EC OPHTHALMOLOGY
Guest Editorial

Peculiarities of Visual Perception in Children

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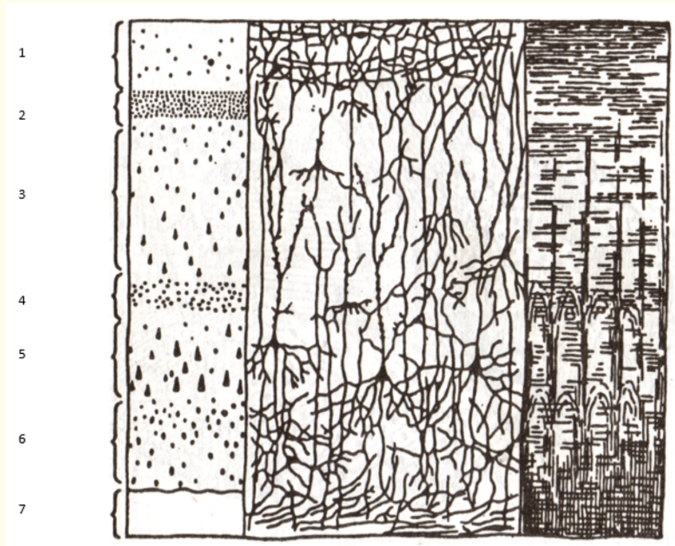
The main property of the visual system, which determines all aspects of its activity and is the basis of such functions as distinguishing the brightness, color, shape and movement of objects, estimating their size and distance, is the ability to respond to the influence of light [1].

Visual perception is a multi-level process that consists of three main stages: 1) sequential transformation of light using the optical structures of the eye into an image projected on the retina, formation of a nerve impulse; 2) transmission of a nerve impulse along the conductive pathways of the nervous system to the cortex of the occipital lobe of the brain, associated with visual perception; 3) an analysis of the nerve impulse is carried out by the brain with the formation of a visual sensation, awareness of the presence of a particular visual image in the field of vision [2,3,9,11,12].

Sensory organs are nervous formations that specialize in the perception, conduct and analysis of nervous excitation. One of the components of the sense organs is the receiving (receptor) apparatus. Perception begins with it. Receptors are excited from three sensitive surfaces of the body: 1) from the outer surface of the body (exteroreceptors), receiving irritation from the external environment; 2) from the inner surface of the body (interoreceptors), receiving irritation from chemicals entering the cavities of internal organs; 3) from the thickness of the walls of the body itself (proprioreceptors), in which bones and muscles are embedded. Receptors from the named fields are connected to afferent neurons, which reach the center and there are switched with the help of a conductor system to efferent conductors, the latter, combining with the working organs, cause one or another effect [18]. Thanks to this, our feelings and knowledge of the world are possible.

From the anatomical and functional positions, each sense organ is divided into three departments: 1) peripheral; 2) conductive; 3) central. The peripheral department (receptor) perceives irritation and transforms it into nervous excitement, which is transmitted through the nerves departing from them, the subcortical structures of the brain to the upper layers of the cortex of the terminal brain (I and II layers: molecular and external granular), where the final analysis and synthesis of excitement and formation of our feelings. It is here that the cores of the sense organs are located.



Picture 1: *Cytoarchitectonic and myeloarchitectonic scheme of the cerebral cortex. 1. Molecular layer. 2. The outer granular layer. 3. A layer of small and medium-sized pyramidal cells. 4. Inner granular layer. 5. A layer of large pyramidal cells. 6. A layer of polymorphic cells. 7. White matter.*

The conductive part is represented by sensitive cranial and spinal nerves. The peripheral department the receptor, perceives only the appropriate types of stimuli caused by the appropriate stimuli [18,21].

The white matter of the hindbrain (both hemispheres) consists of a large number of nerve fibers that go in different directions and form the conducting paths of the hindbrain [13]. Thanks to this structure, when the nuclear part is damaged, it is possible to compensate for the corresponding lost function of the nucleus, which is of great clinical importance [18].

