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Biophysical aspects of electromagnetic theory of human vision perception of light information in the visible range

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Objective. To propose an electromagnetic model for human recognition of light information received by a man in the visible range of light, which allows to prove its consistency strictly and based on the calculations made, as well as models of electronic circuits illustrating how simple connections between rods and cones can ensure its implementation, and construct a hypothesis about the transmission of converted information in real-time to the central nervous system on their basis. The goal also includes proposing a hypothesis for the volumetric perception of external information by the visual analyzer and the central nervous system.

Materials and methods. Mathematical modeling of data approximation in biology and medicine of numerical values of parameters according to experimental data, a set of formulas and equations that describe the properties of the object under study and allow establishing quantitative relationships between them.

Results. The model developed by the authors of electromagnetic perception of electromagnetic waves of the visible spectrum by human vision based on their resonant separation and amplification allows us to propose a solution to the theory of color vision. The given speed calculations based on the saltatory conduction of information from the nerve fiber explain the human subjective feeling of light almost instantly. The hypothesis proposed by the authors of a three-dimensional perception of the external world by a person needs an in-depth mathematical justification. Therefore, we can assume that this is another step in solving the problem of human perception of light information.

Conclusions. The electromagnetic theory of colour perception by the human visual analyser of light information has been constructed in contrast to the corpuscular. Calculations of the electrophysiological parameters of rhodopsin molecules included in the rods are presented, and, a model of resonant perception of electromagnetic oscillations for the visible range of light by the human eye has been developed on this basis. Calculations based on the developed model for converting information in the visible light range of the electromagnetic spectrum made it possible to more accurately determine the number of colour shades distinguishable by the human eye. A mathematical model describing the transmission of information about the spectrum and intensity of the electromagnetic signal of the visible range of the spectrum transformed by the eyes to the central nervous system has been proposed. The speed of information transmission along the optic nerve has been calculated. The hypothesis for the volumetric perception of external information by the visual analyzer and the central nervous system has been proposed. Practical application of the developed model can be devices allowing to restore vision, as well as devices for correcting vision function built on its basis.

Key words: *rhodopsin; CNS; photoelectric effect; femtosecond; 11-cis-retinal; inductance; capacitance; resistance; resonance; membrane.*

Introduction

The first rigorous mathematical proof of the light and colour theory was made by I. Newton in 1672 in his work “New Theory of Light and Colours”, wherein he proved that light is not monochrome [1].

The research results quite advanced for their time were presented in the works of M. Lomonosov, K. Müller, T. Young, H. Helmholtz, and other researchers at the end of the 18th-19th centuries, but they could not create the final basis for the theory of colour vision [2].

Molecular physiology of visual pigment was developed by G. Wald *et al*. in the 60s of the last century (Nobel Prize in Physiology and Medicine, 1967), then by Yu. A. Ovchinnikov at N.M. Emanuel Institute of Biochemical Physics, and then in the works of M.I. Ostrovsky with co-authors [3].

Discussing the intra-molecular mechanisms of spectral adjustment of visual pigments, a series of recent works by Japanese authors should be mentioned [4], wherein combined methods of quantum mechanical calculations and molecular mechanics modelling (QM/MM) were used. The chromophore group in the molecule was considered in these works within the framework of the quantum mechanical approach, and the protein environment - within the framework of the molecular mechanics methods. According to the authors, the results of these calculations show that spectral adjustment is determined by the interaction of the retinal chromophore with the counterion complex and the protein environment. The effect of changes in the chromophore structure itself (the presence of ~~a~~ 11-*cis*-retinal residue) or 11-*cis*-3,4-dehydroretinal) is insignificant [5].

Three factors determining the position of the maximum absorption for visual pigment are considered:

1) the nature of the chromophore and its configuration;

2) interaction of the chromophore with the opposition complex;

3) interaction of the chromophore with the nearest protein environment.

