PROPERTIES OF COLD RECEPTORS

L.M. Kurilova and S.L. Bliakher

Laboratory of the Physiology and Pathology of Sense Organs (Director – Professor P.G. Sniakin), Institute of Normal and Pathologic Physiology (Director – Active Member Acad. Med. Sci. USSR V.N. Chernigovskii), Acad. Med. Sci. USSR

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Modern literature devoted to the question of reception of temperature stimuli tends to the view that the skin possesses punctate temperature sensitivity.

The punctate theory of cutaneous reception was created by Blix [10], Goldscheider [13] and Frey [12]. According to this theory the human skin has sites which, when stimulated by punctate temperature stimuli, give rise to corresponding sensations of cold or heat. The authors mentioned postulated a suggestion, based on experimental data, that the cold and warm spots represented discrete sensory apparatus of two sorts of centripetal nerve endings.

In addition to the theory of discrete specific temperature sensitivity there is also the view, held by a number of authors [3, 9, 11, 14], that there is a single receptor apparatus in the skin which receives all types and degrees of temperature stimuli.

However, the existence of a discrete temperature reception is supported by the fact that conditioned reflexes to heat and cold stimuli are formed from different areas of the skin [4-8].

The question as to which cutaneous morphologic elements correspond to one or another specific sensory spot has not, up to the present, been decided. It is thought, however, that the receptor elements for cold stimuli are the end-bulbs of Krause and those for subserving the sensation of warmth are the Ruffini corpuscles. The cold spots lie nearer the surface of the skin than the warm spots.

According to the data of Sammer various sites measuring 1 cm^2 carry from 6 to 23 cold spots (average 12-13) and up to 3 warm spots. The unequal density of distribution of the receptors underlies the differences in sensitivity of various parts of the body to fluctuations of temperature.

The present communication is limited to the characteristics of the cold spots only.

In investigating the cutaneous cold spots by means of a thermoesthesiometer with a thermoprobe of 1 mm^2 area at a temperature of 0°C, Z.P. Belikova [1] found that the same spots prove to be alternately sensitive and insensitive to a given stimulus depending on the temperature of the surrounding environment. The inconstancy of sensitivity of given spots was also pointed out by Leontovich [2] and Pshonik [3]. They did not, however, offer any explanation of this observation. From our point of view this fact indicates functional mobility [4-7] in the thermoreceptor system of the skin.

It may be supposed that the number of cold spots is determined by the number of functioning receptor elements (nerve endings) which find themselves within the sphere of influence of a cold stimulus.

The present work is devoted to the study of certain features of functioning and distribution of the so-called "cold" spots in human skin.

EXPERIMENTAL METHOD

The properties of receptor cold spots were studied with the help of thermoesthesiometers with various areas of the thermoprobe, viz. 1 mm^2, 2 mm^2, 3mm^2, 4 mm^2, 5 mm^2, 7 mm^2, 8 mm^2, 11 mm^2, 14 mm^2, 16 mm^2 and 20 mm^2. They were all made of the same metal. The temperature of the different thermoprobes was the same and equal to +1, +2°C.

