FUNCTIONAL SIGNIFICANCE OF THE VISUAL ANALYZER

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ABSTRACT

This article examines the physiological characteristics of the human visual analyzer, one of the most complex sensory systems responsible for the perception, analysis, and interpretation of optical stimuli. The anatomical and functional foundations of the visual pathway are revealed, including the structure of the receptor (retina), conduction (optic nerve, chiasm, optic tracts), and cortical sections of the analyzer.

Visual perception is not only a physiological, but also a cognitive process in which memory, attention and thinking are involved. Thus, the visual analyzer does not act as an isolated system, but as an element of a common neurosensory network that unites the analyzers into a single perception system.

The human visual analyzer is one of the most complex and advanced sensory systems, providing up to 80–85% of all information entering the central nervous system.

It is a multi-level system, including the peripheral receptor apparatus (retina), the conductive section (optic nerve, chiasm and optic tracts) and the central cortical center located in the occipital lobe of the cerebral hemispheres.

The main function of the visual analyzer is to receive, encode, transmit and analyze light stimuli, which provides a person with the ability to see, distinguish colors, shape, distance and movement of objects.

The physiology of the visual analyzer covers the processes of photochemical transduction, electrical activity of neurons and the interaction between different levels of the visual system.

The peculiarity of visual perception is that it is not just the registration of light, but the result of complex neural processing of information, including the participation of the retina, thalamus and visual cortex.

Modern neurophysiological research shows that the visual system is able to adapt to changes in illumination, speed of movement and contrast, which makes vision one of the most plastic types of perception.

The structural and functional organization of the visual pathway ensures its precise operation. A light signal entering the retina causes activation of photoreceptors - rods and cones. Rods provide twilight vision and high sensitivity in low light, while cones are responsible for daylight and color vision.

Primary information processing occurs on the retina - the fusion of signals from receptors and the formation of axon potentials in ganglion cells.

From them, impulses along the optic nerve are sent to the lateral geniculate body of the thalamus and further to the occipital cortex (zone V1), where the shape, color and spatial position of objects are analyzed.

Physiological processes in the visual analyzer are based on the mechanism of phototransduction - the conversion of light energy into an electrical signal. This process occurs thanks to photosensitive pigments - rhodopsin and iodopsins.

When a photon is absorbed, the rhodopsin molecule changes its structure, activating transducin and phosphodiesterase, which leads to a change in the concentration of cGMP and, as a consequence, a change in the photoreceptor membrane potential.

Accommodation is another important function that ensures that the image is focused on the retina. It is carried out due to a change in the curvature of the lens under the action of the ciliary muscle and ligamentous apparatus.

When viewing close objects, the muscle contracts, increasing the refractive power of the lens, and when looking into the distance, it relaxes.

Thus, a significant part of the analysis of visual information occurs at eye level. One of the key physiological properties of the visual analyzer is adaptation to light and darkness.

When moving from a dark room to bright light, rhodopsin is rapidly destroyed, which reduces the sensitivity of the retina, and when returning to darkness, it is regenerated, restoring sensitivity.

This process is regulated not only chemically, but also neurogenically - through the interaction of the sympathetic and parasympathetic nervous systems.

The physiology of the visual analyzer is not limited to optical functions. Vision is actively associated with the activity of cortical and subcortical structures. The lateral geniculate body performs spatiotemporal filtering, the thalamus controls attention and gaze direction, and the visual cortex forms conscious perception.

Functional MRI studies have shown that motion perception activates areas V5 and MT, and face recognition activates the FFA area in the temporal cortex. The visual analyzer closely interacts with other sensory systems - auditory, vestibular and somatosensory.

This ensures coordination of movements, orientation in space and the formation of complex ideas about the outside world. Disruption of at least one level of the visual system - for example, damage to the optic nerve or cortex - leads to various types of amaurosis, scotoma and agnosia.

To study the physiological characteristics of the visual analyzer, a complex technique was used, including clinical-physiological, neurophysiological and psychophysiological methods. The study involved 90 volunteers (45 men and 45 women) aged 18 to 60 years, without ophthalmological or neurological diseases.

All subjects were divided into three age groups: young (18–30 years), middle (31–45 years) and older (46–60 years).

The assessment of the functional state of the visual analyzer was carried out in several areas:

Peripheral level - study of visual acuity (Visus), light and color sensitivity, speed of dark adaptation.

Conductive level - registration of visual evoked potentials (VEP) using an electrophysiograph "Neuro-MEP-4".

The central level is the assessment of activity in the visual cortex using electroencephalography (EEG) and functional optical tomography (fNIRS).

The measurements were carried out under standardized lighting conditions (500 lux), at constant temperature and humidity levels. To control adaptation, light stimuli of varying intensities were used - from 0.01 to 1000 cd/m^2.

Light sensitivity was determined using the Goldmann perimeter and the adapted Flick test.

Accommodative abilities were measured using a Huvitz HRK-9000A auto-refractometer, which determines the change in the refractive power of the eye when fixing objects at a distance of 0.3–5 m.

Color perception was assessed using Rabkin's tables and using the computer spectral test "ColorTest 2.0". To analyze electrophysiological data, we used parameters of visual evoked potentials (amplitude and latency of the P100 peak), reflecting the speed and quality of signal transmission from the retina to the visual cortex.

In parallel, ophthalmoscopic monitoring of the condition of the fundus and retinal vasculature was carried out. Biochemical studies included determination of the level of vitamin A, retinal, and the concentration of rhodopsin in retinal tissue samples (in some volunteers examined as part of ophthalmic surgical programs).

Statistical data processing was performed using SPSS Statistics 28.0 and GraphPad Prism 10. Methods of parametric statistics (Student's t-test), analysis of variance and correlation modeling were used. Significance of differences was accepted at a significance level of $p < 0.05$.

Thus, the visual analyzer is an example of a unique biological system that combines the precision of optics, the sensitivity of receptors, the dynamism of neural processing and the ability of the brain to adapt.

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