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Activation of visual system of brain by warming hands and pressing on eyes

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Abstract

Dependence of the pressure phosphene (PP) intensity on the effect of warming hands by various methods and on the pepper mint camphor vapor inhaling has been studied. Studies included subjective evaluation of PP intensity by persons under test and electrobiological activity measurements on the encephalon and cordis with the use of electroencephalography (EEG) and electrocardiography (ECG). The EEG and ECG frequency spectra respond synchronously to pressure, heat and light. The characteristic excitation time for potential oscillation, within the visual cortex of the both cerebral hemispheres, correlates with the time delay of PP flash initial point. Both the stimulation effect and PP intensity can be enhanced by warming hands and body in a wet environment, growing at temperatures over 42 ^{o}C. Activation of PP by warming provides evidence of convergence between the impulses from the lateral geniculate body (LGB) neurrons and thalamic nuclei responsible for thermal reception, in the skin on the heel of hand and fingers. At temperatures exciding 42 ^{o}C, the effect of thermal activation and PP intensity increases because, in these conditions, thermoreceptors take the function of nociceptors. The assumption has been made that the processes of electric charge redistribution and recombination, in the layers of retina and LGB, prevail in PP generation and its biophysical mechanisms.

Key words: phosphene, stimulation, thermoreception, thalamus, convergence, water.

1. Introduction

The development of living organisms' sensory capabilities had started from the mechanic-reception functions followed by formation organs designed to feel solar electromagnetic radiation and heat. Owing to the electromagnetic nature of bio-energetics, in the evolution processes, the sense of vision has occupied the dominant position in the hierarchy of the nervous system of mammalian species and humans [1]. This assumption can be supported by the synesthesia of human sense of vision with that of the majority of receptor complexes of the organism whose number attains 70 items [2, 3]. In Table 1, the most commonly reported types of visual synesthesia and the share of people who possess this ability of the total number of examined synesthetes (1143 people) are presented [3]. The visual nervous system (VNS) plays the major role in the mechanism of homeostasis subordinacy to the circadian rhythm [4, 5] driven by special light-sensitive retinal ganglion cells and neurons of suprachiasmatic nuclei [4, 6, 7]. VNS controls melatonin biosynthesis, in the epiphysis, making its effect on the cerebral metabolism during the hours of darkness. This assumption is supported by, for instance, paradoxical rapid eye movement sleep phase [4, 6]. A possibility to initiate sensation of various glows (phosphene) under an external mechanical pressure or electric current manipulation on closed eyes also indicates the relevance between neurophysiology and visual mechanic-reception [6, 8].

Pressure phosphenes (PP) are well-known since the 5th century. In the medieval period, phosphenes were called 'uncreated light'. Electrically-induced phosphenes (EP) [8, 9] were discovered at the same time as electricity. Experiments on animals and humans [10-12] have shown that activity potentials (AP) responsible for PP are generated only in the retinal ganglion cell axons forming the optic nerve. Producing pressure on the eye globe [6], as well as local mechanical deformation of retinal layers [13] leads to disturbing the membrane structure of Mueller glial cells running through all layers of the eye retina, as well as that of photoreceptor membrane [14-16]. In this case, the electric conductivity of potential-dependent ion channels of the membrane and the ion distribution densities (Ca^{2+}, Na^+, K^+ and Cl^-), in retinal issues, change. Ion currents in the conducting channels of membrane, in cytoplasm and in interstitial fluid, have their response in polarization potentials that attain retinal ganglion cells and activate them, while propagating along the synaptic gaps, in layers of bipolar, horizontal and amacrine cells.

The background bioelectrical activity of retina normally retains in the darkness and appears in form of ganglion cells' activity (5 to 40 impulses per second) [17], as well as in the potential difference between the retina and eye cornea (0.4 mV to 1.0 mV) [18] (see Fig. 1). That is why the eye retina is a perfect object to study the interaction mechanisms between neurons of various layers and zones of cerebral cortex. The (PP and EP) phosphene phenomenon provides the possibility to obtain important information related to the role of subcortical brain structures in PA generation, in VNS, and on its interdependence with other sensory systems [19, 20].

Today, the possibility of developing a cortical visual prosthesis for visually impaired patients is being actively studied [21, 22]. In the process of studying PP and PE neurophysiology one can obtain the data on the activation mechanisms for intact neurons of retina and visual cortex by mechanical [12] and electrical pulses that adequately reflect light information, in an optical implant [23, 24].

In light conditions, alternative current in frequency range from 4 Hz to 40 Hz let go through between points Oz-Cz (see Fig. 1) yields the maximum EP response in frequency range from 16 Hz to 17 Hz [25]. In dark conditions, the intensity of EP is twice as low compared to the light conditions, while its maximum shifts towards ~12 Hz. Therefore, the maximum EP response induced by alternative current, in the darkness and in light conditions, is defined by the electric current resonance interaction with the structures generating alpha- and beta- cerebral rhythms, respectively. The dark LGB activity is responsible for alpha-rhythm [26] while, in open eyes conditions, the beta-rhythm generation is associated with the participation of subcortex structures controlling eye globe motions (quadrigeminal bodies, hypothalamus, etc.), apart from the retina and LGB [27].

The analysis of electric current and field distribution shows that the EP response initiated by application of 10 Hz alternative current between Fpz-Oz (FO) and T7-T8 (TT) electrodes (see Fig. 1) [28], for FO variant, is ~1.7 times higher compared to that, for variant TT. The density of the induced current in the eyes, for FO variant, is ~2.6 times higher compared to TT variant. In this case, the values of current and field density, in the occipital lobe, is only ~1.6 times higher, for FO variant, compared to TT variant. These relationships between the values of EP response and currents, for variants FO and TT, show that EP current activation between the points T7 and T8 is generally defined by PA generation, in both the right and the left LGBs.

It is known [6] that, at high body temperatures, phosphene occur more frequently, and muscular orgasm is sometimes accompanied by an intensive white light flash sensation. The simplicity with which phosphenes can be generated by activating auditory sensory system [29-32] correlates with a high aggregate share of visual synesthesia with four types of acoustic signals (see Table 1). Cross-coupling type activation [33] of the visual and acoustic sensory capabilities gives evidence of physical interactions between LGB cells and those of medial geniculate body (MGB) [31, 32].

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The ganglion cells location order, in the retina, appears in the distribution of zones and cellular layers, in the LGB thalamus structure, projecting onto the visual area of the cerebral cortex via the fibers of Gratiolet radiation [6] (see Fig. 1). Obviously, the hierarchy of the cellular interconnections, in the retina, reproduces itself in the structure of thalamus and cerebral cortex, in one form or another. This statement can be supported by the high level of occurrence of synesthesia and graphemic-color sensory modalities [33] (see Table 1) which can be defined by the easiness of cross-coupling activation and adjacent LGB zones of thalamus, as well as of the cerebral cortex VWFA areas (graphemic processing) and V4 (color processing) [33-37].

Sensory systems' anatomic similarity, as well as the retaining cross-coupling neuron interconnections, in the initial stages of brain perceptual development, contribute to the synesthesia [34, 38]. These interconnections can also develop as a result of cerebral cortex neuroplasticity in response to its local damage or new perceptions [32, 33, 39]. A model of graphemic-color sensory mechanism was developed, in [34], based on the principles of stochastic resonance and synchronization of excessive neuron noise, in parallel modalities. This kind of resonance nay occur between oscillating systems whose frequencies are close to each other. Such systems can consist of coherent LC oscillation circuits modelling the current channels of neurite membrane comprising helical molecular structures [19, 40].

