Thermoresponsive Neurons of the Thermoregulatory Center and Their Functional Characteristics

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It is generally recognized that the hypothalamic thermoregulatory center contains neurons with specific temperature sensitivity (thermosensitive neurons) [1,2,6-8]. In addition, this center accommodates neurons that do not possess direct temperature sensitivity. These latter neurons are referred to as "thermoresponsive", for they perceive signals from peripheral and central thermosensors. The purpose of the present study was to see how such neurons respond to specific stimulation of cutaneous thermoreceptors.

MATERIALS AND METHODS

The experiments were conducted on anesthetized Chinchilla rabbits weighing 3.0-3.5 kg. For anesthesia, urethan (1 g/kg) and chloralose (40 mg/kg) were used. Neuronal activity in the anterior and posterior hypothalamus was recorded by means of tungsten microelectrodes with a tip diameter of 1 to 3 μ introduced into the brain using a stereotaxic apparatus without fixing the head, as described in detail elsewhere [3]. The firing rate of each neuron was automatically measured by an electronic frequency meter and continuously (every second) recorded on the paper ribbon of a self-recording potentiometer. Thermal stimuli were applied to the skin of the dorsum of the rabbit's nose via a thin-walled copper thermode with a working area of about 40 cm^2 perfused with water heated or cooled to various temperatures. The thermode was so stamped out as to fit the shape of the nose and was in close contact with its skin. Skin temperature was measured directly beneath the thermode at two points (under the epithelium and at a depth of 1.5-2.0 mm from the skin surface) and near the hypothalamus with 0.2 mm-thick copper-constantan thermocouples to an accuracy of 0.1°C and 0.01°C per mm of paper ribbon in the skin and the hypothalamus, respectively. The temperature in the chamber where measurements were made was constantly maintained at 22-24°C.

In control tests run to provide baseline data, the thermode was perfused with water having a temperature of 30-31°C. In these tests the skin temperature under the thermode was 33.4±0.5°C at the surface and 35.6±0.6°C at a depth of 1.5-2.0 mm. In tests designed to evaluate responses to cold, the thermode was perfused with water cooled to 7-10°C. The walls of the thermode acquired such temperatures 3 to 5 sec after the start of perfusion. In these tests, the skin surface had a temperature of 26.3±0.5°C. In tests evaluating responses to heat, the thermode was perfused with water heated to 42-45°C, and the skin surface had a temperature of 37.5±0.4°C. The initial rate of change in skin temperature ranged from 0.15 to 0.25°C per second.

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RESULTS

A total of 190 individual neurons were tested in the anterior and posterior hypothalami of 30 rab-

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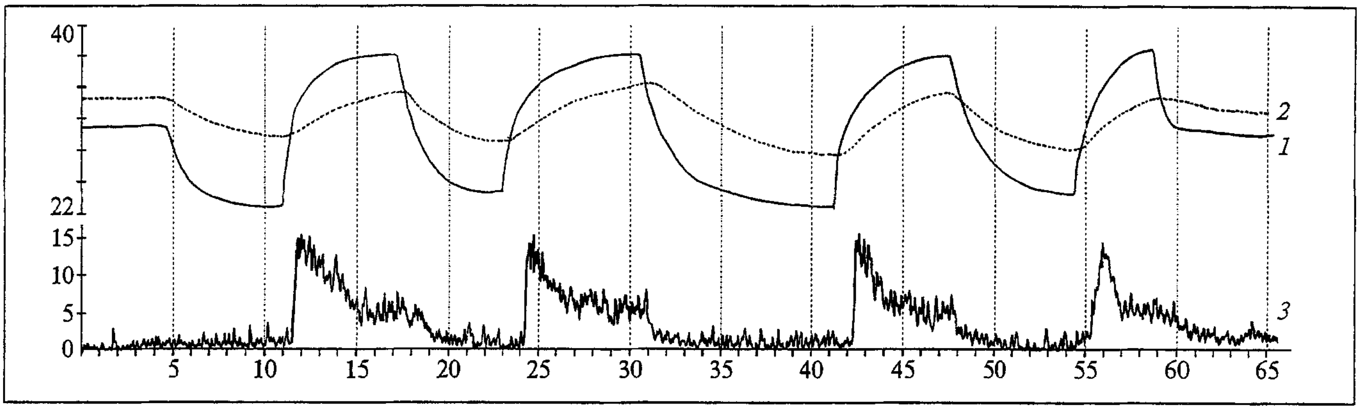

