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The possibility of developing color palettes with the specified color characteristics for use in avionics based on an equal-contrast isotropic space calculated using a spherical (metric) model is considered. Such color palettes are used in ergotic systems to encode information of proximity to the earth, a cartographic landscape in order to develop on-board equipment on aircraft to ensure flight safety.

**Keywords:** color, color palettes, anisotropic color space

The problem of creating equal-contrast (isotropic) spaces for color monitors, in TV, in avionics, and photoiconics is very relevant at the present time. Until recently, the creation of equal-contrast spaces was solved using the MKO-76 (CIE) formulas (ΔE Lab and ΔE Luv) and the calculation of small color differences (SCD). However, there are also large color differences (LCD), which are measured and calculated as well as small differences. In the practice of colorimetry, there was no need to measure such large differences until recently, so for this purpose it is necessary to create isotropic, equal-contrast spaces. It was in avionics that such problems appeared where color coding is successfully applied in systems of proximity to the earth, aircraft navigation systems with color indication of navigation maps, landscapes and in other multifunctional aviation complexes.

The purpose of this work is to create a tool for building equal-contrast and uniform color palettes in avionics. Color coding has a positive effect on the pilots' activity in determining the spatial position of the aircraft and removing it from dangerous situations [1]. In color alarm systems, the following colors are used: red – alarm, green – notifying, blue – notifying, yellow – warning, white – notifying. These colors constitute a minimal color palette that can be expanded to 7-16 colors or more, depending on the purpose of the system. With a large number of colors in the palette, errors in determining the color can be made when it is perceived by the pilot.

1. "Equal-contrast" palettes are considered in which the contrast of color stimuli relative to the background of the display screen is set by the identical sensation. Equal-contrast palettes allow:
   - provide detection of stimuli with a given probability of detection and the required detection time [2];
   - exclude errors in determining the colors of the palette;
   - determine the parameters of the color stimuli of the palette in the design of the equipment, its production and control during operation.

2. It is shown that to create color equal-contrast palettes it is necessary to use the metric color space (MCS) [3]. In the MCS (Fig.1), the color characteristics of stimuli through color tone (φ),
saturation (S) and lightness (B) are uniquely determined. Parameters of stimuli are calculated from their spectra [4].

In the MPC, the achromatic brightness contrast is a particular case of color contrast $k_{rel}$ and can be calculated from the formula [5] (Fig. 2):

$$ k_{rel} = \left\{ 1 + \left( \frac{A}{A_0} \right)^2 - 2\left( \frac{A}{A_0} \right)[SS_0 \cos \Delta \phi + (1 - S^2)^{0.5} \left( 1 - S_{\phi}^2 \right)^{0.5}] \right\}^{0.5}, $$

where $\Delta \phi = | \phi_1 - \phi_2 |$,

where $A, A_0$ – moduli of vectors of stimulus color and background; $S, S_\phi$ – saturations of stimulus color and background; $\Delta \phi$ - the angle between the color tone of the stimulus and the background.

In an equal-contrast palette for all stimuli, the $k_{rel}$ value should be the same for the display background (see Table 1, Fig. 4).

1. **Achromatic (brightness) component $I_w = L$.**

   The photometric brightness $L$ is measured. For measurement, a photometer is used whose spectral characteristic is corrected for the function of the relative spectral efficiency of day vision $V(\lambda)$.

2. **Red-green component $I_{rg}$**

   The determination of $I_{rg}$ is made by measuring the spectral density of the light flux by a TKA-VD type spectrometer and by numerically integrating (summing) the product of the spectral density values of the light flux and the values of the weighting function $V_{rg}(\lambda) = (x(\lambda) \cdot \bar{x}(\lambda))$

3. **Yellow-blue component $I_{yb}$**

   The determination of $I_{yb}$ is performed in the same way as $I_{rg}$ by measuring the spectral density of the light flux by the spectrometer and numerically integrating (summing) the product of the
spectral density values of the light flux and the values of the weighting function $V_{yb}$

\[
(\lambda) = 0.4y(\lambda) - 0.4z(\lambda),
\]

where $x(\lambda)$ are the specific color coordinates XYZ in the MKO-31 system.

4. Calculating the intensity (power) of color $I$.

\[
I = I_w + |I_{rg}| + |I_{yb}|
\]

5. Computing the components (scalar coordinates) and the color vector module $A$

\[
A_c = (I)^{0.5},\ A_w = (L)^{0.5},\ A_{rg} = (I_{rg})^{0.5},\ A_{yb} = (I_{yb})^{0.5}.\n\]

6. Calculating the color component (scalar coordinate) $A_c$

\[
A_c = (A_{rg}^2 + A_{yb}^2)^{0.5}
\]

7. Calculating saturation $S$

\[
S = A_c / A_w
\]

8. Calculation of the component (scalar coordinate) of the uniformly energetic white $W$ (whitenesses)

\[
W = A_w / A_c = (1 - S^2)^{0.5}
\]

9. Calculating the color tone $\phi$ (angle in the color plane) in degrees

\[
\phi [\text{deg}] = (-1)^m \arccos(A_{rg} / A_c) + n 180,
\]

\[
m = 0,\ n=0,\ \text{for}\ I_{rg} \geq 0,\ I_{yb} \geq 0
\]

\[
m = 1,\ n=1,\ \text{for}\ I_{rg} \leq 0,\ I_{yb} \geq 0
\]

\[
m = 0,\ n=1,\ \text{for}\ I_{rg} \leq 0,\ I_{yb} \leq 0
\]

\[
m = 1,\ n=2,\ \text{for}\ I_{rg} \geq 0,\ I_{yb} \leq 0
\]

The angles in the plane in the chromaticity are measured with respect to the direction "0-3 hours", counterclockwise.

10. The results of measurements and calculations are presented in Table 1 for two photometric brightness values of 150 cd/m$^2$ and 75 cd/m$^2$. 

radiation – lightness $B$.

\[
B = (L)^{0.5} / W = (L)^{0.5} / (1 - S^2)^{0.5}
\]

It is known that the ability to provide a perception of the difference between the details of the light field of a visual indicator screen is a decisive characteristic of the operation of the display equipment. Ergonomic design, as well as other stages of the life cycle of the visual information display equipment, needs a numerical indicator characterizing the perception of the difference in the details of the color image, based on measuring the physical characteristics of the light stimuli. Such indicator, determined in a metric color space(MCS), is relative contrast to $k_{rel}$.

Relative contrast $k_{rel}$ can serve as a working tool for determining the technical specification of the indicator, setting the regulatory requirements for the light indicators of a color indicator, their production and operational control of the relevant psychophysiological characteristics of human
perception of the light. For example, we refer to such standards as the effectiveness of detecting colored objects, separating the multicolored fragments of the image and the background, distinguishing the details of the image with color coding, a palette of encoding colors, optimizing the choice of colors for various combinations of "color mark" – "background color" and others. The standards $k_{rel}$ in these cases should be no less than some maximum permissible value. In the same way, $k_{rel}$ can be used to normalize the permissible color and lightness irregularities. To ensure that the irregularities are not visually detected, the values of $k_{rel}$ should not exceed the threshold values. Similarly, it is possible to normalize other image defects, the perception of which is not permissible.

The initial data for the calculation of $k_{rel}$ are presented in Table 1, the indices 1 and 2 in the formula for $k_{rel}$ are assigned so that $A1/A2 \leq 1$.

The results of calculations $k_{rel}$ with the identical photometric brightness equal to 150 cd/m$^2$ are given in Table 1.

In the MCS, the achromatic brightness contrast is a particular case of color contrast $k_{rel}$ and can be calculated by the above formula, where $A1, A2$ are the moduli of the stimulus and background color vectors; $S_1, S_2$ are saturation of stimulus and background colors; $\Delta \phi$ is the angle between the color tone of the stimulus and the background.

In an equal-contrast palette for all stimuli, the values of $k_{rel}$ should be the same for the display background (Fig.4).

