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in the Context of Neurotechnologies**

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Prepared for publication by

Olga Vakhrameeva

Yuri Shelepin

Konstantin Glasman

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# Proceedings of the Symposium

## Localization of the lagged moving sound in the precedence effect paradigm

Agaeva M. Yu., Petropavlovskaja E. A.

*I. P. Pavlov Institute of Physiology, Russian Academy of Sciences, SPb, Russia*

*e-mail: agamu\_1@mail.ru*

In reverberant environment, humans are able to localize sound source. The auditory system assigns greater weight to the direct sound (lead) than to the later-arriving sound (lag). In this study, sound localization was studied for moving lag in the lead-lag paradigm with stationary lead, compared to the localization of the single moving sound. Lead-lag delays ranged from 1 to 40 ms. Testing was conducted in the free field. The lead was located at azimuth of 15deg (in the right hemisphere). The lag moved from the lead in the left hemisphere (from -52 deg to -86 deg). Subjects were asked to point at the beginning and the end of the lag motion trajectory. Results indicate that at short delays (up to 9 ms) the lead strongly dominates sound localization, suggesting precedence effect. At delays from 9 to 18 ms subjects pointed either to the lead or to the lag. At longer delays all listeners perceived two sounds and pointed only the lag trajectory. The length of the lag motion trajectory decreased relative to the single stimulus, suggesting the masking effect. Perceived starting point shifted toward the left ear depending on the delay, which means that masking mainly affected the initial part of the trajectory.

### Introduction

When sound is produced in a room, it propagates in multiple directions and then it is reflected from all surfaces in the room. Usually, the sound coming from the source will reach the listener before any reflection because the reflection travels a greater distance. The perceived direction to the sound source is usually determined by the first arriving wave front. This phenomenon is known as the “law of the first wave front” or the “precedence effect”. Consequently, humans are able to localize sound sources in reverberant environment. The auditory system assigns greater weight to the direct sound (lead) than to the later-arriving sound (lag) [1].

David (1959) assumed that forward masking is involved in precedence effect [2]. To date, the interaction of these mechanisms is still unclear. The main focus of the present study is the question to what extent masking is included in precedence effect.

### Methods

Experiments were carried out with 11 subjects in the anechoic chamber using 49 loudspeakers situated over the arc. The subject was seated in the center of the arc which was placed in the

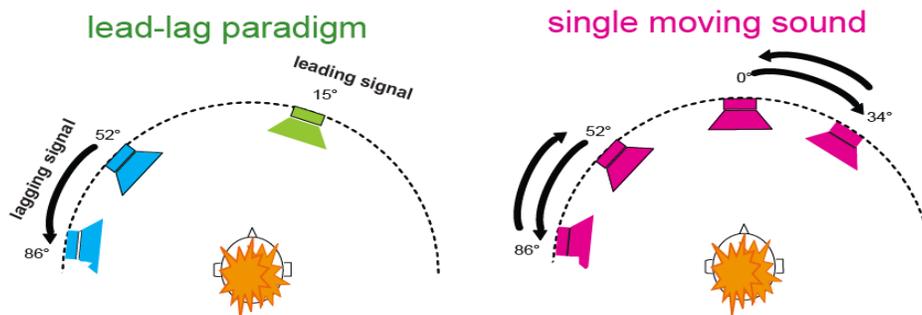


Fig. 1. Schematic listener's head relative to the loudspeaker array for two sound conditions.

horizontal plane at the level of the subject's ears (Fig. 1). The stationary leading signal was presented from one loudspeaker located at azimuth of 15 deg in the right hemisphere, and 10 loudspeakers were employed to deliver the lagging signal moving leftward from -52 deg to -86 deg in the left hemisphere. The sound motion was created by successive switching of the loudspeakers.

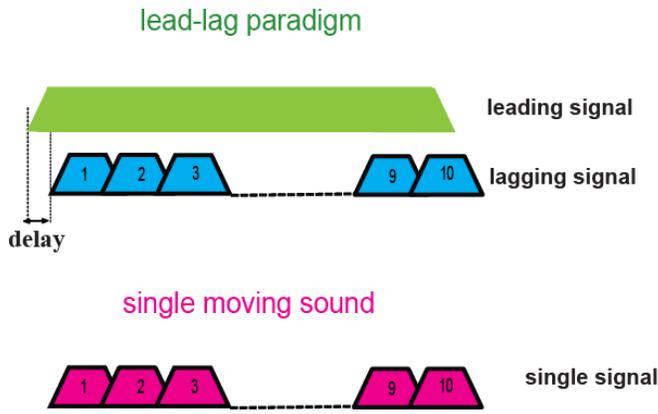


Fig. 2. Schematic representation of the stimuli for two conditions.

All stimuli consisted of two signals (lead and lag) with the same spectral characteristics. The duration of the lead and the lag was 1 s (Fig. 2). The leading signal was 1 s noise burst presented from one loudspeaker. The lagging signal consisted of a train of 10 broadband noise bursts with 96 ms onset-to-onset interval. Duration of each burst was 100 ms. This stimulation evoked a sensation of continuously moving sound image. Stimuli with nine lead-lag onset delays ranged from 1ms to 40 ms were delivered in pseudorandom order.

Subjects were asked to indicate the perceived location of the moving target at his/her left (i.e. to point at the beginning and the end of the lag) on the graphic tablet (Genious G-pen 450).

### Results and Discussion

The results showed a strong effect of the delay for all 11 listeners. Regardless of the instructions, at short delays all listeners perceived one sound located near the lead (“lead response”) (Fig. 3). It implies that the lead strongly suppressed the localization of the lag. As the delay increased, the subjects pointed either to the lead or to the lag for the same pair of signals. At the longest delays two distinct sounds were perceived, and all subjects pointed only to the lag (“lag response”).

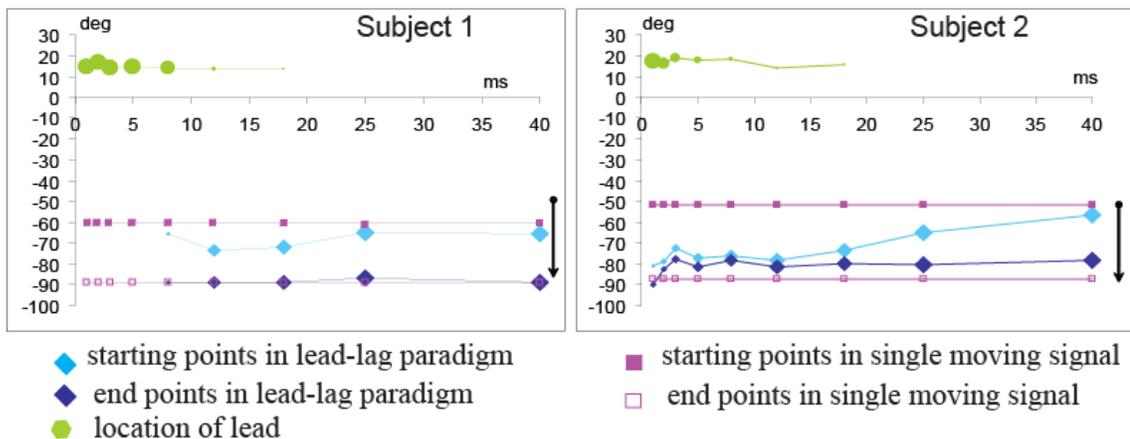


Fig. 3. Responses for the two conditions (lead-lag paradigm and single moving signal) are shown for two subjects as a function of condition/delay. The size of the symbols in the lead-lag paradigm reflects the percentage of “lead” and “lag” responses. Objective trajectory of the lag (and single moving signal) is shown by black arrows.

The length of the lag trajectory decreased relative to the trajectory of the same stimulus presented separately (without lead). Perceived starting points of the lag in the lead-lag paradigm were shifted from the lead toward the left ear (in the motion direction) in comparison with perceived starting points of the single moving signal. The displacement of the perceived end points was less pronounced.

To compare the positions of the starting and end points of the perceived trajectory between the two conditions, the differences between conditions were computed as the angular position of the starting points in the lead-lag paradigm minus the corresponding value for the single moving sound (Fig. 4). The same differences were obtained for the end points.

Displacements of the starting points were similar for all subjects and depended on the delay. This

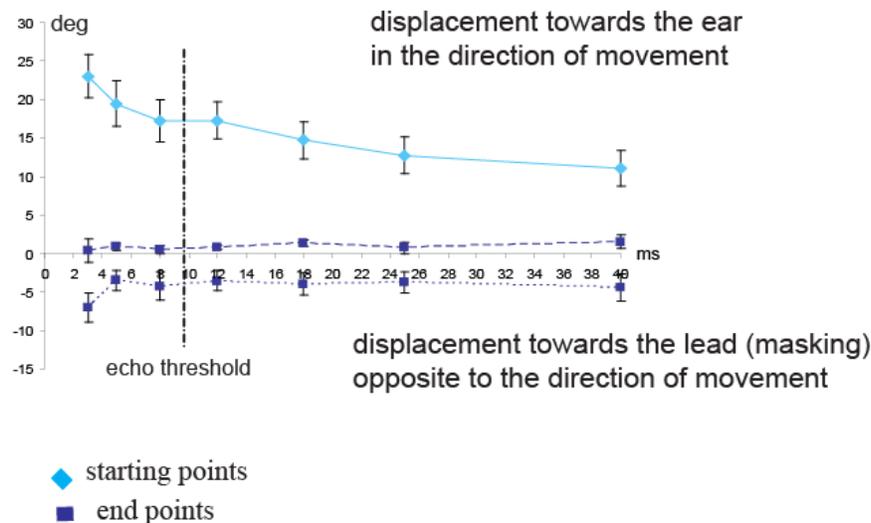


Fig. 4. Displacement of the starting and end points of the perceived lag trajectory as a function of the delay. Dotted and dashed lines correspond to different groups of subjects.

pattern of changes is similar to observed in forward masking studies.

As for the displacements of the end points, the subjects could be divided in two groups. In the first group the end points displaced towards the ear (in the direction of movement). In the second group the end points displaced towards the lead (opposite to the direction of movement).

## Conclusion

The results obtained may reflect the interaction of two phenomena. The precedence effect operates at short delays while at larger delays masking mechanisms begin to come out.

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# Precedence effect for moving sounds in the horizontal plane

Agaeva M. Yu., Petropavlovskaja E. A.