The retina is the light-receiving system of the eye. It contains concentrated sensory cells capable of perceiving electromagnetic waves with a length from 390 to 720 nm. These light-sensitive cells are called rods and cones. Rods, of which there are about 100 million in the retina, have high sensitivity, but low resolution. These cells provide twilight vision. They are not capable of color perception. Cones are day vision receptors that are characterized by low light sensitivity, but greater resolution and the ability to distinguish colors. There are about 5 million cones in the retina. Rods and cones, in addition, have different spectral sensitivity. Cones are more sensitive to radiation with a wavelength of 554 nm, and sticks-513 nm.

The sensitivity of different areas of the retina to light is not the same. The area of the central fossa has the lowest sensitivity, where there are no rods at all, and only cones. The highest light sensitivity of areas 10-12 degrees away from the center, where the largest number of sticks are concentrated. There is another place on the retina that is devoid of receptors and therefore insensitive to light. This is the so-called blind spot. It corresponds to the disc of the optic nerve.

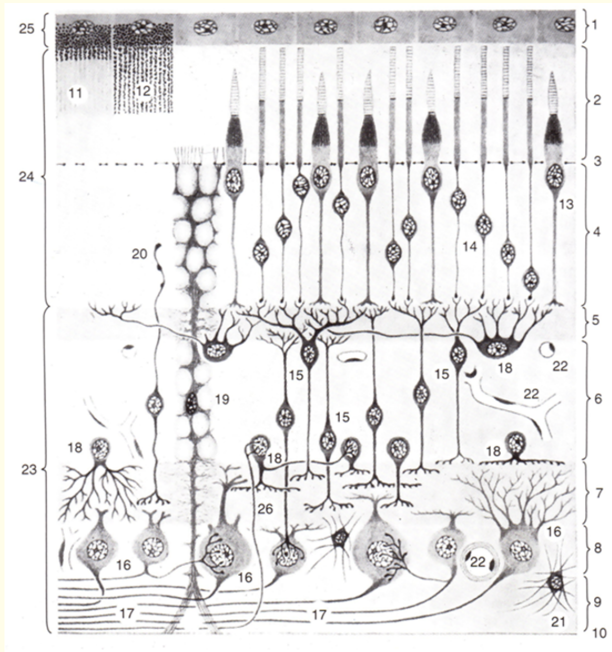
Rods and cones occupy the layer of the retina that is adjacent to the choroid, separated from it by the pigment epithelium (the outer layer of the retina). The outer segments of photoreceptors contain a light-receiving visual pigment (rhodopsin - in rods, iodopsin - in cones). As mentioned, the cones provide color perception. There are three types of cones, each of which contains a pigment. This is erythrolab - the maximum sensitivity to the long-wave part of the spectrum (red-sensitive), or L-cones, which have the maximum sensitivity to light radiation with a wavelength of 558 nm, chlorolab - medium-wave, green-sensitive or M-cones, which are maximally sensitive to radiation with a wavelength of 531 nm, cyanolab - short-wavelength, blue-sensitive S-cones, sensitive to light waves with a length of 420 nm. As a result, when rays of one or another spectral composition hit the retina, there is a clearly localized excitation of each type of cone, which reaches the visual centers, where perception occurs [16].

Due to the fact that the rods and cones occupy the outer layer of the retina (touching and establishing close functional connections with the pigment layer), the light to reach them must pass through all the inner layers of the retina, which are adjacent to the vitreous body. Then, when the light reaches and affects the photoreceptors in the retina, nerve impulses must travel back through the chain of nerve cells toward the vitreous. The outer members of the photoreceptors are in close relationship with the pigment epithelium. This connection is the basis for the normal functioning of the light-receiving apparatus. Cases of retinal detachment along the line of contact of photoreceptors with the pigment epithelium are well know. At the same time, these areas of the retina undergo degenerative changes, as the outer layers of the retina depend on substances that diffuse from the choroid through the pigment epithelium. In addition, the pigment epithelium performs the function of light absorption, phagocytosis, production of acidic glycosaminoglycans, which fill the space between the cilia of the pigment epithelium and the outer members of the photoreceptors, and the accumulation of vitamin A. The apical parts of these cells contain pigment granules and lipofuscin. The pigment epithelium is the place where rhodopsin is regenerated in the dark. Vitamin A, which is not synthesized in the body, takes a direct part in these reactions. We get it only with food. With a decrease in this vitamin, vision decreases significantly [16].