Table 1. The percentage of synesthetes with a specific type (1143 synesthetes in total, from [3])

Type of synesthesia	**%**
graphemes - vision	61.26*
time units - vision	22.96*
musical sounds - vision	18.05*
general sounds - vision	16.21
musical notes - vision	7.80 *
personalities - vision	6.49*
phonemes - vision	7.54*
odors - vision	6.13
flavors - vision	5.78*
pain - vision	5.43
touch - vision	3.94
emotions - vision	3.24*
orgasm - vision	1.93
temperatures - vision	1.84
lexemes - vision	0.70*
kinetics - vision	0.53
proprioception - vision	0.09
vision - flavors	2.98*
vision - odors	1.14
vision - sounds	3.07*
vision - touch	1.58

*) Synesthesias related to cognitive functions of the brain

It has been supposed, in [37], that synesthesia involving the chromatic sensitivity sector (V4) is associated with the network activity of a number of brain regions located in the sensory and motoric areas, as well as in 'higher level' areas of parietal lobe and frontal cortex. Multiple types of visually induced synesthesia [3], as well as the strong influence of eye electrophysics on the electrical activity of fronto-temporal brain regions provide VNS with the function of the chief 'kapellmeister' of neurophysiological and cognitive processes [19]. This conclusion also illustrates phosphenes related to synesthesia associated with orgasm, hearing, tactual and thermal sensitivity [1, 2, 41]. Therefore, studying the physics of pressure phosphenes cap help to understand the mechanisms of the cross-linked neuron activation of various regions of thalamus and cerebral cortex [42, 43] and to evaluate the role of the subcortex structure in neurophysiology of ideation and consciousness [19, 36, 37, 44, 45]. In practical terms, these data will be useful for goal-oriented selection of biologically active areas in acupuncture and in cranial electrotherapy stimulation.

In this work, the dependence of pressure phosphene and bioelectric activity of human brain and heart on stimulations applied to eyes and brain by means of light with various values of wavelength and heating has been studied with the use of EEG and ECG techniques.

2. Materials and methods.

2.1. Subjects and objects of research.

Ten physically healthy men at the age of 40 to 72 years took part in the experiments. In a majority of tests, objects of research were the authors of this article A. Kholmanskiy (AKN where N is age) and A. Minakhin (AM62), chiropractic with normal vision. AK had asymmetric nearsightedness: -3^D, for the right eye (OD), and -3.75^D, for the left eye (OS). He was diagnosed with negative scotoma with visual field damage OS by 14% and OD by 7%.

Sauna with temperatures (T) in the range of 60 °C to 90 °C was used during 10 min to 15 min in order to warm the entire body in wet and flavored atmosphere for which purpose pure water or solutions of various ethereal oils were scattered over the hot stones. The value of body surface temperature measured in sauna with the use of a touch-free infrared temperature gauge was 43 °C [46]. The body temperature in the sauna could increase significantly when steam condensed on the skin [47]. In the rest-room, the temperature of body was 36.4±0.2 °C while in the sauna, at ambient temperature T ~70 °C, a thermometer in the hand clenched into hard fists or in the armpit indicated 37.4±0.2 °C. Hands were heated during 3 to 5 min in hot water (45 °C to 50 °C) or with the help of 0.5 l plastic bottle filled with hot water. AK72 applied a 0.2 plastic bottle for local heating his two closed eyes during 1 to 2 min.

2.2. Methods of activation of visual system.

Temperature of body, hands, water and air, in sauna, was also measured with the use of alcohol-in-glass and mercury-filled thermometers. PP were activated after a period of relaxation (R) at normal ambient temperature T (22 °C to 24 °C) during 10 to 15 min. Pressure was applied to eyes during 10 s to 30 s with proximal phalanx of thumbs and forefingers of the right hand. The intensity (I_P) of PP was evaluated subjectively in accordance with 1 to 10 scoring scale ('1' corresponds to barely discernible light spots in the visual field while ‘10’ corresponds to bright white light flash all over the visual field). The effect of white PP on LGB and visual cortex was modeled by illuminating retina with light emitted by a wax candle, alcohol lamp or white LED. For this purpose, a light spot having the size of eye pupil was projected onto the eye with the help of 8 cm glass lens having focal length 20 cm.

2.3. Methods for recording reactions of heart and brain.

Intraocular pressure (IOP) was measured by Maklakov method with the use of Topcon CT-20 device with an accuracy of $\pm$1 mmHg, as well as with the use of HNT-7000 HUVITZ whose measurement accuracy was $\pm$0.5 mmHg. Measurements have shown that, within the range of measuring error, the reference values of IOP in OS and OD are equal to each other and that application of pressure on AM60’s sound eyes lead to a reduction of IOP by equal values. Contrariwise, in AK case, the percentage of IOP reduction induced by external pressure application and heating is, as a rule, higher in OS compared to OD (see Table 2). These measurements of IOP correlate with the asymmetry nearsightedness and scotoma between OS and OD.

Table 2. Intraocular pressure (IOP) versus external pressure and temperature.
In parentheses, the percentage reduction from the Control

Subject	Method, device	IOP (mmHg)	OD	OS
AK70	Maklakov	Control	17	19
		Pressure on eyes	16.5 (-3%)	14.5 (-24%)
AM60	HNT-7000 HUVTTZ	Control	~16	
		Pressure on eyes	~14 (-12.5%)	
AK72	HNT-7000 HUVTTZ	Control	17	18
		Eye warming (50 ºC, 1 min)	16 (-6%)	15.7 (-13%)
		Pressure on eyes	17	17 (-5.5%)
	Topcon C T-20	Control	21	20
		Eye warming (42 ºC, 1.5 min)	19 (-9.5%)	17 (-10.5%)
		Pressure on eyes	21	19 (-5%)

Bioelectrical activity of heart and brain was registered with the use of electroencephalograph ‘Entsephalan-EEGP-19/26’ (EG-1) with the sampling frequency of 250 Hz. The equipment made it possible to detect oscillation frequencies (ν) in the range of ~1 Hz to 100 Hz and electric potential (V) amplitudes in the range of 0 mV to 0.5 mV. Four points from the left (F3, C3, P3, O1) and four points from the right (F4, C4, P4, O2) were chosen on the standard ’10-20’ potential picking-up circuit. The sampling and neutral electrodes were fixed on the ear lobe and on the forehead, respectively (see Fig. 1).