*I.P. Pavlov Institute of Physiology, Russian Academy of Sciences, Saint - Petersburg, Russia*  
e-mail: agamu\_1@mail.ru

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 two moving signals. The first signal was the direct signal (lead) and the other was the delayed (lag). Sound source movement was created by successive switching of 10 loudspeakers. The path length of the lead and lag movement was  $34^{\circ}$ . The lead moved leftward in the right hemisphere (from  $34^{\circ}$  to  $0^{\circ}$ ) and the lag moved leftward in the left hemisphere (from  $-52^{\circ}$  to  $-86^{\circ}$ ). The duration of the lead and the lag was 1s. Lead-lag delays ranged from 1 to 40 ms (onset-to-onset interval). The listeners indicated the location of the beginning and the end of the lag. The results suggest that at short delays (up to 18 ms), the lead strongly dominates the localization of the lag signal. All listeners indicated that they perceived one location near the lead, regardless of instructions. At the longest delays two distinct sounds were perceived. The average value of the echo thresholds in eight subjects was 9.6 ms.

## Introduction

When a sound is produced in a room, it propagates in multiple directions and then is reflected from all surfaces in the room. In most cases, the sound coming from the source will reach the listener before any reflection because the reflection travels a greater distance. The perceived direction to the sound source is usually determined by the first arriving wave front. This phenomenon is known as the “law of the first wave front” or the “precedence effect” [1, 2].

To simplify the natural situation, most experiments on the precedence effect have been conducted with two stationary sound sources. The precedence effect is often tested in an anechoic room using two loudspeakers: one loudspeaker produces the original or leading sound (lead), and the other produces the reflection or lagging sound (lag) [2, 3]. Precedence effect for the moving sound source has not been studied yet, although this situation occurs fairly often in the natural environment. In the present study the precedence effect was explored using two moving signals.

## Methods

Experiments were carried out with 8 subjects in an anechoic room using 49 loudspeakers situated over the arc. The subject was seated in the center of the arc, which was placed in the horizontal plane on the level of the subject’s ears (Fig. 1).

The motion of signals was created by successive switching of the loudspeakers. 10 loudspeakers were employed to create the leading signal that moved leftward in the right hemisphere from  $34^{\circ}$  deg to  $0^{\circ}$  deg, and another 10 loudspeakers were employed to create the lagging signal moving leftward from  $-52^{\circ}$  deg to  $-86^{\circ}$  deg in the left hemisphere.

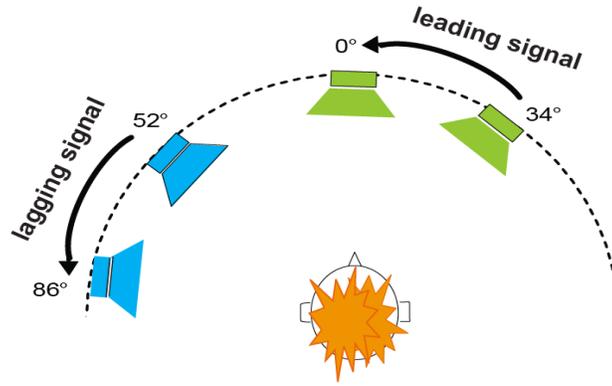


Fig. 1. Schematic listener's head relative to the loudspeaker array.

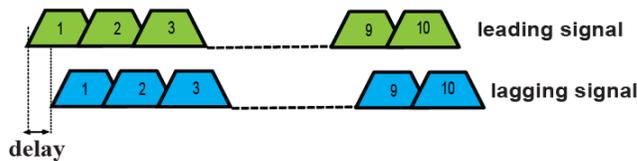


Fig.2. Stimulus timing for the leading and lagging signals.

All stimuli consisted of two signals (lead and lag). Each signal was composed of 10 broadband noise bursts of 100 ms duration with 96 ms onset-onset interval (Fig.2). This stimulation evoked a feeling of continuous moving sound image. The duration of the lead and the lag was 1s. The echo delay for all ten

pairs of bursts was fixed within the stimulus pairs. Nine echo delays ranging from 1ms to 40 ms were used in different stimuli in pseudorandom order.

Subjects were asked to indicate the perceived location of the moving target at his/her left (i.e. to point at the beginning and the end of the lag) by means of data tablet (Genious G-pen 450).

## Results

The results show a strong effect of the delay for all 8 listeners. At short delays, regardless of the instructions, all listeners indicated that they perceived only one sound located near the lead. Thus,

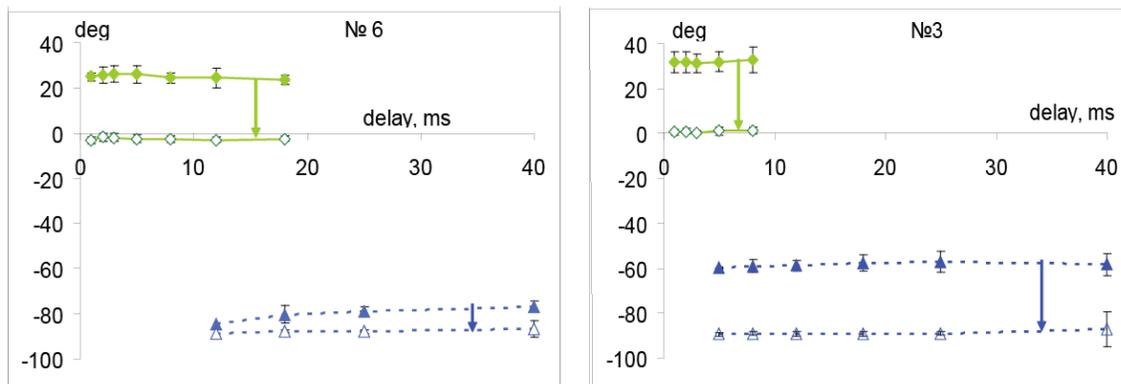


Fig.3. Lead (green diamonds) and lag (blue triangles) localization in two subjects.

at short delays the lead strongly dominated the localization of the lag. As the delay increased, subjects pointed either to the lead or to the lag for the same stimulus. At the longest delays two distinct sounds were perceived, and all subjects pointed only to the lag (Fig. 3).

The results suggest that at short delays (up to 9 ms) the lead strongly dominates sound localization. The precedence effect for moving signals is observed in the range of delays from 4 ms to 18 ms (Fig. 4). The average value of the echo suppression thresholds in eight subjects was about 10 ms (Fig. 5). According to the literature, the corresponding ranges of delay for stationary signals were similar [3, 4].

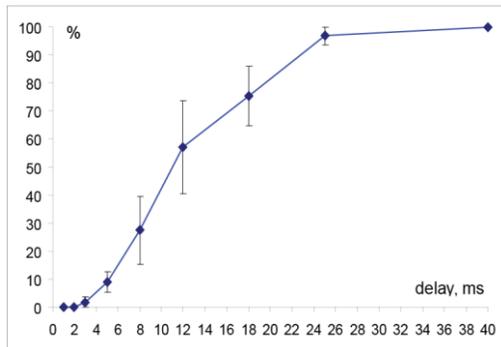


Fig.4. The percentage of trials in which the listeners pointed to the lagging signal plotted as a function of delay.

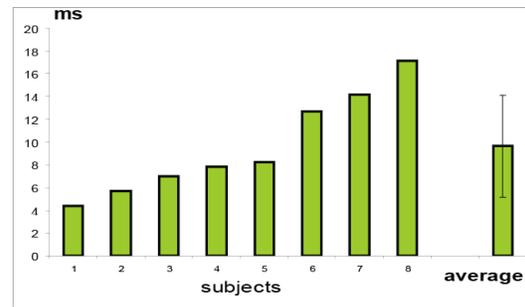


Fig.5. Echo thresholds for two moving signals.

Perceived starting and end points of the lead at delay 2 ms didn't differ significantly from the starting and end points of a single moving stimulus (see M. Yu. Agaeva, E.A. Petropavlovskaja, Localization of the lagged moving sound in the precedence effect paradigm, in this issue).

## Conclusion

Similarity of the temporal characteristics obtained for stationary and moving signals suggest that precedence effect for both categories of sound stimuli is mediated by common underlying mechanisms.

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# Signal Processing in MRI: new challenges with ultra-high field 7T scanners

Costagli M.

*IRCCS Stella Maris and IMAGO7 Foundation, Pisa, Italy*  
*email: me@maurocostagli.info*

This contribution presents a brief overview of post-processing techniques in brain Magnetic Resonance Imaging, specifically tailored for Ultra-High Field systems, in order to improve data quality and extracting meaningful information.

Magnetic Resonance Imaging (MRI) is one of the most widely used techniques in medical diagnosis and research. Different MRI pulse sequences produce images with different contrasts, and offer a wealth of information that is either readily available for visual inspection, or it has to be extracted with post-processing and dedicated analysis routines.

With respect to MRI systems operating at standard magnetic fields ( $\leq 3\text{T}$ ), the new scanners operating at ultra-high fields (UHF,  $\geq 7\text{T}$ ) enable improved signal-to-noise ratio that can be spent in increasing the spatial resolution, as well as new types of image contrasts. In particular, UHF MRI is exquisitely sensitive to the subtle variations in magnetic field caused by differences in magnetic susceptibility of tissues, enabling excellent contrast to noise ratio in both anatomical and functional imaging. However, as a consequence of the Larmor equation  $\omega = \gamma B$  (where  $\omega$  is the precession frequency,  $\gamma$  is the gyromagnetic ratio of the nucleus under investigation – most commonly, hydrogen – and  $B$  is the static magnetic field), the excitation pulses used at UHF have higher frequency, hence shorter wavelength, than in conventional MR system; it follows that, while on standard MR systems the transmitted radiofrequency field can be assumed to be homogeneous within the sample under examination, at UHF the transmitted electromagnetic field might present significant inhomogeneities in the region of interest. This scenario has two principal undesired consequences: on the one hand, the unevenly distributed radiofrequency causes spatial inhomogeneities in the MR images. On the other hand, local maxima in the transmitted electric field violate the assumptions of spatial homogeneity used in the automated routines for evaluating the specific absorption rate (SAR), therefore unmonitored increments in the local temperature of the patient's body constitute a major safety concern. This overview aims to highlighting some of the techniques for improving image quality at UHF, while the problem concerning SAR is beyond the scope of this contribution (however, for examples of current studies on this topic, see the recent studies of Tiberi and colleagues [1, 2]).

Image uniformity is of particular importance in diagnostic imaging evaluation, which is based on the qualitative comparison between the relative intensity of tissues. Intensity homogeneity is also important for the automated post-processing chain, which includes data co-registration, image segmentation, and quantification of tissue physical properties. Image intensity correction techniques can be applied *a posteriori* without additional information [3, 4] or by using additional acquisitions [5]. When possible, imaging techniques that are less prone to intensity inhomogeneities should be preferred [6, 7]. Other acquisition strategies provide non-conventional image contrasts to circumvent the problem of spatial inhomogeneities, such as the Tissue Border Enhancement technique [8], which requires further analysis methods to automatically extract the features of interest [9].

