INFLUENCE OF AREA OF APPLICATION AND DURATION OF THERMAL STIMULATION OF CUTANEOUS RECEPTORS ON FUNCTIONAL CHANGES IN THE VISUAL ANALYZER

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A study of the functional relationship between the visual and thermal cutaneous analyzers is of considerable interest. There is an evolutionary basis for the connection between these two systems, because at the early stages of the development of the animal world the perception of warmth and light, whose common source is the sun, was mediated by the skin. During subsequent development the perception of light and heat comes about through the differentiation of two different receptor systems, but the functional relationship between them was preserved. Such a relationship between the visual and thermal cutaneous receptors having its basis in evolution is a very important feature in the process of the adaptation of the organism to varying environmental conditions. It represents a supplementary reserve which enables the organism to adjust itself more sensitively to the environment. Many indications have been published that visual function changes when the surface of the skin is heated or cooled [1-8, 12-15].

It has been shown previously that the nature of the functional changes undergone by the visual analyzer in response to thermal cutaneous stimulation are of the same kind as occur during light stimulation of the retina, that is to say when the light threshold is raised. When the skin is cooled the functional condition of the visual analyzer also alters in the same way as during dark adaptation, i.e., the light threshold falls. We have observed not only a drop in light sensitivity but also a functional reorganization of the retinal receptor system in response to cutaneous thermal stimulation. The relationship which has been established between the response of the visual analyzer to thermal stimulation holds both for heating and cooling the skin of the back. In this case the heating device is set up at a distance of one meter from the surface of the back of the individual.

In a study of the reflex interaction with the thermoreceptor system we determined the relationship between the response of the thermal receptors and the area and duration of the thermal stimulus [9, 10, 16]. It was natural to suppose that the response of the visual analyzer in response to thermal stimulation of the skin would also depend upon the area and duration of the stimulus.

Our aim has been to determine how the functional condition of the visual analyzer depends upon the intensity of the thermal stimulus applied to the cutaneous receptor surface.

EXPERIMENTAL METHOD

We determined the response of the visual analyzer in terms of the change in sensitivity of the photoreceptors of the dark adapted retina. The level of sensitivity was determined by means of an AM adaptometer. To apply this thermal stimulus we heated the arm with an infra-red lamp, and in several experiments we either heated or cooled the arm by means of a rubber coil filled with ice or with water at 45°. After 25-30 min of preliminary dark adaptation we determined the initial level of sensitivity of the retina over a period of 10 min; we then determined its change during the period of heating or cooling the skin of the forearm, making measurements 1, 5, 10, and 15 min after the onset of application of the thermal stimulus. The eye remained under constant conditions of dark adaptation, and

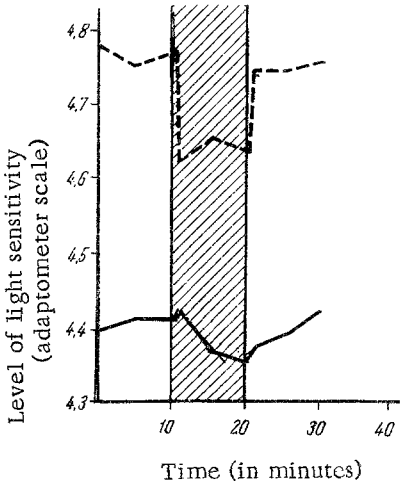

Fig. 1. Reflex response of the visual analyzer to heat applied to various parts of the skin from an infra-red heater at a distance of 1 m for 10 min. Dotted portion – period of heating. Continuous line – light sensitivity during stimulation of the cutaneous surface of the forearm; dotted line – ditto, during stimulation of the surface of the skin of the back.

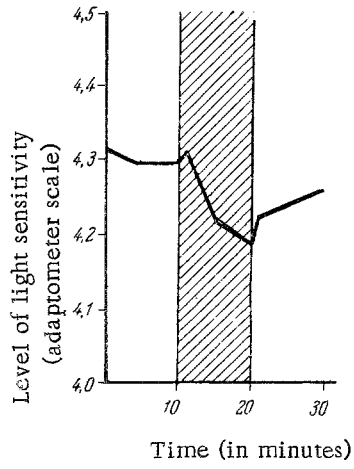

Fig. 2. Reflex response of the visual analyzer to heat applied to the skin of the forearm from an infra-red heater placed at a distance of 50 cm, for 10 min. Indications as in Fig. 1.

was completely isolated from the direct influence of the thermal stimulus. We carried out six sets of experiments: I – determination of the change in level of sensitivity of the dark-adapted retina to heating the arm with infra-red radiation from a distance of 1 meter for 10 min; II – ditto during heating of the arm by infra-red rays from a distance of 50 cm for 10 min; III – during heating of the arm with infra-red rays from a distance of 1 m for 15 min; IV – during heating of the arm with infra-red rays from a distance of 50 cm for 15 min; V – during heating of the arm with a coil filled with water at 45°; VI –during cooling of the arm by a coil filled with crushed ice. Altogether 150 observations were made on six people.

