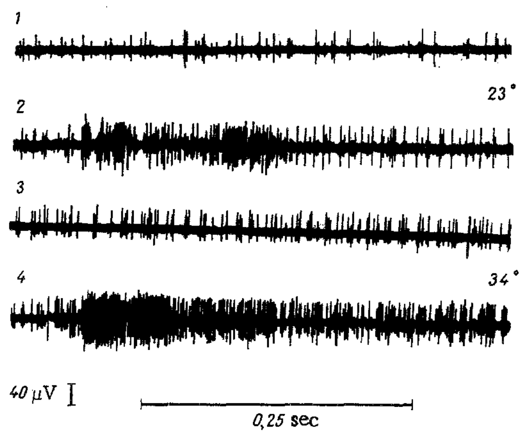

Fig. 3. Neurograms of spike activity of thermo- and mechanoreceptors of the skin of a rabbit's nose recorded from branches of the infraorbital nerve at a low (23°C) and high (34°C) temperature. 1, 3) Effect of temperature only; 2, 4) effect of temperature + mechanical stimulation of the skin of the nose.

tape of the ÉPP-09 potentiometer. Every 10 min during changes in the ambient temperature mechanical stimulation of the region of the rabbit's nose was carried out with a soft bristle. Regularly every 5-7 min, changes in the frequency of the potentials were recorded photographically. The response of the thermoreceptors (10-40 μV) and mechanoreceptors (50-120 μV) was analyzed separately on motion picture film.

EXPERIMENTAL RESULTS

With an ambient temperature in the chamber of 22-23°C the skin temperature of the animal's nose was 28-30°C. Under these circumstances the potentials recorded from the nerve varied in amplitude from 10 to 120 μV. Depending on the differences in their responses to a change of temperature they were divided into two distinct groups. Spikes with an amplitude of 10-40 μV, arising from very thin fibers of groups AΔ and C, not responding to mechanical stimulation, were regarded as thermoreceptors. Potentials with an amplitude above 50 μV reflected the activity of the mechanoreceptors. The spontaneous activity of these receptors was observed in the animal at rest and could be produced by different causes: movement of the surrounding air, microcontractions of the masseteric muscles. These receptors responded to mechanical stimulation with a volley of spikes of even higher amplitude (100-120 μV).

During cooling of the skin of the rabbit's nose (Fig. 1) the spike activity of the skin thermoreceptors began to increase and it reached a maximum at 23-22°C. Spontaneous activity of the mechanoreceptors decreased during cooling, the sharpest decrease in their activity being observed at 26-22°C.

During warming (Fig. 2) the frequency of the thermoreceptor potentials recorded from the nerve began to decrease and reached a minimum at 31-35°C. The firing rate of the mechanoreceptors rose during warming and reached a maximum at 34-31°C.

Records of spike activity of the skin thermo- and mechanoreceptors when the skin temperature of the rabbit's nose was 23 and 34°C are shown in Fig. 3. At the lower skin temperature there were very many low-amplitude potentials, whereas potentials of higher amplitude were hardly visible. During warming the number of potentials of the mechanoreceptors increased whereas the number from the thermoreceptors fell considerably. The number of mechanoreceptor potentials evoked by stimulation also was smaller at a low skin temperature than at a high temperature.

Two groups of receptors responding to temperature and mechanical stimulation were examined. Skin thermoreceptors of the dorsum of the rabbit's nose evidently are of the cold receptor type, for their firing rate decreased during warming of the skin and increased during cooling. Having investigated 60 branches of the infraorbital nerve in the rabbit, no increase in firing rate of the thermoreceptors could be found at a comparatively high nasal skin temperature (32-35°C). This, however, by no means implies that heat fibers are absent in the skin of the dorsum of the rabbit's nose. According to data in the literature, the temperature of the static maximum of heat fibers averages 46°C [8]. In the temperature limits studied the response evidently took place mainly on account of the activity of cold thermoreceptors.

Comparison of the response of the skin thermo- and mechanoreceptors to changes in temperature showed that they differed. Whereas the thermoreceptors increased their activity during cooling of the nasal skin, the mechanoreceptors, by contrast, reduced their activity during cooling of the skin, and vice versa.

In their paper [11], Witt and Hensel also point out that the spontaneous firing rate of the mechanoreceptors, unlike that of the thermoreceptors, never decreased between 40 and 30°C.

In the present experiments an attempt was made to study the response of the thermo- and mechanoreceptors during comparatively slow changes in skin temperature, such as are much more typical of the life of animals than stepwise temperature drops. The interval chosen (22-35°C), in which changes in the skin temperature of the dorsum of the nose took place, is also more physiological for animals than the temperature range of 20-15°C. Moreover, not only the response of the skin mechanoreceptors evoked by specific stimulation, but also changes in their spontaneous activity in response to changes of temperature, were studied in these experiments.

Cold cutaneous sensation, according to Minut-Sorokhtina, is a function of mechanoreceptors located directly in the skin itself and of mechanoreceptors of the cutaneous and subcutaneous vessels. In her own investigations she also observed an increase in the spike activity of the mechanoreceptors to correspond to the higher level of stable skin temperature and a decrease in impulse activity during cooling of the skin [2].

It can be postulated on the basis of the results of the present experiments that thermoreceptors responding specifically by an increase in firing rate to cooling of the skin and mechanoreceptors responding nonspecifically to changes in temperature exist in the skin.

An important and undisputed fact is that the mechanoreceptors participate in thermoregulation, in which they are an important source of temperature information.

During a change in the ambient temperature the spike activity of the skin thermo- and mechanoreceptors thus changed in opposite directions: activity of the thermoreceptors was reduced whereas activity of the mechanoreceptors was increased as the skin temperature rose; the combined activity of the skin thermo- and mechanoreceptors, producing a continuous flow of sensory information into the central nervous system, plays an important role in the maintenance of the temperature homeostasis of the organism.

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