### Table 1

<table>
<thead>
<tr>
<th>Color</th>
<th>Brightness, ([\text{cd/m}^2])</th>
<th>Color tone, ([\text{degrees}])</th>
<th>Saturation</th>
<th>Color contrast (on white background 860 cd/m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$ (нм)</td>
<td>$L$</td>
<td>$\varphi$</td>
<td>$S$</td>
<td>$K_{rel}$</td>
</tr>
<tr>
<td>white</td>
<td>35</td>
<td>–</td>
<td>–</td>
<td>0,8</td>
</tr>
<tr>
<td>red: 628</td>
<td>480</td>
<td>28</td>
<td>0,78</td>
<td>0,8</td>
</tr>
<tr>
<td>green: 555</td>
<td>43</td>
<td>146</td>
<td>0,73</td>
<td>0,8</td>
</tr>
<tr>
<td>blue: 470</td>
<td>165</td>
<td>314</td>
<td>0,77</td>
<td>0,8</td>
</tr>
<tr>
<td>yellow: 574</td>
<td>40</td>
<td>120</td>
<td>0,59</td>
<td>0,8</td>
</tr>
</tbody>
</table>

3. **A special case of a "uniform" palette is considered**, in which the hue changes from a red color ($\lambda = 700$ nm) to a green ($\lambda = 555$ nm) monotonically through equal intervals (angles) (Fig. 4). In the MCS, the angles that contract the arcs of 1-2, 2-3, ... 6-7 are the same. Therefore, the change in the color tone in the palette by sensation should be uniform. The table 1 shows the calculation data between the corners of the color tone $\theta$ and the magnitude of the dominant wavelength $\lambda_{dom}$ by the color tone of the palette of seven colors with uniform color tone variation. Using the MPC allows to implement color palettes with the specified properties: "equal-contrast" color palettes and "uniform" color palettes.
References
Anisotropy and gold proportions in visual apparent motion

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Visual phenomenon of apparent motion (β-motion) was investigated monocularly and binocularly in 22 men. Distance between light sources was 6˚ in each of eight meridians of visual field, flash duration – 25 ms, variable time delay between flashes – from 75 to 150 ms. Time ranges of the phenomenon were from 75 to 140 ms in the centre of visual field and from 80 to 150 ms in parafoveal areas. In the region of blind spot apparent motion had the same character as in other meridians within 12-18˚ eccentricity. Minimal time delay with phenomenon beginning was in left meridian, with phenomenon disappearance – in left, right and lower meridians of visual field. Maximal time interval for phenomenon disappearance was in the upper part of visual field. Differences between meridians were similar during the monocular and binocular observations, but binocular variations were smaller. These results make it possible assuming that brain mechanisms of the visual apparent motion are kindred with analysis of real motion.

Keywords: light flashes, central and periphery vision, monocular and binocular observation, visual apparent motion, anisotropy

Introduction
Apparent motion is the visual illusion in which the visual movement perception appear in the absence real object motion. First investigator who discovered this phenomenon was S.Exner [1], but by far later M.Wertheimer [12] made first attempt to analyse in detail the dependence this illusion on several parameters complex. For the phenomenon explanation Wertheimer proposed a hypothesis of excitation spreading according to which interaction between excitations conditioned by both stimuli take place in brain or in the retina. According to Wertheimer opinion the phenomenon may appear with pause between light stimuli from 60 to 200 ms. Later by efforts of many authors another parameters of apparent motion were studied and classified. According to majority of classifications apparent motion was named as optimal motion (φ-phenomenon) or as β- motion. Its appearance is conditioned by many parameters among which next may be named as main:

- stimuli intensity,
- stimuli dimensions and forms,
- exposition duration,
- angular distance between stimuli,
- time delay between stimuli,
- repetition frequency of stimuli pair,
- observation continuance.

Interdependence between these parameters does not studied finally, but some fundamental interrelations were formulated in form five laws of Korte [7]. According these laws optimal motion may appear within delay range 80 … 400 ms [9].

Results of some authors investigations demonstrate perceptive nature of this illusion. Phenomenon beginning are connected with existence of motion direction detectors selective oriented and having anisotropic peculiarities [4]. Visual "motion inertia" is explained by special
connections between directoral sensitive motion detectors which create feedback and provide “pre-tuning” of detectors disposed farther along the rectilinear trajectory [10].

Arguments in favour of central mechanisms of apparent motion presumably in primary cortex regions are received indirectly. Notions about cortical interaction between adjacent neurons have a central place in explanations of physiological essence of this illusion [2].

In comparison of real and apparent motions perception some distinctions are revealed [5], but psychophysiological investigations much more convince in correctness of hypothesis about identity their mechanisms [11]. Probability of apparent motion appearance in dependence on time delay showed relative uniformity within the limits about 6° [6]. However minimal distance between stimuli (threshold) increased with eccentricity from 6 to 25 degrees [3].

**Methods**

This investigation purpose was the elucidation (clearing up) of anisotropy character in apparent motion phenomenon.

The panel in frontal flatness (campimeter) with light emitting diodes was used for the phenomenon investigation along eight meridian of visual field. Apparent motion was observed monocularly and binocularly by 22 adult men. Light flashes duration and time interval between two flashes were provided by circular rotation of metal conductor gliding along the arc with two stripe of metal closing the electric circuit. Distance between stripes was changing for the regulation time delay between two stimuli. Contact and pause were conditioned by motor rotation with angular velocity 1 per second. Distance between light source in each meridian was redirected to visual field centre (0 … 6 degrees) or to near periphery (12 … 18 degrees). Flash succession had a centrifugal character.

Background illuminance was 10 lx, both stimuli had angular size 14 minutes in diameter, flashes luminance – 5 cd/m², each flash duration – 25 ms.

**Results and Discussion**

The investigation results are demonstrated in tables 1 and 2. Both tables have identical construction. In first column are named visual field meridians, at columns 2 and 5 – time intervals between flashes appropriate to phenomenon appearance (A, ms), columns 3 and 6 – disappearance time (D, ms), columns 4 and 7 – ratio of appearance to disappearance time (A/D).

<table>
<thead>
<tr>
<th>Meridians</th>
<th>Monocular vision</th>
<th></th>
<th>Binocular vision</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>D</td>
<td>A/D</td>
<td>A</td>
</tr>
<tr>
<td>Left</td>
<td>79.5±3.2</td>
<td>129.0±4.8</td>
<td>0.616</td>
<td>76.8±2.9</td>
</tr>
<tr>
<td>Left-upper</td>
<td>82.0±3.1</td>
<td>134.1±5.0</td>
<td>0.611</td>
<td>78.7±3.0</td>
</tr>
<tr>
<td>Upper</td>
<td>86.7±3.1</td>
<td>140.0±4.9</td>
<td>0.619</td>
<td>82.7±3.0</td>
</tr>
<tr>
<td>Upper-right</td>
<td>84.1±3.2</td>
<td>139.3±4.9</td>
<td>0.619</td>
<td>81.3±3.1</td>
</tr>
<tr>
<td>Right</td>
<td>80.9±3.2</td>
<td>133.0±5.2</td>
<td>0.608</td>
<td>79.3±3.0</td>
</tr>
<tr>
<td>Right-lower</td>
<td>83.3±3.2</td>
<td>137.0±5.0</td>
<td>0.608</td>
<td>79.6±3.1</td>
</tr>
<tr>
<td>Lower</td>
<td>79.4±2.9</td>
<td>129.0±4.9</td>
<td>0.616</td>
<td>76.4±3.0</td>
</tr>
<tr>
<td>Lower-left</td>
<td>82.2±3.3</td>
<td>134.7±5.1</td>
<td>0.610</td>
<td>77.2±2.9</td>
</tr>
</tbody>
</table>

Table 1

Table 2
Intervals between light flashes (ms) producing apparent motion in paracentral parts of visual field

<table>
<thead>
<tr>
<th>Meridians</th>
<th>Monocular vision</th>
<th>Binocular vision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>Left</td>
<td>90.6±3.3</td>
<td>146.7±4.9</td>
</tr>
<tr>
<td>Left-upper</td>
<td>95.5±3.3</td>
<td>156.2±5.1</td>
</tr>
<tr>
<td>Upper</td>
<td>96.7±3.3</td>
<td>157.0±5.3</td>
</tr>
<tr>
<td>Upper-right</td>
<td>94.6±3.3</td>
<td>155.0±5.7</td>
</tr>
<tr>
<td>Right</td>
<td>90.9±3.4</td>
<td>149.4±5.5</td>
</tr>
<tr>
<td>Right-lower</td>
<td>91.0±3.3</td>
<td>147.3±5.5</td>
</tr>
<tr>
<td>Lower</td>
<td>90.1±3.1</td>
<td>146.2±5.6</td>
</tr>
<tr>
<td>Lower-left</td>
<td>91.1±3.2</td>
<td>147.8±5.6</td>
</tr>
</tbody>
</table>

Obtained results permit notice that pauses between flashes corresponding to phenomenon appearing and disappearing always are less in the visual field centre than at near periphery. Thresholds of time delays decrease when observation is binocular against monocular. Differences between meridians have almost identical character with monocular and binocular observations, but they have quantitative distinction only. Threshold light flashes delay is minimal in the lower half of visual field. By indirect way these results testify about mainly central nervous phenomenon mechanisms so far as images incidence on the non-identical retinal regions can't provide information cultivate identity in retinal neuronal chains. Binocular interaction facilitating the phenomenon appearance can't find the explanation of the illusion essence by peripheral mechanisms only. These mechanisms localized probably in central neuronal nets of visual system, accomplishing furthermore real motion analysis. In region of the blind spot apparent motion retain same qualitative peculiarities as in other meridians attached to same eccentricity. There was not a single event of phantom flash in the region of blind spot as in Lockhead a.o. investigations [8]. Optimal motion in this zone preserve its smoothness and thus confirm its central origin.

