REACTION OF CUTANEOUS RECEPTORS TO LOCAL, REFLEX, AND GENERAL THERMAL INFLUENCES

L. M. Kurilova

Laboratory of the Physiology and Pathology of Sense Organs (Head — Prof. P. G. Snıakin), Institute of Normal and Pathological Physiology (Director — Active Member AMN SSSR V. N. Chernigovskii), AMN SSSR, Moscow.

(Presented by Active Member AMN SSSR V. N. Chernigovskii)
Translated from Byulleten' éksperimental'noi biologii i meditsiny Vol. 49
No. 3, pp. 3-7, March, 1960
Original article submitted April 28, 1959.

The significance of the thermoreceptive apparatus of the skin in the processes of heat regulation of the organism has not been studied sufficiently. And yet it is obvious that the first signals concerning changes in temperature, which lead to appropriate changes in the relationship between the processes of heat production and heat loss, emanate precisely from the cutaneous thermoreceptors.

METHODS

The method used for study of the reactions of the thermoreceptors utilized the examination of functional mobility. The research was carried out with the aid of cold and hot thermoesthesiometers, the diameter of the thermal probes being 1 mm. The method worked out earlier by Z. P. Belikova and O. D.Kolyutska, had been used for the finding or mapping out of (thermal) spots.

Previous use of this method, in the finding of thermosensitive points on the skin of the palmar surface of the forearm with the aid of an appropriate thermoesthesiometer, revealed 10-15 such cold and hot spots, which were marked with indelible dye or ink. This method of investigation is convenient for clarifying the reaction of the thermoreceptors to local or reflex action of thermal stimulation. In using the method for mapping the palmar surface of the forearm, the sensitive points were marked on a stamped grid, the intersecting lines of which formed 25 points. This was a convenient method for establishing the functional level of the thermoreceptors during differing ambient temperatures.

During investigation of cold receptors by means of successive touching of the cold thermoesthesiometer to each of the previously mapped out points, points were found in which the sensation of cold was detected, i.e. functional receptive elements for cold.

The research on warm receptors was carried out by this same method with the aid of a warm thermoesthesiometer. The method described allowed one to judge the number of functioning cold or warm receptive elements, i.e. the level of their mobilization at any particular instant of investigation.

Observations were carried out on five subjects.

After a 15-20 minute adaptation to the temperature of the experimental room, the background level of mobilization of the thermoreceptors was determined, after which observations were made on change of level of mobilization of the thermoreceptors of the skin during a particular thermal influence.

By means of the systematic method described, we investigated the reaction to cold and heat of the cutaneous receptive systems of man during local, reflex, and general action of a thermal stimulus.

RESULTS

Reaction of cutaneous thermoreceptors to local thermal stimulation. During investigation of the cutaneous receptive system for cold, a distinct reaction of the cold receptors was noted in response to a local thermal stimulus. This reaction was expressed as a significant reduction of the level of mobilization of the elements receptive for cold at the site of application of the cold or warm stimulation.

Local cooling was brought about either by an ice bath or a rubber bag filled with water (from 5 to 12°). For local warming the bag was filled with water at a temperature of 42° to 46°, or else a sun lamp was used. (In the latter case, tactile stimulation was avoided.)

In the upper part of Fig. 1, it can be seen that during a brief (2-5 minute) cooling of the right forearm, a rapid and significant demobilization of the receptive elements for cold took place at the site of application of the stimulus — the level of mobilization was significantly reduced in comparison with the control. In the investigation of the symmetrical portion of the skin of the forearm on the left side no such changes of level of mobilization of the receptive elements for cold were noted. On the right of the same figure, the reaction of the receptors for cold to local heating is seen. The reaction was also expressed as a reduction of the level of mobilization of the receptive elements for cold at the place where the warm stimulation was applied, and absence of a pronounced reaction on the other side.