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## Stereovision

Krasilnikov N. N., Doctor of Sciences, Invited

*St.Petersburg State University of Aerospace Instrumentation, Russia*

Already in the 3rd century BC by Euclid, it was noted that the perception of spatial depth and relief of the depicted objects is achieved due to the fact that each eye sees a slightly different images of the same object, because it sees it from two different points of space. Further stereovision was researched by Leonardo da Vinci, Johannes Kepler and other scientists. In 1837 Charles Wheatstone demonstrated the device for viewing stereoscopic images. The first 3D film was a short film "Arrival of a Train at La Ciotat," shot by the Lumiere brothers in 1896. Thus 1896 can be considered the year of birth of stereoscopic cinematography.

In the next hundred years the methods of creation and especially the demonstration of stereoscopic films were developed and improved, first for cinema and then for television. However, until recently, is the unsolved problem of guaranteed comfortable observation of stereoscopic films and television programs.

Since 2010 the development of digital technology has ensured sustainable development for 3D movie and 3D TV, based on the use of stereoscopic effect. We can assume that by this time methods and technologies to receive and display the 3D content mainly developed. It was found that for a number of viewers with normal binocular vision when viewing 3D movies and 3D television, there is a feeling of discomfort, eye fatigue, dizziness, and even headaches.

Studies of 3D content has shown that this occurs when using an overly large screen parallaxes, resorted to by the content creators for the sake of giving the scenes more depth. The question arises - why the observation of stereoscopic images with a large depth causes discomfort, and the observation of real scenes with the same depth of such feelings does not matter?

Carried out research and experiments showed that when observing stereoscopic images:

- the mutual fixation of the optical axes of the eyes is implemented more difficult;

- a conflict situation arises when we focus our eyes between the images of the object on the screen and the virtual object;
- in order to avoid double vision it is necessary to experimentally determine the critical angle for the correction  $a_{cr}$  and not exceed it.

We have obtained the dependence of the critical angle of correction  $a_{cr}$  on the distance to the screen  $d_{sc}$ , shown in Fig.1.

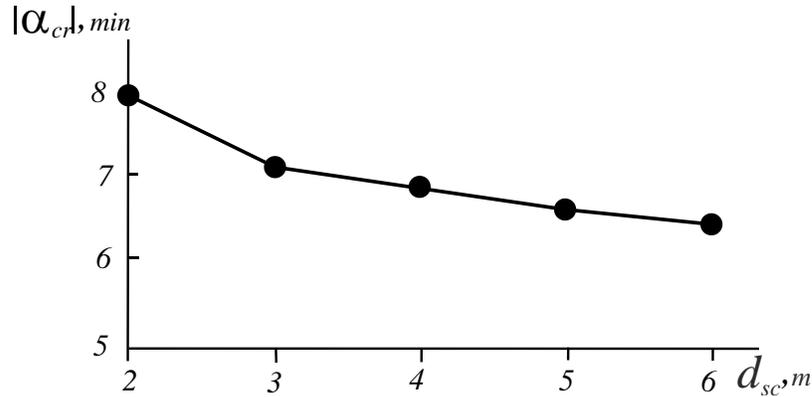


Fig.1. Dependence of the critical angle of correction  $a_{cr}$  on the distance to the screen  $d_{sc}$

In practice the value for the angle of the correction  $a_{cr}$ , under which when observing the real scene image no discomfort occurs, can be assumed equal to 17 angular minutes.

Also, it was found that with increasing distance from the viewer to the screen interval depth, in which stereoscopic images are perceived without any ghosting or discomfort, increases dramatically. So the scene need to be shooting so that all objects constituting the scene, would have been placed inside this interval.

When the distance to the screen equals to 8m depth interval without discomfort and ghosting equals to 15 meters, so for 3D movies there is no problem.

When observing “3D” television programs distance from the viewer to the screen is small, so the depth interval in limits of which the image is perceived without discomfort and any ghosting is too small. When viewing images on small screens there is an effect of puppet theatre.

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# Eye movements during recognition of facial expression of contradictory photo portraits

Luniakova E.<sup>1</sup>, Ganizada J.<sup>2</sup>

<sup>1</sup> Faculty of Psychology, Lomonosov Moscow State University, Moscow, Russia

<sup>2</sup> Faculty of Psychology, Baku branch of Lomonosov Moscow State University, Baku, Azerbaijan  
email: eluniakova@gmail.com

Recognition of facial expressions of normal and composite contradictory photo portraits and eye-movement pattern during facial processing were studied.

## Introduction

The problem of perception of facial expressions has a long history. Charles Darwin was the first who suggested the universality of coding and decoding mechanisms of emotions in different cultures. Paul Ekman and Carrol Izard proved experimentally this hypothesis and revealed so called basic emotions, which had a universal facial expressions [1, 2].

Different regions of a face are more or less informative for recognition of basic facial expression. It was shown that anger, fear, and sadness were more readily recognized from the top half of the face, whereas happiness and disgust were more recognizable from the bottom half [3]. The results of some eye-tracking studies are in good agreement with those data [4].

At the same time it is well known that looking at human face a person mostly look on the eyes region. Does eyes region particularly informative for decoding of basic emotions? If it is so the artificial modification of the eye region (namely replacing it by the eye region from the photo portrait with another expression) would cause changes in accuracy of expression recognition and in eye-movements pattern in comparison with perception of non-modified images.

## The preliminary study

**Stimuli.** Three sets of images were used in experiment: one set of colored photo portraits and two sets of composite contradictory photo portraits (fig. 1).

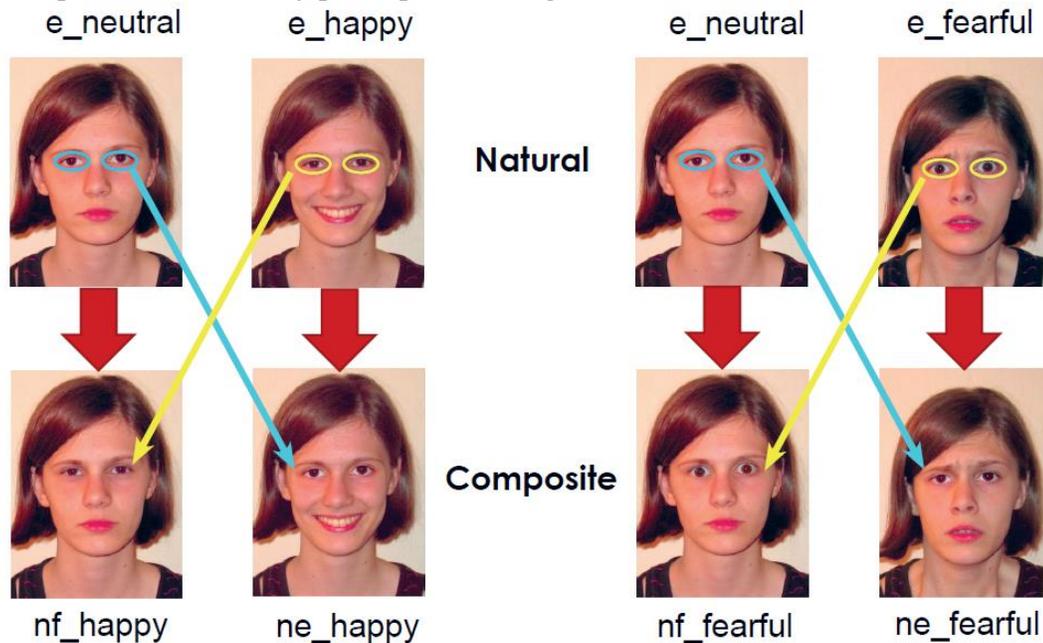


Fig. 1. The example of stimulus creation

Composite images were made by the following way. Two photo portraits of the same person – one posing neutrality and the other displaying one of basic emotional expressions – were combined to construct a composite photo. Eye region from one photo was pasted in the same place of the other photo.

Stimulus set of type «e» (emotion) consisted of 24 photographs of 4 models (2 m, 2 f), each posing 6 basic facial expressions: anger, disgust, fear, happiness, sadness, and neutral expression.

Stimulus set of type «ne» (neutral eyes) consisted of 20 composite photo portraits. Every image was a combination of neutral eye region and emotional face of the same poser.

Stimulus set of type «nf» (neutral face) consisted of 20 composite photos portraits. Every image was a combination of emotional eye region and neutral face of the poser.

**Procedure.** A set of 16 photos – natural and composite – of one male model was presented to 24 subjects. Each photo was demonstrated for 2 sec. A participant was to name an emotion displaying by the poser on the image.

77 words describing facial expressions were used by all the participants. Synonyms were combined and rare categories were excluded. A set of 14 words describing facial expressions was obtained for the main study: apathy, concentration, anger, neutral expression, hatred, resentment, disgust, sadness, contempt, happiness, distrust, fear, shame, surprise.

### The main study

52 participants (24 male, 28 female, mean age = 22) with normal or corrected to normal vision took part in the main experiment.

**Stimuli.** Three sets of stimuli described in the previous text section were used.

**Procedure.** 64 natural and composite photos were randomly presented to every participant. The duration of presentation of a photo was not limited. A participant was to recognize the facial expression as quickly as possible and click a spacebar. Then he was to choose an answer from the 14 alternative categories obtained in the preliminary study.

A 9-point calibration procedure preceded an experiment.

Stimuli were displayed on a 21,5 inch LCD monitor, with a spatial resolution of 1680x1050 pixels. Eye movements were recorded monocularly with an SMI iViewX™ RED500 at a sampling rate of 250 Hz.