The spectral adjustment of the pigment is determined by the last two. The nature of the chromophore and its isomeric configuration is the same for all pigments - this is the retinal residue with the 11-*cis* configuration. Consequently, the "adjustment" of the modelling visual pigment spectral sensitivity is one of the most important physiological functions of the retinal chromophore in the chromophore centre. According to the authors, this intramolecular adjustment ensures adaptation of the photoreceptor cells in the visual organs of invertebrates and vertebrates to the light environment and formation of the colour perception mechanism [6].

Despite a large amount of work on the three-component theory of colour vision, so far it has not been possible to find any differences between the cone receptors of the retina, aside from the presence of three different types of retinal cones.

In addition, the existence of only two light-sensitive pigments, chlorolab and erythrolab, has been proven, and their simultaneous presence in all retinal cones has not been proved, while the sensitive pigments spectra have a broadband spectrum, i.e., across the entire visible spectrum.

And, at first glance, a simple question has not yet been sufficiently studied: why a person has from 5 to 6 million cones, and 10 times more rods, according to various sources, i.e., 80 - 90 million, and what evolutionary processes in the development of human vision have determined that 10 times fewer receptors should be responsible for light perception than for sensitivity to light brightness, and the question of how colour separation occurs at the level of the retina has not yet been studied.

Thus, none of the hypotheses proposed so far will be able to confirm or refute the three main hypotheses existing to date, these are:

- three-component theory of colour vision;
- opponent colour vision theory;
- nonlinear theory of vision.

It is generally accepted that colour vision theory can be considered acceptable when the following conditions are met:

- the theory should be based on objective, reliably established experimental data only;
- the model should be objective and described by mathematical dependencies in real three-dimensional space;
- the theory should be based on specific physical laws, without any approximations and exceptions [7].

This work is devoted to the development of the theory of human visual perception of electromagnetic radiation in the visible range based on scientifically proven physical properties of electromagnetic nature of light, as well as anatomical characteristics of the eye, well-known experimental studies in the field of rhodopsin photochemistry, and theoretical studies of electromagnetic characteristics for rhodopsin have been carried out on this basis, using which a new theory of spectral adjustment of the visual analyser, based on the principle of the occurrence of resonance, which is present in human organs as a means of isolating and amplifying information coming from the external environment, is proposed. Calculations of possible amount of colour perception by the human eye in conditional frequency ranges were carried out based on the proposed model; the problem of subjective sensation of the speed of transmitted information perception from the eye to the central nervous system has been studied; calculations of the model of saltatory conduction of the potential along the nerve fibre are proposed; electromagnetic theory of light information perception for human visual analyser is proposed in contrast to the corpuscular theory; a mathematical model of information transmission to the brain and its identification has been developed; a hypothesis of volumetric perception of external information by the organs of vision and the central nervous system is proposed. The devices able to solve the problem of vision prosthetics for people with functional impairments can be created based on the theoretical results of this work.

Most theoretical works devoted to the processing of information about the effect of light on the visual organs are based on its corpuscular properties without taking into account the features of its electromagnetic nature.

The model of light perception by human vision, which is based on the available proven physical characteristics and physiological characteristics of the perception of electromagnetic light energy by the eye, is considered in this paper. First of all, it is the wavelength of visible light, which lies in the range from 400 nm to 750 nm, and associated energy of the luminous flux to which the eye reacts.

The goal is to propose an electromagnetic model for human recognition of light information received by a man in the visible range of light, which allows to prove its consistency strictly and based on the calculations made, as well as models of electronic circuits illustrating how simple connections between rods and cones can ensure its implementation, and to construct a hypothesis about the transmission of converted information in real-time to the central nervous system on their basis. The goal also includes proposing a hypothesis for the volumetric perception of external information by the visual analyzer and the central nervous system.

Materials and methods

Mathematical modeling of data approximation in biology and medicine of numerical values of parameters according to experimental data, a set of formulas and equations that describe the properties of the object under study and allow establishing quantitative relationships between them.

Results and discussion

It is known that human eye perceives light information by receptors located in the retina — these are rods and cones. These are specialized nerve cells capable of generating electrical signals when exposed to light.