Therefore, light causes irritation of light-sensitive elements embedded in the retina. Nerve elements of the retina form a chain of three neurons. The first chain is the light-sensitive cells of the retina (rods and cones), which make up the receptor of the organ of vision. The second chain is bipolar neurocytes (the bodies of these cells are located in the inner nuclear layer, and their processes extend to the outer and inner plexiform layers) and the third ganglion neurocytes, the processes of which continue into the nerve fibers of the optic nerve. Along with these cells, there are so-called horizontal and amacrine cells in the retina. They carry out cross-interaction between photoreceptors, bipolar and ganglion cells.

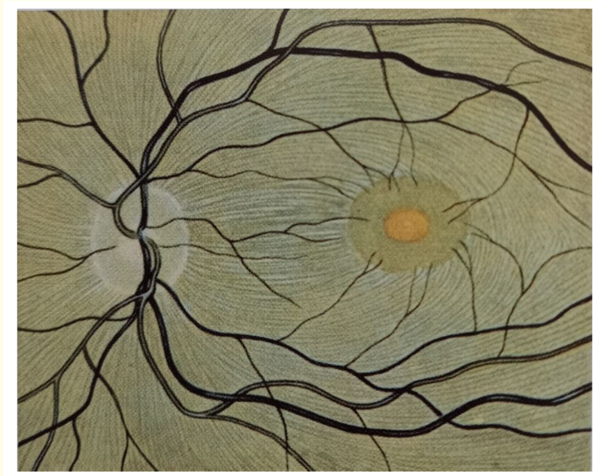
Research by physiologists and neurophysiologists has established that the visual system is organized into clearly distinct parallel paths (P-channel, which processes information about form, M-channel, which transmits information about movement, connecting the retina with higher visual centers and corresponding the main task of vision is to distinguish the object and its localization in space). P and M channels have an anatomical and functional organization and begin in the retina. Small cells (P) of the retina, located mainly in its macular zone; large ganglion cells (M), located in the paramacular-peripheral parts of the retina, give rise to these channels, and in the subcortical-cortical formations, the path is continued by the axons of the corresponding P- and M- cells of the external geniculate body, upper bicuspids and cortex. These cells, both in the retina and in the higher parts of the visual pathway, have similar morphological and functional properties, the organization of receptive fields and ensure the arrival of well-defined visual information (about the shape and color, spatial localization, movement of the object) in the corresponding part of the visual pathway. The main differences in the work of P- and M-channel retinal ganglion cells are determined by the structure of the receptive fields (chromatic and achromatic), in which information about the color and contrast of objects in the environment is already separated at the level of the retina [4-7].

The optic nerve (n.opticus) begins with a disc formed by axons of ganglion cells of the retina, enters the cranial cavity through the foramen opticum and ends in the chiasm. The total length in an adult is from 35 to 55 mm, in a newborn - 26.5 - 41.5 mm; in children 1 year old - 33 - 52 mm; after 1 year of age, the length is practically the same as that of an adult. There are four divisions in it: intraocular (1 mm