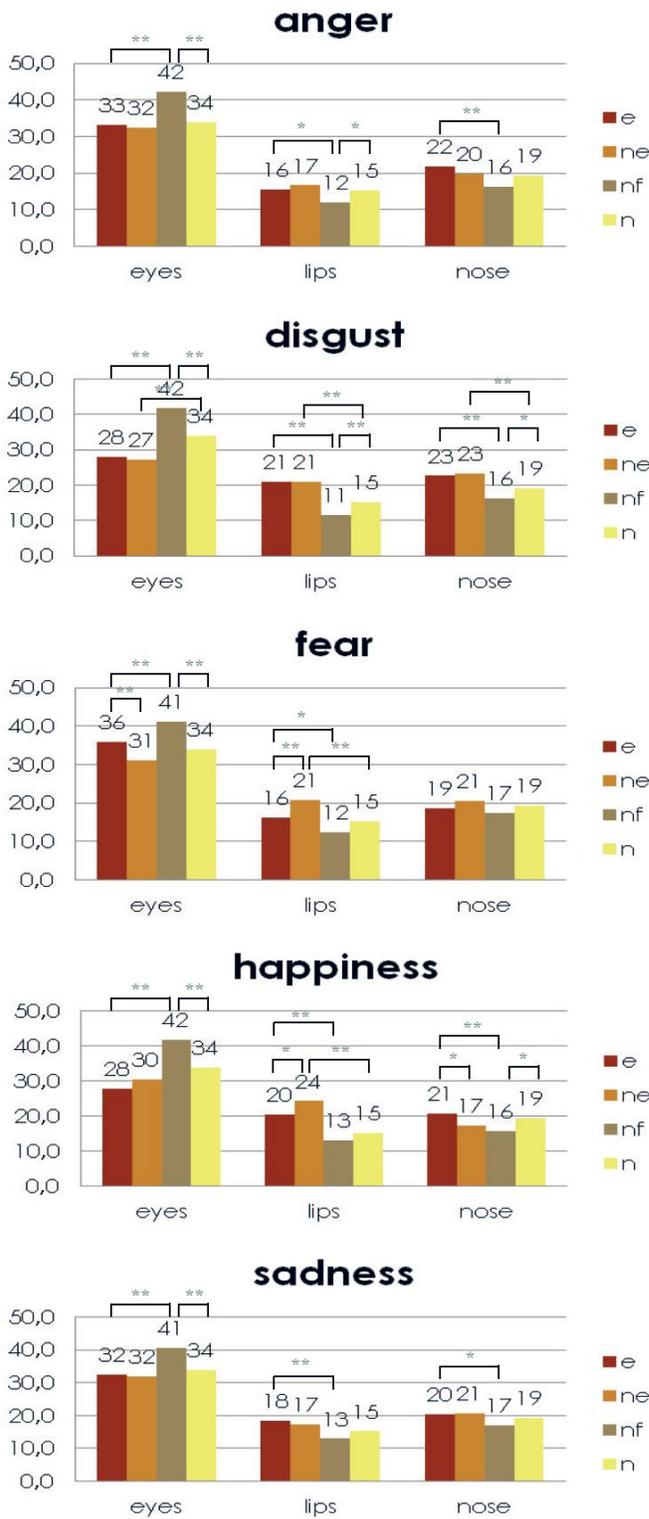
Fig. 2. Areas of Interests

### Results

**Facial expression recognition.** All natural (type «e») expressions were simply recognized. The best recognized expressions were happiness (91%), neutral expression (70%), disgust (76%) and fear (65%).

Replacing of the eye region on emotional photos by neutral eyes (type «ne») had a slight effect on emotion recognition except fear expression (fig. 2). The accuracy of expression recognition decreased non-significantly for most basic emotions except fear.

Facial expressions on images “nf” were described as “concentration”, “contempt”, “distrust”, rarely as “neutral expression”, and never as the same basic emotions which were posed on the prototype photo portraits. So, the configuration of eye region itself was not enough for accurate expression recognition.



n - neutral expression  
 \* - p < 0,05; \*\* - p < 0,01

Fig. 3. AOIs Dwell Time, %

**Eye-tracking data.** Four Areas of Interests (AOIs) have been allocated on each photo portrait for eye movements analysis: nose, lips, eyes, brows&forehead (fig. 3).

Dwell time on eye region significantly increased for all composite photos with emotional eyes on the neutral face (“nf”) comparing with natural facial expressions (“e”). There were no significant differences in dwell time on eye region between images “ne” and “e” except neutral expression. Noninformative eyes on emotional face attracted less attention than the same eyes on the neutral face.

Dwell time on other areas significantly increased for fear and happiness “ne” images (lips area) and decreased for anger, disgust, happiness and sadness “nf” images (lips and nose areas) comparing with natural facial expressions (fig. 3).

**Fixation distributions for the first three fixations on emotional face image.** It is known that facial expression recognition is very quick process. 2-3 fixations are enough to decode a basic emotion.

The distribution for the first three fixations over different parts of faces was analyzed. The results showed that the distribution for the first fixation was universal for all images. Fixations were distributed between different parts of the face by unique way with the gaze hit mainly on nose or eyes independently of types of stimuli. There were significant difference (p < 0,05) between “ne” and “nf” stimuli in fixation distributions for the second and third fixations. The gaze mainly fall on the most informative areas - on eyes area in “nf” stimuli and on lips area in “ne” stimuli.

### Conclusions

Specific expression of eye region is indispensable only for decoding of fear emotion. But eyes configuration is not crucial for the recognition of other basic emotions.

Modification of eye region on the non-expressive (neutral) face leads to recognition of some secondary emotions such as “concentration”, “contempt”, “distrust” etc. So, variations in eyes configuration change the neutral expression of the face as a whole.

Eye-movements pattern is not universal and seems to be driven by the properties of the emotional face. The feature processing starts with first fixation and effects the direction of the following saccade. So, the second and the third fixations distributions over different facial features and dwell time in the main informative areas differ for natural and contradictory stimulus.

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## Modeling Convolutional neural networks for text detection task

Malakhova E., Shelepin Yu.

*I. P. Pavlov Institute of Physiology, Russian Academy of Sciences, SPb, Russia*

*email: katerina.malahova@gmail.com*

Reading is an essential part of everyday life. Humans use textual information to identify objects, communicate, make decisions, and navigate. Although majority of texts processed by traditional text recognition techniques are represented as scanned or electronic documents, people do encounter texts in natural environment, where the task is more challenging, due to variation of forms, lighting, distortions and complex backgrounds. Here we propose an approach for differentiating between text and non-text images and for text-heavy region detection. We implement a Convolutional Neural Network, which generates a saliency map based on probability of observing text in an image region. The candidate regions can be extracted in order to perform additional text recognition task. We evaluate the proposed model on a dataset of natural images in a variety of scenarios.

## Introduction

Experiments in recent psychophysiological studies often include natural images as experimental stimuli. While measuring and analyzing subject's reaction to the presented stimuli it is important to pay attention to properties of natural images. Textual content in natural scenes can provide essential information about the environment and change subject's behavior. Therefore a posteriori or a priori analysis of stimuli in order to detect text regions can be useful for research purposes.

Previously most popular approaches for text detection were methods applying low-level feature processing, such as Stroke Width Transform [2] or traditional OCR methods. However, quality of text imprinted in natural images significantly differs from scanned documents. Pictures taken with the camera are more diverse, due to the variations in camera quality, scene type, illumination, text language, and layout, etc.

In this work, we apply Convolutional Neural Networks (CNNs) for the text detection task. In contrast to traditional methods of text recognition, CNNs perform higher level feature processing. CNNs allow achieving impressive results in classification task with an error rate less than 7.5% [4]. Moreover, artificial networks, showing representational similarity to the visual cortex, can predict individual IT multi-unit responses [1].

## Implementation and results

Here we use textDis dataset [3] of 15302 images, collected from the Internet. The dataset contains mostly natural images, with a small number of born-digital images and scanned document images. The dataset is challenging, because of variations in shot quality, distortions, presence of highly styled text, different text layouts, and complex backgrounds. The training set contains 5302 text images and 6000 non-text images. For text images, vertices of a bounding polygon are provided. We converted the coordinates to produce ground-truth image masks, where label “1” corresponds to a pixel inside a text area, and label “0” to a pixel outside. The dataset was split into training and test set with a 0.8/0.2 ratio.

All images were resized to 227\*227 px size and normalized by subtracting mean value from each RGB color channel. All layers except last two were initialized with pre-trained weights from FCN-32s-PASCAL, 32-pixel prediction stride net, based on VGG-16 architecture and trained for semantic segmentation task [5]. We replaced the weights of the last two layers with small random values. The neural network was trained 5000 iterations. During training process loss significantly reduced during first 500 iterations, and was slowly decreasing until the end of training (Fig. 1).

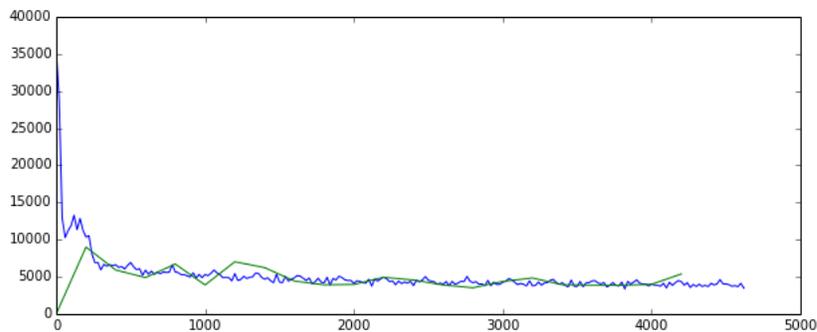


Fig. 1. Training (blue line) and test (green line) loss during the training process.

To perform segmentation we use weights of the model 4000 iteration state. The Fig. 2 presents a result of text detection on the image from the test set. It can be seen that neural network detects regions with text information. Results can be more precise with further training and fine-tuning of strides as was suggested in [5].

## Discussion

Text in natural scenes has a high variety of fonts, background, and lightening. To improve text detection performance the scene context should be taken into account. CNN allows to process low-level features and high-level context and perform semantic segmentation. In order to improve segmentation, training dataset should contain images with precise regions and reduced background presence within these regions. Also, the bigger dataset the better is coverage of the variety of natural scenes.

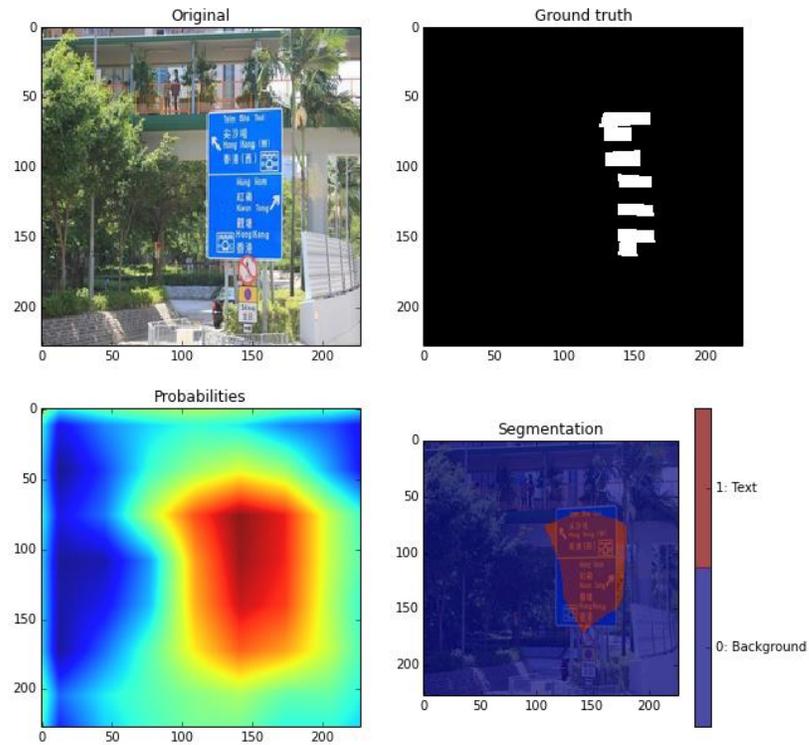


Fig. 2. Probability map of text presence on the image. Red color indicates regions with high probability of text, blue and green colors indicate low probability. Upper left corner - original image; upper right - ground truth labels; bottom left corner - probability map, bottom right - final semantic segmentation mask overlays original image.