EXPERIMENTAL RESULTS

To demonstrate the influence of the area stimulated, the thermal stimulus was applied not to the back, but to the arm. Then the infra-red heating device was set up in the same way as for heating the back, at a distance of 1 m. In these experiments the response of the visual analyzer was perfectly definite. In most experiments, in response to heating the skin of the forearm there was a small reflex reduction in the level of sensitivity of the retina, but at the same time there were also cases when there was no change of sensitivity or when the sensitivity rose.

Figure 1 shows the curves obtained as a result of taking the average of all the observations made. For comparison a mean curve is shown which indicates the reflex change in the level of sensitivity of the dark-adapted retina in response to heating the skin of the back. While the conditions of the experiment remained constant there was a difference in the response of the visual analyzer according to the extent of the cutaneous surface which received the thermal stimulus. When the heating device was set up at a distance of 1 meter and the back was heated for 10 min the sensitivity of the retina fell sharply, whereas when the skin of the forearm was heated there was only a small functional change in the visual analyzer, and it occurred more slowly. This effect may easily be explained on the basis of results we have obtained previously [9], when heat applied to the back was found to be an effective temperature stimulus causing corresponding changes in the thermoregulatory mechanisms. Heat applied to the skin of the forearm under the same circumstances was a much less powerful stimulus. Greater heat had to be applied to the arm in order to obtain a marked reflex reaction on the part of the visual analyzer.

When the time for which the arm was heated was increased to 15 min, or when the distance from the infra-red heater was reduced to 50 cm a marked reflex response of the visual analyzer was observed (Fig. 2).

From these observations it follows that to display the reflex changes in the visual analyzer system as brought about by thermal cutaneous stimulation, the intensity of the thermal action must be taken into account, and it depends upon the area and duration of the thermal stimulus (while the thermal radiation remains constant). A marked reflex response of the visual analyzer was recorded when the infra-red heater was placed at a distance of 50 cm from the cutaneous surface, and when the heating time was 15 min (see Fig. 2). When the heating ceased the sensitivity of the dark-adapted eye increased. It has been suggested that under such conditions switching off the heater did not correspond to a cessation of the thermal stimulus. On the contrary a thermal stimulus of the opposite sign begins to act, there is a cold

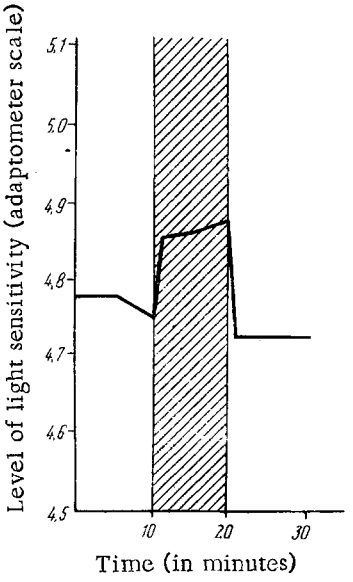

Fig. 3. Reflex response of the visual analyzer to cooling the skin of the forearm by a coil containing crushed ice, for 10 min. Indications as in Fig. 1. Shaded portion – period of cooling.

radiation which also exerts a corresponding reflex response on the part of the visual analyzer. To confirm this hypothesis we carried out separate experiments in which a rubber coil filled with water at 45° or with crushed ice at 0° was used as a stimulus. These experiments showed that application of the coil containing hot water to the skin of the forearm elicited scarcely any reaction from the visual analyzer. Apparently in this case the area of the thermal stimulus is too small. However, application of the same coil filled with crushed ice to the same surface caused a marked response to the visual receptor system which took the form of an increase of light sensitivity of the dark-adapted eye (Fig. 3).

The results given in the present article confirm the idea put forward previously that there is a functional relationship between the visual and thermal-cutaneous receptor system. From these results it follows that the reflex influence of the cutaneous thermal receptor system on the functional condition of the visual analyzer is related to the cutaneous area to which the thermal stimulus was applied and to the intensity of the thermal stimulus. The stimulus can be varied either by prolongation of the period of action of the thermal stimulus or by approaching the radiant source to the skin being heated. Consequently the reflex changes in the visual analyzer system can be observed only in cases when a sufficiently intense thermal stimulus is used, the intensity depending both on the area and on the duration of thermal stimulation.

SUMMARY

We discuss the problem of the functional interrelationship between thermal cutaneous and visual analyzers. The area of skin stimulated and the period of stimulation were shown to be significant in relation to their influence on the functional state of the visual analyzer. Reflex changes in the visual analyzer system can be observed only if the temperature of stimulus is adequate. The effectiveness of the stimulus is directly proportional to the area of the skin and to the time for which it is applied.

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