EFFECT OF THERMAL STIMULATION OF THE SKIN ON THE FUNCTIONAL STATE OF THE OPTIC ANALYZER

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Soviet authors have described the effect of accessory stimuli, especially thermal, on sensitivity to light [3,4-9,13]. Most workers have explained the facts obtained in terms of humoral mechanisms, with the exception of S. V. Kravkov, who has stressed the importance of nervous connections. The investigations of P. G. Snyakin and co-workers [10,12, 14-19] have shown that illumination of the dark-adapted eye leads to a lowering of the level of sensitivity and to changes in the functional "tuning" of the optic analyzer which may be detected by changes in the number of functioning photoreceptors. If illumination is used as an unconditioned stimulus, conditioned-reflex changes may be observed in the functional state of the optic receptor system [1,2,9,11,15,17,18,19].

The object of the present study was to discover whether changes occur in the level of sensitivity and the "tuning" of the optic analyzer during thermal stimulation of the receptor surface of the skin and to examine the character of these changes.

EXPERIMENTAL METHOD

Investigations were conducted in an experimental dark room after preliminary adaptation of the eye to darkness for 30-40 min. The process of dark adaptation is usually complete after this period and the curve indicating the development of dark adaptation attains a constant level. This level was determined 2-3 times during the period of 5-10 min after the preliminary dark adaptation. When it was certain that the threshold values indicating the level of sensitivity were practically constant, heating of the skin of the dorsal region by means of a Sollux lamp and an infrared lamp began. To ensure that the thermal action was the same in each case, the magnitude of the thermal radiation was first determined by means of a radiometer. The Sollux lamp was placed at a distance of 25 cm from the subject's back and the infrared lamp at a distance of 1 m. By placing the heating apparatuses at these distances the quantity of heat emitted per unit area was the same. Besides heat, however, the Sollux lamp also acted on the skin with visible light.

In all the experiments the eyes were totally shielded from the effect of either factor. The thresholds were determined 1, 5, and 10 min after the beginning of action of the thermal stimulus. The heating apparatus was then switched off and the level of sensitivity restored. In some observations heating was repeated 2-3 times in the course of the experiment, and corresponding changes took place in the functional state of the optic analyzer during the action of the thermal stimulus on the skin.

The index used to characterize the functional state of the optic analyzer was the value of the threshold of intensity of the photic stimulus and of the threshold of area of the photic stimulus. The threshold of area of the stimulus was determined by means of a specially constructed apparatus [14]. The level of photic sensitivity was deduced from the indices of the threshold of intensity of photic stimulation, obtained by means of a model AM adaptometer.

EXPERIMENTAL RESULTS

When the skin was heated the level of sensitivity to light fell, and when the heating apparatus was switched off the sensitivity rose again to its initial level (Figs. 1 and 2). These changes in the functional state of the optic analyzer were observed despite the fact that the eye remained throughout this period in constant conditions of dark adaptation.

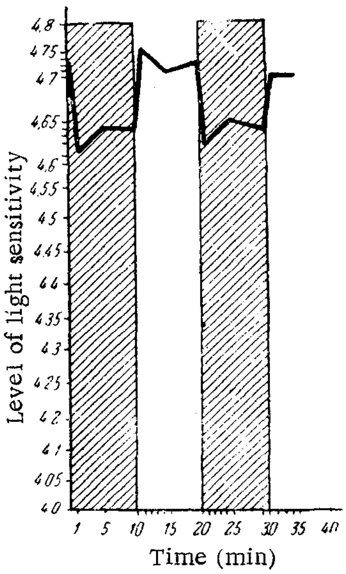

Fig. 1. Changes in the level of light sensitivity of the dark-adapted eye during heating of the skin with an infra-red lamp. The period of heating is shown by shading.

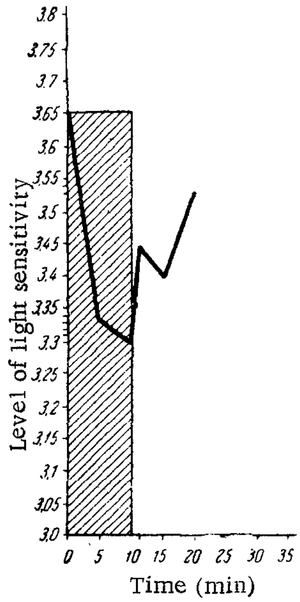

Fig. 2. Changes in the level of light sensitivity of the dark-adapted eye during the action of a Sollux lamp on the skin. The period of action of the Sollux lamp is shaded.