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# Training Deep Neural Network for accurate age and gender recognition on small set of data

Malashin R. O.<sup>1,2</sup>, Anisimov N. A.<sup>1</sup>

<sup>1</sup> *Chair of Computer Photonics and Digital Video Processing, ITMO University, Spb, Russia*

<sup>2</sup> *Image Processing Department, Vavilov State Optical Institute, Spb, Russia*

*email: malashinroman@mail.ru*

Recent works have shown that deep convolutional neural networks (DCNN) trained on large datasets provide state-of-the-art solution for automatic age and gender recognition by means of image analysis. In this work we fine-tuned DCNN learned on ImageNet dataset and have achieved good accuracy using only 2400 training images. We have studied several aspects of weights transferring, including neural network architectures, number of fine-tuned layers and usage of non-linear activation functions in fine-tuned layers.

## Introduction

Deep convolutional neural networks (DCNN) provide state-of-the-art results in many image analysis tasks, such as image recognition and detection, image deblurring, image labeling and others. Despite unarguable success of modern DCNNs in general they have two major drawbacks: poor generalization abilities for primitive image transformations [1] and need of lots of training data for stable results [2]. To use DCNN when there is few images for training "transferring" is usually applied: neuron weights "pretrained" on large dataset (ImageNet [3] as usual) are fine-tuned on small target dataset. The transfer technique has provided state of the art results in recognition of plants [4], Chinese characters [5] and car models [6]. Though ImageNet's content is very broad still there is a question about generalization abilities of high-level features formed inside the network, because effectiveness of feature transfer declines as the base and target datasets become less similar [7]. In the paper we consider the task of age and gender recognition. The results should be of interest to researchers because ImageNet doesn't have labels that relate to faces, though humans are often a "background" relatively to the target classes. Moreover, recognizing age of a person requires good image resolution (otherwise important details such as wrinkles are not available) and therefore large network. That justifies weights transferring for the task.

## Dataset and base neural network

We collected and manually labeled 3000 images of faces for six classes: 2 categories for gender (man and woman), and 3 categories for age: young, middle aged, old. We used 80% of images for fine-tuning and 20% for validation. Though the dataset has only 6 classes we made sure that it contains enough examples, that are rather challenging even for a human. There are broader dataset for age and gender recognition available in the internet [8] but we wanted to obtain a difficult task on a small dataset. In experiments we mainly used well-known "AlexNet" neural network [8] that gave the best result on ImageNet in 2012. It has five convolutional and 3 fully connected layers. First layer kernels looks much alike Gabor filters and color blobs detectors, layer 2 responds to corners and other edge/color conjunctions [9] (therefore the first two layers can be "frozen" during fine-tuning without loss in accuracy [7]). Third and following layers are object specific. It's interesting that despite the fact that there are no labels for faces in ImageNet there are neurons that are responsible for face detection [9]. So one of interests in our work was to investigate how high-level features will work for face analysis.

## Experiments

It was shown in [4] that transferring  $n$  first layers weights gives better results than transferring  $n-1$  layers and this holds up-to  $n=7$  [4]. In other words fine-tuning as many layers as possible is preferable. We have observed the same behavior for our dataset. It may look that 8-th layer provides only discrimination rule upon features formed deeper and therefore it is useless for fine-tuning, but according to our experiments  $n=8$  is advantageous to  $n=7$  by a measurable amount. To use weights of the 8-th layer we have removed softmax from the top of the network, added nonlinearity and have added 9-th extra fully connected layer. Figure 1 compares the proposed way of fine-tuning with one recommended in [7]. We used 6000 iterations of backpropagation algorithm with 100 images in one batch (200 epochs). Learning rate was decreased by a factor of 10 every 2000 iterations. We also increased learning rate of the newly initialized weights by a factor of 10. Caffe library [10] was used for our experiments.

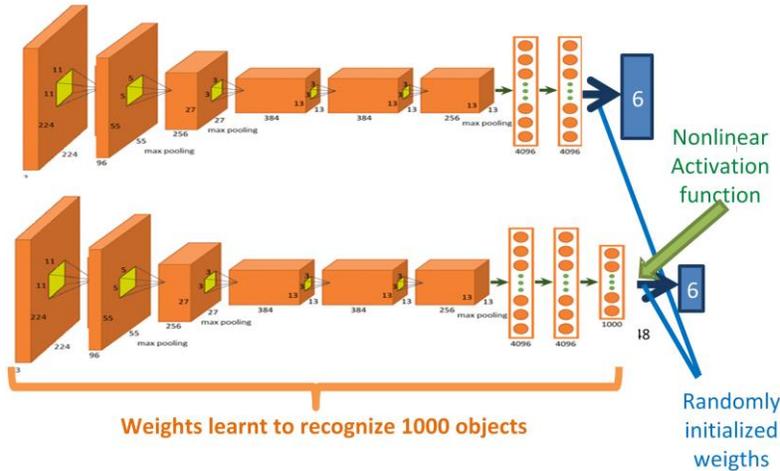


Fig 1. Fine tuning AlexNet for age and gender recognition. Top – fine tuning 7 layers as recommended in [4], bottom – fine tuning 8 layers proposed in the paper.

As was expected modern activation functions significantly outperformed tahn and sigmoid which are known to saturate. Recently introduced PReLU [11] performed slightly better than BNLL [10] and RELU though the difference is negligible. In the case of PReLU output is calculated as:

$$f(y_i) = \begin{cases} y_i, & \text{if } y > 0 \\ \alpha_i y_i, & \text{if } y \leq 0 \end{cases}$$

where  $y_i$  is the output of the nonlinear activation  $f$  on the  $i$ -th channel, and  $\alpha_i$  is a coefficient controlling the slope of the negative part that is learned as a free parameter during back propagation. The results are summarized in Table 1 (for ease of interpretation results are ordered according to accuracy in descending order). To minimize influence of random weight initialization we averaged the results over 5 launches in every experiment.

Table 1. Accuracy on validation set for different fine-tuning schemes

Number of fine-tuned layers	Activation function before extra layer	Accuracy on validation set
8	PReLU	0,74
8	BNLL	0,737
8	ReLU	0,735
8	Linear	0,729
7	-	0,725
8	Tahn	0,710
8	Sigmoid	0,705

Figure 2a shows dependency of accuracy on validation set vs number of training images per class. Interestingly the dependency in logarithmic scale has a near linear shape (figure 2b). That might be useful rule of thumb for evaluating approximate number of data needed to improve accuracy by a known value. For example if there is 20% accuracy with 10 images, 25% with 100 images, then probably you need around 1000 images to get 30%.

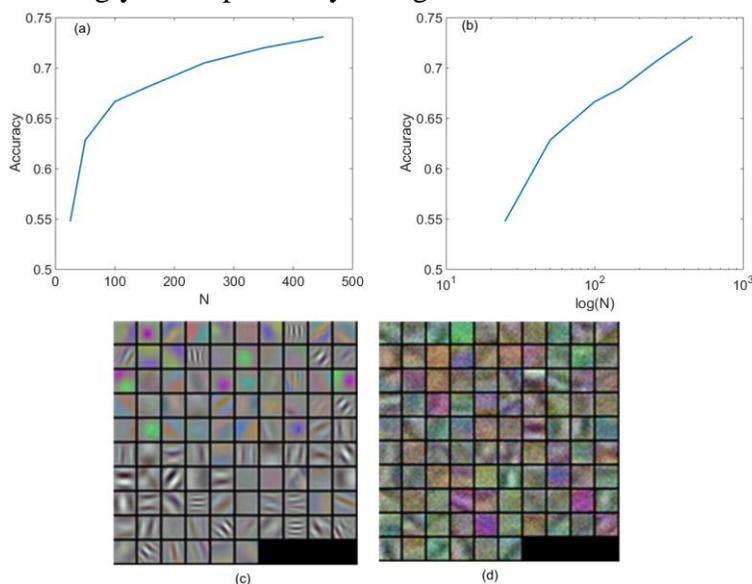


Fig 2. (a) – accuracy on validation set vs number of training images per class used for fine-tuning in linear scale, (b) – accuracy vs number of training images per class in logarithmic scale, (c) – first layer filters for fine-tuned network, (d) – first layer filters for learned from scratch network.

such small set of data. We consider the result to be practically useful because fine-tuned and learned networks form different features (figure 2c and figure 2d) and therefore should produce uncorrelated results. Two models can be combined to give better accuracy. We are going to investigate this impact in our future works.

### Experiments with different models

We have reproduced the experiments and observed the same behavior described above with more complex architecture of GoogleNet [12]. In average GoogLenet provided slightly better accuracy than AlexNet on validation set.

### Conclusion

We studied the problem of weight transferring for age and gender recognition on a small set of data. It was shown that using weights of the last layer aside with nonlinear activation function in AlexNet and GoogleNet is useful for obtaining the best result. Also we were able to train AlexNet from scratch on small set of data and have obtained similar results to fine-tuned network. Two models can be combined to give better final accuracy.

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## **Influence of lexical context on mismatch negativity elicited by pseudowords processing**

Memetova K., Aleksandrov A. A., Stankevich L.

*Saint Petersburg State University, St.Petersburg, Russia*

*e-mail: [k.memetova@spbu.ru](mailto:k.memetova@spbu.ru)*

The present study is designed to establish how lexical context influences the MMN latency and amplitude when the pseudowords are presented. The ERPs were recorded by using only pseudowords or a pseudoword and words with different lexical frequencies. We found the generation of different MMN patterns when the same pseudoword was presented in different contexts. The pseudoword presented in context with another pseudowords demonstrated the smaller amplitude and the bigger MMN latency. Whereas the same pseudoword presented in context with words led to the significantly enhanced amplitude and the decreased latency of MMN. It is supposed that the pseudoword presented in context with words is perceived as conceptually different stimulus leading to the significantly enhanced MMN. Moreover, the hypothesis of lexical frequency influence on MMN has been supported. We found that the presentation of a high-frequency word led to the significantly more pronounced MMN response relative to a low-frequency one [1, 2, 3]. We hypothesize that different amounts of activation depend on the words lexical representation strength.