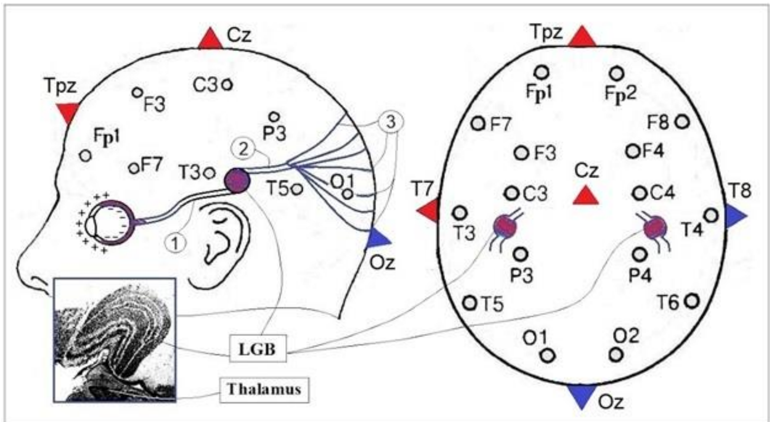

Fig. 1. The standard scheme for the electrodes "10-20" on the projection of the brain and the layout of the structures of the visual apparatus in the brain: eye; 1 - optic nerve; LGB - lateral geniculate body, 2 - optic tract; 3 - fibers of the Graziole bundle. Inset LGB and thalamus. The triangles indicate the locations [20] of the anodes (red) and cathodes (blue).

For timing ν of the heart, the electrodes were placed similarly to the standard lead on the wrists of the left and right hands at the point of a distinct pulse. The contact area of all electrodes was ~0.7 cm^2. While applying pressure to the eyes, in the course of ν values registration, a latex glove was put on the hand, for electric insulation. Mainly those frequency spectra were used for the analysis that occurred to be the most sensitive to the effect of pressure, heat and light on the eyes compared to *V* spectra. For comparison purposes, the distribution of *V* spectra dependence on the external pressure applied to the eyes, over the scalp, was also measured with the use of electroencephalograph 'Kompakt-Neiro' (EG-2) and 16 electrodes applied in accordance with the mono-polar sampling method, in standard '10-20' test circuit (see Figure 1). The sampling frequency and scan velocity were, respectively, 500 Hz and 30 mm/s.

3. Results

After visiting sauna, all the ten tested men demonstrated the ability to detect bright white PP in response to pressure application to their both eyes. In the majority of tests, a glow started to develop beginning from the third second attaining its maximum intensity of I_p ~ 7-10 by the time moment 7 s to 10 s, and faded to black by 15 s to 20 s. Upon completing the pressure on the eyes, blue-violet points could appear against the weak white light background. Similar phosphene were sometimes detected, in the morning hours, by AK49, at wake-up, in response to application of slight pressure to the both eyes. The PP intensity reduced substantially in case of external pressure alternatively applied to the right or the left eye. AK70 and AK72 detected PP more easily when their hands were warmed in water with temperature T from ~45 °C to ~50 °C. On the other hand, PP did not occur after warming their feet, ankle-deep, in water with temperature in the range 50 °C to 60 °C, in similar conditions. No positive effect was detected from warming hands and eyes with the use of dry plastic bottles filled with water having T in the range between ~45 °C and 50 °C. In case that ambient air in sauna contained high concentration of water vapor or calendula oil extract, the intensity I_p of PP did not change but application of pepper mint vapors reduced substantially the values of I_p.

3.1. Information content of EEG and ECG signals

The frequency (ν) and amplitude (*V*) of EEG and ECG spectra are given in Appendix and are presented in Figures 2 to 7. The information encryption principle used by receptors is based on the AP repetition frequency modulation ([1, 6, 18]. The ν-spectra are also sensitive to the change of local cerebral blood flow, in neurons [48], depending on the oscillations of blood electrolytes generated by cardiac myocytes [42]. That is why, in this case, ECG and EEG frequency spectra (see Fig. 2) represent, to the best extent, the electrobiological reactions of encephalon on external factors. The information content of ECG and EEG ν-spectra obtained with the use of EG-1 method by pressure application to the eyes with the hands without gloves reduces substantially, in all areas of encephalon, particularly, in points F8 and F7 (see Figures 2 and 6). This may be associated with currents shunting, in encephalon, when the electrode attached on the wrist is close to the neutral electrode placed on the forehead. In addition, the approach of the hands in this case, as well as in experiments with warming and irradiation of the eyes, in AK leads to an increase in the ECG frequency (Fig. 2, 4, 6).

3.2. Asymmetry and kinetics of the vision system reactions on light and pressure

It is known [49-51] that both the area of the nasal half of the eye-globe and the number of photoreceptors in it exceed those of the temporal one. Since the neuron axons of the nasal part and retina propagate, in optic chiasm, into the visual tract of the opposite cerebral hemisphere, EEG signals from contralateral hemisphere in response to illuminating the eyes are normally higher, in all *ν*-spectra, compared to the lateral hemisphere (see Fig. 4b). In case of AK70, this effect occurs in a greater degree, for OD and is not practically detected, for OS (see Figures 2 and 4a). This kind of VNS asymmetry, for AK70, can be explained by the specifics of his creative intellectual work [52-54], as well as by the physiological difference between his OS and OD that appears in the scotomae, nearsightedness and IOP (see Table 2). This contralateral effect depends on the light source spectrum and is most clearly detected for wax candle reducing for alcohol lamp flame (see Figures 2 and 4) and, practically, fading away for LED (see Fig. 5). The first two thermal-type light sources have their radiation maximums for ~1000 nm, while that of LED is in the range from 400 nm to 600 nm. Obviously, the sensitivity values of the nasal and lateral hemispheres of retina to LED light are identical. Contrariwise, in the IR-spectrum, the nasal hemisphere appears to be more sensitive that the lateral one.

From the analysis of the *V*-spectra obtained with the use of EG-2 (see Fig. 3) we can conclude that applying external pressure to the both eyes induces oscillations with a period of ~2 s and initial *V* value ~1.5 mv in the nearest, in relation to the eyes, points F7 and F8. These oscillations fade out within two oscillation periods. Their amplitude decreases to ~0.3 mV and the oscillation duration becomes twice as low when we try to apply an external pressure to the eyes, one more time. It has to be noted that the oscillation difference between the pairs of contralateral points poorly appears in *V*-spectra.

Values of *V* are comparable with those of potential on the eye corneae, and oscillations in points F7 and F8 start synchronously with the moment of pressure application. Taking this into consideration and in light of the fact that the eye dipoles are directed towards points F7 and F8, the 'short-life' *V* oscillation can be attributed to the electrooculogram signals induced by deformation of the eye-muscle and eye-globe dipole (see Fig. 1) [20]. The directions towards points Fp1 and Fp2 are perpendicular to those of eye dipoles. That is why *V* oscillations, in these points, have an amplitude of ~0.2 mV. At the same time, *V* amplitudes in pairs of points (T3, T4) and (T5, T6) attain their values in the range of 0.3 mV to 0.4 mV with a delay of ~0.7 s, in relation to the moment of pressure application. It follows herefrom that a probable trigger of oscillations arising in these points is the charge redistribution in LGB layers initiated by electric currents occurring due to retina deformation. Oscillations of *V* in the pairs of points (C3, C4) have lower amplitudes and start with the same delay while in the pairs of points (P3, P4), (O1, O2) the delay attains ~1 s (see Fig. 3a) which corresponds to PP development delay. The reduction of the frequency-amplitude characteristics of EEG signals, in case of a subsequent pressure application to the eyes, can be explained by the reduction of the electric charge density, in lamellar issues of retina and LGB, due to its recombination during the previous pressure application. Such structures have been modelled, in [19], involving condenser systems integrated into the neuron networks.