It may be seen in Fig. 1 that on this particular day of the experiment the level of light sensitivity of the dark-adapted eye of subject K. fell from 4.75 to 4.64, i.e., by 0.11, but it returned to its initial value after switching off the heating apparatus. A similar reaction was also observed when the heating was repeated. Both in this experiment and in others on different subjects, during the first minute of heating with the infra-red lamp the level of sensitivity of the eye fell significantly, after which it became stabilized at relatively higher values. This physiological phenomenon, observable when a sharp change takes place in the external environmental conditions (P. G. Snyakin termed it "overinsurance"), is such that "any increase or decrease in the intensity of the active factor causes mobilization or demobilization with a small additional margin" [17]. We observed this initial additional margin in the reaction of the optic analyzer to heating the skin with the infra-red lamp.

The reaction of the optic analyzer to heating the skin with the Sollux lamp was rather different. It is clear from Fig. 2 that on this particular day of the experiment the level of light sensitivity of the dark-adapted eye of the same subject K. fell successively during the period of heating from 3.66 to 3.3, i.e., by 0.36, and began to rise again after the Sollux lamp was switched off.

From a comparison of the two figures it is possible to detect certain differences in the reaction of the optic analyzer. During heating with the infra-red lamp the reaction was smaller in magnitude (0.11) than during heating with the Sollux, and it was accompanied by slight "overinsurance." The results of these experiments showed that the magnitude of the reaction of the optic analyzer to heating by the infra-red lamp, as shown by the change in the level of light sensitivity, taking into account the "overinsurance"phenomenon, varied in all the subjects from 0.03 to 0.47 (average 0.14). The corresponding variation during exposure to the Sollux lamp was from 0.08 to 0.76 (average 0.23). If we remember that the adaptometer scale is logarithmic, it is clear that these values are significant.

The results of the experiments undertaken in order to detect changes in the level of mobilization of the photoreceptors during thermal stimulation of the thermoreceptors of the skin showed that the level of mobilization of the rods of the retina of the dark-adapted eye fell during heating of the skin surface. This may be judged from the changes in the threshold of area of stimulation of the retina. In previous investigations [12] we showed that the magnitude of the threshold of area of stimulation of the retina varies in accordance with the number of functioning photoreceptor elements lying in the zone of projection of photic stimulation. This value thus is an index of the number of functioning receptor elements in the investigated area of the receptor surface.

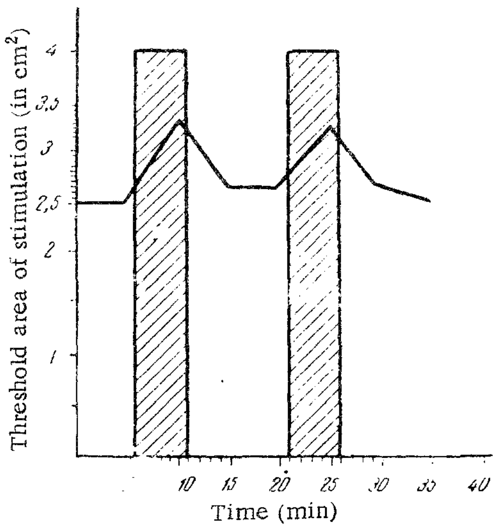

Fig. 3. Changes in the magnitude of the threshold of area of stimulation of the dark-adapted retina during heating of the skin. The period of action of the heating apparatus is shown by shading.

In the observations cited in this article, heating the skin surface led to an increase in the threshold area of stimulation of the retina, which indicates a decrease in the number of functioning photoreceptors in the investigated area of the dark-adapted retina in these conditions (Fig. 3).

It may be concluded from these results that the optic analyzer in constant conditions of dark adaptation undergoes functional modifications during heating similar to those observed during the action of photic stimuli on the retina. This was revealed by changes both in the level of sensitivity of the dark-adapted eye and in the level of mobilization of the photoreceptors. According to previous findings, the latter is an index of the functional "tuning" of the optic analyzer to a corresponding level of perception. Consequently, in response to stimulation of the thermoreceptor system of the skin it is not only the level of sensitivity of the dark-adapted eye which is changed, as other investigators have noted, but also the functional "tuning" of the optic analyzer.

These experimental findings may be examined in terms of general biological principles. Thermal stimuli occupy a special position among the other so-called accessory stimuli affecting the function of the optic analyzer, because in nature heat is usually associated with light and cold with darkness. This is due to the fact that in natural conditions of life the sun is the source of both light and heat. The solar spectrum, of course, includes ultraviolet and infra-red radiation besides visible light. The visible part of the spectrum is perceived by the eye, but the ultraviolet and infra-red rays are mainly perceived by the skin. During a decrease in the level of natural illumination at sunset, the solar spectrum shifts towards the short-wave blue region, with predominance of ultraviolet radiation. When the sun is at its zenith, red and infra-red (heat) rays predominate in the solar spectrum. This fact has a bearing on the receptors of the eye and skin, which react by a suitable functional "tuning."

It must also be remembered that at various stages in the development of animals the perception of photic and thermal energy took place through the skin. Differentiation of receptor systems took place in the course of evolutional development, although the functional connection between the optic and the skin-temperature systems has persisted.

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