Keywords: ERP, pseudowords, words frequency, MMN.

### **Introduction**

In present work based on Russian language we have studied how linguistical differences between input signals (pseudowords and words) influence the true mismatch negativity brain potential latency and amplitude. The MMN means that it is not the refractoriness differences. The MMN responses relative to a physically identical stimulus were compared between two different scenarios for the MMN analysis: 1) when the stimulus was presented as a deviant in the odd-ball paradigm; 2) when the stimulus was presented as a standard in the odd-ball paradigm; [5 6, 8]. Therefore, some acoustic confounds were reduced and the standard–deviant acoustic-phonetic contrast, the critical variable determining the MMN response, was identical in both conditions. The pseudoword '*chash*' had been chosen as the examined sound. We used the multistimulus odd-ball paradigm and presented two conditions: 1) experimental – including words with different frequencies of occurrence in the Russian language and 2) control – including only pseudowords. Thus, integrating a pseudoword in a sequence of acoustical similar high- and low-frequency words in the experimental condition, the lexical context has been supplied. The MMN responses were

elicited either by high- or low-frequency deviant items. The experimental design gave us an opportunity to estimate the lexical influence because the MMN responses were elicited either by high- or low-frequency items. All stimuli were matched for their duration, fundamental frequency and peak amplitude. The word frequency was estimated according to the word frequency dictionary of the Russian language. In the control condition we used only acoustical similar pseudowords which have no lexical representation in a mental lexicon. In this condition the ERP effect was elicited by the sounds from one pseudoword's category. To examine ERP effects further and minimize the acoustic confounds, we created pseudowords differing only by one phoneme in a real word according to the Russian language rules.

## Method

We used the passive multistimulus odd-ball paradigm which was designed by R. Näätänen [5]. The important characteristic of this paradigm is the opportunity to present one standard and several deviant items. As a result the experimental time is shortened but the number of examined stimuli is risen. The aim of this study was to investigate the influence of lexical context on MMN elicited by pseudowords processing.

We calculated MMN values by subtracting the ERPs elicited by the same sound presented as the deviant and the standard stimulus. Firstly, the peak latencies of responses were obtained for each subject and condition. MMN peaks were determined as the highest amplitude of negative polarity at midline electrodes between 100 and 200 ms, when MMN peaks were the most typically reported. The analysis indicated the different mean long latencies windows for two main conditions: experimental - 88-188 ms, control - 128-224 ms. For the statistical assessment of physical acoustical confounds, we compared all standard items from the beginning to the point of divergence. For the statistical assessment of results, we performed a repeated measures analysis of variance (ANOVA) with Stimulus Type (three levels: examinee vs 2 contextual items), Condition (standard vs. deviant response), Electrode Position (six levels: F3, Fz, F4, C3, Cz, C4), the Bonferroni correction was applied.

## Results

No significant main effects were found for the standard stimulus ( $p > 0.05$ ). This means that the influence of acoustic features was minimal.

In the control condition no significant main effects were found for the MMN responses. This may imply that multiple semantic representations do not exist for this pseudoword-form and the influence of acoustic features was minimal.

In experimental condition no significant main effects were found for the MMN responses elicited by the pseudoword '*chash*' and low-frequency word '*chan*' (*tub*) ( $p = 0.709$ ) while the presentation of a pseudoword led to the more pronounced MMN response relative to a low-frequency one. The word '*chan*' is occurred very rare in Russian language and has only a lemma frequency of 5,2 ipm (instances per million words) [9]. Thus, the lexical dissociation between a low-frequency word and a pseudoword was minimal and that contrast was not enough for statistical significant effect in our conditions. However, the response elicited by high-frequency word '*chas*' (*hour*) demonstrated the significantly greater MMN amplitude (5,16 mV) than the response elicited by a pseudoword (1,95 mV) ( $p = 0.036$ ).

The results of the study have demonstrated significant main effects ( $p = 0.006$ ) for the MMN responses elicited by the same pseudoword that was presented in different conditions: in the control condition with pseudowords only the smaller amplitude and the bigger MMN latency was

shown. Whereas the same pseudoword presented in a context in the experimental condition with words led to the significantly enhanced amplitude and the decreased latency of MMN. It is supposed that the pseudoword presented in context with words is perceived as conceptually different stimulus leading to the significantly enhanced MMN. Therefore, this may imply that if a strong dissociation between stimuli (like word vs pseudoword), so-called “novel” reaction is shown this led to the significantly enhanced MMN. Furthermore, the results of this study support the idea that if only pseudowords are presented, the reaction time is risen because pseudowords have no lexical representation in the mental lexicon and they are processed like unknown sounds. However, if the pseudoword is presented in a lexical context with real words, the MMN response demonstrates the processing of the mechanism for novel stimuli.

Finally, we found that the high-frequency stimulus led to a significantly more pronounced MMN response than a low-frequency one in the long latencies window (88-188 ms). This finding is similar to earlier reports that the enhancement of lexical word frequency lead to the enhancement of MMN amplitude [1, 2, 3].

## **Conclusion**

In sum, this results support the hypothesis about the influence of lexical context on MMN. It was shown the generation of different MMN patterns when the same pseudoword was presented in different contexts. The pseudoword presented in a context with another pseudowords demonstrated the smaller amplitude and the bigger MMN latency. Whereas the same pseudoword presented in context with words led to the significantly enhanced amplitude and the decreased latency of MMN in 100-200 ms. It is supposed that the pseudoword presented in context with words is perceived as conceptually different stimulus leading to the significantly enhanced MMN as for processing on the mechanism for novel stimulus.

Moreover, the hypothesis of lexical frequency influence on MMN has been supported. We found that the presentation of a high-frequency word led to the significantly more pronounced MMN response relative to a low-frequency one. We hypothesize that different amounts of activation depend on the words lexical representation strength.

## **Acknowledgements**

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## **Evaluation of deep features for global visual localization**

Nedoshivina L., Peterson M.

*Department of Computer Photonics and Digital Video Processing, ITMO University,  
Saint-Petersburg, Russia  
email: nedshivina@gmail.com*

The paper is devoted to evaluation of features generated by deep convolutional neural networks in the context of indoor visual localization problem. Adjacent key frames in the indoor environment map could have low content variability, so here we experimentally tried to examine the ability to construct distinguishable descriptors on the base of deep features in contrast to more classical approaches.

### **Introduction**

Visual localization is a crucial task for navigation systems in mobile robotics, especially in the case of indoor navigation where GPS signal couldn't be received. In general, there are three types of localization problem, differing in the amount of a prior information: tracking, global localization and localization in uncertain environment (kidnapping) [1]. In the last two cases, which are considered in our work, a robot should determine its location by matching the current image of the environment with a set of key frames stored in the map. It's necessary to have methods that provide high success rate of preliminary matching of the current frame with the set of key frames to reduce the number of possible candidates for further more accurate matching based on epipolar constraints.

Since in the global visual localization problem no additional data can be used except the set of key frames, it can be considered as a content-based image retrieval task. In this case an image is described by a numerical vector (a global descriptor), which is used for matching. Recent works on image retrieval [2-4] have shown that deep convolutional neural networks (CNN) trained on large image sets provide relatively high matching success rate. However, in the case of visual localization task the adjacent key frames in the indoor environment map could have low content variability in comparison to the large multicategorical image sets. It's therefore interesting to examine the ability to construct distinguishable descriptors using deep features constructed by a CNN in a such case and compare it to more classical approaches.

### **Methods of global descriptor construction for image matching**

A relatively effective way to construct an image descriptor is an aggregation of local features, such as SIFT. Today there are a lot of variations of local features aggregation techniques; in our research along with the deep features we considered three commonly used approaches: the bag of features (BOF) representation with spatial pyramid matching kernel (SPMK)[5], the Fisher kernel [6] and the vector of locally aggregated descriptors (VLAD) [7].

There are two ways to construct an image descriptor using deep CNN. The first one is to directly use outputs from the fully connected layers as a descriptor, and the second one is to consider outputs from a convolutional layer as a set of local features and aggregate them into a global

descriptor. Here we used an aggregation technique on the base of sum-pooled convolutional features (SPoC) proposed by Babenko & Lempitsky in [4]. For an image  $\mathbf{I}$  we have the following expression for the  $i$ -th element of the descriptor vector  $\boldsymbol{\psi}(\mathbf{I})$ :

$$\psi_i(\mathbf{I}) = \sum_{y=1}^H \sum_{x=1}^W f_i(x, y), \quad (1)$$

where  $(x, y)$  – feature coordinates in the  $i$ -th ( $i = 1, \dots, K$ ) features map of a convolutional layer. On the post-processing step  $L_2$  normalization, PCA compression and whitening transformation are applied. Thus, in the case of the SPoC features an image descriptor is formed integrally over the feature map, so it's impossible to explicitly select a distinct feature for a local area. In this regard it's important to evaluate stability of that approach in the context of visual localization, i.e. robustness to occlusions, geometrical and brightness distortions.

### Experiments and Results

Several indoor image sequences were formed to test description methods: Corridor\_itmo (CI), 418 images; Corridor\_itmo2 (CI2), 1818 images; Corridor\_Itmo\_Gr (CIG), 221 images; Corridor\_kennedy(CK) [8], 205 images; Freiburg\_kidnap (FK)[9], 433 images. Images from CI and CI2 were acquired in the same environment but have different initial resolution. Examples of images from the formed sets are presented in Figure 1.



Fig. 1. Examples of images from testing sets.

For every testing sequence a set of key frames was extracted, modeling frames that would be stored in the environment map. The first image in sequence is considered as the first key frame, and next key frames are determined using a threshold constraint on the distance between descriptors of the last key frame and the current image. Outputs from the last fully connected layer of a CNN were used as a descriptor vector. Here we made an assumption that in our case testing sequences have low inter frame content variability, thus the following matching criteria was applied. Let  $N_C$  be the current frame number in the testing set, and  $N_K$  is the number of key frame with index  $K$ . The current frame  $C$  and the key frame  $K$  are considered as relevant, if  $N_C \neq N_K$  and  $N_{K-1} \leq N_C \leq N_{K+1}$ . For testing descriptors on the base of Fisher kernel and VLAD we used implementations from the VLFeat library [10], acquired results are presented in Figure 2.