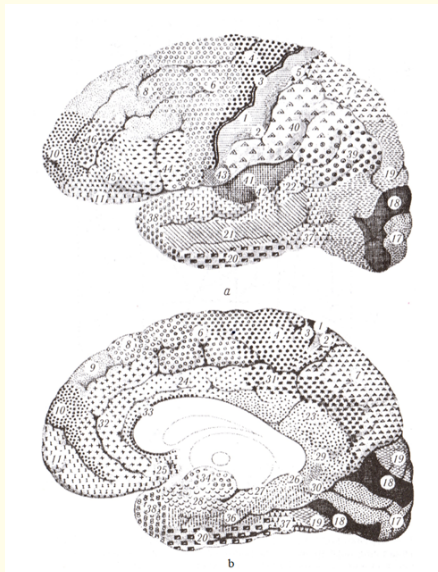
Picture 2: *Scheme of the histological structure of the retina of an adult (from the work of Eisler P, 1930). 1. Pigment epithelium in the state of dark [11] and light [12] adaptation. 2. A layer of sticks and cones. 3. Outer boundary membrane. 4. Outer nuclear layer. 5. Outer plexiform layer. 6. Inner nuclear layer. 7. Inner plexiform layer. 8. A layer of ganglion cells. 9. A layer of nerve fibers. 10. Internal boundary membrane. 13. and 14. Core of cones and rods. 15. Bipolar cells. 16. Ganglion cells. 17. Axons of cells. 18. Amacrines (diffuse, associative, forming layers). 19. Muller supporting fiber with funnel-shaped extension and cores. 20. "Stick" of Landolt. 21. Glial cells. 22. Blood vessels of different caliber. 23, 24 and 25. Functional layers of the retina (brain, neuroepithelial and outer).*

long), orbital (25 - 30 mm long), intracanalular (5 - 6 mm long) and intracranial (4 - 17 mm long). In percentage terms, the total length of the optic nerve in a newborn is 75 percent, and at 1 year of age - 95 percent of the length in an adult. The optic nerve in the orbit has an S-shaped shape, due to which it does not limit the movements of the eyeball and is stretched in exophthalmos [11,12,18-20]. Over a considerable length (from the exit from the eyeball to the entrance to the canalis opticus), the nerve, like the brain, has three shells: hard, arachnoid and soft. Together with them, its thickness is 4 - 4.5 mm, without them - 3 - 3.5 mm. After leaving the eye socket through the canalis opticus, the optic nerve approaches the lower surface of the brain, where it undergoes an incomplete crossing in the area of the chiasmae optici. Only fibers that go from the nasal (inner) halves of the retinas are exposed to the cross; fibers from the temporal halves pass through the chiasm uncrossed. All nerve fibers that make up the optic nerve are grouped into three main bundles. The axons of ganglion cells, which depart from the central (macular) area of the retina, make up the papillomacular bundle, which enters the temporal half of the optic nerve disc. Fibers from the ganglion cells of the nasal half of the retina go along radial lines to the same half of the retina. Similar fibers, but from the temporal half of the retina, "flow around" the papillomacular bundle on the way to the optic nerve disc from above and below.



Picture 3: *The course of nerve fibers (thin lines) in the central part of the retina of the left eye photo of the fundus in red light, from Thiel R, 1946).*