Extrapolation of apparent motion trajectory is fulfilled some better during binocular observation than at monocular. Apparently this advantage is conditioned by binocular summation least of all. Interocular distinctions and excitation synchronization in visual centres have far greater importance in such case.

Common peculiarity is exposed in all visual field meridians. Time intervals of phenomenon appearance in ratio to disappearance time (A/D) fluctuate near to 0.618 in accordance to the law of “gold section”

References
Abstracts of the Conference

Development of a method for increasing noise immunity in the filtration of phonocardiograms
Aimukhanbetov E., Koishybaev D., Abdulkhairov M.
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To increase the accuracy and stability of the registration of phonocardiograms in electronic stethoscopes, a new treatment method is needed which will allow us to obtain clear waves of cardiograms. To eliminate the negative effects of phonocardiograms, a cascade algorithm based on a bandpass filter was constructed. This cascade algorithm, in contrast to others, can enhance low-frequency sound waves of the heart and improve the accuracy of identifying the components of phonocardiograms. In order to demonstrate the work, the developed cascade algorithm was modeled in the computer-aided design system Proteus. The results of the study show the limitations of all methods for processing phonocardiograms based on the electronic stethoscope and full compensation for the influencing noise. The article also presents the results of simulation of the electronic stethoscope printed circuit board, tracing and its 3D model. The algorithm of cascade filtration is recommended to be used in tasks of preliminary processing of biomedical signals, where it is possible to isolate the diagnostic features of the analyzed signals.

Echo thresholds in horizontal plane for stationary and moving lagging signals
Agaeva M.Yu.
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The precedence effect refers to a group of auditory phenomena that is related to ability to localize sound sources in reverberant environment. In the present study, the precedence effect was explored using a sound localization task in the free field for lead-lag paradigm. This study compared the echo thresholds for stationary lag and moving lag. The lead was always stationary (+15°). The stationary lags were located at -86°, -52°, -18°. The moving lags traveled to or from the lead along two paths situated at two locations (-86° ±52° and -52° ±18°). Results suggest that for the moving lag, the echo thresholds were not affected by path location and direction of movement (to or from the lead). The averaged echo thresholds ranged from 6.2 to 6.9 ms. In contrast, for the stationary lag, the echo thresholds depended on the lag location. The averaged echo thresholds increased from 5.1 to 7.1 ms when the lag was getting closer to the lead.

Noise robust processing of a speech signal in robot control tasks
Abdulkhairov M., Aimukhanbetov E., Koishybaev D., Serikkazhiyeva R.
ITMO University, St. Petersburg, Russia

Existing algorithms for filtering voice signals in the presence of intense noise do not satisfy the requirements. Therefore, the development of methods for increasing noise robust in the transmission of speech signals for robot control is an actual task. To improve the efficiency of filtering, adaptive filters with extended frequency bands can be used. This approach can improve noise robust and reduce the value of errors in the robot control task. The review of algorithms of filtering of speech signals is presented. Based on the proposed algorithm for filtering the speech signal, which significantly expands the range of the signal-to-noise ratio of the control noisy speech signal. A comparative analysis of the characteristics of the developed algorithm with known
methods of filtering the speech signal is carried out. The developed algorithm of an adaptive speech signal processing. The efficiency of the proposed cascade filter is demonstrated by computer simulation. The presented noise robust algorithm allows you to extract information about yourself during the characteristic in conditions of unstable dynamics and in the presence of interference, which allow you to control mobile robots. Practical application of this method allows to significantly expanding the management capabilities of mobile robots.

**Visually evoked emotional reaction recognition based on physiological tremor acquisition**
Saint-Petersburg State University, St. Petersburg, Russia

The paper is dedicated to novel technique for emotionally significant stimuli recognition assessment based on physiological tremor analysis under various experimentally emulated types of affective load. Physiological tremor acquisition was implemented by bilaterally attached 3-axial digital accelerometers, fixed on external side of index fingers. The first experimental protocol includes randomized presentation of four variant visual stimuli, one from the followed - subject’s second name, random shuffled letters of second name, graphic representation of simple arithmetic expression with correct or incorrect answer. The other one was the experimental remake of applied polygraph testing technique “concealed information test” with visually presented simple number set from zero to seven. Data preprocessing was realized basing on singular spectrum analysis filtration and trend reduction. Amplitude and instantaneous frequency dynamics was assessed by Hilbert transform. The data analysis explained unconscious psychomotor reactions under emotionally loaded visual stimuli perception. The same result was obtained in both experimental protocols. The significant changes in short-term (250 – 750 ms) evoked physiological tremor dynamics were established on visually applied stimuli with the most significant affective load.

**The neural basis for absolute disparity coding in the primary visual cortex**
Alekseenko S.V.
Pavllov Institute of Physiology Russian Academy of Sciences, St. Petersburg, Russia

The human visual system is sensitive to disparity between the two retinal images. Disparity is analysed by binocular neurons located in many cortical areas and is used for spatial localization, 3D shape perception, scene segmentation and guidance of eye movements. Disparity analysis is first performed in area V1, where visual pathways from two eyes are combined for the first time. Cumming and Parker (1999) have shown that V1 neurons do only detect absolute disparity which is the difference in the two retinal images with respect to the point of bifoveal fixation.

To understand the mechanism of absolute disparity detection we have analysed the distribution of monocular signals within V1 for dot-objects located in different spatial locations. The positions of monocular neurons activated by such objects are defined by the retinotopic organization of area V1 and by different directions of visual pathways from nasal, temporal and naso-temporal overlap zones in retinae. Viewing distance and gaze direction will not change this pattern of retinal projections to cortical area. It means that disparity-tuned binocular neurons of V1 (formed by the convergence of monocular cells) should encode the absolute disparity only.
Justification of the use of empirical mode decomposition for the processing of bioelectrical signals in the time-frequency domain: ECG, EEG, EMG
Altay Y.A., Kremlev A.S.
ITMO University, St. Petersburg, Russia

In the last five years actively developed preprocessing bioelectric signals technology (BES), which allows identifying the functional state of the organism (FSO) of a person at an early stage of the disease. In connection with the diversity of features and characteristics of BES in comparison with physical signals, the choice of the algorithm for processing and analyzing BES is a difficult task, namely for signals of electrocardiograms, electroencephalograms, electromyograms (ECG, EEG, EMG). By the time the problem of automatic processing and analysis of bioelectric ECG, EEG, EMG signals against noise, interferences and artifacts has developed into a separate direction of modern information processing methods. To solve the above problem, the existing algorithms for processing BES involve the use of stationary signals and linear algorithms. As a result of the processing, the diagnostic features are distorted and partially removed from the mixture of analyzed signals. However, BES is nonlinear and non-stationary. To solve this problem currently BES processing technique chosen based on empirical mode decomposition on that are designed to handle non-linear and non-stationary signals. The essence of this technique is an adaptive decomposition into empirical modes and then the Hilbert transform is applied to the obtained modes for the subsequent use of diagnostic information in the time-frequency domain. Also of note, BES processing in time-frequency domain allows to visualize the analyzed signals on the 3D surface, which will allow researchers to identify new diagnostic features which are invisible when 2D surface.

Power and shift invariant detection of dynamically coupled networks (PSIICOS) from non-invasive MEG data
Altukhov D., Ossaditch A.
HSE, faculty of computer science; HSE, center for cognition and decision making; MSUPE, MEG-Center, Moscow, Russia

One of the most important tasks of modern brain electrophysiology is the study of so-called functional connectivity, a phenomenon in which spatially separated regions of the cortex and subcortical structures of the brain synchronize their electrical activity to solve a particular cognitive task. At the same time, there is no single "correct" method for assessing connectivity. Rather, the existing methods are a set of heuristics, each of which has its own advantages and disadvantages. Such a variety of methods is associated, on the one hand, with the fundamental limitations of electromagnetism and the ill-posedness of the inverse problem in electrophysiology, and on the other hand, the fact that the problem of assessing connectivity in non-invasive data is relatively new and poorly understood. The report will review existing methods in the field of connectivity estimation, and also offer an original approach to the problem, allowing under certain conditions to improve the quality of network detection in comparison with existing algorithms.
Algorithms and software for detecting neurons in images of the cat's spinal cord slices
Bakhshiev A.V., Mikhailov V.V., Merkulyeva N.S., Veshchitskii A.A., Musienko P.E.
The Russian State Scientific Center for Robotics and Technical Cybernetics, St. Petersburg, Russia

The development of data analysis tools for neuromorphological experiments is significant task that can increase the effectiveness of studying the neuronal control of sensorimotor activity and information processing. We proposed the method for semiautomatic detection of neurons at histological slices. The algorithm is based on converting the original image into the LAB color format and subsequent threshold filtering. It allows to detect neurons without knowing the size, shape and number of objects. A disadvantage of such solutions may be mentioned occurrence of noise caused by poor-quality images, and the presence of foreign elements in the image. A software has been developed to systematize information from a variety of experiments, perform neuron detection on selected slices, visualize the detection data and make their post-processing in a manual mode by adding and removing rectangles describing neurons from the original cut image. In addition to solving the problem of systematizing these experiments, the developed software can be used to mark up data and form training samples. Such samples can be used to synthesize new algorithms for detecting neurons, based on methods of machine learning.