Fig. 1. Cyclic temperature variation at skin surface (*1*) and in deep skin layers (*2*) and increased firing rate (*3*) by a "heat" neuron in response to skin temperature elevation.

bits. Of these neurons, 22 exhibited well-defined alterations in firing rate in response to thermal stimulation of the skin, although the nature and patterns of their reactions varied. Thus, one neuron in the medial preoptic area ("heat" neuron) and one in a dorsomedial nucleus of the posterior hypothalamus ("cold" neuron) virtually repeated the response of cutaneous thermoreceptors to rapid temperature stimulation. The response consisted in a sharp rise of the firing rate at the moment when the skin temperature was rapidly changed (dynamic component of the response). Once a new constant level of skin temperature was achieved, the firing rate fell but remained somewhat higher than the baseline rate (static component of the response). When the skin temperature returned to its baseline level, so did (immediately) the firing rate. This type of response is well illustrated in Fig. 1, which shows the variation in the firing rate of the above-mentioned neuron in the medial preoptic area: this neuron responded to a temperature elevation at the skin surface by greatly and consistently increasing the frequency of its discharges, which indicates that the neuron in question may be linked up with thermoreceptors present at the skin surface [9].

The responses of the other 20 anterior and posterior hypothalamic neurons were devoid of a dynamic component and varied widely. Some of them responded to a rapid change in skin temperature by very rapidly increasing the firing rate, which then remained at the increased level throughout the period of temperature stimulation of the skin. Other neurons responded by a slow rise of the firing rate, while the firing rate of still other neurons declined at a relatively slow pace so that it remained increased even when the skin temperature had returned to its baseline level. It is important to stress that the same neuron could respond in a different way to two or three sequential skin stimulations, as is illustrated in Fig. 2.

In evaluating the present results, it should be noted that while neurons whose reactions were similar to those of cutaneous thermoreceptors have also been identified in nuclei of the spinal cord and medulla oblongata and in the thalamus [4,5,11,12], the presence of such cells in the hypothalamic thermoregulatory center has not been