In the orbital part of the optic nerve near the eyeball, the ratio between nerve fibers remains the same as in its disc. Next, the papillomacular bundle moves to the axial position, and the fibers from the temporal and nasal parts of the retina move to the entire corresponding half of the optic nerve. Thus, the optic nerve is clearly divided into right and left halves. Its division into upper and lower halves is less pronounced. An important clinical feature is that its tissue is devoid of sensitive nerve endings [18-20]. In the cavity of the skull, together with the same optic nerve on the other side, it forms on optic cross, chiasma opticum, which is located in the sulcus chiasmatis of the sphenoid bone (the cross is incomplete, only the medial fibers of the nerve cross). Having moved to the opposite side, they connect with fibers from the temporal halves of the retinas of the other eye and form visual tracts - tr.opticum. Papillomacular bundles also partially cross here. In the optic tracts (as well as in the optic nerves), fibers from individual fields of the retina are located is specific areas of the cross-section. Thus, fibers from the upper fields of the retina go in the upper parts of the nerve and tract; fibers from the lower fields of the retina - in the lower sections. In the visual tracts, the length of which in an adult is 30 - 40 mm, the papillomacular bundle also occupies a central position, and the crossed and uncrossed fibers go in separate bundles. At the same time, the crossed ones are located ventromedially, and the uncrossed ones are located dorsolaterally [18-20]. Both crossed and uncrossed fibers of the visual tracts end in two bundles in the subcortical visual centers: 1) in the upper bicuspids of the roof of the midbrain; 2) in the cushion of the optic tubercle and the lateral geniculate body. The first bundle ends in the upper bicuspids of the midbrain, where the visual centers are located, connected to the nuclei of nerves embedded in the midbrain, innervating the striated muscles of the eyeball and the smooth muscles of the iris. Thanks to this relationship, in response to the corresponding light stimuli, convergence, accommodation and a change in the size of the pupil occur, respectively. The second bundle ends in the pulvinar of the thalamus and in the corpus geniculatum laterale, where the bodies of new (fourth) neurons are embedded. The axons of the latter pass through the back part of the posterior leg of the capsulae internae and further form the optic radiation, radiation optica, in the white matter of the hemispheres of the cerebrum, reaching the cortex of the occipital lobe of the brain. The indicated conductive paths from light receptors to the cerebral cortex, starting with bipolar neurons (the second chain of nerve elements of the retina), are the conductive part of the organ of vision. The nerve path of the organ of vision ends on the inner surface of the occipital lobe, along the edges and in the depth of sulci calcarini. The cortical part is the cerebral cortex (I and II layers of the cerebral cortex, molecular and external granular) in the area of the sulcus calcarinus [18,21]. The core of the visual analyzer is located in the occipital lobe (area striata) - fields 17, 18, 19 (according to Brodmann).



Picture 4: *Cytoarchitectonic map of the cerebral cortex according to Brodmann. a) Outer surface b) Inner surface.*

The retina of the eye is projected here, and the visual organ of each hemisphere is connected to the visual fields and corresponding halves of the retina of both eyes (for example, the left hemisphere is connected to the lateral half of the left eye and the medial half of the right eye). In addition, the area located above sulco calcarino (cuneus) corresponds to the lower, and the area below it (gyrus lingualis, or occipitotemporalis medialis) to the upper quadrants of the visual fields [18-21]. The primary visual area (field 17) is located along the sulcus calcarinus. Adjacent to it is the "evaluative" visual area (field 18), which converts the signals received by field 17 into visual images. Field 17 of the occipital cortex is the area of reception and processing of visual information and has important connections with motor visual areas of the cortex. It is at this level of the visual cortex that the value of what is seen is assessed. Motor connections of the occipital lobe are important in optokinetic nystagmus, accommodation reflex and regulation of binocular vision. Fields 18 and 19 are interconnected and have many connections with the rest of the brain. Field 18 is more interested in combining the visual information received in field 17, and field 19 translates this information into more complex motor and thinking activities [13].

The development of the visual pathway begins quite early and runs parallel to the development of the eyeball and brain. Embryonic laying of the organ of vision - the eyeball occurs in the third week of the fetal period [13]. The maturation of individual parts and the development of the functions of the visual system occurs individually and in different age periods, in general - during the entire period of human growth, approximately: in females up to 18 years, in males - up to 22 years [19].

A full-term baby is born with the following features of the visual system. The weight of the eyeball in a newborn is 2.3 grams, in an adult - 7.5 grams; anterior - posterior axis length 17 - 18 mm, in an adult - 22-24 mm, the lens has a spherical shape, optical power 35.0 - 36.0D, in an adult - 20.0 D; the depth of the anterior chamber is 1.0 - 1.5 mm, in 1 year-olds - 2.5 mm, in adults - 3.5 - 4.0 mm, due to such features, light rays are focused not on the retina, but behind it. This explains the presence of hypermetropia at birth is approximately 4.0 D. This hypermetropia decreases with growth and development and disappears completely by 6 - 7 years. The eyeball increases significantly in the first year of life [8,19].

