DEVELOPMENT OF THE RELATIONSHIP BETWEEN OCULAR AND DERMAL LIGHT PERCEPTION

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The very high, precise sensitivity of the skin of Roza Kuleshova's fingers to nuances of light and color, which enables her to read and to identify drawings with the 3rd and 4th fingers of her right hand, has attracted wide attention. Certain physicists have hastened to advance incompetent hypotheses, even publishing them in the central press. Thus, it has been concluded that the subject's skin contains photoreceptor elements. However, this hypothesis is unfounded, since even in the most extraordinary embryogenetic pathology we cannot consider it possible for cellular structures such as photosensitive elements to arise and develop in the vicinity of the palmar or plantar surfaces.

Individuals similar to Roza Kuleshova have been encountered previously in medical practice. Thus, in his "Physiological Dictionary" (1894) Richet mentions a hysterical girl who was able to read material written on paper with her fingers and to feel colors; the author believed that this was done with the aid of thermal sensations. A. N. Khovrin [4] described a similar case as a rare form of hyperesthesia of the higher sense organs; this case also involved a young girl.

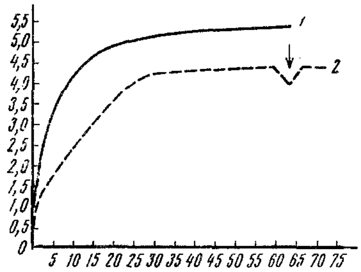

Fig. 1. Curves representing dark adaptation in a normal individual (1) and in the subject, Roza Kuleshova (2). The time (in min) is shown along the abscissa and the photosensitivity level, as shown by the readings on an adaptometer scale, is shown along the ordinate. The arrow indicates the instant at which the fingers of the right hand were illuminated.

Roza Kuleshova is 22 years old. She has normal visual acuity with a visus of 1. Working in the distribution of cultural materials to the blind from the age of 16, she practiced reading ordinary typescript with her fingers. Persistently training herself daily in the development of this ability, within a year she achieved very good results in the differentiation of hues, not only on touching them directly with her fingers, but even when they were covered with thick glass. She easily tells time with her fingers through the glass of household clocks, with an accuracy of up to 1 min, using the positions of the hands on the dial.

During the several weeks for which Roza Kuleshova was in Moscow we conducted physiological investigations of her sense organs, especially the sensory apparatus of the skin and eyes and their relationship. We used very diverse methods to elucidate sensitivity, the adaptive reactions of the receptors to environmental changes, physiological compensation and concurrence in the sense-organ sphere, and the strength of the linkages among the cortical analyzer endings. All these problems are of great importance in the physiology of the sense organs.

RESULT OF INVESTIGATIONS

With visual perceptions completely excluded, the subject reads newspaper text with the 3rd and 4th fingers of her right hand under natural and artificial illumination and easily distinguishes the details of illustrations with respect to hue and intensity, as well as the details of small pictures. The skin

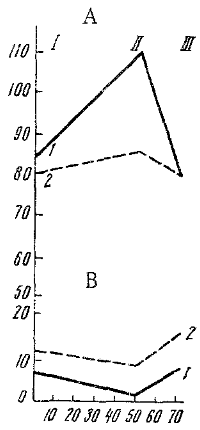

Fig. 2. Change in areas of retinal light sensitivity (A) and color sensitivity (B) in a normal individual (1) and in the subject, Roza Kuleshova (2). I) Initial background; II) after dark adaptation; III) after light adaptation. The time (in min) is shown along the abscissa and the areas of light and color sensitivity (in cm^2) are shown along the ordinate.

of her fingers has a comparatively high resolving and analytic capacity only when there is sufficient illumination. When the illumination is reduced to 3 lx her ability to identify colors is reduced to the differentiation of black and white and she cannot distinguish chromatic hues (green, red). At an illumination of approximately 30 lx she can identify the color of an illustration with difficulty; it is only at an illumination of 40 lx that she begins to identify colors faultlessly, the accuracy of her tonal analysis increasing with illumination to 400 lx. However, greater illumination not only fails to increase the discriminatory photosensitivity of the skin of her fingers, but even reduces it. This is reminiscent of the phenomenon which develops as a result of exposure of the retina to blinding light.

Evaluation of retinal mobility at the threshold of the photostimulation area has shown that the retinal adjustment changes gradually, just as in the normal state, the mobilization level depending on the intensity of the illumination. However, the amplitude of the adjustment of the retinal rod apparatus (crepuscular vision) is limited in comparison with the customarily assumed norm. Investigation of the functional state of these elements during the development of dark adaptation confirmed this inadequacy of the reaction of the retinal rod apparatus. Figure 1 shows a curve for dark adaptation during the twilight hours in comparison with normal dark adaptation. In healthy individuals the sensitivity level and the rate at which it rises are greater at this time than during other periods of the day [1]. These indices proved to be reduced in our subject. It is characteristic that illumination of the fingers of the right hand for 10 sec during the phase of high ocular sensitivity in dark adaptation causes a decrease in ocular sensitivity (see Fig. 1). This is normally observed only when the adapting eye or the other eye (reflexively) are illuminated, it being possible to produce such an effect on illumination of the skin only when the light acts on a large area (for example, according to the data of L. M. Kurilova, over the surface of the back).