In the investigation of the cutaneous receptive system for heat, the same reaction to local cooling or heating

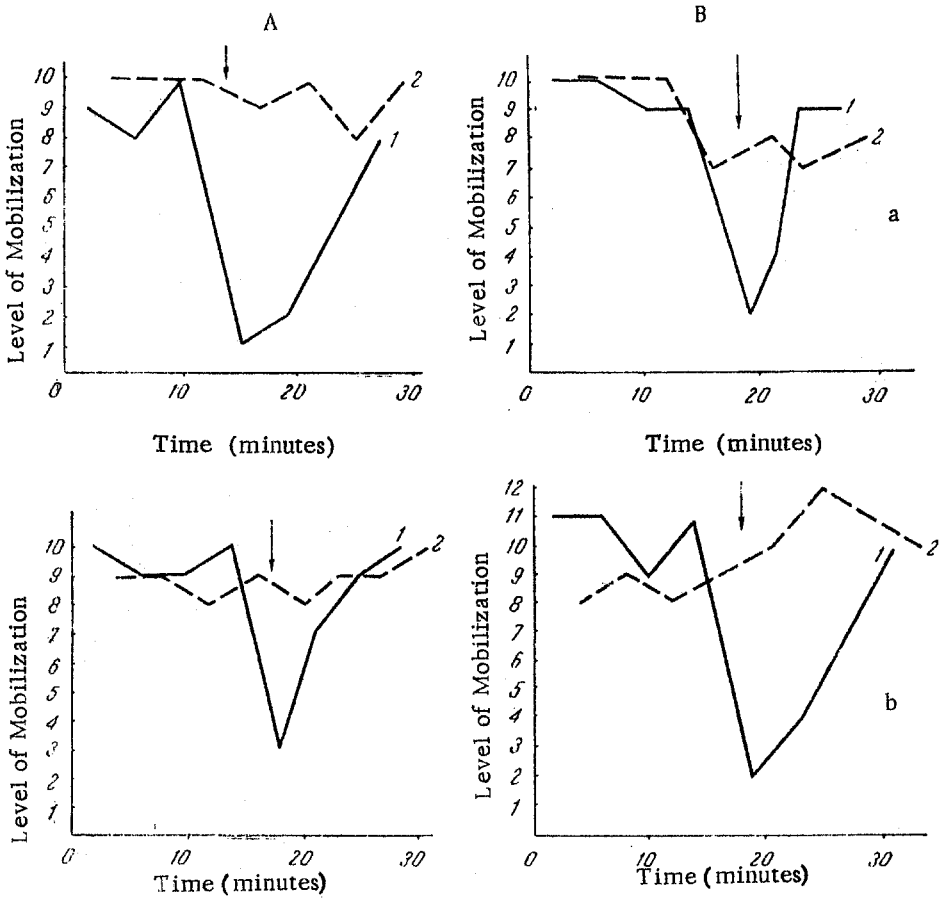

Fig. 1. Reaction of cutaneous thermoreceptors to local thermal stimulation. A) Local cooling; B) local heating. a) Cold reception; b) heat reception. 1) Right arm; 2) left arm.

was observed. The bottom part of Fig. 1 illustrates the reaction of the heat receptors to a local thermal stimulus. Both heat and cold led to a reduction of the level of mobilization of the receptive elements for heat at the place where thermal stimulation was given. Hardly any reaction was noted in the other arm. Thus, during a brief local cooling or warming, a rapid and significant demobilization of the receptors for both cold and heat is observed at the locus of application of a thermal stimulus. The reaction is local and not differentiated. No reflex variations of the temperature-sensing system of the skin is observed.

Reaction of the temperature receptors of the skin during reflex action of a thermal stimulus. With a longer lasting and more superficial thermal-stimulation (10-15 minutes) of the skin, a reflex effect of the thermoreceptive system was noted, and was expressed as a change of the tuning of the cutaneous thermal receptive apparatus which had not been exposed to the thermal influence. This reaction was noted during heating of the back with one meter infrared rays. The skin on the surface of the subject's forearm was not exposed to the warming action of the rays. In these cases, the reaction of the thermoreceptors was expressed as a lowering of the level of mobilization of cold and hot receptor elements of the skin of the arm to a warming, and a rise in their mobilization level during radiant cooling of the back. In Fig. 2, it can be seen that when a thermal stimulus brought about a reflex effect, a differentiated reaction of the thermo-