In a newborn, the retina has 10 layers all the way to the dentate line. After the first six months and as the eye grows, not only the outer, but also the inner layers of the retina stretch and thin. In this regard, significant changes occur in the retina in the macular and especially the foveal area: only 1, 2, 3 and 10 layers remain here, which ensures high resolution vision in this area [1]. In a newborn, the foveal pit is not fully formed, which contains immature cones, indistinct contours of the macular area, the background is light yellow, the foveal reflex and clear borders appear at 1 year of age; optic nerve disc from light gray to saturated with a bluish tint, the boundaries are clear, the physiological excavation is not determined, begins to form at the age of 1 year, is fully formed at the age of 7, the density of cells of the pigment epithelium, rods and cones is reduced, which increases to 5 - 8 one year old; incomplete myelination of the optic nerve, reduced system of synaptic contacts in the retina, higher visual centers and occipital cortex. The ophthalmoscopic picture of newborns is distinguished by three variants of a normal fundus: parquet appearance pale pink, bright pink, red. The general background of the fundus in children is formed by the age of 12 - 15 and becomes the same as in adults. For normal postnatal development of the visual system, its subsequent physiological maturation and the presence of the child's sensory experience in the surrounding environment are necessary [17,19].

A feature of the activity of the child's nervous system after birth is the predominance of subcortical formations. The newborn's brain is not yet sufficiently developed, the differentiation of the cortex and pyramidal pathways is incomplete. As a result, newborns are prone to diffuse reactions, their generalization and irradiation, and such reflexes are evoked that in adults occur only with pathology. This property of the central nervous system of newborns also affects the activity of the sensory systems, including the visual one. With sharp, bright and sudden lighting of the eyes, generalized protective reflexes occur - tremors of the body and Paper's phenomenon, which is expressed in the narrowing of the pupil, closing of the eyelids, and strong throwing of the child's head back. There is a blinking reflex and an upward movement of the eyeballs. Eye reflexes also appear when other receptors are irritated, mostly tactile. Thus, with intensive skin combing, the pupils dilate, with light tapping on the nose, the eyelids close. The phenomenon of « doll eyes » is observed, in which the eyeballs move in the opposite direction to the passive movement of the head. Such a protective reaction of the organ of vision to the action of a specific stimulus is due to the fact that the visual system is the only one of all sensory systems that receives adequate afferentation only after the birth of a child. There is a need to get used to the light. As is known, other afferentations - auditory, tactile, interoceptive, proprioceptive - exert their influence on the corresponding systems even during the period of intrauterine development. However, in postnatal ontogeny, the visual system develops at an accelerated pace and visual orientation precedes auditory and tactile-proprioceptive. Therefore, light sensitivity appears immediately after birth. During this period, the eyeballs wander aimlessly independently of each other. True, under the influence of light, even an elementary visual image does not arise in a newborn, mainly inadequate general and local protective reactions, which are given above, are caused. At the same time, from the first days of a child's life, light has a stimulating effect on the development of the visual system as a whole and is the basis for the formation of all its functions. A number of unconditional visual reflexes are also noted - a direct and cooperative reaction of the pupils to light, a short - term orienting reflex of turning both eyes and head to the light source, an attempt to follow a moving object. The expansion of the pupil in the dark occurs more slowly than its narrowing in the light. In the second-third week of life, as a result of the appearance of conditioned reflex connections and the influence of light, the visual system becomes more complicated, forming and improving the functions of objective, color and spatial vision. The sensitivity of the eye to light increases in the first months of life and reaches the same level as adults at school age. Absolute light sensitivity in newborns is sharply reduced, and in the conditions of dark adaptation it is 100 times higher than during adaptation to light. By the end of the first six months of a child's life, light sensitivity increases significantly and, accordingly, is 2/3 of its adult level [1].