A perimetric investigation of the area of retinal light and color sensitivity conducted over a period of 1.5 h with the illumination being artificially varied revealed an inadequacy on the part of the retinal rod apparatus. Thus, keeping the subject in darkness for 50 min produced almost no increase in the photosensitive area, while subsequent 20-min adaptation to natural light caused it to decrease slightly; this is one indication of the limited character of the retinal reaction. The area of retinal color sensitivity varied normally under the aforementioned conditions: dark adaptation caused it to decrease and light adaptation produced an increase (Fig. 2).

Investigation of the color sensitivity (using the Rabkin polychromatic and pigment tables), color thresholds, and discriminatory and contrast sensitivity of the eye revealed a slight inadequacy of color vision. This took the form of a reduced accuracy of hue differentiation, an increase in color-perception thresholds, and a retarded discriminatory ability. However, the subject's digital color sensitivity, especially her discriminatory ability, was found to be higher with respect to these indices.

We made mention above of the remote effect of light on the subject's fingers when their skin is illuminated in darkness. This effect causes a reflex change in ocular sensitivity, the fingers serving as the receptive zone. It must be noted that photostimulation of the fingers is more effective when accompanied by stimulation of the ordinary digital dermal receptors (tactile,thermal, pain). This explains why the subject, when she has difficulty in analyzing an illustration, presses firmly with her fingers and moves them along the surface of the object being "examined."

Our investigations of Roza Kuleshova's tactile, thermal, and pain reception showed that the digital area of high photosensitivity also exhibited a high tactile-, pain-, and thermal-receptor sensitivity. Thus, investigation of the tactile and pain sensitivity of the photosensitivie fingers by Ryazanov's method showed that neither the fingers of the other hand nor other areas of the skin (the back of the wrist, the inner surface of the forearm) could match them in this respect. As may be seen from the table, the threshold of sensitivity was lower with the eyes closed than with them open.

Investigation of the interaction of the visual analyzer with the skin-temperature analyzer showed that heating the back with an electric heater positioned 1 m away did not produce a decrease in the photosensitivity of the dark-

Thresholds of Maximum Sensitivity of Various Dermal Areas Investigated by Ryazanov's Method

Wt. of hair (in g)	Photosensitive zone of 3rd and 4th fingers				Back of wrist				Inner surface of forearm			
	eyes closed		eyes open		eyes closed		eyes open		eyes closed		eyes open	
	right hand	left hand	right hand	left hand	right hand	left hand	right hand	left hand	right hand	left hand	right hand	left hand
0,003	+	—	—	—	—	—	—	—	—	—	—	—
0,006	+	—	—	—	—	—	—	—	—	—	—	—
0,008	+	—	—	—	—	—	—	—	—	—	—	—
0,01	+	—	—	—	—	—	—	—	—	—	—	—
0,02	+	+	+	—	—	—	—	—	—	—	—	—
0,04	+	+	+	+	—	—	—	—	+	—	—	—
0,05	+	+	+	+	+	—	—	—	+	+	—	—
0,06	+	+	+	+	+	+	+	—	+	+	+	+
0,08	+	+	+	+	+	+	+	+	+	+	+	+
0,09	+	+	+	+	+	+	+	+	+	+	+	+
0,1	+	+	+	+	+	+	+	+	+	+	+	+
0,2	+	+	+	+	+	+	+	+	+	+	+	+
0,3	+	+	+	+	+	+	+	+	+	+	+	+
0,4	+	+	+	+	+	+	+	+	+	+	+	+
0,5	+	+	+	+	+	+	+	+	+	+	+	+
0,6	+	+	+	+	+	+	+	+	+	+	+	+
0,7	+	+	+	+	+	+	+	+	+	+	+	+
0,8	+	+	+	+	+	+	+	+	+	+	+	+
0,9	+	+	+	+	+	+	+	+	+	+	+	+
1,0	+	+	+	+	+	+	+	+	+	+	+	+

adapted eye, as is usually the case in experimental subjects [3], but caused it to increase (a reflex proceeding from the skin to the eyes). At the same time, although dark adaptation of the eye caused an increase in the mobilization level of the cold receptors on the palmar surface of the forearm and light adaptation caused it to decrease (a reflex proceeding from the eye to the skin), the amplitude of this reaction was extremely low. After the wrist was bound with black fabric the mobilization level of the cold receptors on the skin surface under investigation (the skin of the forearm) was considerably increased during dark adaptation of the eye and was greatly reduced during light adaptation. The thermoreceptor reflex from one point on the skin to another was manifested in normal fashion [2].