According to the third law of the photoelectric effect, there is a cut-off frequency for each substance such that a lower frequency radiation, whatever the intensity of the incident radiation, does not cause the photoelectric effect. This minimum frequency is called the red border of the photoelectric effect (λ_{red}) [8]:

$$\lambda_r = \frac{ch}{A_{out}},$$

$$A_{out} = hf_{min},$$

where λ is a red border of the photoelectric effect,
f is radiation frequency,
A is the electronic work function,
c is the light velocity,
h is Planck's constant.
$h = 4{,}135667669 \cdot 10^{-15}$ eV/s.

Therefore, the red border for the eye is 405 THz (740 nm), and the entire frequency range lies in the range from red to violet. The photon energy lies in the range from 1.97 to 2.75 eV in this case. This range is conditional. In reality, colours blend smoothly into each other.

We calculate the average energy the eye perceives over the entire range:

$$BW_{av} = \frac{\Sigma кр + \dots \Sigma ф}{8} \approx 1.6875 \text{ eV} \approx 1.7 \text{ eV}$$

Energy is expressed in erg/s in the SI system:
$1 \text{ eV} = 1.6 \cdot 10^{-12}$ erg/s.
Thus, the average sensitivity is:
2.72 erg/s $\cdot 10^{-12}$.

This is the sensitivity of the photodetector per second according to the energy conservation law.

In recent works on the study of the rate of reactions of biochemical transformations of rhodopsin under the influence of the photoelectric effect, it was shown that it is equal to femtoseconds, i.e., 10^{-15} (200 fsec) [9].

Determine the sensitivity of the eye over a period of 200 fsec. It equals $544 \cdot 10^{-27}$ erg/fs.

The sensitivity was previously established equal to $10^{-10} \div 10^{-11}$ erg/s in the studies on the photosensitivity of the eye [10].

Such insignificant energy makes it difficult to perform complex biochemical rearrangements, which essence is reduced to a change in rhodopsin, the reaction of visual pigment absorption - a chromophore and its configurations. This is the first fact questioning that only the biochemical function of the retinal chromophore is the reason for the "adjustment" of the visual pigment spectral sensitivity. At the same time, the nature itself of very complex transformations of completely unexplored processes occurring in cones and rods is different, for example:

It has been proven that the opsins of cones and rods are different.

Thus, despite significant advances in the study of complex biochemical transformations associated with the conversion of 11-cis-retinal chromophore into its trans-formula as a photochemical reaction in vision, it does not strictly prove how the process of extracting the colour spectrum of visible light with rods occurs and cones [11].

This theoretical model is based on the fact that nature, as a result of human evolution, has created a mechanism based on the phenomenon of resonance, which allows to selectively enhance information coming from the external environment. One example of such an evolutionary solution, for example, is the cochlea, where sound is amplified depending on its frequency due to its geometric dimensions [12].

Nature has implemented the same principle of resonance for the analysis of the energy of light, which is about 10 million times more in frequency and as much weaker in power.

To prove this, it is necessary to consider a number of issues related to molecular biophysics.

In accordance with the valence bond theory (W. Geimer and F. London), it is proved that two electrons with opposite spins belonging to two atoms give an overlap of the electrons wave functions and, as a result, a zone with a significant electron density arises between the atoms, which leads to a decrease in the potential energy of the system, and this, in turn, leads to the formation of a two-centre, two-electron bond, indicated in the formulas by a dash and called covalent, which we have in the structural molecule of rhodopsin ***(Fig. 1)*** [13].

The structure of the molecule is based on the CH_3 structure, in which the main energy role is played by hydrogen, the spin of the H atom is ½, and the spin of the carbon atom is C0 [14].

Biochemical processes in rhodopsin under the influence of light permit it to be confidently stated that the process of accumulation and redistribution of energy occurs at the moment of its transformation.