Measurement and computer animation of phase shifts in EEG
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During the multielectrode EEG recording one can see that oscillation arises in one point, then spreads on the head surface and runs around it on some trajectory. Possible trajectory and rate variants of «EEG travelling wave» are very multiform and changeable. The general character of the dynamics described varied from man to man, depends on functional state and follows the certain regularities. In the laboratory of EEG in S-Petersburg State University there was created the technique of computer animation of EEG parameters with the overlay of the picture on the brain cortex 3-dimentional model. Oscillations originally arise in the areas marked as red ones and then spread from these epicentres. On the contrary, the blue areas indicate the «flowing points» of the potential travelling waves. It is possible to observe the brain model from any point or to depict it on plane as well as to launch animation with accelerated, slowed down or real time speed. It should be noted, that here we are dealing with not a simple visualisation of potential, but more complex original mathematical apparatus is used We use of cross-correlation function to estimation of time (or phase) shifts between EEG recordings of neighbouring electrodes.

Due to its mobility, animation has the advantages of traditional EEG in the form of curves, which represent the accurate time description of the processes. But in addition animation makes obvious the spatial processes correlation – it may be approximately considered, that we see through the skull how something spreads on the cortex surface on the changeable trajectory with the variable rate. So this technique combine to some extent the advantages of traditional EEG and tomography. Now the studies are conducting, which will allow the differentiation of pathological and normal EEG as well as distinguishing of the different forms of bioelectrical activity disturbances using animation.
Modelling of the psychophysical experiments results by neural networks
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We compared experimental psychophysical data with modeling results to the study of signal processing mechanisms in visual system. It is believed that some visual illusions arise from the spatial-frequency filtering of images on the level of the primary visual cortex. In psychophysical experiments we investigated the Oppel-Kundt illusion. Spatial intervals were limited by two straight or curved parallel lines. Several additional lines divided spatial intervals into equal parts. The width of spatial intervals varied from 2.56 to 3.12 angular degrees. We founded the invariant dependence of the illusion on number of lines with respect to the interval size. Maximum of illusion was between the four and seven lines. The distortions of size relations of certain parts of the stimulus were determined by processes with receptive fields of the visual system. The spatial properties of simple and complex receptive fields of neurons of striate cortex were used. Model of modules (Gleser, 1985), consisting of 4-5 harmonics, gave a qualitative agreement between psychophysical measurement of the strength value of the illusions and the predictions of physical model. The size of module which gave maximal response on spatial interval with additional lines was taken as a size of illusion.

Development of the technology of microwave encephalography (MVEG) for the diagnosis of nervous diseases and mental disorders of the human brain, the study of human activity in the norm and the organization of a new type of neuro-computer interface
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In the course of their own research, the authors were the first in the world to provide experimental evidence of the existence of human brain (HB) electromagnetic activity in the range of electromagnetic waves of UHF and MWF frequencies from 1.5 to 5.0 GHz with a signal power of -100 dBm .. 80 dBm (1e-13..1 e-11 W). In fact, a new channel for transmitting information to the HB has been discovered. The experimental studies made it possible to propose a fundamentally new technology for diagnosing and visualizing the state of HB, which the authors called microwave encephalography (MVEG), for diagnosing the norm and pathology of a number of functional and emotional states of hypoxia (depression, aggression, emotional instability), mental disorders and mental illness. The instrumental base of MVEG is the developed complex of high-sensitivity microwave equipment, software and program-method that will allow recording the amplitude-frequency characteristics of the electromagnetic activity of the HB in the UHF and MWF frequencies in real time and transmit data to the computer for further processing.

Features of visual processing in children with atypical development
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The effect of pre-exposure stimuli with a low spatial frequency on the time parameters of identification in pre-school children with typical and atypical development was investigated. Analysis of the dependence of the reaction time on the interval between the low-frequency prime and the high-frequency test stimuli showed that, in typical development, a significant decrease in the time of recognition of stimuli in the
interval from 100 to 300 ms after presentation of the prime is observed. In children with a delay in mental development, the effect of facilitating the recognition of the test stimulus begins to appear after 200 ms after the prime, but stabilizes after 400 ms. In children with autism spectrum disorder, there was no reliable dependence of the reaction time on the interval between the primer and the test stimulus. However, we can note a tendency to decrease this parameter when identifying stimuli with a high spatial frequency in the interval 300-500 ms. In general, the results obtained indicate that, with typical development, the process of processing information in the low-frequency channel of the visual system affects the processing of information in the high-frequency channel of the visual system. When mental retardation is delayed, this effect is weakened, and in the disorder of the autistic spectrum is significantly impaired.

**Local linearity approach for extracting physiologically plausible interpretations of non-linear decision rules in EEG classification**

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Interpretation of decision rules provided by trained classifiers is of a great importance in neuroimaging studies. Explanations in terms of physiologically plausible activation patterns (corresponding to the forward model of a signal) are especially significant in cognitive science. However, whereas it can be easily done for a linear classifier, non-linear classifiers do not provide a straightforward way to derive such activation patterns. Here we propose a novel algorithm for extracting activation patterns from the trained neural network's decision rule. After a neural network has been trained to discriminate between two classes, one can derive physiologically plausible activation patterns given that the classes have an underlying XOR structure. These activation patterns will correspond to the forward model’s vectors reflecting the sources that vary between conditions. The derivation of these activation patterns is possible since the decision boundary found by the network is piecewise linear; that is, it is approximately linear in regions of the input space corresponding to the XOR conditions. Given that the identification of such regions is feasible, one can treat the neural network as a linear classifier at these regions. We demonstrate the validity of the present algorithm on both simulated and real data.

**Application of scalable heterogeneous classifier of EEG patterns of fine motor imaginary decoding for Brain-computer interfaces (BCI)**

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The study aimed development of BCI on base of EEG single-trials decoding during fine imaginary movements. EEG registrations were made with participation of 10 subjects [mean age – 26.2±3.1[SD] by means of portable EEG-amplifier ”SmartBCI” (“Mitsar”, St. Petersburg) from 19 AgCl electrodes(10-20), in a frequency band 0.53 Hz-30Hz. The subjects performed real and imaginary movements in given rhythm, separately for four fingers of one hand. Only trials (600 ms length) with imaginary finger’s movements were analyzed. Comparative analysis of preprocessing of EEG signal transformations (weighted average reference, independent component analysis, current source density transform), extraction of new features from EEG patterns of imaginary movements (wavelet transforms, Mel-frequency cepstrum coefficients) was applied. Decoding of EEG patterns was carried out by committee of classifiers on base of ANN and SVM. Analysis of classification accuracy for motor imagery EEG pattern decoding in single-trial approach revealed that the best result was obtained using current source
density transform together with feature extraction of cepstrum coefficients and the complexity of a signal curve. Classification accuracy of 4 classes of fine imaginary movements was 66%±8[SD] at average and 79%- max.
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**EEG of rhesus monkeys in resting-state conditions and under photic stimulation**
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Monkeys are considered as a closest animal model for investigation of the human brain functioning. In our experiments we recorded intracranial EEG of rhesus monkeys by epidural electrodes placed on frontal, central, parietal and occipital lobes and also by subdural electrodes placed on the medial surface of parietal area (PGm). Recordings were performed in resting state conditions and in response to flash stimulations with frequencies ranging from 4 to 38 Hz with the step of 2 Hz.
Spectral analysis of the monkey’s EEG recorded in resting-state conditions revealed two dominant frequencies: at around 10 and 20 Hz. Frequency of 9-10Hz was more prominent at occipital and PGm areas, whereas frequency of 20 Hz was maximal at electrodes placed on lateral parts of parietal lobes. The third robust but small amplitude peak in the spectrum was observed in central frontal areas. Its frequency was about 38 Hz. EEG responses to photic stimulation depended on frequency applied and were maximal in occipital and medial parietal areas at flash frequencies of 14 and 28 Hz.

