CHANGE IN THE REFLEX ORGANIZATION OF THE VISUAL RECEPTOR IN RESPONSE TO THERMAL CUTANEOUS STIMULATION

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The functional condition of the exteroceptor systems which enable an animal to obtain precise information from the environment is not influenced by adequate stimuli only. Many investigators [4-7, 10-14], have observed that thermal cutaneous stimulation influences visual function. It is interesting that all observers have noted that an increased sensitivity of the dark adapted eye occurs in response to cold stimulation, and that sensitivity is reduced by heat. We have also observed such effects. We have shown that cutaneous stimulation leads to a change not only of the level of sensitivity but also of the number of functional retinal receptors, and so determines the setting of the visual analyzor at a particular level.

Previously [9] when pointing out functional visual changes induced by thermal cutaneous stimulation we were concerned with the general biological significance of the functional relationship between the systems, and our starting point was the concept that the sun constituted a common source of light and heat. In the observations which we have described, in studying the influence of thermal stimulation on the visual function, we took as our index the threshold of intensity and threshold area of photic stimulation, which indicated the functional condition of the rod apparatus. However, because in the visual system there are two afferent systems, associated with the rods and cones respectively, here we have paid special attention to the interaction of these systems under conditions of thermal stimulation of the cutaneous receptor surface. The experiments were carried out on human subjects.

EXPERIMENTAL METHOD

As an index of the level of mobilization of the rod and cone apparatus we followed M. V. Galuzo [2] in measuring the horizontal (0-180°) and vertical (90-270°) diameters of the visual field, a quantity which represents effectively changes in the magnitude of the whole field. By this means time spent in making the measurement is greatly shortened which was a great help in making observations. The diameter of the black-and-white and colored fields was made by means of a PRP projection perimeter in a dark room; the initial measurements were made before adaptation (initial condition). Then after 30-40 minutes of dark adaptation, for 6-10 minutes after the values had become stable we made two or three repeated determinations during a period when the skin was heated; the measurements were made 1, 5, 10 and 15 minutes after the start of heating. Heat was supplied from an infra-red lamp placed at a distance of 1 m from the heated surface. After the lamp had been switched off the surface of the skin cooled by radiation. During this period too we made measurements of the diameter of the black-and-white and the color fields 1, 5, 10, and 15 minutes after heating had stopped. In many experiments we used an iron cooled in crushed ice as a thermal stimulus.

With this arrangement of the experiment we were able to observe simultaneous changes in the diameter of the black-and-white and color fields during heating and cooling, so that we could deduce the functional condition of the rod and cone apparatuses of the dark-adapted retina during thermal cutaneous stimulation.

EXPERIMENTAL RESULTS

When the skin was heated the diameter of the colorless field was reduced while that of the color field is increased. Figure 1 shows the results obtained on one day. After dark adaptation for 20 minutes the achromatic field

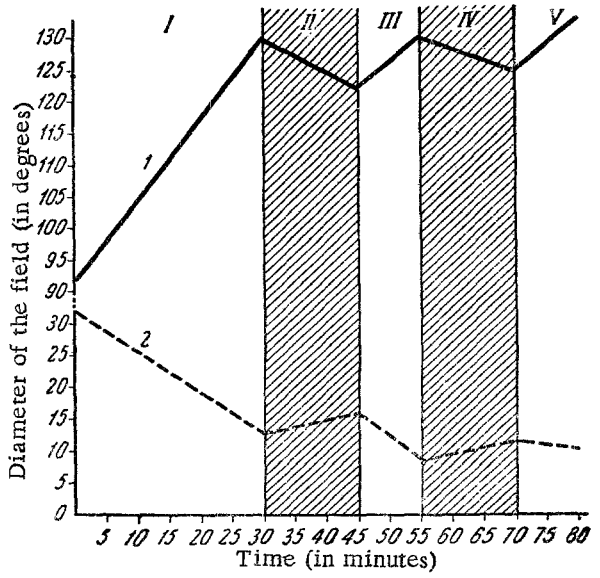

Fig. 1. Change in horizontal diameter of (1) the achromatic and (2) the chromatic fields of view in relation to cutaneous thermal stimulation. 1) Period of dark-adaptation; II and IV) heating (shaded); III and V) cooling.