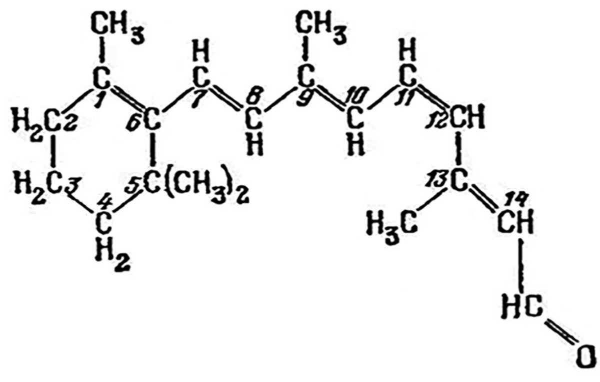

Fig. 1. Structural formula of rhodopsin molecule

Inductance in the general physical sense is the ability of a substance to accumulate electromagnetic field energy. In diamagnets, the rhodopsin can be attributed to, this phenomenon is also present, due to the molecular polarization.

Rhodopsin is a diamagnetic. The inductive interaction between non-polar and polar molecules, which occurs under the action of the field of a polar molecule, has an electromagnetic nature. It is determined by the action of electric dipoles in molecules [15]:

$B = \chi H$,

where χ is much less than 1,

$$U_{ing} = \frac{1}{(3{,}8A^0)^6}$$

It is known that inductive connections arise under the action of light exposure and cease after it.

The inductance of one disk based on the available data was calculated. This is the number of molecules in the disk and the energy, which is responsible for the energy balance, equal to 12.6 eV.

$$W_M = \frac{B^2}{2M_0M},$$

$$B = \sqrt{\frac{W_M}{2M_0M}},$$

where m_0 = 12.56 H/m · 10^{-7}.

Take M = 1, substitute the values of the energy of one molecule, equal to:

3.2 · 10^{37}, we get an approximate value for the inductance of one molecule, equal to 3.65 · 10^{-16} H.

According to calculations, the inductance of one disk, given that one disk contains approximately 8 · $10^4$4 molecules, is equal approximately to: 28.48 · 10^{-12} H.

It was found that the capacity of the biological membrane is approximately 0.9 $\frac{\mu F}{cm^2}$ [16].

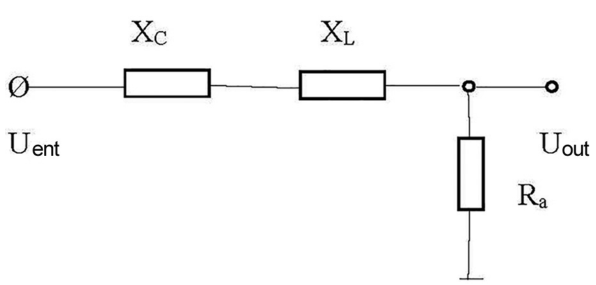

Fig. 2. Filter circuit: where XC is the capacity of rods, cones, XL is the inductance of rods, cones, Ra is their active resistance

Find the capacity of one rhodopsin molecule with a diameter of 4.2 nm:

$$S = \frac{3{,}14 \cdot 4{,}2^2}{4} nm \approx 14.0\ nm^2 = 14 \cdot 10^{-14}\ cm^2,$$

then, the capacity

C = 14 · 10^{-14} cm^2 · 0.9 μF/cm^2 = 12.6 ·10^{-14} μF.

Therefore, the capacity of 1 molecule will be approximately 14 · 10^{-10} μF.

One disk contains 8 · 10^4 molecules.

The capacity of one disk ~ 14 · 10^{-14} μF · 8 · 10^4, 112 · 10^{-10} μF.

Let's calculate complex resistance of one rhodopsin molecule using the well-known Thomson formula:

X_L = 2πfL.

If the performance period is 200 Fs, substituting it into the formula, we get:

X_L = 6.28 · 0,005 · 10^{15} · 3.56 · 10^{-16} = 112 · 10^{-4} Ohm;

$$X_C = \frac{1}{2\pi fL} = \frac{1}{6{,}28 \cdot 0{,}005 \cdot 10^{15} \cdot 112 \cdot 10^{-10}} = 0.28 \cdot 10^5\ Ohm.$$

Based on the theoretical calculated data, it can be assumed that rods and cones, having certain electrical characteristics, can be combined in the form of a filter circuit, due to which only the frequency of a certain wavelength is transmitted (selected) from the general monochromatic spectrum.