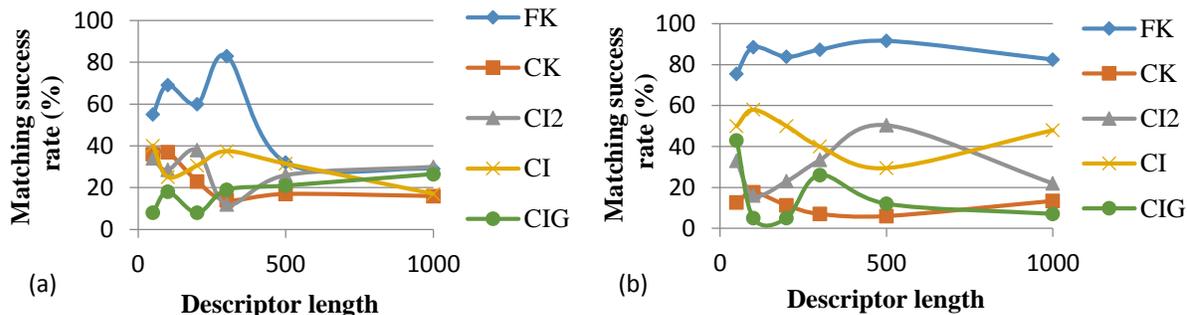


Fig. 2. Results for VLAD (a) and Fisher kernel (b) based on SIFT.

One can see that these types of global descriptors provide low matching success rate according to the introduced criteria, so it doesn't look reasonable to use them in our task. Much better results were obtained with 4-level BOF-SPMK with vocabulary containing 4000 visual words (Figure 3). This approach provides high-dimensional descriptors, and along with SIFT features it could take a long time for description and matching especially for large image sets. Thus we tested it on the base of more simple ORB features, which can be extracted and matched much faster.

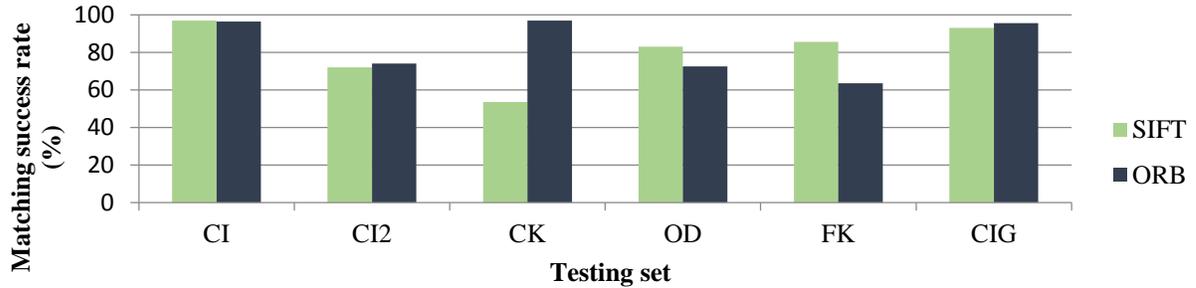


Fig. 3. Results for 4-level BOF-SPMK (4000 visual words) on the base of SIFT and ORB.

Along with local features aggregation techniques we conducted experiments with modification of the AlexNet, called Places-CNN [11] using Caffe library (Figure. 4).

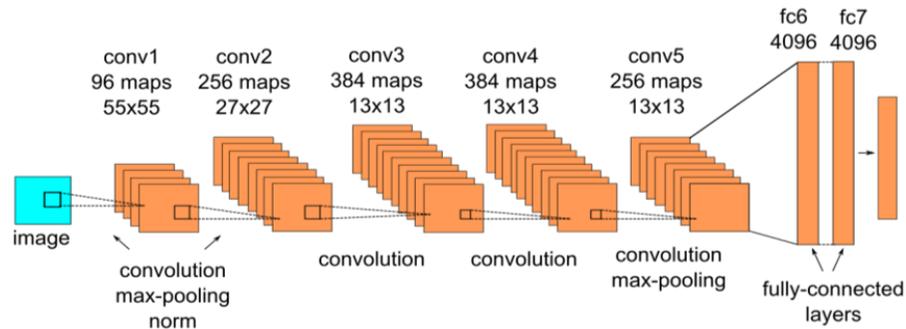


Fig. 4. Scheme of the Places-CNN [11].

Two kinds of this net were tested: Places205-AlexNet (pre-trained on 205 scenes and 2.5 million indoor images from PlacesDatabase [11]) and Hybrid-CNN (pre-trained on 1183 scenes and 3.6 million images). It was established that both global descriptors based on the last fully-connected layers (fc6 and fc7) and on the base of SPoC features give high matching success rate for our testing sets, see Figure 5, 6.

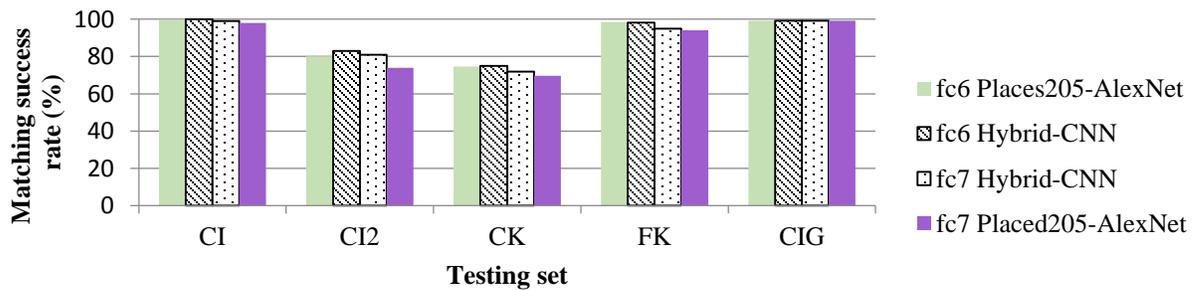


Fig. 5. Results for descriptor on the base of the last fully-connected layers (fc6 and fc7).

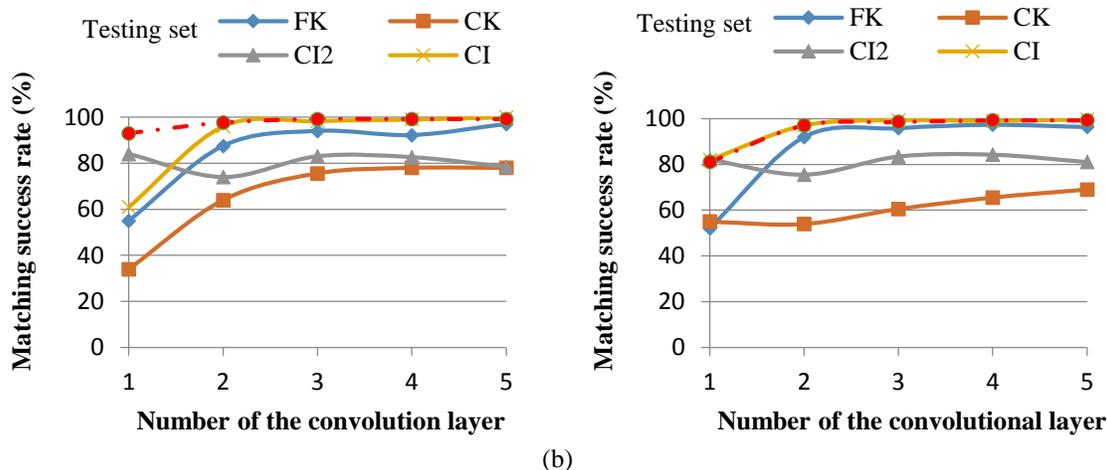


Fig. 6. Results for SPoC features on the base of different layers of (a) Places205-AlexNet and (b) Hybrid-CNN.

Descriptors which had shown the best results were tested on resistance to occlusions and geometrical and brightness distortions. For this purpose two additional sets on the base of CI sequence were formed. Examples of testing images and results of these experiments are shown in Figure 7, 8. As it shown in Figure 8, descriptors on the base of deep features provide high matching success rate on the set with occlusions, whereas histograms of visual words based on ORB and SIFT local features have greater resistance to distortions.



Fig. 7. Examples of images used for additional testing on robustness. (a) original image; (b) image with occlusions; (c) image with brightness distortion

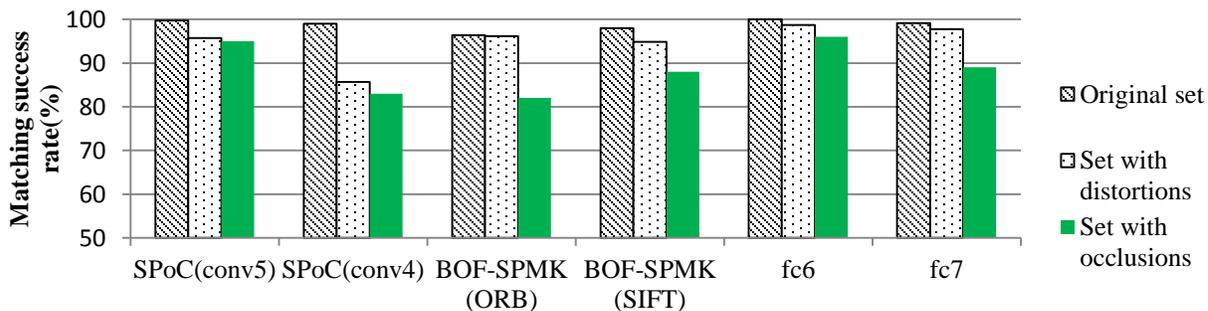


Fig. 8. Results of testing on robustness to occlusions and distortions.

It should be noted, that additional training of the CNN on the set of distorted key frames provided slightly better robustness. For the SPoC features based on the conv4 layer there is an improvement up to 88.1% from initial 85.7% successful matches, whereas the SPoC features based on the conv5 layer showed the same level of successful matches: 95% of successful matches.

## Conclusion

The conducted experiments have shown that descriptors on the base of deep CNN provide relatively high matching success rate and is not inferior to histograms of visual words with spatial pyramid matching kernel. Thanks to the convolutional and pooling layers a CNN also considers spatial relationships between local features, which are important for matching indoor images with low content variability. Moreover, descriptors on the base of deep features have shown greater robustness to occlusions and distortions, indicating its better applicability to the global visual localization problem.

## Acknowledgments

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## Human brain functional asymmetry and moving sound localization

Petropavlovskaja E. A.<sup>1</sup>, Shestopalova L. B.<sup>1</sup>, Shkurko A. A.<sup>2</sup>, Semenova V. V.<sup>1</sup>, Nikitin N. I.<sup>1</sup>  
<sup>1</sup> I. P. Pavlov Institute of Physiology, Russian Academy of Sciences, SPb, Russia  
<sup>2</sup> Saint-Petersburg State University, SPb, Russia  
email: petekat@yandex.ru

Functional asymmetry is a basic property of the human brain which affects motor, sensory and cognitive processes. There is a lot of evidence that in right-handed people right hemisphere of the brain is better fitted for the spatial information processing, regardless of sensory modality. The ability to localize short stationary and moving sounds under dichotic stimulation was tested in 9 right-handers and 7 left-handers. The stimuli were white noise bursts of 100, 200 and 400 ms duration with constant or linearly changing interaural time differences (ITD).