The visual function of the subject's eyes was thus somewhat attenuated, this being especially marked in our evaluation of adaptive reactions to changing illumination conditions; at the same time, her dermal sensitivity (tactile, pain) was very high.

On the basis of the investigations which we conducted how can we most reliably explain the peripheral process of dermal light perception exhibited by Roza Kuleshova's fingers?

The skin contains a number of pigments, including melanin, carotene and its derivatives, etc. We obviously must here consider the principal photochemical substance to be carotene and many of its derivatives (carotinoids), which are the sources for the formation of the vitamin A group. The latter enters into the composition of the visual pigments of the retinal receptor elements (rhodopsin, iodopsin, et al.), which provide for the photochemical dynamics of the retina under the action of visible light. It is characteristic that the carotinoids react to the visible spectrum with different absorption maxima in individual spectral regions (from violet to red inclusive). This means that each group of carotene derivatives has its own light absorption curve in the visible portion of the spectrum and indicates the possibility that photochemical reactions occur in very diverse combinations under the action of light of various wave lengths and different energy levels.

Since in the horny layer of the skin carotene and its derivatives are found predominantly extracellularly, they are in solution, filling the intercellular spaces. It is well known that carotene in solution alters its molecular structure and undergoes decomposition under the action of light. However, carotene derivatives undergo different chemical changes, depending on the wavelength and intensity of the light; this is indicated by the shifts in the spectroscopic curve. According to the data of certain authors [5], extrastructural carotene is distributed nonuniformly in the horny layer of the skin. It is found in greatest quantity where this layer is thickest—on the palmar surface of the wrist and the sole of the foot. The skin of females contains larger amounts than the skin of males. Thus, if we assume an extraordinarily developed network of nerve-ending ramifications in the skin of the palmar surface of the fingers, we can understand how they may react to both mechanical stimuli (the tactile effect) and chemical stimuli originating in the surrounding medium. The high sensitization level of the entire analyzer system enabled the subject, by training, to develop a conditioned-reflex association, the reinforcement being visual evaluation of her perception of a two-dimensional picture. During her training she reinforced the cortical pathways and made more precise her perception of hues by simultaneous stimulation of the visual and dermal analyzers of the cerebral cortex.

Here it is pertinent to recall I. P. Pavlov's assertion that any variations in the external and internal environments of the organism may serve as stimuli for the formation of a conditioned association. K. M. Bykov expressed this idea in the following fashion: "A change in the physical or chemical state of the fluid systems of the organism (the blood, tissue fluid, and lymph) occurring simultaneously with a stimulus reaching the cerebral cortex from any receptor may serve as the basis for the formation of a conditioned reflex" (The Cerebral Cortex and the Internal Organs" [in Russian], 1944, p. 157).

There is every reason to believe that Roza Kuleshova's dermal sensitivity results from the ability of the nerve endings of her skin to perceive the chemical transformations which occur under the influence of light, these proceeding in mosaic fashion and being correlated with the visual image.

The correctness of the hypothesis of the photochemical nature of dermal reception is confirmed by the following facts.

1. The ability of the digital skin to distinguish nuances of hue and intensity disappears in darkness and under weak illumination. If this differentiation were based on a thermal distinction, as Richet suggested, the subject would not have lost her discriminatory ability under these conditions, since the difference in the infrared radiation of areas of different colors obviously remains unchanged in darkness.

2. The existence of an illumination optimum, at which the photochemical transformations of carotinoids in the horny layer of the digital skin are somewhat contrasting in character, the different groups of carotinoids having their own absorption curves. The contrast among colors and among hues of light disappears under extremely high illumination and this explains the loss of perception.

3. Careful washing of the fingers with soap and hot water leads to a substantial extraction of carotinoids from the horny layer of the skin and this causes a decrease in the photosensitivity of the fingers.

In connection with the problem of dermal photoperception, certain other neurophysiological questions have arisen, particularly that of the physiological compensation and concurrence of the analyzers. It is possible that the phenomenon which we studied is a manifestation of unusual physiological compensation for a somewhat reduced ocular function; this is seen in the fact that in visual analysis the subject involuntarily resorts to checking (for greater accuracy) and the use of her fingers. We cannot exclude the converse possibility, i.e., that the role of the eyes has been somewhat reduced by maximum utilization of the fingers, and this phenomenon must thus be considered the result of physiological concurrence in perception.

SUMMARY

The paper presents material obtained from the investigation of the so-called "skin vision" in Roza Kuleshova, capable of perceiving with her fingers the light and color stimuli, the resolving power of which enables digital reading of the printed text in a book.

To elucidate this skin property so seldom occurring in human beings the subject was thoroughly examined in respect to several indices of vision physiology, the tactile and thermal sensitivity of the skin, etc. The paper includes data on the state of these organs of perception. The most probable explanation of such subtle skin perception in the author's opinion, is a chemodynamic process envolving splitting of carotinoids in the palm skin under the effect of direct and reflected visible spectral rays.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