Fig. 3 shows a graphical characteristic of such a filter for the conditional frequency range, and ***Fig. 2*** shows a simple diagram of such a filter.

Rods and cones can be combined to create resonant filters in series for the frequencies of the entire visible spectrum of light. Let's determine the number of filters: to do that, select the average frequency for each range and the quantization step for this, which will be equal to the change in energy per unit of frequency ***(Table 1).***

It is known that rods are mainly responsible for the perception of the lighting brightness. To solve this issue of gradation, it is necessary to determine how many shades the eye can determine in each conditional range of the spectrum in terms of sensitivity to the luminous flux intensity.

To do this, the energy of all impinging light is defined. It is equal to 16.25 eV. The perception of sensations by the eye of different colours is uneven. Let's determine the number of shares for each conditional frequency range of the visible spectrum. It will be equal to the energy of the entire spectrum divided by the change in energy in each range ***(Table 2).***

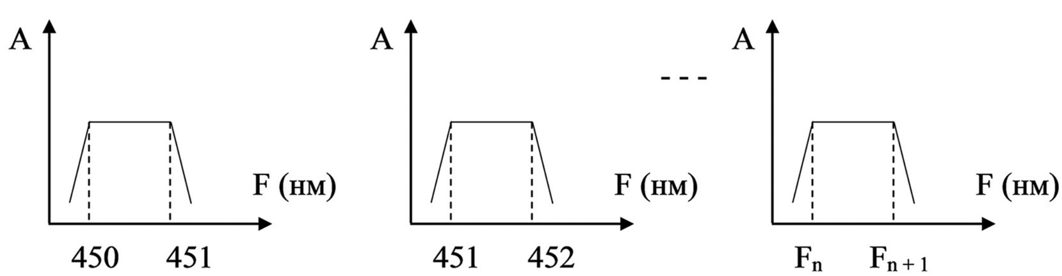

Fig. 3. Filter characteristic curve

Table 1. Spectral characteristics of visible light

Legend colours	Midband frequency, (nm)	Range energy, (eV)	Energy change in the range, (eV)	Minimum number of filters, (p)
V	450	≤2,75	0,17	2647
C	465	2,58–2,75	0,17	2735
LB	495	2,43–2,58	0,15	3300
G	530	2,25–2,43	0,18	2944
Y	582	2,10–2,43	0,33	1763
O	600	1,97–2,10	0,13	4615
R	610	≥1,97	0,13	4692

Table 2. Number of colour shades

Conditional midband frequency, (nm)	Energy change in the range, (ev)	Minimum number of shades in the range, (p)
450	0,17	95
465	0,17	95
495	0,15	108
530	0,18	90
582	0,07	232
600	0,13	125
610	0,13	125

The calculations show that the number of counts for violet will be 95, for blue - about 95, blue - 108, green - 90, yellow - 232, orange - 125, red - 125. Totally, 1073 reference points for the entire spectral range.

Let's calculate the possibilities of energy perception by rods for changing luminous flux. For a diatomic molecule, the main energy is equal to the energy of hydrogen, and it is equal to [17]:

$$E = 4.4763\ \text{eV}$$
$$4.4763 \cdot 3 \approx 12.6\ \text{eV}$$

The energy of the rhodopsin molecule is 12.6 eV. Representation for this value in volts is:

$$U_B = \frac{1{,}6 \cdot 10^{-19} \cdot 12{,}6}{6{,}248 \cdot 10^{8}} = 3.2 \cdot 10^{-37}\ V$$

One disc contains $8 \cdot 10^4$ rhodopsin molecules, one rod contains about 10^3 discs, the eye has about 10^8 rods. Comparing the available data parameters, it becomes clear that this is not enough for a potential on the ganglion cell to appear under the action of light, for the order of 60–70 mV. It is necessary to create such physical conditions for this allowing the rods to transmit through bipolar and ganglionic neurons a potential equal to 60 ÷ 70 mV to the brain.