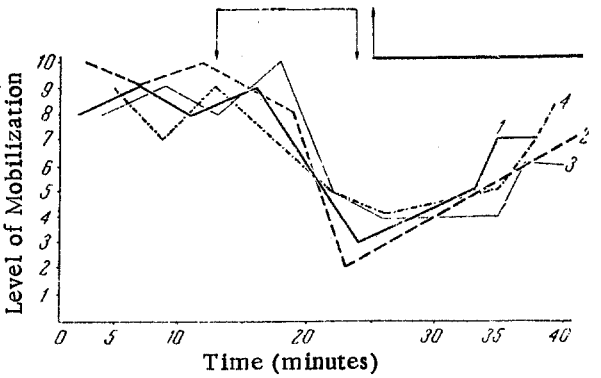

Fig. 2. Reflex reaction of the cold and heat receptors of the skin of the arm in response to heating and radiation cooling of the back. Heat reception of right (1) and left (2) arms. Cold reception of right (3) and left (4) arms.

↓ ↓ Heating;

↑ Cooling.

receptors to heating and cooling was observed: Reflex heating produced demobilization, while (reflex) cooling brought about a mobilization of the thermoreceptors.

The reflex lowering of the level of mobilization of the cutaneous thermoreceptors to infrared ray warming of the back was accompanied by a vigorous outpouring of sweat (the number of functioning sweat glands was increased), which is indicative of the increased heat loss.

The experimental data we have obtained can be interpreted as being due to the fact that during local, brief heating or cooling the temperature-regulating processes of the organism are not disrupted and therefore reactions are limited to local ones.

In those cases where heating of a significant square of skin on the surface of the body is achieved, some disturbance in the relationship between the thermoregulatory processes (heat production and heat loss) results. This leads to the reflex reduction of the level of mobilization of the cold-sensitive elements, which are located superficially and react to the change of the external temperature. The reduction of the level of mobilization of the heat-sensing elements observed during this situation evidently may be ascribed to the lowering of the temperature of the internal environment of the organism as a result of the increase in heat loss (increased sweat secretion).

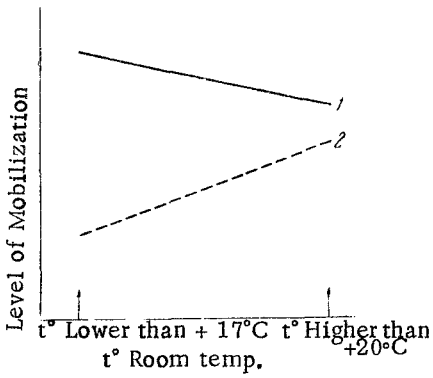

Fig. 3. Change of control functional level of the heat and cold receptive systems during different room temperatures. 1) Cold reception; 2) heat reception.

From the material we have presented, it is evident that during either local or reflex action of a thermal stimulus no reciprocity is manifested between the heat and cold-sensing receptive systems of the skin the receptive system for cold being the main one which responds more quickly and actively to change in the external temperature. The system for heat reception is more passive and changes in it proceed in parallel with changes in cold reception.

P. G. Snyakin has suggested that the lack of reciprocal action could be explained by the fact that in our geographical region, with an average yearly temperature of 4-7°, the danger of excessive cooling is more of a threat to man than that of overheating. In connection with this, the cold-sensing system acquires a greater signalling significance than does the heat-sensing apparatus; and, second, Snyakin has suggested that the absence of reciprocity can be explained by anatomical and physiological peculiarities.

The receiving elements for cold are disposed more toward the surface, and their number significantly exceeds that of the heat receptors. Connected with this, there are also physiological features of one or the other system of thermoreceptors. The cold receptors found near the surface respond quickly to a change in the external temperature. The receiving apparatus for heat is more sensitive to changes in the internal temperature and react to a change in the heat balance of the organism. Therefore they react to changes in external temperature only when such changes lead to an alteration of the temperature of the internal environment of the organism.