**Investigation of cognitive abilities of rhesus monkeys**
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In behavioral experiments we studied the ability *Macaca mulatta* monkeys to perform cognitive tests with different levels of difficulty presented on a touchscreen. The task was to determine a dominant orientation within patterns ordered in different way. We analyzed learning rate, the number of correct answers and reaction time in dependence of the task complexity. At the same time we estimated investigatory activity by measuring time of reaction to a novel object.
The percentage of the correct answers was higher for more ordered test images and close to the one obtained before for human subjects in similar experiments. The investigatory activity index correlated with the learning rate and was lower for those monkeys, who demonstrated longer reaction time and had a tendency for attention distraction. The results enable us to model neuronal processes occurring in the human brain during object recognition, from coding of image physical characteristics to decision making.
The relationship between the level of investigatory activity and the learning rate makes the novel-object test a promising evaluative tool for choosing perspective monkeys for behavioral experiments, which can significantly reduce the time of training.
Neural networks as a tool for forecasting innovation activity
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In order to understand the possible scenarios and develop strategies for responding to them, specialists from different fields of activity necessary to conduct a thorough analysis of the initial data that describes some phenomenon or process. Based on this analysis, predictions of these phenomena or processes using different methods. The results of this prediction are the basis for making strategic decisions. The field of innovation is no exception. Now more and more attention is paid to innovation at all its levels, from the scale of a private company and to the level of innovative activity of the country. This is so important because everyone is interested in improving own achievements in research and development. Therefore, forecasting of such activity is essential to adjust plans.

One of the most common methods for predicting indicators is application of neural networks. The popularity of neural networks is primarily based on their ability to learn and improve themselves. An important advantage of ANN is their high resistance to noise in the input data (the network is able to filter out unnecessary information). In addition, neural networks have a large computational power of neural networks. They are able to analyze large amounts of data with many variables. The same number of input variables, for example, in regression models would have reduced their effectiveness. Ann shows the best performance prediction accuracy compared to alternative methods.

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Peculiarities of perception by first-graders of texts with a different format of visualization
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The interrelations between the quality of perception and understanding of the text by first-graders and the text format were studied: the presence or absence of illustrations, the length of lines. 30 first-graders were examined, 15 of them were diagnosed with dyslexia. Using the specially formulated questionnaire of the respondent, the quality of perception and understanding of the text was measured, then the results were evaluated by student experts. Also with the help of the device "eyetracker" zones of interest and features of perception were defined. The results of children reading texts with different formats were compared, as well as the results of children with dyslexia and children without disrupting the reading skill. The results: a link was found between the children's better perception of the text and the shortened length of the lines. There is no significant connection between the presence of illustrations and the perception of the text. The connection of dyslexia with the worst perception of the text and a slower rate of reading has been revealed.

Working memory load in simultaneous language interpretation: an ERP study
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We utilized the event-related potential (ERP) technique to study neural activity associated with different levels of working memory (WM) load during simultaneous language interpretation (SLI). We pioneered the use of the technique on conference interpreters articulating overtly. The amplitude of the N1 component elicited by task-irrelevant tone probes was significantly modulated as a function of WM load.
but not the direction of interpretation. The N1 amplitude decreased with WM load suggesting shallower processing under high WM load regardless of the direction. Using our novel projection-based method we identified otherwise hidden WM load-dependent regularities in the P3 range. The results are discussed in terms of the Efforts Model of simultaneous language interpreting.

Localizing hidden regularities with known temporal structure in the EEG evoked response data
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We describe a novel data driven spatial filtering technique that can be applied to the evoked potentials in the EEG data in order to find statistically significant hidden differential activations, which can not be found by standard single-channel analysis. Underlying optimization problem is formulated as a generalized Rayleigh quotient maximization problem. The technique is based on the known morphological characteristics of the response: the optimal filter maximizes the difference in the target interval when the component typically occurs and at the same time minimizes the difference in the flanker interval. The technique is equipped with a relevant randomization-based statistical test to assess the significance of thus discovered phenomenon. The performance of the proposed method was evaluated with the simulated ERP data, the results are compared with the competing ICA-based method. Furthermore, we describe an application of the proposed method to the EEG data acquired in two studies: study devoted to the simultaneous language interpreting (group analysis) and analysis of the auditory neuroplasticity (single subject application). We show how the differential components can be detected after filtration and support our results with the permutation statistical test, topographies analysis and single-trial evidences.

Dependence of the characteristics of eye movements on the spatial-frequency properties of the stimulus
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During the reading process, the activity of the visual system depends on the activity of the visual channels, which distinguish different parts of the visible spatial-frequency range. We investigated the change in the nature of the eye movements during reading of texts, which images were subjected to digital filtering using wavelets. Provided data showing the dependence of the nature of eye movements on the space-frequency structure of the images. To explain the results, the role of mango- and parvo- systems in visual information processing within the visual field was considered. The spatial-frequency characteristics of the observed images are established, providing a completely unique type of eye movement - scan lines of text. Effective work with text is possible only in the presence and prevalence of spatial frequencies in the range from 3 to 8 cycle / degree. The decrease in the proportion of high spatial frequencies and the predominance of spatial frequencies to 2.5-3 cycle / degree results in the parvo-system, sensitive to high spatial frequencies, receiving insufficient information for efficient operation, but under the influence of the instruction, the reader continues scanning the still present lines, similar to the reading pattern of eye movements.
Some aspects of emotional response during social advertising’s perception by higher-educated students
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This work is devoted to the social advertising’s effect on the emotional potential of youth and includes complex psycholinguistic analysis of short movies with social orientation (social advertising). The analysis of several aspects of student's emotional response to the different stimulus zones of social advertising with use of methods of direct poll and eye-tracking was made. Respondents fix their comprehension of the main idea of the movie and allocate episodes which made the greatest impression on them. Eye-tracking allows specifying zones which mainly attract attention of students. The main emotions described by students after viewing of short movies with social orientation are “sympathy” and "compassion", more than "pity", "grief" and "regret". Different episodes and shots of social advertising have the different affective potential, taking into account specific features of students, as it’s seen on the eye-tracking data: time of the first fixation, diameter of the pupil, fixation duration, number of fixations on the interest zones (faces of people, used images and symbols, verbal information - slogans and texts). Fixing of the respondents on significant stimulus led to emergence of so-called dead/white zones (phenomena of change blindness) round them, so information which is in these zones is not perceived by students.

Representation of high-level visual information in biological and artificial neural networks
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Convolutional neural networks (CNNs) share some properties with early stages of processing made by the human visual system in the way of processing natural images. Visualization of CNN kernels showed that they are tuned to detect space-frequency characteristics as well as color opponency, which is well-studied properties of neurons in the primary visual cortex. Visual signal passed through the initial stage of decomposition with mentioned kernels allows to build a semantically-separable representation of objects at the highest levels and make a decision about seen object. Here I investigate the way semantic categories such as faces, age and emotions can be represented in artificial neural networks and what kind of operations can be performed with inner representation. I hypothesize that functional correlates of invariant representations from artificial networks can be found in the higher levels of ventral visual pathway, such as inferotemporal cortex. Also, I compare approaches used for studying functions of higher levels of visual pathway, such as one-neuron recording and tuning curves, to available methods of visualization in artificial neural networks with a purpose to find advantages emerging from using the latest as a model of the human visual system.

Regularities of animate and inanimate objects in artificial Neural Networks
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Deep neural networks produce state of the art results in object recognition and detection of thousand image classes. As usual researches do not use relation between classes (hierarhy) during training, but "underlining factors" have to be taken into account by neural networks to achieve efficient recognition of variety of classes. We did experiments on singular value decomposition of CNN confusion matrix to perform object clustering by means of error analysis. The more powerful method of representing a confusion matrix as a graph and finding its cut was also considered. For a small CNN trained on CIFAR-
10 the two methods have shown similar results, which justify more efficient SVD-approach. Experiments with Alexnet have shown that animate and inanimate objects of ImageNet dataset represent two major clusters with strongest inner relations. The obtained results can be considered to be the prove of presence of subject invariant regularities inside groups of artificial and natural visual patterns.