The physical method, making it possible to obtain the necessary potential, is a voltage resonance, which can be performed in the human eye by connecting the rods in series according to a well-known scheme ***(Fig. 4)***, where the active and reactive resistance of the circuit, respectively. In accordance with theoretical calculations, the resonance in the circuit occurs when the loop oscillations coincide with the oscillation frequency of the external signal.

Let's calculate the speed of information transfer to the brain, the average length of the optic nerve is 0.045 m (45 mm). Since, a human subjectively sees almost instantly, according to the sensation, we will choose the maximum known speed of information transmission along the nerve fibre, which is 120 m/sec. Thus, the signal conduction time will be equal to: 0.000375 sec or 0.374 msec, if the time required for signal processing in the central nervous system is taken into account, then this is a fairly long period of time not observed in reality.

The solution to the problem lies in saltatory conduction of a signal along the nerve fibre, which is implemented by nature, due to the myelinated membranes of ganglion cells [18]. The model of such a fibre can be represented as capacitors connected in series. The potential transmitted along the ganglion cell, 45 mm long, has approximately 30 Ranvier's node along its entire length (the distance between constrictions is 12 mm) [19]. Thus, the charge time for C1 will be equal to:

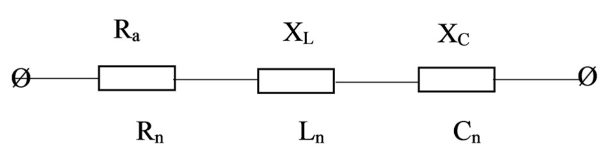

Fig. 4. Resonant circuit diagram: where Ra is an active resistance of rods, XL is inductive resistance of rods, XC is capacitive resistance of rods

$T = RC$,
where C is a capacity equal to the capacity of one node,
R is average resistance equal to 35 Ohm/cm^2.

The Ranvier's node capacity is calculated using the formula for a plane capacitor:

$C = ee_0 S/D$,
where e is 1,
$e_0 = 8.85 \cdot 10^{-12}$ F/m,
$S = 1.6 \cdot 10^{-10}$ m^2 is the area of Ranvier's node;
D is ganglion cell thickness - 1.5 μm/2 = 0.75 μm.

Substituting the values, we get: $C = 18 \cdot 10^{-18}$ F.
$T = 35$ Ohm/μm$^2 \cdot 10^8 \cdot 18 \cdot 10^{-18}$ F $= 630 \cdot 10^{-10}$ s.

Thus, the rate of potential conduction throughout the entire nerve fibre will be approximately 190 ns, considering that approximately 30 Ranvier's nodes are located throughout the entire ganglion cell. This time of holding the potential is much closer to real subjective sensations.

Human eyes can be imagined as a source of optical information simultaneously converting electromagnetic oscillations in spectrum and intensity into electrical impulses entering the central nervous system [20]. According to the information theory, there is an exact coding method allowing the transmission of all information generated by the source with an arbitrarily small error probability for any performance of the message source, less than the channel performance [21]. Let us represent the transmitted information in the form of a function including a finite number of points at the end time T. A function in a discrete form can be depicted in this case as a table of neurons, not arbitrarily connected to each other, but in the form of connections allowing the transferring all the information coming from the eyes in such a way that semantic information corresponding to the original one will be obtained from individual points.