3.3. Dependence of EEG and ECG frequency spectra on warming the hands and the eyes

The kinetics of the decrease in the ECG frequency after warming and pressing on the eyes (Fig. 6) is approximated by linear dependences (kt), which have close values of k~0.6 Hz/min. This result correlates with the same decrease IOP of AK after warming and pressing on the eyes (Table 2) and is consistent with the well-known method of lowering the pulse rate by painless pressure on the eyeballs [6]. Warming the eyes did not lead to PP activation. A subsequent pressure application, just as in experiments without preliminary warming, did not stimulate PP esthesia ($I_p \sim 0$) but it resulted in a change of the background EEG and ECG frequency spectra during relaxation (see Figures 2 and 6). Similar results were obtained from the reference experiment in which pressure was applied to the eyes prior to warming the hands (see Fig. 7a). Pressure application to the eyes after warming the hands with the help of plastic bottles filled with hot (T_1 ~ 50 °C) water induced a week glow, over the entire visual field, whose intensity grew in the direction of the equator line (I_p ~ 1-2). The intensity of glow grew during 5 s to 7 s rapidly fading out upon pressure application termination. A 30 second frequency jump, in all EEG spectra, was observed ~1 min after pressure application to the eyes, in all points, particularly in the left hemisphere, and ECG *ν*-spectrum was excited synchronously. The areas of ECG and EEG spectra excitation are marked with oval curves, in Fig. 7a. After warming the both hands in water (T_2 ~48 °C) during 1 min, the intensity of PP increased up to 5 to 6. Two minutes later, after one more warming the hands in water (T_3 ~43 °C) during 2 min, pressure application to the eyes did not induced considerable glow (see Fig. 7b). Both the intensity and excitation frequency of ECG and EEG spectra activated by pressure application to the eyes, for the hands warmed in water with temperatures T_2 and T_3, and for dry objects with temperature T_1, differed substantially (see Fig. 7b).

4. Discussion

The time of PA propagation from retina along VNS correlates with that of PP signal delay while electrobiological activity of retina and LGB was detected in EEG potential spectra in a sequential order, in points (F7, F8), (T3, T4), (C3, C4) and (O2, O1). The dynamics of potentials generated, in each pair of points, can be modelled with the use of rapidly damping sine signal initiated by recombination of electric charge currents that fade out first between the retina layers and then between those of LGB [19]. Within the retina layers, these processes are activated by mechanic deformation of its issues, while the electrobiological activity in LGB layers is triggered by PA flows generated in retina and by the corresponding PPs. Since direct warming the eyes does not stimulate PP generation this effect has to be implemented on the level of neurophysiology and LGB. Presence of neuron interactions between LGB and MGB (visual and acoustic synesthesia) provides evidence of probable interaction of LGB with hypothalamus and thalamus nuclei responsible for thermal reception [1, 6, 55, 56]. The latter include those located close to LGB: ventral medial (VM) nucleus, ventral posteromedial (VPM) nucleus and pulvinar (PUL) nucleus.

In the process of evolution, thermal receptors developed as modifications of mechanicoreceptors, first of all, in the skin of fingers, hands and in eye corneae [1]. Molecular mechanisms of nociceptor and thermal receptor functioning are not yet fully studied [55, 56]. It is known [1, 2, 6, 57, 58] that at temperatures $T \geq 42$ °C cold and heat receptors begin to perform the function of nociceptors. It can be assumed that, in these conditions, mint camphor (as a mediator of cold receptors) [59, 60] will also produce a certain effect on the conductivity of other protein ion channels in receptors belonging to TRPA, TRPV and TRPM family [55, 57, 58]. Mint camphor, capable to form hydrogen bonds with proteins, initiates opening Ca^{2+} ion channels in which case the flow of Ca^{2+} ions through the receptor cell membrane leads to their inactivation and loss of the ability to respond to various excitants [55, 59, 60]. The effect of mint camphor whose concentration in pepper mint is ~40 % can be explained by the reduction of the heating excitation of PP when mint vapor is spread in sauna at temperatures in the range 60 °C to 90 °C. Suppression of the thermal effect in case of direct warming the eyes and eye cornea is, probably, defined by the absence of convergence between VNS centers and trigeminal nerve fibers that innervate heat and pain receptors, in eye cornea.

Owing to its incompressibility property, water contained in vitreous humor and in interstitial fluid in retina distributes evenly the force of pressure over all retina issues tightly adjoining to flexible and inextensible sclera. Absence of PP in areas of retinal detachment from the feeding vascular membrane [60] demonstrates the key role of physiological fluids of retina and of the sclera mechanic counteraction in the process of PP generation. The epidermic issue of heel of hands and of fingers does not contain special moisture receptors. Their absence is compensated owing to the reactions of tactual mechanoreceptors on water pressure, as well as those of thermal receptors on cooling the skin as a result of water evaporation [47, 62]. Skin hydrophilic property defines hydrogen bonds formation between water molecules and those of epidermis, whenever hands are dipped in the water. Thanks to these bonds, the effectiveness of the heat transfer from water to blood, to the epidermic issue and, therefore, to thermal receptors increases. In case when a plastic bottle with hot water is used the rate of the heat transfer to the hands will be substantially lower. That is why no heat effect has been registered in the corresponding PP activation tests.

Hydrogen bonds of water and of other physiological liquids with proteins of ion channels, in cellular membrane [63, 64], may contribute to their thermal activation involving the resonance mechanism [65, 66]. Apart from water in the ion hydration shells bonded with biomolecules, both the blood plasma and interstitial fluid contain a certain share of free water [63, 64]. It has been found out [65-67] that the thermal motion of water molecules at temperatures near 42 °C change drastically as a result of dissociation of large clusters, in the cross-linked hydrogen bond structure. The assumption can be made that this dynamic phase transition in water contained in interstitial fluid of epidermis takes its contribution to the change of thermal receptor functioning mechanism at $T>42$ °C.

5. Limitations

Computation program algorithm for processing and representing EG-1 output signals in form of ν-spectra was mainly oriented on studying the kinetics of the brain bioelectric activity. It did not provide the possibility to detect the change of energy-related parameters of electric processes, in brain, that could be characterized using EEG *V*-spectra. In case of adequate correlation between frequency and amplitude of EEG spectra, product (vV) could be proportional to the power of EEG signal, and the analysis of an adequate vV-spectra could contribute to the information content of *V*-spectra obtained with the use of EG-2.

In the case of EG-1 application, insufficient number of points for measuring brain and heart potentials was the reason for impossibility to find reliable interpretations of the brain active zones nature and of the interaction mechanisms between its visual system and heart somatosensory and neurophysiology functions. Obviously, participation of women in the tests could be rather helpful, in terms of understanding the role of functions asymmetry between the two hemispheres, in phosphene generation mechanisms [68].