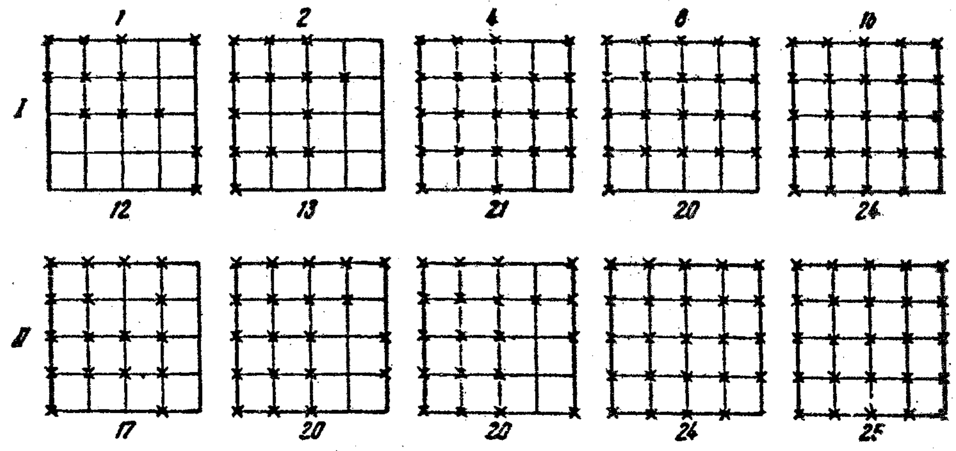

Fig. 1. Scheme showing experimental records.

The area of skin under investigation was stamped with a grid-stamp consisting of 16 squares each 1 cm^2 in area. The intersections of these squares formed 25 points. Each of these points was touched with a thermoesthesiometer with a definite area of thermoprobe. The subject had to indicate by a positive response that moment at which the touch of the thermoesthesiometer produced a sensation of a "cold drop." Such a sensation occurred on investigation with thermoesthesiometers with any area of the thermoprobe.

Tactile and vague sensations were not considered. The subjects were isolated from the experimenter by a special screen. This allowed the experimenter to change the thermoesthesiometers of various thermoprobe areas without drawing the subject's attention to the fact. Under such experimental conditions the subject could not distinguish visually the different thermoprobe areas (at least within the range of 1 to 11 mm^2).

Points corresponding to points on the skin from which a sensation of cold had been obtained in response to stimulation were plotted on the grids stamped in the record book. The number of positive responses (+), obtained on testing the 25 points indicated with a thermoesthesiometer of certain thermoprobe area, was recorded (Figure 1).

Figure 1 represents a protocol record of the investigation. Figures 1, 2, 4, 8, 16 over each stamp denote the areas of the thermoprobes in square millimeters. The number of positive responses obtained on testing with thermoesthesiometers of one or another thermoprobe area is marked by a figure under the appropriate stamp.

Each skin area was tested twice by each thermoprobe area and the average value was found for the number of positive responses.

The time of contact with the thermoesthesiometer and the intervals between the contacts were always the same. Each contact was of 2-3 seconds duration and the intervals were of 3-4 seconds. The experiments were performed on the dorsal aspect of the hand and on the anterior surface of the forearm. Symmetrical areas were tested on each upper extremity. A total of 1140 observations was made on 5 subjects. Each of the thermoesthesio meters was used over 100 times.

EXPERIMENTAL RESULTS

The occurrence of sensation indicates that there are functioning cold receptor elements in the projection zone of the cold stimulus. The larger the number of receptor elements in a given area under investigation the

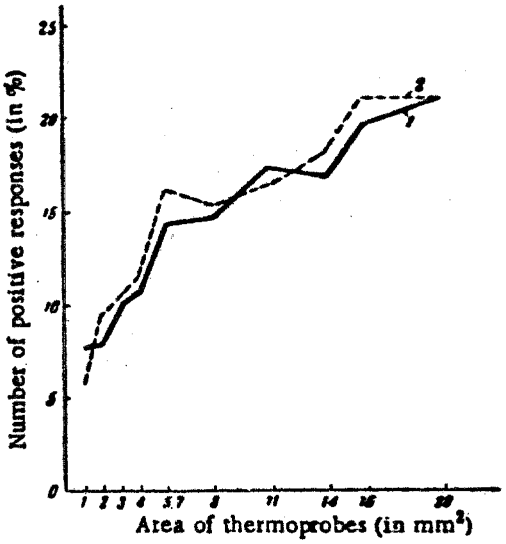

Fig. 2. Graphic representation of the relation between the area of the thermoprobes and the average number of positive responses on testing the right (1) and left (2) upper extremity in the subject L.K.