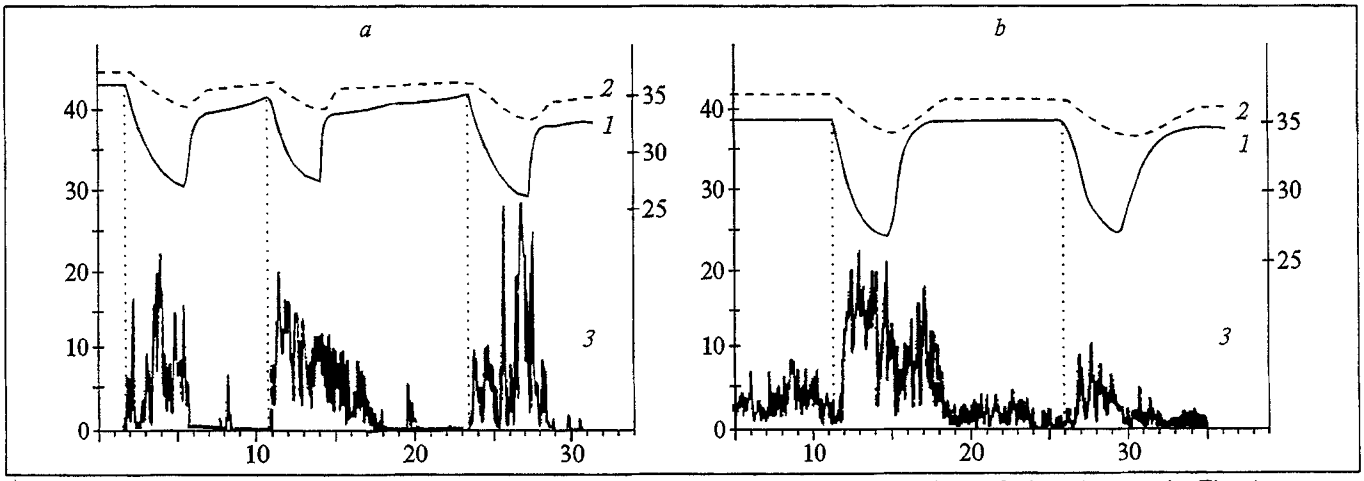

Fig. 2. Responses of two "cold" neurons (*a* and *b*) to reduction of skin temperature. Same designations as in Fig. 1

reported. Although Japanese scientists [10] described dynamic responses of preoptic neurons in response to thermostimulation of the scrotal skin in rats, they suggested that the thermal input from this particular skin area was highly specific. In this study we have been able to show that individual neurons of the thermoregulatory center in both the anterior and posterior hypothalamus respond to thermostimulation of other receptive skin areas in much the same way as do the respective cutaneous thermoreceptors. In fact, the complete reproduction by some such neurons of the responses typically displayed by thermoreceptors indicates that at least a proportion of temperature signals from the skin pass through the various levels of the central nervous system to the hypothalamus without undergoing any specific processing. That this is indeed so can hardly be doubted. The neuron illustrated in Fig. 1 displayed an almost "machine-like" precision in responding in an identical manner to all four sequential temperature stimulations of the skin. The other 20 neurons that responded to cutaneous stimulation appear to belong to that type of thermoresponsive nerve cells which perform integrating functions as they receive temperature signals from central or peripheral thermosensors. This may explain why their responses were so varied and why the same neuron could change its response from one type to another within the 4 to 8 minutes that elapsed between two successive temperature stimulations. The temperature situation varies continuously even in thermally neutral zones in various parts of the body. The diversity of responses shown by neurons of the thermoregulatory center probably reflects the latter's intensive work in maintaining the temperature homeostasis in the body.

REFERENCES

1. E. M. Belyavskii, *Fiziol. Zh. SSSR*, **62**, № 2, 175-182 (1976).
2. L. P. Dymnikova, *Neirofiziologiya*, 5, № 5, 490-496 (1973).
3. V. A. Konstantinov, O. V. Ivanov, K. P. Ivanov, and L. P. Dymnikova, *Fiziol. Zh. SSSR*, **55**, № 4, 517-519 (1969).
4. H. Burton, *J. Neurophysiol.*, **38**, № 5, 1060-1079 (1975).
5. J. O. Dostrovsky and R. F. Hellon, *J. Physiol.* (London), **277**, № 1, 29-47 (1978).
6. H. M. Edinger and J.S. Eisenman, *Amer. J. Physiol.*, **219**, № 4, 1098-1103 (1970).
7. J. D. Hardy, R. F. Hellon, and K. Sutherland, *J. Physiol.* (London), **175**, № 2, 242-253 (1964).
8. R. F. Hellon, *J. Physiol. (London)*, **193**, № 2, 381-395 (1967).
9. K. P. Ivanov, L. P. Dymnikova, and N. Danilova, *J. Therm. Biol.*, **12**, № 4, 289-293 (1987).
10. T. Nakayama, K. Kanosue, J. Ishikawa, *et al.*, *Pflug. Arch.*, **396**, № 1, 23-26 (1983).
11. D. A. Poulos and R. M. Benjamin, *J. Neurophysiol.*, **31**, № 1, 28-43 (1968).
12. G. Schingnitz and J. Werner, *J. Therm. Biol.*, **5**, № 1, 53-61 (1980).