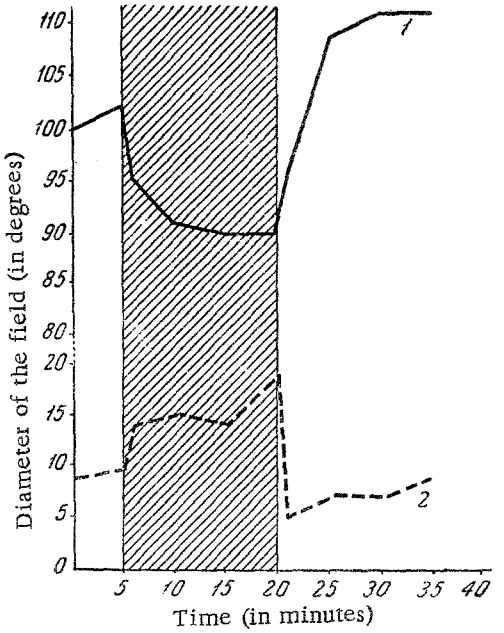

Fig. 2. Changes in the diameter of (1) the achromatic and (2) the chromatic field during heat (shaded area) and cooling of the skin.

had a diameter of 130°, as compared with an initial value of 92°. At the same time the diameter of the chromatic field was reduced from 32° to 13°. When the skin of the back was heated for 15 minutes the diameter of the achromatic field was reduced to 122° while the chromatic field extended from 13° to 16°. After the source of heat had been switched off the surface of the skin cooled by radiation, which led to a reversal of the changes in the condition of the visual analyzer; the diameter of the field then returned to the original value. The achromatic field once more rose from 122° to 131°, while the chromatic field was reduced from 15° to 9°. The same type of change was observed when the skin was once more heated and then once more allowed to cool.

The question now arises as to what is the latent period associated with such functional changes. As can be seen from Fig. 2, as early as one minute after application of heat to the skin of the back the diameter of the field fell 10° (from 105° to 95°) below the level in the dark-adapted condition, while the color field increased from 10° to 14°. As time passed heating caused greater changes, and after 15 minutes (at the end of the heating period) the diameter of the achromatic field had been reduced from 105° to 90°, and the chromatic field had increased from 10° to 19°. After the heating device had been switched off the skin cooled by radiation, and even after one minute changes in the functional condition of the visual analyzer could be recorded. One minute after the start of the cooling the diameter of the achromatic field had once more increased from 90° to 96°, while the chromatic field had fallen (after the certain period of "holding on") from 19° to 5°, i.e., it had become smaller than it was originally. After 15 minutes the diameter of the achromatic field had increased to 111°, i.e., it had come to exceed the value recorded before heating, while the diameter of the chromatic field had returned to the original size. These experiments indicate that the latent period of the change in the functional condition of the rod and cone apparatuses of the dark-adapted retina induced by thermal cutaneous stimulation is 1 minute.

The results we have obtained once more confirm that thermal influence on the cutaneous receptor surface alters not only the level of sensitivity but also the functional organization of the visual analyzor. Indeed, if such stimulations caused merely change in the level of excitability of the visual receptor system then we would expect there to be a reduction or an elevation of the functional level of both the rods and cones. However, during the thermal cutaneous stimulation the functional condition of the visual analyzer, which was maintained under constant conditions of dark-adaptation and completely isolated from the direct action of either light or thermal stimulation, alters in such a way that the reciprocity between the two different retinal systems is maintained. This effect is shown in the change in the achromatic and chromatic fields.

As has been shown previously [2, 8, 14-20] a change in the light-sensitive area occurs through a change in the number of functional rods lying within the achromatic field. However, the area of color sensitivity depends upon the number of functional cones within the chromatic field.

Consequently when the cutaneous receptor surface is heated the number of functional rods is reduced (demobilization), and the number of functional cones is increased. On cooling, the functional level of these afferent systems alters in opposite directions. From this it follows that the functional organization of the visual analyzer depends not only on the action of an adequate light stimulus, but also on thermal stimulation from the cutaneous thermoreceptor.

Many investigators [1, 3, 7, 13] have attempted to attribute these influences to humoral mechanisms. Without denying this possibility we are inclined to think that the changes we have observed are reflex in nature. Evidence to this effect is that the change in the functional condition of both the rod and cone retinal apparatus occurs within the first minute of thermal stimulation. In this case we are concerned with the reflex influences of one receptor system on another. On stimulation the receptors the skin sends signals through the central nervous system to the visual cortex which then brings about the relevant functional change of the visual receptor system. In this case the initial link in the reflex chain of events is formed by the cutaneous thermoreceptors, which are exposed to the direct thermal influence, and the link at the other end of the chain is formed by the retinal photoreceptors, which not being under the direct action of the stimulus undergo functional changes due to centrifugal influences passing from the center to the peripheral receptors. In our view these results must be considered from the viewpoint of centrifugal regulation of receptor function.

SUMMARY

It was shown by perimetry that when the skin is heated or cooled the setting of the human visual system under constant conditions of dark adaptation changes in such a way that the reciprocal relationship between the rod and cone system is retained. Heating the skin caused the rod field to be reduced, but the cone field was increased. Cooling caused the reverse change, i.e., the rod field increased and the cone field was reduced. These functional changes in the visual system induced by cutaneous thermal stimulation are evidently brought about reflexly.

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