Let us write the value of the information received as a result of the spectral component decomposition in the visible spectrum, reflecting the state of neurons, in the form of a quadratic matrix according to a simple principle: if there is information – «1» is written, if there is no information – «0» is written. For example, we will write a matrix for the violet part of the spectrum, indicating the initial values ***(Fig. 5)***:

Then, according to the law of matrix multiplication, their result will be:

$A1 \cdot B1 = AB$,
the result obtained reflects the state of the information coming from the eye to the central nervous system for each moment of time.

$$\text{using (a) - } \left\| \begin{matrix} a11\ a12\ a13 \dots\ a1n \\ a21\ a22\ a23 \dots a2n \end{matrix} \right\|$$

$$\text{by intensity (b) - } \left\| \begin{matrix} b11\ b12\ b13 \dots\ b1n \\ b21\ b22\ b23 \dots b2n \end{matrix} \right\|$$

Fig. 5. Spectral matrix

In accordance with the theory of information coding [22], information adequacy

$T < 1/2Fn$,
where T is the sampling period,
Fn is the highest frequency in the F(T) signal spectrum.

Information obtained from two independent sources is equal to the sum of the amount of information received from each source, and the proposed measure for the amount of information gives the following product in this case:

N1 +N2 N1N2
$N = m + M \cdot M = N1 \cdot N2$,
where N1, N2 is the number of possible messages from two message sources.

The performance of a message source (P) is the average amount of information generated by the source per unit of time:

$p = 1/t$.

The information capacity of a message (R) is the average amount of information contained in a message of unit duration:

$R = I/t$,
where I is the amount of information,
t is the length of the message.

In accordance with the theory, the rate of creation (generation) of information is denoted as (Q):

$Q = W \cdot H$,
where W is the symbol transmission rate,
H is the average amount of information per character bit.

Thus, the information capacity of a binary discrete message is numerically equal to the signal frequency band through which the message symbols are transmitted, expressed in Hertz.

It follows from Kotelnikov theorem that any continuous message R(T) with duration T and high-frequency cut-off in the spectrum *Fm* can be represented by a sequence of equidistant instantaneous values of this message taken with an interval $\Delta t = \frac{1}{2Fm}$ [23].

If one filter is taken as a source of information, then the average amount of information from one filter will be equal to the number of filters per range, divided by the speed of the rhodopsin molecule.

This is the speed of the rhodopsin molecule equal to $F = 1/t = 1/200\ 10^{-15}$ s, or 5 THz. Let us determine how many information transmission lines are there per filter, where 2647 is the number of filters per one conditional range (22696 is the total number of filters):

$$2647 \cdot 1.2 \cdot 10^5 / 22696 = \frac{2647 \cdot 1{,}2 \cdot 10^5}{22696} = 0.3 \cdot 10^5 \text{ (lines).}$$

Then the conversion frequency of one filter in the conditional range is equal to:

790 THz / 2647 (filters) = 0.3 THz.

Let us determine the transfer capability of 1 line (optic nerve). It will be equal to:

$0{,}3$ THz : $(0{,}3 \cdot 10^5) = (0{,}3 \cdot 10^{12}) : (0{,}3 \cdot 10^5) =$
$= 1 \cdot 10^7$ imp/s = 0,5 Mb/s.

Express 0.5 Mbit/s in bits. It will be different for different conventional frequency ranges, but not more than calculated for the highest frequency of the ultraviolet range.

The explanation for the process of volumetric perception of the external environment has a special place in studies on the description of the visual analyser operating principle. The perception process of real three-dimensional space by human vision cannot be explained based on the rectilinear laws of the light propagation in the form of corpuscles moving at the speed of light. Only electromagnetic theory, which describes the processes of changing the wavelength during reflection of waves and when they bend around obstacles, gives an understanding of how eye object is perceived, and subsequently, interpretation in the central nervous system of the surrounding space in real form.

This assumption is based on the Huygens-Fresnel theory, which states that each element of the wave front can be considered as the centre of a secondary disturbance generating secondary spherical waves, and the resulting light field will be determined by the interference of these waves at each point in space [24].

There is no need to provide rigorous mathematical proofs that explain the nature of physical phenomena in this work, since they were made more than 200 years ago.

Thus, it can be assumed that the perception of a real three-dimensional space by a human vision analyser occurs as a result of the appearance of oscillations resonance due to the phenomena of diffraction and interference, recorded by a person's retina due to the registration of changes in wavelength envelopes and changes in the amplitude of their values by vision.