6. Conclusion

Pressure phosphene generation is based on the mechanic activation of bioelectrical processes, in retina layers, that normally occur in it, in dark conditions. The effectiveness of activity potentials generation, in ganglion cells, depend on the eye physiology and its adaptability to the professional specifics of the vision system application. The possibility to trigger the pressure phosphene generation process by pre-testing warming the hands gives evidence of convergence between LGB neurons adjacent to LGB thalamic nuclei that control thermal receptors functioning, in the skin of heels of hands and of fingers. The effect of pressure phosphene thermal activation can be enhanced with the help of hot water at temperatures over 42 °C and in a wet environment, in sauna with temperature in the range of 60 °C to 90 °C. At such temperatures, the heat receptors perform the function of pain receptors. Besides, the heat transfer ratio between water and hands grows owing to the formation of hydrogen bonds between water molecules and those of epidermis including the bonds with proteins of ion channels, in the thermal receptor membrane.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

Data sharing not applicable to this narrative review

Competing interests

We have no competing interest

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Application. Figs. 2-7

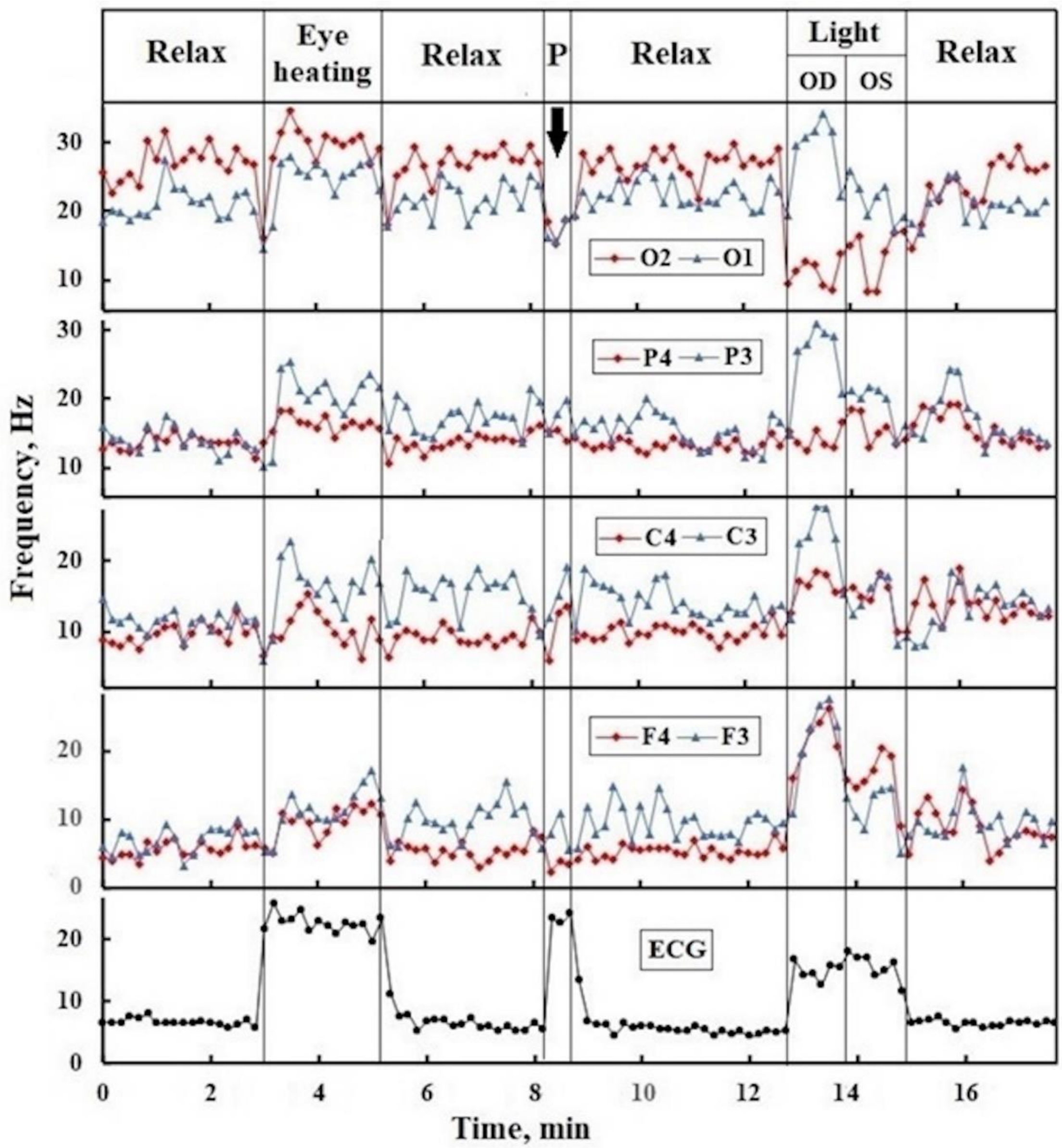


Fig. 2. Dependence of the frequency *ν*-spectra of EEG and ECG AK72 on heating of both eyes by objects with a temperature of ~50 ℃, pressure on the eyes with gloved fingers (**P**) alternating wax candle lighting of the right (OD) and left (OS) eyes AK72.

