Temperature-Sensitive Neurons in the Brain Stem: Their Responses to Brain Temperature at Different Ambient Temperatures

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Summary. Unit recordings have been made in the hypothalamus of cats and rabbits under urethane anaesthesia. The final position of each electrode penetration was marked by the ejection of a dye. Techniques used enabled brain temperature and ambient temperature to be controlled.

Neurons were found whose mean firing rate was positively or negatively correlated with changes of brain temperature over a range of 4°C. Some of these neurons also responded when ambient temperature was raised to 40°C or lowered to 10°C. In four cases, lowering, but not raising, ambient temperature was found to modify the neuron's responses to brain temperature changes. Two forms of modulation were found. In one, the curve relating brain temperature and firing rate was shifted without showing a change in slope (sensitivity). In the other, the slope of curve changed, so that the sensitivity of the neuron to brain temperature was altered. Both types of modulation are consistent with current models of temperature regulation involving receptors in the hypothalamus and in the skin.

Key words: Temperature Neurons - Hypothalamus - Ambient Temperature.

In the last ten years there have been several descriptions of the responses of single neurons in the brain stem to temperatures changes in their immediate vicinity (Nakayama, Hammel, Hardy and Eisenman, 1963; Hardy, Hellon and Sutherland, 1964; Eisenman and Jackson, 1967; Hellon, 1967; Nakayama and Hardy, 1969; Edinger and Eisenman, 1970). It is generally agreed that the small proportion of neurons in this region which change their firing rate with small temperature displacements are either thermal sensors or synaptically connected to such sensors. Sensors of deep body temperature have also been described in the spinal cord (Simon and Iriki, 1971; Wünnenberg and Brück, 1970) and it has recently been shown that these cells relay to the preoptic region of the hypothalamus where they synapse with neurons responding to hypothalamic temperature (Guieu and Hardy, 1970). These two groups of central receptors are assumed to be important in the regulation of body temperature, but their exact role has yet to be determined.
At the moment it seems unlikely that the thermal sensitivity of these neurons is directly involved in an resting animal’s responses to a hot or cold environment. Careful measurement of hypothalamic temperature has usually failed to show any displacement at a time when an animal is showing vigorous thermoregulatory responses (Forster and Ferguson, 1952; Hammel, Jackson, Stolwijk, Hardy and Stromme, 1963). This suggests that the activating signal for such responses must arise from other thermal receptors and those in the skin are obvious candidates. There have been several studies which show the presence of neurons in the pre-optic region, the posterior hypothalamus and the midbrain which responded both to brain temperature and to environmental (skin) temperature (Wit and Wang, 1968; Nakayama and Hardy, 1969; Hellon, 1970a; Nutik, 1971).

The purpose of the present experiments was to investigate in more detail the interaction between brain temperature and external temperature on the same hypothalamic neuron. The control equations of Stolwijk and Hardy (1966) suggest that altering external temperature might change the sensitivity of neurons to hypothalamic temperature. On the other hand Hammel’s model (1965, 1968) indicates that there would be no change in sensitivity to brain temperature but that the position of the curve relating temperature to firing rate might shift when external temperature was changed. A direct test of these two hypotheses was possible with the techniques used in the present experiments. A preliminary account of some of these results has been published (Hillon, 1970b).

**Methods**

Rabbits and cats of both sexes were used. The weight range of the rabbits was 2.0—4.75 kg and of the cats 2.25—4.2 kg. They were all anaesthetized with urethane (1 g/kg) given intraperitoneally; supplementary doses were given as necessary. A rectal thermistor was inserted and used to measure and control body temperature at 39°C for rabbits and 38.5°C for cats by means of a heating pad.

The animal’s head was inserted in an appropriate head holder and, after drilling the skull, four thermode tubes were fixed vertically in the brain, two on each side of the midline. Details of the arrangements for passing water through the thermodes and for controlling its temperature have been given previously (Hillon, 1967). For rabbits the stereotaxic system of Sawyer, Everett and Green (1954) was used and the pairs of thermodes were placed in coronal planes A 2 and P 2, 5 mm from the midline. The atlas of Jasper and Ajmone-Marsan (1954) was used for the cats and the pairs of thermodes were implanted 10 and 17 mm anterior to the inter-aural plane at either 5 or 6 mm from the midline.

After the surgical preparations were complete the animal and stereotaxic machine were placed in a small wind tunnel facing upstream. The tunnel was equipped to supply air at temperatures between 10°C and 40°C, and the time taken to effect a change from one temperature to another was 30 sec (Hillon, 1970a). Air