Visual statistics in spatially organized sets
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Imagine beads on a table. Observers can effortlessly estimate summary statistics of such ensembles (Ariely, 2001). However, these beads look like isolated objects, whereas beads in a necklace look as a string. Would their summary statistics improve? We studied effect of spatial organization of perceptual ensembles on summary statistics using an implicit and an explicit procedures. We hypothesized that well-organized ensembles would be pre-attentionally grouped thus changing precision of estimated statistics. For the explicit task, observers made 4-AFC judgements about mean (Marchant et al, 2013) orientation of tilted lines sets positioned either randomly or in circle. Bayesian ANOVA showed no effect of organisation on explicit averaging. In the implicit task observers searched for an oddly tilted line among distractors. Lines’ centres were either aligned or jittered. A priming “streak” of several trials with distractors oriented with one distribution was followed by test trials with different distribution. Distractors’ distribution representation was estimated using test trials’ RTs. RTs were analyzed as a function of orientation difference between test trials targets and priming streaks distractors’ means (Chetverikov, Campana, Kristjansson, 2016).

Results showed that explicit averaging is insensitive to spatial organization. In contrast, the implicit procedure showed less accurate distribution estimate with well-organized stimuli.

Fractal analysis in post-processing of tomographic images
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Cancer is one of the most common causes of human mortality. Early diagnosis allows several times to reduce the death rate from cancer. Screening is used for mass early diagnosis of cancer. Fractal analysis of medical images can be useful in this field of application. In the study, we used magnetic resonance (MR) images of healthy tissues and tissues containing metastatic cancer. The fractal dimension of the image and the Hurst index were selected as diagnostic features for tomographic imaging. ImageJ software package for image processing and special application FracLac for fractal analysis. MR images were processed in the ImageJ software. The area size of 120x150 pixels was selected and then processed in the FracLac application. The fractal dimension of pathological and healthy tissue samples was calculated. To determine the fractal dimension, the method of cell counting was chosen. Results: In the case of pathology (foci formation), the Hurst index is less than 0.5 (the region of unstable statistical characteristics), and for healthy tissue the Hearst index is more than 0.5 (zone of stable characteristics). Conclusions: The study examined the possibility of creating a fractal rapid analysis to identify focal lesions of tissues and recommendations for its use. The Hurst index can be used as an important diagnostic characteristic for the analysis of medical images.
Neurophysiological correlates of efficient learning in the neurofeedback paradigm
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There is a number of studies made on activation evoked by the operant conditioning [1]. A group of brain structures responsible for the process are widely recognized to belong to the rewarding system [2] and the entire process of neurofeedback training is considered to be adequately described as a reinforcement learning process [3]. In this paradigm, the feedback signal presented to the subject is interpreted as a secondary reinforcer by the neural system. Depending on the ergonomic parameters of the feedback signal (latency, color, shape, pitch, timbre, etc) the efficiency of learning and the intensity of plastic changes will vary. Can we identify the correlates of efficient learning in the ongoing EEG recording? Can we use these correlates to tune the parameters of the feedback signal to achieve optimal performance?


Influence of the foveola size on the characteristics of the evoked potentials in image recognition tasks
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The aim is to study the visual evoked potentials characteristics (VEP) in the objects recognition task depending on the foveola size.

The study involved 27 healthy subjects aged 22 to 35 years with visual acuity of 0.5 to 2 (15 emmetrops and 12 - with myopia from 0.25 to 5.5 D). Using VEP two studies series were carried out at the resolution limit of the visual system. The VEP registration was carried out according to the scheme 10-20 with reference ear electrodes. In both series the images were displayed monocularly. The 1st type of stimulus - reversible chess pattern. The chess cell size on the monitor screen was 13.8 ang. min. Further, the relationship between the amplitudes and latent periods of the P100 component in the occipital regions with the foveal diameters was analyzed. The second stimulus type - an image of animate and inanimate nature. The images size - 24 ang. min. The relationship between the components characteristics of N170 and P200 in the occipital, in the temporal, and in the frontal regions with the foveal diameters was analyzed.

The dependence of the characteristics of the VEP, early and first cognitive components on the foveola size, was first revealed.
The influence of virtual environments presented on small and large screens on magno- and parvocellular visual pathways
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In this paper we present the results of experiments which show the effects of interactive virtual environments (VEs) with large and small angular size screens on the human visual system, particularly on the magno- and parvocellular systems. To evaluate the effects of these VEs we used comparative analysis of visual evoked potentials for visual stimuli, which differed in their semantic (living/non-living) and physical (wavelet filtrated high/low spatial frequencies for selective exposure to the magno- and parvocellular systems) characteristics. We have shown that the small screen stimulation mainly improves perception and analysis of high-frequency stimuli (parvo-system), whether the large screen stimulation improves both perception of high-frequency (parvo-system) and low-frequency (magno-system) stimuli. We obtained data on the influence of VEs on various levels of image processing. The obtained results are important for understanding of the processing of visual stimuli in different channels of human visual system.

Auditory masking of moving sound
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Spatial masking of moving sound is expressed in the spatial displacement of the subjective trajectory and in changing of its length. Masking effects depend on the time delay between the masker and moving stimulus, and on their relative spatial location and mutual correlation strength, and the direction of sound source motion.

Auditory training in patients with hearing and speech impairments
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The main indication for auditory training is central auditory processing disorder (CAPD), which inevitably develop in patients with chronic sensorineural hearing loss as a sequence of auditory deprivation, but may be present as well in patients with normal hearing thresholds. In these cases, regardless of a good ability to perceive simple sounds patients have difficulties with understanding complex signals, especially, in background noise. We tested the algorithm of auditory training in 57 patients of different ages with various hearing-speech disorders: 21 pupils (9-10 years old) with normal hearing thresholds and normal (n=11) or impaired speech development and CAPD (n=10); 29 adults (19-22 years old) with normal hearing thresholds and with CAPD and speech disorders (n=7), with chronic sensorineural hearing loss, with CAPD, but without speech disorders (n=12), with normal hearing thresholds and speech (n=10); 7 patients (60-74 years old) with chronic sensorineural hearing loss, signs of CAPD including decreased speech intelligibility in noise. Auditory training lasted for 8 weeks, with lessons 2 times a week during 35 minutes (for pupils) or 60 minutes (for adults). Auditory training improves central auditory pathways functioning, which makes it essential to be included in the rehabilitation of hearing aid users with poor speech-in-noise recognition.
The neural substrates of the auditory biological motion analysis are multimodal areas of cortex
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Motion perception is complex multimodal function. The hypothesis of our work: visual (and tactile) areas participated in motion analysis and spatial orientation should be activated to auditory biological motion. The group of 21 subjects with normal hearing participated in the study, which was performed on MR tomograph Magnetom Verio 3T (Siemens, Germany) using a 32-channel MR head coil in two stages: 1) collecting of anatomical data with high resolution based on T1-weighted sequence (TR 1900 ms, TE 2.21 ms, 176 slices, voxel size of 1x1x1 mm³); 2) recording data on the basis of functional EPI-sequence (TR 500 ms, TE 33 ms, 56 slices, voxel size 2x2x2 mm³). To increase the signal/noise ratio and improve the quality of stimulation compared with standard MR-compatible headphones were used optical OptoACTIVE (Israel) one with active noise cancellation for stimuli presentation. Stereo recordings of approaching, receding steps and the steps-in-place, done in a long corridor with reverberation, were applied as sound stimuli. One sample T test revealed significant fMRI signal changes in angular and supramarginal gyrus, MT/V5, precuneus. The work was supported by RFBR, grant N 15-04-02816.

Effects of attention and sound motion on the event-related rhythmic activity
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Event-related changes of EEG spectral power and phase coherence were analyzed during the moving sound localization task. The sound motion (Slow, Fast or Stepwise) delayed relative to the sound onset was presented to human subjects under the passive listening condition or when subjects’ attention was drawn to the sound localization. Event-Related Spectral Perturbation (ERSP) and Inter-Trial Coherence (ITC) indices were measured by using trial-by-trial wavelet decomposition and averaged in delta, theta, alpha, beta and gamma frequency ranges for each stimulus type and experimental condition. Dynamics of the ERSP and ITC clearly varied in different conditions and frequency ranges. In the active conditions, the ERSP amplitudes in delta, theta and alpha frequency ranges were higher around the stimulus onset and motion onset. By contrast, beta and gamma activity exhibited strong and long-lasting ERSP desynchronization in active conditions, which was most likely associated with preparation of the delayed motor response. The ITC-index measured in delta, theta, alpha and beta frequency ranges revealed that phase alignment related to the stimulus onset was stronger in active conditions. The phase alignment that followed the motion onset increased with motion velocity similarly in the active and passive conditions.