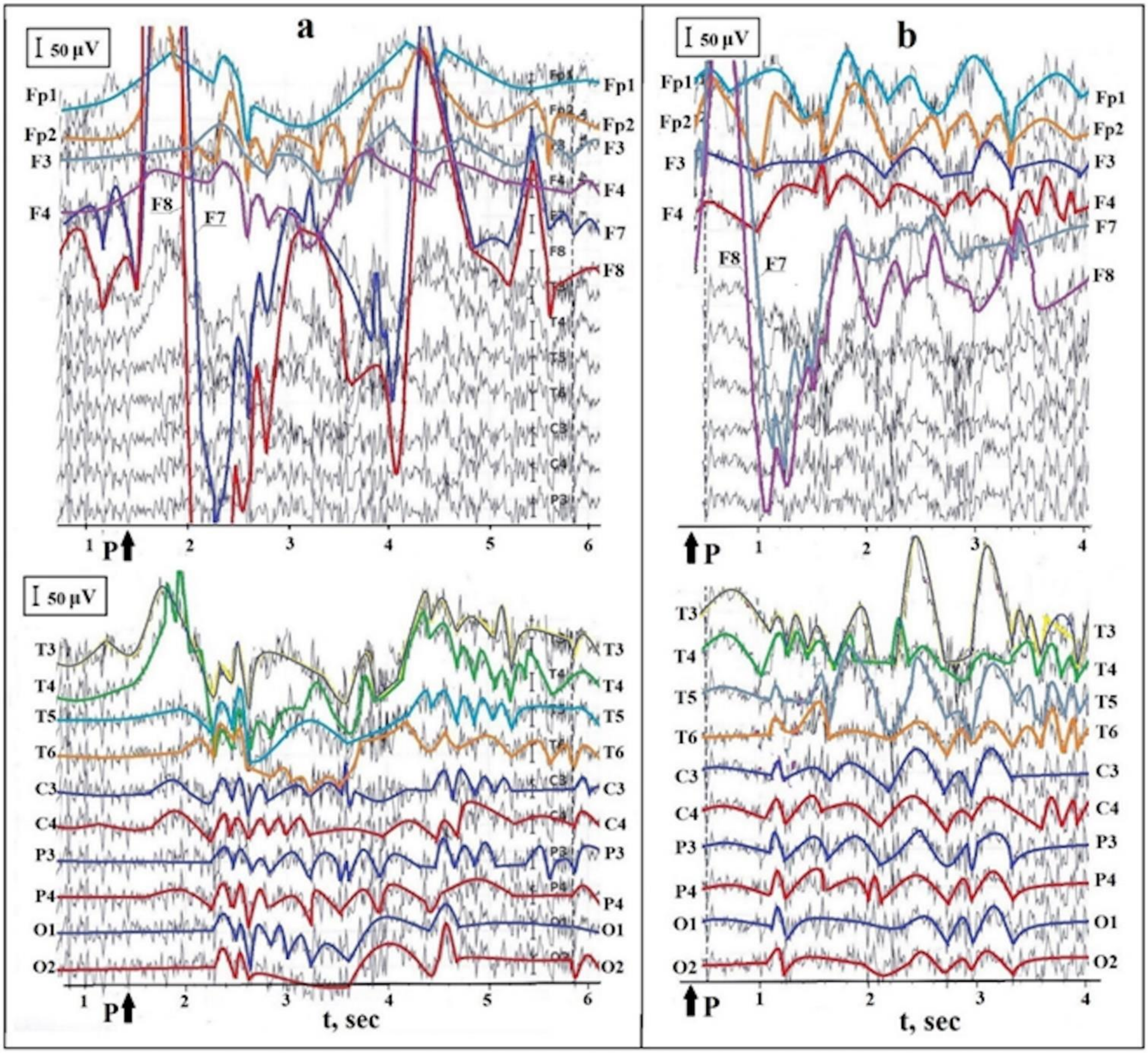


Fig.3. Dependence of *V*-spectra of AK70 on the pressure (**P**) on the eyes with fingers without gloves (**a**) and a repeat of the experiment after ~2 min (**b**). Colored lines bend around the low-frequency *V* oscillations at each contact point.

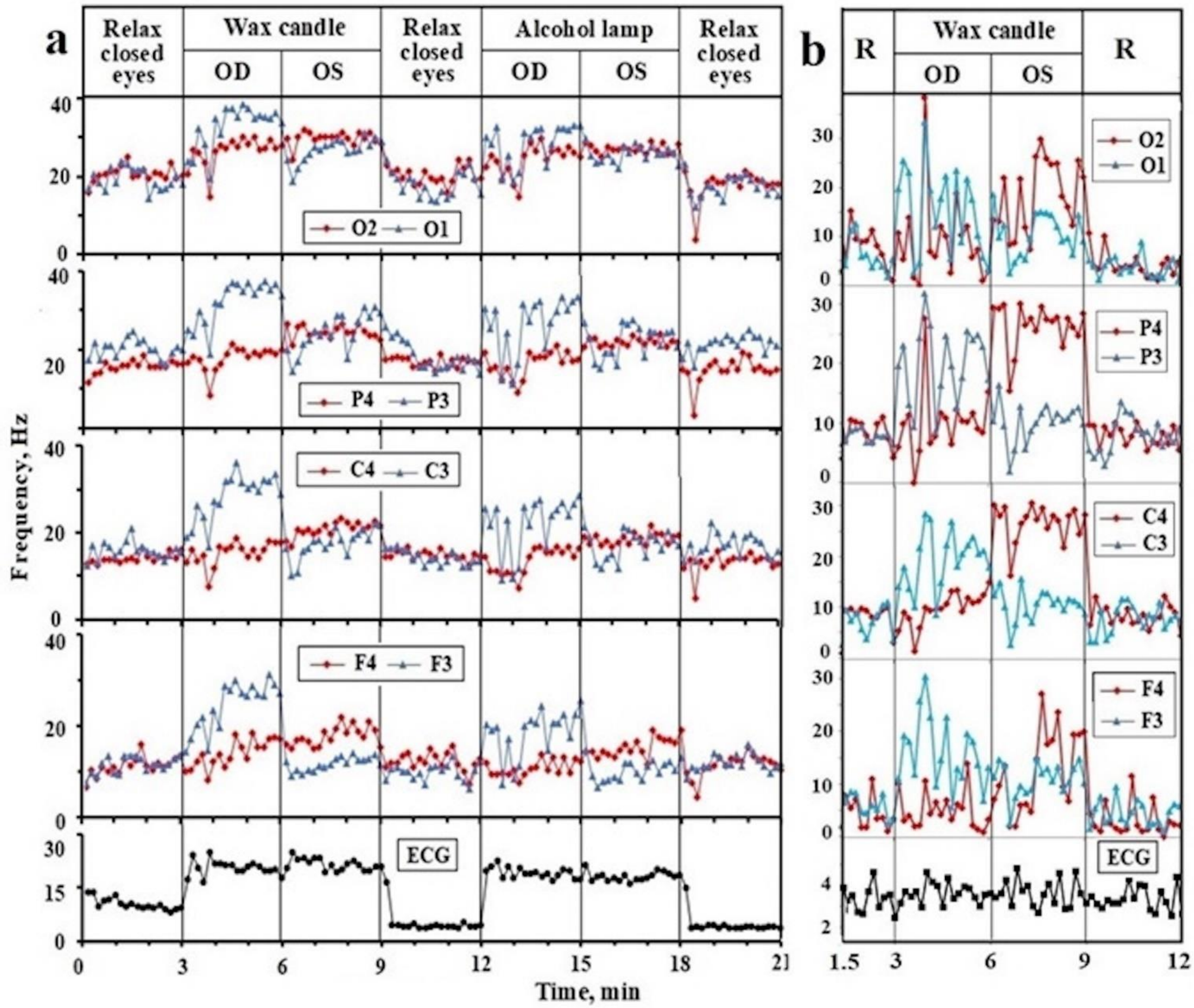


Fig. 4. Dependence of ν-spectra of EEG and ECG (**a**) AK70 and (**b**) AM on irradiation of the eyes with the light of a wax candle and an alcohol lamp.