By the end of the first month of a child's life, optical stimulation of the periphery of the retina causes reflex eye movements, as a result of which the light object is perceived by the center of the retina. This central fixation is initially carried out instantaneously and only on one side, but gradually due to repetition it becomes stable and bilateral. Without a goal, the wandering movements of each eye are replaced by cooperative movements of both eyes. Convergent and fusional movements arise, the physiological basis of binocular vision is formed - the optomotor mechanism of bifixation. During this period, the child's average visual acuity (measured by optokinetic nystagmus) is 0.1. Binocular visual system begins to form, ignoring the still obvious inferiority of monocular visual systems, and outpaces their development. This happens in order to provide spatial perception, which contributes to the perfect adaptation of the organism to the conditions of the external environment. By the time when high foveal vision puts more and more demands on the binocular vision apparatus, it is already sufficiently developed.

Form central vision appears in a child only in the second or third month of life. In the future, its gradual improvement takes place - from the ability to find an object to the ability to distinguish and recognize it. It has been established that in the fourth to sixth month of life, the child reacts to the appearance of the persons serving it, and even earlier, in the second to third month, it notices the mother's breast. In the seventh-tenth month, the child develops the ability to recognize geometric shapes: a cube, pyramid, cone, circle, and in the second-third year of life - painted images of object.

Parallel to the development of form vision is the formation of color perception, which is also mainly a function of the cone apparatus of the retina. It has been established that distinguishing colors begins first of all with the perception of red, while the ability to distinguish between green and blue appears later. By the age of four or five, children's color vision is already well developed, but it continues to improve.

The emergence of binocular vision requires a functional relationship between both halves of the visual system, as well as between the optical and motor apparatus of the eyes. Binocular vision develops later than other visual functions. The main feature of binocular vision is a clearer assessment of three-dimensional depth space. During the second month of life, the child begins to master the near space. It involves visual, proprioceptive and tactile stimuli that control and complement each other. At first, nearby objects are perceived in two dimensions: height and width, but thanks to touch, they are felt in three dimensions: height, width and depth. This is how the first idea about the integrity of objects is formed. In the fourth month, children develop a grasping reflex. At the same time, most children determine the direction of objects correctly, but the distance is estimated incorrectly. The child is also mistaken in determining the volume of objects, which is also based on distance estimation: the child tries to grasp sunspots and moving shadows. From the second half of life, the development of further space begins. At the same time, tactility is replaced by crawling and walking. They make it possible to compare the distance over which the body moves with changes in the size of the images on the retina and the tone of the oculomotor muscles: visual representations of the distance are created. As a result, this feature develops later than others. It provides a three-dimensional perception of space and is compatible only with a complete commonality of movement of the eyeballs and their symmetrical position. Significant qualitative changes in spatial perception occur at the age of 2 - 7 years, when the child acquires the ability to communicate and develops abstract thinking [1].

The immaturity of the anatomical structure determines the immaturity of the evoked potentials of the retina and visual cortex, the changes of which in the process of postnatal development should be taken into account when analyzing the results of electrophysiological studies. The period of accelerated development of nerve cells, axonal branches and the formation of numerous synaptic contacts is replaced by a period of destruction and a sharp reduction in the number of redundant, rapidly developing neurons in the previous period and their ineffective contacts, contributing to an increase in the specificity of the nervous tissue and fine-buning of its function. Synaptogenesis is an important process of brain development and plasticity in the first years of life. The results of studies of the density of synaptic contacts indicate that the excess formation of synapses within 2 years after birth is followed by the process of synapse reduction, which continues into the adolescent period. These processes occur according to a specific time schedule that differs in different parts of the brain. According to research by P. Huttenlocher and A. Dabholkar, the synaptic density in the visual cortex reaches its peak around the age of 9-15 months and then decreases, reaching the adult level in teenagers [8,10,14,15]. The age of 6-7 years is considered critical and sensitive for the improvement of the mechanisms of visual perception, the development of holistic perception of images, since it is during this period that the intensive maturation of intercentral connections of the cortical areas of the organ of vision takes place [17].

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