Extracting the characteristics of event-related EEG dynamics in the visual GO/NOGO task using Parallel Factor Analysis
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The event-related EEG dynamics associated with visual stimuli and movements overlap in space and time, and it is difficult to separate them from each other. In this study, a specific decomposition known as Parallel Factor Analysis (PARAFAC) was used, in order to retrieve the task-related activity from the raw
event-related EEG dynamics. The EEG data from the visual GO/NOGO task obtained in 610 adult healthy subjects was transformed to a spectral density dynamic using the Morlet wavelet and arranged in multiway arrays. Different multiway arrays were considered, including: five-way array – Subjects × Channels × Time × Frequency × Condition, four-way array – Subjects × Channels × (Time, Frequency) × Condition, four-way array – Subjects × Channels × (Time, Condition) × Frequency and three-way array Subjects × Channels × (Time, Frequency, Condition). The PARAFAC decompositions of these arrays were obtained and compared with initial data. This analysis had showed that the last two PARAFAC models adequately describe the event-related EEG dynamics. Moreover, the event-related changes of EEG power related to the visual stimuli and movements are described by different PARAFAC components. These results indicate that PARAFAC can be considered as an effective method for separation the task-related activity.

Latent components of ERPs in Go/NoGo tests
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It is suggested that executive system of the brain is responsible for behavior. It provides the formation, storage, initiation, implementation, monitoring and correction of action programs. In neurophysiological researches, event-related potentials are widely used for studying functioning of executive system. Recently a new mathematical method of blind source separation was adapted for separating ERPs signals in order to pick out activity from different brain sources, which reflects different operations. We used four modifications of the visual cued Go/NoGo test, which consisted of pairs of images for animal and plants. After some pairs participants were instructed to press the button (Go condition), and after others - refrain from pressing (NoGo condition). Images in pairs and Go pairs varied across test modifications. 40 healthy participants in age from 24 to 33 took part in the study. Applying of the method of blind source separation to the ERPs data recorded during the tests allowed picking out 7 latent components. It made possible to identify the functional significance of the latent components of ERPs, reflecting the stages of processing visual information, making decisions and action control. The study is supported by grant RSF 16-15-10213.

The role of psycho-emotional status in the control of BCI systems
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Learning of brain-computer interface (BCI) control by means movement training was studied. The training included slow cyclic movements of the right and the left hand, the imagery of these movements, and the sitting quietly before and after it (each of the conditions for 3 min). Before and after the training, subjects performed BCI control. All subjects were tested by Eysenck personality questionnaire (57 questions, 24-point scale of neuroticism and extraversion-introversion). The comparison of the values of the classification accuracy of brain states during motor imagery before and after the training showed that the success of BCI control learning depends on the result of subjects on a scale of neuroticism (emotional instability). The classification accuracy of brain states during imagination of hands was significantly
increased after training in users with low levels of neuroticism (values in the range 4 to 11), but not in users with high levels (15 to 22). Moreover, the classification accuracy between brain states during imagination of the right hand and in the rest decreased significantly after training in the users with high levels of neuroticism. The results specify the need to consider the level of user’s neuroticism when designing the methods to learn BCI control.

Detection of rising and falling intensity sounds: mismatch negativity and perceptual measures
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Perceptual priority for rising intensity sounds compared with falling level sounds is demonstrated by human subjects. The aim of the present study was to investigate whether or not the perceptual preference for rising intensity can be found in the preattentive processing indexed by mismatch negativity (MMN). The reversed oddball stimulation was used to produce the MMNs and to test the behavioral discrimination of rising, falling and constant level sounds. We used three types of stimuli as standards or deviants in different blocks: constant level sounds and two kinds of rising/falling sounds with gradual or stepwise change of intensity. The MMN amplitudes were calculated by subtracting ERPs to identical stimuli presented as standard in one block and deviant in another block. Both rising and falling level deviants elicited MMNs which peaked after 250 ms and did not overlap with N1 wave. MMN was elicited by intensity changes even in the case of behaviorally undetectable deviants. The MMN responses to the intensity change were mostly affected by the direction of deviance (increment or decrement) within the sequence, whereas behavioral performance depended on the direction of the intensity change within the stimuli (rise or fall).

Understanding of texts with various level of visual complexity among school students with learning difficulties
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We investigated the characteristics of comprehension and recognition of complex visual text and images patterns by high school students with learning difficulties. Stimuli was 8 texts (Russian fairy-tales) and 8 comics (Herluf Bidstrup) with different levels of wavelet blur. Students watched all 8+8 stimuli, high school students watched 3 texts (1, 3 and 5 level of blur) and 2 comics (1 and 3). Stimuli was 8 texts (Russian fairy-tales) and 8 comics (Herluf Bidstrup) with different levels of wavelet blur. Students watched all 8+8 stimuli, high school students watched 3 texts (1, 3 and 5 level of blur) and 2 comics (1 and 3). Methods: • method of content analysis • eye-tracking • mathematical and statistical data processing methods: Scheffe multiple comparisons, the Wilcoxon signed rank test understanding texts and images by group C students as compared to their (group B). The subjects of both groups bring their life experience in the plot while they retell the story. Group C students are more focused on the emotional aspect in the analysis of texts and images, on notions of security events. They show a lower level of cognitive and volitional activity when viewing a high degree of visual stimuli complexity. Group B students are more related to the identification of main characters of the plot and their actions, security concepts are not fundamental in the interpretation of the story the students. Normally developing peers (group A) are focused on the identification of the key figures in terms of the changes happening to them, ie, for their important procedural side event analysis. Understanding texts and images by group C students as compared to their (group B). The subjects of both groups bring their life experience in the plot while
they retell the story. Group C students are more focused on the emotional aspect in the analysis of texts and images, on notions of security events. They show a lower level of cognitive and volitional activity when viewing a high degree of visual stimuli complexity. Group B students are more related to the identification of main characters of the plot and their actions, security concepts are not fundamental in the interpretation of the story the students. Normally developing peers (group A) are focused on the identification of the key figures in terms of the changes happening to them, ie, for their important procedural side event analysis.

Interaction of magno and parvocellular visual systems functioning as marker of brain functional state in extreme conditions
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As a model for studying the nature of the interaction of magno- and parvosystems under extreme conditions of functioning and disadaptation, professional burnout, which is a state of chronic stress, and psychopathology, in particular schizophrenia, was used. Recorded contrast sensitivity in the range of low, medium and high spatial frequencies, to which the neurons of the magno- and parvosystems are sensitive to varying degrees. Persistent sensory disturbances were observed, accompanied by a mismatch in the work of magno- and parvocellular systems in subject with different stages of development of schizophrenia under conditions of antipsychotic therapy and without it (Shoshina, Shelepin, 2016). In this case, the nature of the discrepancy was determined by the stage of development of psychosis. Thus, the importance of the coherent work of the magnetoo- and parvocellular systems, or the mechanisms of global and local information analysis, was shown to provide a mental state corresponding to the norm. Due to the fact that mental disorders are considered as a result of disadaptation, a hypothesis arose about the change in the nature of the interaction of these systems and mechanisms under conditions of chronic stress on the model of professional burnout. Twenty employees of the perinatal center participated in the study. Burnout was assessed using the Proficiency Diagnostics Method of Prof. V.V. Boyko. The contrast sensitivity was measured by the method of visocontrastometry (Shelepin et al., 1985). A different character of the mismatch between the magnetic and parvocellular systems was established at the stage of the formation of burnout symptoms and at the stage of obvious burnout symptoms. This shows the importance of the coherent work of the magno- and parvocellular system for adaptive human behavior. In this connection, one can say that the degree of mismatch in the work of the magno- and parvocellular systems, or mechanisms of global and local analysis, can serve as a marker of the functional state of the neuropsychic processes and adaptation to extreme effects.

Peculiarities of understanding texts by students of the third and ninth grades with different levels of intelligence
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The study was conducted to study patterns of recognition and understanding of text and picture visual stimuli by students of the third and ninth grades with intellectual deficiency. The sample of the study was 120 schoolchildren: 60 3-grade pupils and 60 9-grade pupils. In each age group, 20 pupils of the general education school were examined, and 20 schoolchildren with diagnoses: "mixed specific mental development disorders" (F83) and "mild mental retardation" (F70). As a verbal stimulus was used a small excerpt from the Russian folk tale "The Wolf and the Seven Little Kids," and as a non-verbal stimulus, H.
Bidstrup’s comic was used. The main research method was a survey presented by the author's questionnaire and interviews with questions on a simplified modification of the questionnaire for youngsters. When developing the design of the research, the method of eyetracking was used, which allowed recording the number of fixations, duration of viewing and length of saccades. The ability of schoolchildren to distinguish and generalize the meaning, consistently retell, name the main characters was studied. Cognitive interest was also taken into account. Statistical processing was carried out using regression, dispersion and factor analysis. The presence of patterns of perception and understanding of text and picture visual stimuli by students with intellectual insufficiency has been established, and the specificity of visual information recognition has been revealed. A statistically significant high influence of age on all the studied variables of perception and understanding was found. The level of intelligence significantly affects the parameters of perception.