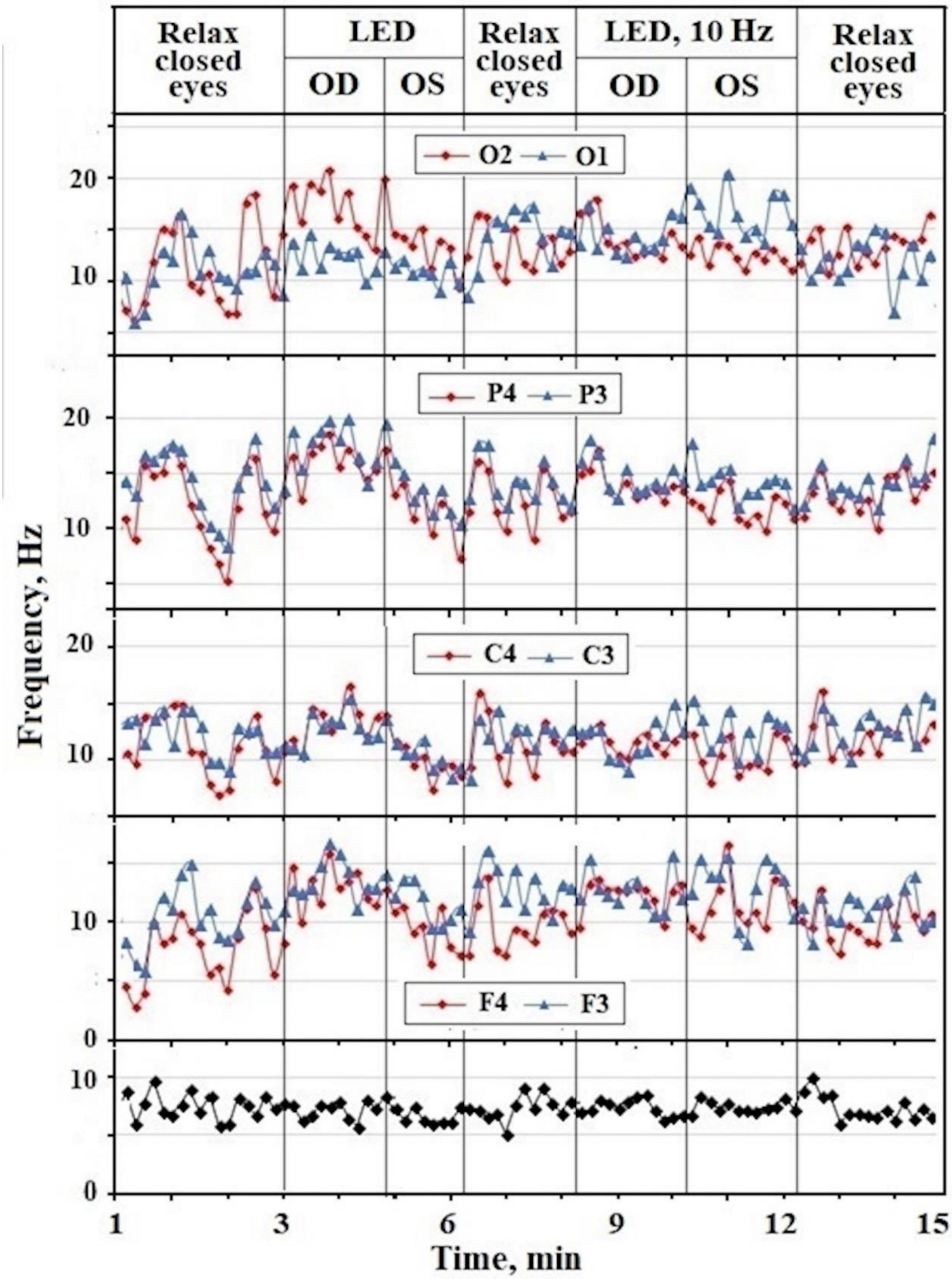


Fig. 5. Dependence of ν-spectra of EEG and ECG AK70 on irradiation with continuous and flashing (10 Hz) LED light.

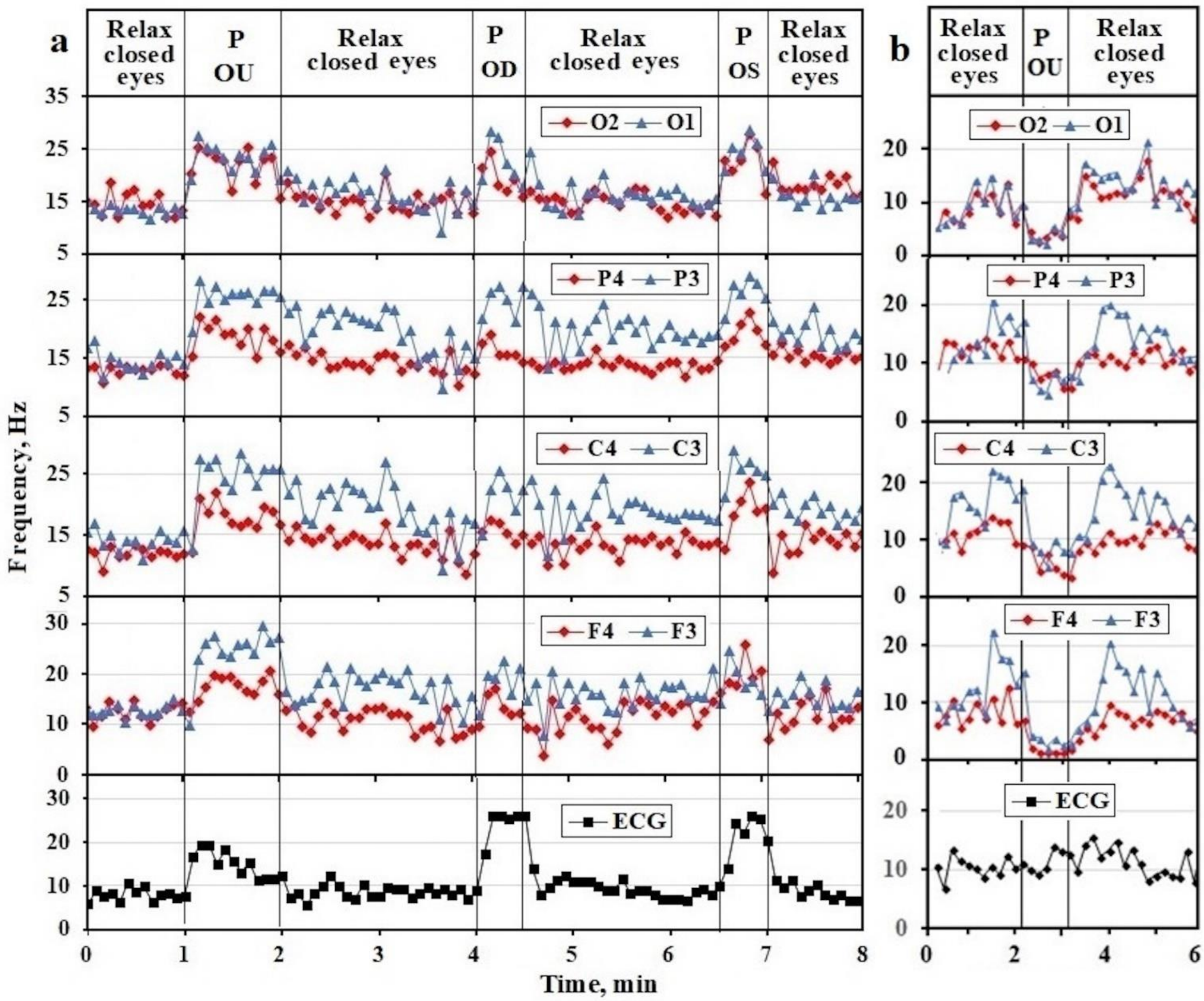
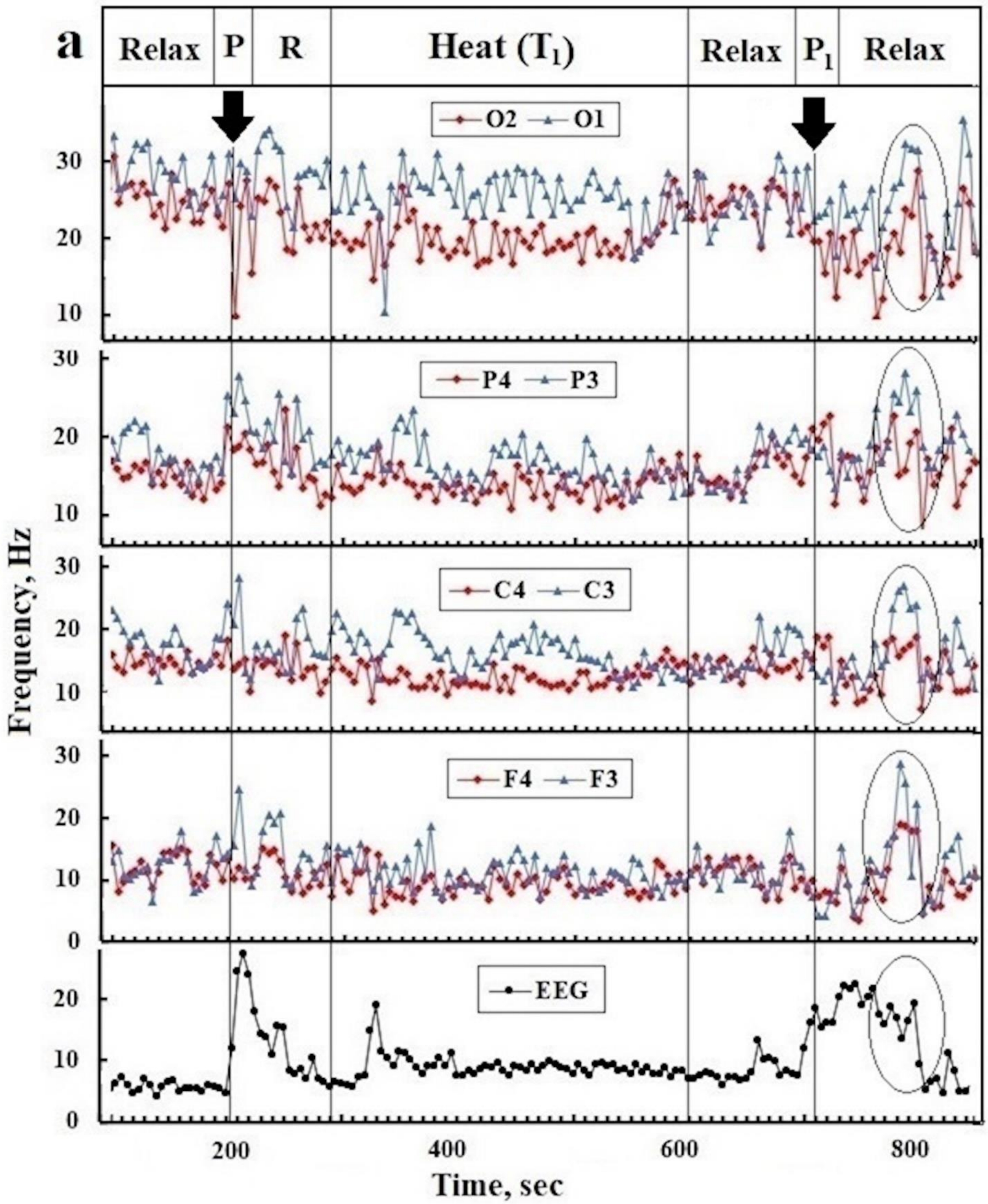