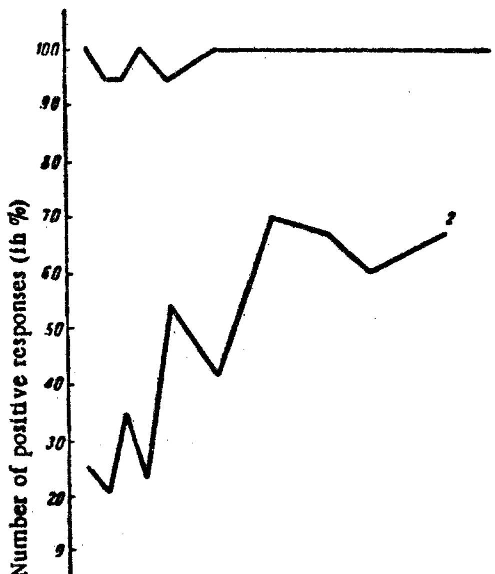

Fig. 3. Average number of positive responses as percentage of the total number of tests in the subject T.O. Abscissa – areas of thermoprobes; ordinate – percentage of positive responses: 1) areas with high density of receptor elements; 2) areas with low density of receptor elements.

smaller the area of stimulus required to give rise to the sensation. Therefore, the relation of the thermoprobe area and the number of cold spots detected can be used for determining the density of distribution of thermoreceptor elements in the skin.

The experiments showed that as the area of the thermoprobe increased a fairly regular increase in the average number of detected cold spots could be observed (Figure 1).

This relationship held for both upper extremities (Figure 2).

These data suggest that there are discrete receptor elements with sufficient density of distribution causing even a slight increase in the thermoprobe area (1-2-3-4 mm^2) to increase the probability of functioning elements being involved in the projection zone for the stimulus.

In a special series of observations the stamp was not washed off the skin over a period of days (5-6). This permitted observation of the functional changes in the receptor apparatus at the same points.

Observations revealed that the points tested differed from each other in their properties.

Some of these points show high percentage of positive responses coinciding from day to day when both small-area and large-area thermoprobes are used. Others show low percentage of coincidence of positive responses.

Figure 3 presents the graphic results of investigation of 25 randomly marked points in one subject over a period of a week. Each curve unites a group of points which gave a similar percentage of positive responses when tested with a thermoesthesiometer with thermoprobe area of 1 mm^2.

It can be seen from Figure 3 that there are points which only produce a sensation when the area of stimulation is considerably extended, and fail to give a 100% positive response even when the largest thermoprobe area employed in the investigation is used. Other points, on the contrary, give 100% positive responses even when the smallest thermoprobe area (1 mm^2) is used.

These data signify that receptor elements subserving the sensation of cold are distributed nonuniformly in the skin.

It must, moreover, be taken into account that there is functional mobility, expressed in alternate mobilization and demobilization of receptor elements.

Functional mobility is associated with a constantly varying number of reactive elements within a receptor. Therefore, in those skin areas where the density of distribution of thermoreceptor elements is relatively low and where, moreover, there is a certain number of nonfunctioning elements, sensation can only be achieved by increasing the area subjected to stimulation.

It must be stressed that the phenomenon of functional mobility was observed when thermoesthesiometers with thermoprobe areas from 1 to 20 mm^2 were used. However, the amplitude of mobility is brought out more definitely when the thermoprobe area is small (from 1 to 3 mm^2) than when larger thermoprobe areas are used (Figure 3). This justifies the choice of thermoesthesiometer with thermoprobe area of 1 mm^2 for investigation of functional mobility for cold receptor elements. Such a thermoesthesiometer elicits a definite sensation of cold and at the same time ensures a more precise evaluation of change in the level of functional mobility.

SUMMARY

Experiments were performed using a set of temperature stimuli of the same intensity but of a different extent. This allowed determination of a number of important properties of the cold receptors of human skin.

The "cold spot" may include a single receptor element or a group of receptors depending on the size of the area subjected to the stimulus used in investigation of cold spots.

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