Conclusions

1. The electromagnetic theory of colour perception by the human visual analyser of light information has been constructed in contrast to the corpuscular.
2. Calculations of the electrophysiological parameters of rhodopsin molecules included in the rods are presented, and, a model of resonant perception of electromagnetic oscillations for the visible range of light by the human eye has been developed on this basis.
3. Calculations based on the developed model for converting information in the visible light range of the electromagnetic spectrum made it possible to more accurately determine the number of colour shades distinguishable by the human eye.
4. A mathematical model describing the transmission of information about the spectrum and intensity of the electromagnetic signal of the visible range of the spectrum transformed by the eyes to the central nervous system has been proposed.
5. The speed of information transmission along the optic nerve has been calculated.
6. The hypothesis for the volumetric perception of external information by the visual analyzer and the central nervous system has been proposed.
7. Practical application of the developed model can be devices allowing to restore vision, as well as devices for correcting vision function built on its basis.

Disclosure

Conflict of interest

The authors declare no conflict of interest.

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Comments to the article by Olexandr V. Polishchuk, Olena F. Tykhanova "Biophysical aspects of electromagnetic theory of human vision perception of light information in the visible range"

Vision is one of the most important human senses, since the visual analyzer provides 90% of the information received by the brain from all receptors. It is evolutionarily adapted to the visible light perception - a narrow part of electromagnetic radiation range (from 400 to 800 nm).

The human visual analyzer consists of peripheral, conductive and central parts. Perception of light by the eye and its subsequent transformation and conduction through the structures of the visual system is a complex process, which is still under study.

The article is relevant because it is devoted to the development of the theory of human vision perception of electromagnetic radiation in the visible range.

The authors have analyzed the theories of light and color, the physical properties of the electromagnetic nature of light, and proposed an electromagnetic model of human recognition of light information received in the visible range of light.

Undoubtedly, the strong point of the article is in-depth calculations of electrophysiological parameters of rhodopsin molecules, which are part of rods, and on this basis a model of resonant perception of electromagnetic oscillations of the visible light range by the human eye was developed.

A mathematical model describing the transmission of information about the spectrum and intensity of the electromagnetic signal in the visible range to the central nervous system, has been proposed.

The rate of information transmission in the optic nerve was calculated and the hypothesis of volumetric perception of external information by the visual analyzer and the CNS was proposed. According to the data obtained, it is assumed that the perception of the three-dimensional space by the visual analyzer occurs as a result of oscillations resonance due to the phenomena of diffraction and interference, which are recorded in the human retina due to the registration of changes in wavelength envelopes and changes in the amplitude of their values. The data presented in the article deepen and supplement the existing theories of perception of light information by the human eye and are a basis for further research in this direction.

The article may be recommended for publication in scientific editions in terms of its relevance, content, foregoing provisions and conclusions.

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The theoretical article deals with topical issues about the human vision perception of electromagnetic radiation in the visible light spectral range. Experimental studies in the field of vision biophysics, the theory of electromagnetic oscillations of light, modern ideas about the properties of molecular magnetic resonance, as well as the theory of information transmission are analyzed. Despite the large number of experimental and theoretical studies published on this topic, many issues related to the rigorous proof of the mechanisms of human perception, such as, color information, as well as the subsequent transformation of human light information into the corresponding electrical signal, remain completely unexplored due to the great difficulty of conducting direct studies *in vivo*. Therefore, I consider theoretical developments in this direction to be relevant.

The authors provide theoretical calculations of the dielectric properties of rhodopsin and propose a hypothesis about the resonant interaction of rods and cones, and on this basis calculations of the number of colors recognized by the eye are given. A model that describes the information transmission rate along the optic nerve and the mathematical law of visual information transmission to the human central nervous system is proposed.

The last section of the article is devoted to human perception of volumetric information based on the mathematical laws of diffraction and coherence of electromagnetic radiation, but the authors do not provide clear physiological evidence for this statement.

The practical application of the developed model described in the article, devices can be built on its basis, which allow restoring vision, as well as devices for the correction of visual function.

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