Reaction of the thermoreceptors of the skin to the general action of thermal stimulation. Reciprocal action of the cold and heat receptive systems is observed during a generalized change of temperature in the surrounding environment. The level of mobilization of the heat receptors is significantly higher during elevated ambient temperature than when the surrounding temperature is low. In low ambient temperatures the level of mobilization of the cold receptors is increased in comparison with their level of mobilization in surroundings of high temperatures.

Figure 3 presents an average of the data from all experiments. Reciprocal dependence of the cold and heat receptors on changes in room temperature is obvious. It can be seen from the figure that when the room temperature is lower than 17°, the level of mobilization of the cold receptors is higher than in a room with higher temperature (as when the room temperature is higher than 20°). The reaction of the heat-sensitive receptive system to these same room temperatures changes in the opposite direction.

In our view, such a redistribution of the functional levels of the cold and heat receptor systems in large measure ensures maintenance of the constancy of temperature of the human body.

Thus, in order to preserve the homeothermy of the organism, these two thermoreceptive systems - for cold and heat - are set at a level corresponding to the particular functional state of the thermoregulatory centers. The reaction of the thermoreceptors ensures the adaptation of the organism to a change in temperature conditions. Functional mobility is one of the mechanisms contributing to the maintenance of a constant body temperature.

SUMMARY

In studying the reaction of thermoreceptors the author used the method of investigating the functional mobility. It was shown by observations that during local heating or cooling of short duration there occurs a rapid and considerable demobilization of the receptor elements responding to

both heat and cold at the site of application of the thermal stimuli. Evidently, in this case the thermoregulating processes of the organism are not disturbed and therefore the reaction is only local. With a prolonged action of T° stimulation extended over a larger surface of the skin - a reflex reaction of the thermoreceptor system is observed which is manifested in the changed adjustment of cutaneous thermoceptors, not subjected to the effect of thermal stimulation. In this instance a differentiated reaction to heating and cooling is being noted: heating provokes demobilization, while cooling - mobilization of the thermoreceptors. With this temperature changes of outside or inside air a reciprocal relationship is observed between the reaction of cold and heat receptor systems of the skin.

The data obtained demonstrate that the cold receptor system reacts more rapidly and adequately to changes of external temperature while the heat receptor system responds more readily to the temperature changes in the body.

LITERATURE CITED

[1] O. A. Balandina, Byull. Éksptl. Biol. i Med. 39, 3, 10 (1955).

[2] Z. P. Belikova, Dynamics of Cold Reception in the Skin and Mucous Membranes of the Oral Cavity (Dissertation) [in Russian] (Moscow, 1953).

[3] M. V. Busygina, Experiments with Administration of Negative Aeroionization in the Treatment of Recurrent Aphthous Stomatitis (Dissertation) [in Russian] (Moscow, 1954).

[4] M. V. Busygina and A. A. Minkh, Gig. i San. 12, 5 (1956).

[5] O. D. Kolyutskaya, Functional Mobility of the Heat Receptors During Plastic Surgery of the Skin (Dissertation) [in Russian] (Moscow, 1953).

[6] L. M. Kurilova and S. L. Blyakher, Byull. Éksptl. Biol. i Med. 45, 4, 13, (1958).*

[7] P. G. Snyakin, Abstracts of Proceedings of the Scientific Session of Moscow Stomatological Institute [in Russian] (Moscow, 1952) p. 6.

[8] P. G. Snyakin and O. D. Kolyutskaya, Fiziol. Zhur. SSSR 1, 60 (1952).

[9] P. G. Snyakin, Vestn. AMN SSSR 1, 18 (1957) (Moscow).

[10] N. A. Sukhovskaya, E. V. Schmidt, N. B. Galuzo, et. al., Abstracts of Proceedings of the Guest Session of Institute of Neurology of the USSR Academy of Medical Sciences (Held in Conjunction with the Uzbekistan Society of Neuropathologists and Psychiatrists and the Tashkent State Medical Institute) [in Russian] (Tashkent, 1958) p. 34.

*Original Russian pagination. See English translation.