Software for flexible EEG and MEG neurofeedback experiments design, real-time processing and data analysis
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Neurofeedback is a type of operant conditioning paradigm based on visualizing and learning to control a particular aspect of brain activity, typically measured non-invasively and with fine temporal resolution by means of electro- and magnetoencephalography (EEG, MEG). Our project (NFB Lab) focuses on development of real-time software for EEG/MEG neurofeedback experiments based on classic and novel signal processing algorithms used to denoise the signal and extract the brain activity to be then used for feedback signal generation. The developed software has an interactive module to configure the filter pipeline based on the spatial and temporal filters extracted from the spatial decompositions of the data. There is also a possibility to implement mock feedback condition and perform training of the composite indexes involving combination of measurements derived from different frequency bands and brain areas. The software implements the advanced algorithms and yields minimal latency estimates of the narrow band components' instantaneous power.

Cryptogenic epilepsy. Resting-state functional MRI study
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Purpose. To establish the presence of brain default mode network (DMN) and functional connectivity (FC) changes in patients with cryptogenic epilepsy (CE).

Methods and Materials. All 15 patients with CE (10 men, 5 women) and 15 healthy controls (HC) (10 men, 5 women) underwent MRI (incl. resting state fMRI) on 3,0T field strength MR system. Functional images were acquired using an echo planar imaging sequence (repetition time = 3000 ms, echo time = 30 ms, and flip angle = 90°). 29 slices (field of view = 192 × 192 mm², in-plane matrix = 64 × 64, slice thickness = 4,5 mm, no interslice gap, and voxel size = 3x3x4,5 mm³) aligned along the anterior commissure-posterior commissure line were acquired. In each session, a total of 80 volumes were collected, resulting in a total scan time of 480 s. For each patient, one or two sessions were acquired. Subjects were instructed simply to rest with their eyes closed, not to think of anything in particular, and not to fall asleep. Subsequently, 3D T1-weighted anatomical images were acquired in the sagittal
orientation using a magnetization prepared rapid acquisition gradient-echo sequence (repetition time = 8.06 ms, echo time = 2.98 ms, flip angle = 9°, field of view = 256 × 240 mm², matrix size = 256 × 256, slice thickness = 1.2 mm, no interslice gap, voxel size = 1×1×1.2 mm³, and 160 slices) on each subject. DMNs were analysed using Matlab-based software (SPM12, CONN14). Physical examination, electroencephalography (EEG) was performed for every subject.

Results. None visible structural changes were found by conventional MRI data nor in CE group neither in HCs. We found most significant differences in FC within CE group: decrease of FC in posterior part of the DMN (incl. posterior cingulate cortex, bilateral inferior parietal gyrius), the anterior part of the DMN (incl. primarily superior frontal gyrus and medial frontal gyrus), decrease of FC in hippocampal network. Although we detected correlation of FC impairment with localization of seizure focus (by EEG) in 12 of 15 CE patients (individual analysis), there has been no statistically significant differences between groups (two-sample t-test) except patterns of hippocampal network FC decrease.

Conclusion. Changes in patients’ DMNs reveal reorganization of resting-state brain networks, that probably happens due to epileptiform activity. Further studies are necessary to juxtapose these changes to morphological data for better understanding of the pathophysiology of this disease. Contact: Sokolov Andrei Valeryevich, e-mail: falcon.and@mail.ru, tel. +7-921-799-74-68

Comparison of objects brightness threshold for naked eye adapted to the dark and the eye, equipped EMCCD camera
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Using the technical characteristics of modern serial EMCCD cameras with a cooled matrix and the latest physiology data on the functioning of the eye-adapted eye, the authors show that the adapted vision is not inferior in sensitivity to image amplifiers. The reason for this paradoxical situation is:
- The fundamental advantage of molecular photodetectors used by nature in the organization of vision, in front of semiconductor photoproducers, used by technology.
- Excess of the area of the retina over the area of serial EMCCD matrices by an order of magnitude.
- Perfect signal processing system in retina.
- The quantum nature of light and the narrowing of the range of problems for systems of higher sensitivity.

Foveola and foveolar avascular zone diameter measurement and comparison using enface images of the fundus and line scans obtained with spectral domain optical coherent tomography
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The foveola and especially fovea sizes vary, depending on the method of measurements. Some of the methods are using functional (for ex. psychophysical) approaches to detect fovea and foveola. The other methods are morphological. The least also can vary, generally saying one can use enface image of the eye fundus, while the others are using the profile with all retina layers visible to detect foveola region. In this research we combined all the approaches. In morphological part we used the blood vessels map obtained from enface image of the fundus to define foveolar avascular zone, and profiles of the retina in the macula region, to detect the foveola diameter. We compared those data, and found that foveola diameter correlate with diameter of the foveolar avascular zone. Moreover, measured diameters did not vary strongly from one another. In addition to morphological research we measured contrast sensitivity function and we
Combining utterance-level and frame-level feature representations for emotion classification from speech
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Much attention in the field of emotion recognition was devoted to feature extraction, selection, and representation methods. Experiments were done on extracting features on different levels: fixed-size frame level, variable size phoneme, word, and turn-level, as well as the whole utterance level. All these categories of features possess advantages and disadvantages: the smaller the time segment, the more of a temporal context it is possible to capture within a model, which is crucial for emotion classification task. However, functionals applied to low-level descriptors on the utterance-level also provide important information about speaker’s emotional state. Therefore, it is necessary to combine feature representations on different levels to take advantage of all the information available in the data. This paper proposes a method for combining frame-level LLD feature representation based on RNN-LSTM network and utterance-level functionals applied to LLD sequences with PCA dimensionality reduction.

Decision making about facial expressions in the threshold observation conditions
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The study of mechanisms of facial recognition in threshold observation conditions is the most important problem of cognitive sciences. We used FaceGen software (Singular Inversions, Canada) for the synthesis of model images. In the psychophysical study, the thresholds for recognizing mimic expressions and the turn of individuals, their dependence on the gradation of expression characteristics, the level of additive uncorrelated interference, and the number of modified pixels of the images were established. In a series of fMRI studies, "brain responses" to test images with an expression of mimicry at the subthreshold, threshold and above-threshold levels were studied. Using the local blood flow evaluation method, it was shown that the amplitude of the BOLD-signal under threshold observation conditions is statistically significant (p <0.001), which differs from other experimental conditions. In this case, in the threshold conditions, an increase in the BOLD signal occurs in almost all areas of the brain, which provide recognition, decision-making and the organization of the motor response. Using the fMRI-method, we identified a minimum of information that is necessary for recognizing the facial expression.

Metamaterials for magnetic resonance imaging
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Contemporary magnetic resonance imaging (MRI) employs either volume or surface coils for receiving or transmitting radiofrequency (RF) power required for performing imaging procedures. Metamaterials (i.e., man-made periodic structures with naturally unattainable properties) provide a way of creating new types of RF coils. Particular designs allow metamaterial-inspired coils to have higher signal-to-noise ratio (SNR), higher (or lower, if needed) RF field penetration depth, better field homogeneity over larger
volumes or to be used wirelessly. Metamaterial-based designs can be applied to imaging in low, high and ultra-high magnetic fields, making the designs universally applicable. Here we present a number of designs of metamaterial-based devices for MRI and their applications to phantom, animal and human imaging.

**Innovative developments in the field of rehabilitation of patients with schizophrenia**
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To restore mental and motor functions, a test-training stand was created. The hardware and software complex of the stand is made of modules that can be connected in various combinations, depending on the task. The stimulation module consists of a panoramic 3D-display for demonstrating virtual scenes with given spatial-frequency and time characteristics. The human condition monitoring module includes EEG, ECG, eye tracking system, as well as systems for capturing and describing body movements, facial expression. A proprietary software has been developed that synchronizes the set signals and the entire complex of measured parameters. The training module, which is very important for a neurological clinic [Adar Pelah, iPerception, 3 (4), 2012], is a treadmill, or an exercise bike, depending on the condition of the patient. The system for collecting and describing body movements includes a training module and software that form a statistical model of human movements. In the experiments, patients were presented with virtual environments - a video that simulates a walk or bike tour in different landscapes with different terrain. The patient's task was not only to carefully look at the landscape, but also to focus on its individual objects. The technology is based on the use of interactive video, fully synchronized with the user's movements. The training course provided simultaneous exposure to the visual (stimulated both object and spatial vision), and cardiovascular, and the musculoskeletal system. Experimental studies have shown the effectiveness of this software and hardware system. The complex is intended for rehabilitation of patients with impaired motor activity after stroke, patients with psychoses (schizophrenia) in remission, psychopathies and neuroses. The research was carried out at the expense of a grant from the Russian Science Foundation (project No. 14-15-00918).
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