Fig. 6. Dependence of *ν*-spectra of EEG AK70 on pressure (**P**) on both eyes (OU) and alternately on the right (OD) and left (OS) eyes with fingers in a latex glove (**a**) and without it (**b**).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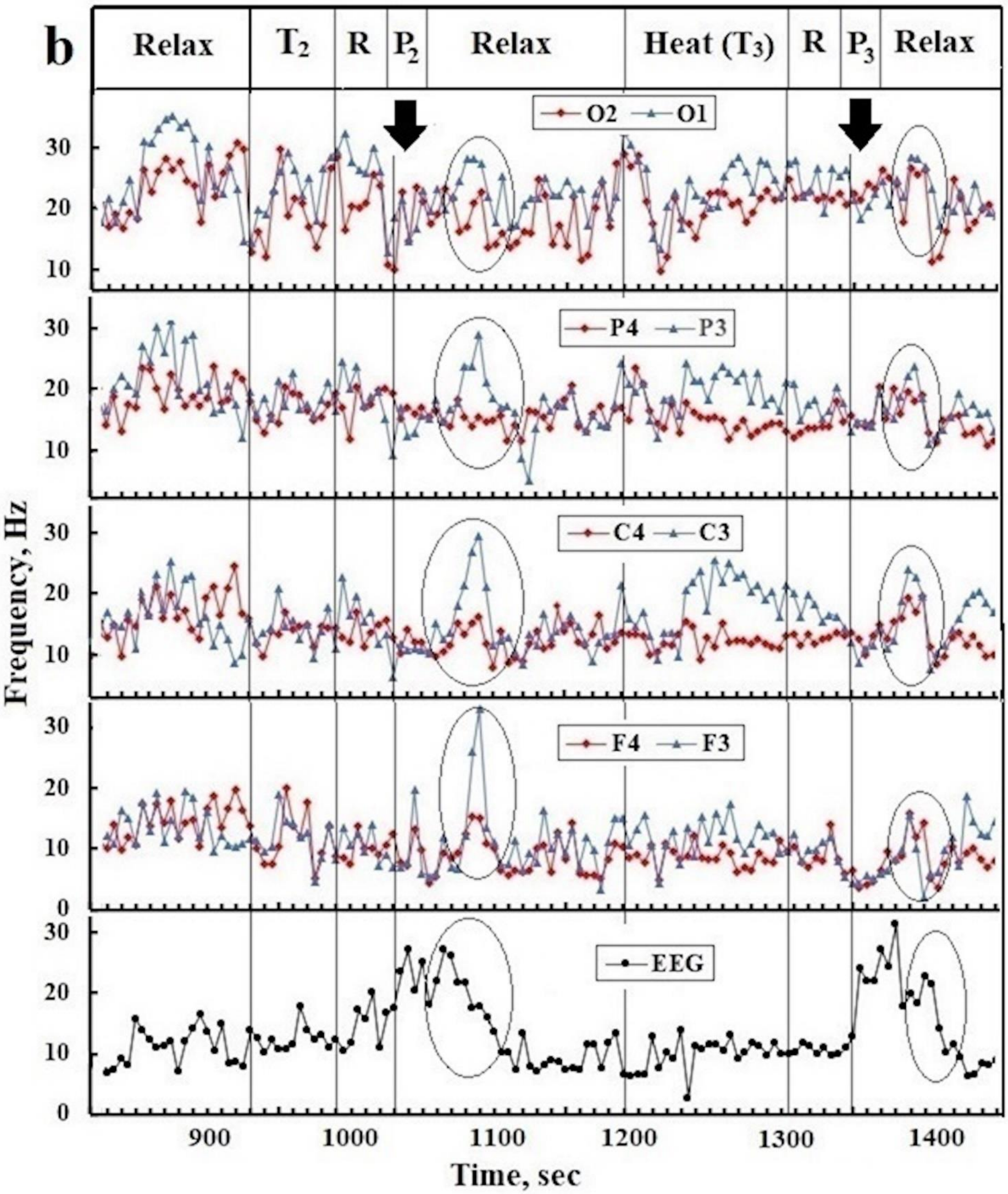

Fig. 7. Dependence of *ν*-spectra of EEG AK72 on pressure on both eyes for 20 seconds with gloved fingers before (**P**) and after warming up the hands (**P$_1$, P$_2$, P$_3$**); (**a**) dry objects with T_1 ~ 50 ℃; (**b**) in water with T_2 ~ 48 ℃ and T_3 ~ 43 ℃. R - relaxation with closed eyes. Ovals mark the frequency deviations caused by pressure.