Both groups of subjects exhibited symmetrical subjective acoustic space and equal percentage of moving stimuli perceived as stationary. In the right-handed subjects, the stationary stimuli of similar ITDs were lateralized further from the head midline. This suggests that the functional asymmetry affects subjective acoustic space metrics. The subjective onset position of moving stimuli was shifted further in the direction of motion in right-handers than in left-handers. The offset position shift differently depended on the motion parameters in two groups of subjects. The observed differences are related to specialization

and dynamic interaction of the right and left hemisphere of the brain during localization of a moving sound source.

## Introduction

Functional asymmetry is a basic property of the human brain which affects motor, sensory and cognitive processes. There is a lot of evidence that in right-handed people right hemisphere of the brain is better fitted for the spatial information processing, regardless of sensory modality. Several studies confirm the existence of such asymmetry in sound localization and auditory motion processing [2, for review]. A few studies have shown that handedness has an impact on auditory spatial abilities [1, for review].

During localization of the moving stimulus every sensory system should take into account the delay of incoming information about the stimulus position. Successful interaction with any moving object can be performed only if the perception sluggishness has been compensated by some predictive mechanisms. Displacement of the perceived onset position relative to the objective one during localization of the moving sound source is an example of the auditory perception sluggishness. Localization of the moving sound offset position is a result of the “sluggishness vs. prediction” competition. Using the short stimuli (i.e. durations near movement detection threshold) makes it possible to investigate the influence of sound motion parameters on perception sluggishness and predictive abilities at a wide range of velocities.

## Methods

16 healthy paid volunteers (aged 18 – 45, 11 females, 9 right-handed) participated in the experiments. The subjects were seated in a sound-attenuated and electrically shielded chamber. Lateralization of stationary and moving sound images was studied under dichotic stimulation. Stimuli were presented directly to tympanic membrane via insert earphones ER-2 (Etymotic Research Inc., USA) with sound conducting tubes and insert tips. The signal intensity was adjusted

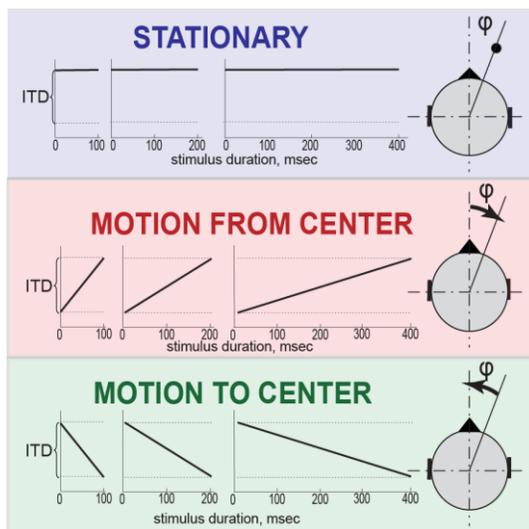


Fig 1. Schematic of ITD patterns of the sound stimuli. Upper panel - stationary stimuli, middle panel – stimuli moving from the head midline to the left or right, lower panel - stimuli moving to the head midline from the left or right.

at the level of 50 dB above the audibility threshold of each ear. The stimuli were noise bursts (bandwidth 100 – 1300 Hz, duration 100, 200 or 400 ms). Stationary position or gradual motion of the sound image was simulated by manipulating the interaural time delay (ITD).

The stimuli can be classified into three types according to the pattern of ITD changes:

1) ITD value was constant and could be equal to 0,  $\pm 40$ ,  $\pm 120$ ,  $\pm 200$ ,  $\pm 300$ ,  $\pm 400$ ,  $\pm 500$ ,  $\pm 600$ ,  $\pm 700$ ,  $\pm 800$   $\mu\text{s}$ , which corresponded to the stationary sound image (Fig. 1, upper panel).

2) ITD changed gradually from 0  $\mu\text{s}$  to one of the above-listed values. It was perceived as gradual motion of the sound image from the head midline to the left or right (Fig. 1, middle panel).

3) ITD changed gradually from one of the above-listed values to 0  $\mu$ s. It was perceived as gradual motion of the sound image to the head midline from the left or right (Fig. 1, lower panel). Each series consisted of 95 stimuli of similar type (stationary, moving from the center or moving to the center) and duration (100, 200 or 400 ms) with 19 ITD values presented in pseudorandom order (each ITD value was presented 5 times during each series). Each test stimulus was presented three times with 1s onset-to-onset interval, thereafter the subject's response was recorded. The next stimulus was presented 1.5 – 2.0 s later. 2-4 series of each stimulus type and duration were presented in pseudorandom order. All 16 subjects completed the full set of experiments. The subjects were asked to estimate the position of the sound images using graphic tablet (Genius G-pen 450) as a coordinate input device. Subjective acoustic space was depicted in the effective area of graphic tablet. The subjects were instructed to touch the point where they localize the sound image. For gradually moving stimuli, the subjects estimated the sound image onset and offset positions (i.e., starting and final points of the sound image trajectory). The results obtained were averaged for each subject separately and across subjects. Azimuthal positions ( $\varphi$ , deg) of starting and final points of the sound image motion trajectories as well as stationary sound image positions were measured for each ITD value. The extent of the right hand dominance was estimated by a standard handedness preference questionnaire. The data were averaged across the groups of left-handed and right-handed subjects separately and compared.

## Results and Discussion

The Stationary stimulus position depended on the ITD value (Fig.2). No significant difference was found for the Stationary stimuli of different durations and for stimuli localized in the left and right parts of the subjective acoustic space. Both groups of subjects exhibited symmetrical subjective acoustic space. In the right-handed subjects, the stationary stimuli of similar ITDs were lateralized further from the head midline. This suggests that the functional asymmetry affects subjective acoustic space metrics.

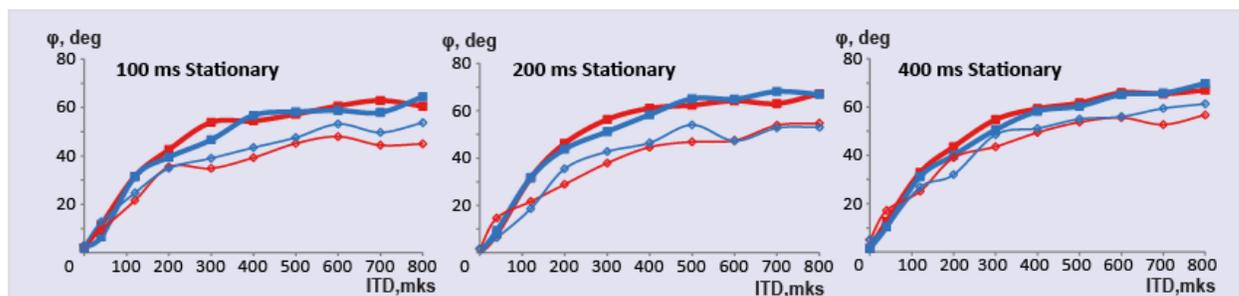


Fig. 2. Perceived azimuthal positions ( $\varphi$ ) of Stationary stimuli. Red and blue curves represent the lateralization of the sound image in the right and left hemisphere of the subjective acoustic space, respectively. Thick lines correspond to the data averaged across right-handed subjects, thin lines correspond to the data averaged across left-handed subjects.

Stationary stimulus position averaged across all three durations for each ITD value was considered as objective position for corresponding onset and offset positions of moving stimuli. Comparing with Stationary stimuli, perceived onset and offset positions of Moving stimuli were generally biased in the direction of motion. The displacement of the onset (offset) position was calculated as a difference between mean Stationary stimulus position and corresponding onset (offset) position of Moving stimulus for each ITD value.

Motion onset position displacement changed as a function of the motion distance (and velocity) for stimuli moving from the center to periphery (Fig. 3, upper panel). For stimuli moving in opposite direction, it was mainly a function of duration (Fig. 3, lower panel). The subjective onset position of moving stimuli was shifted further in the direction of motion in right-handers than in left-handers.

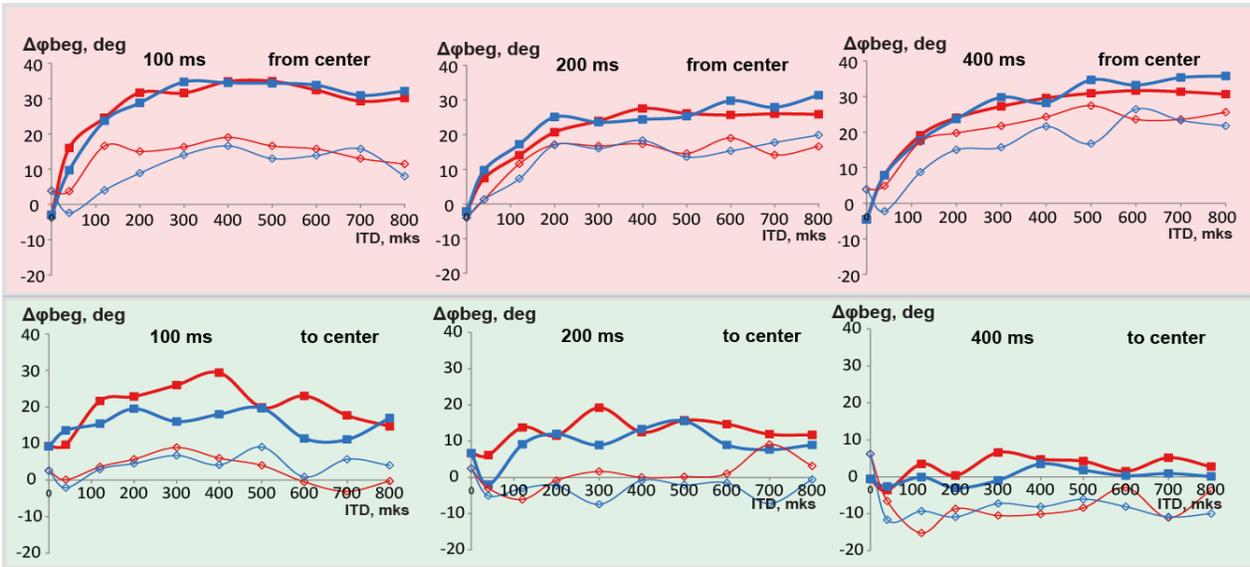


Fig. 3. Displacement of the perceived Motion onset position ( $\Delta\phi_{beg}$ ).

General designations are the same as in Fig.2.

For the perceived offset positions the systematic “overshooting” was observed for all moving stimuli except the shortest and fastest ones moving from the center. The offset position

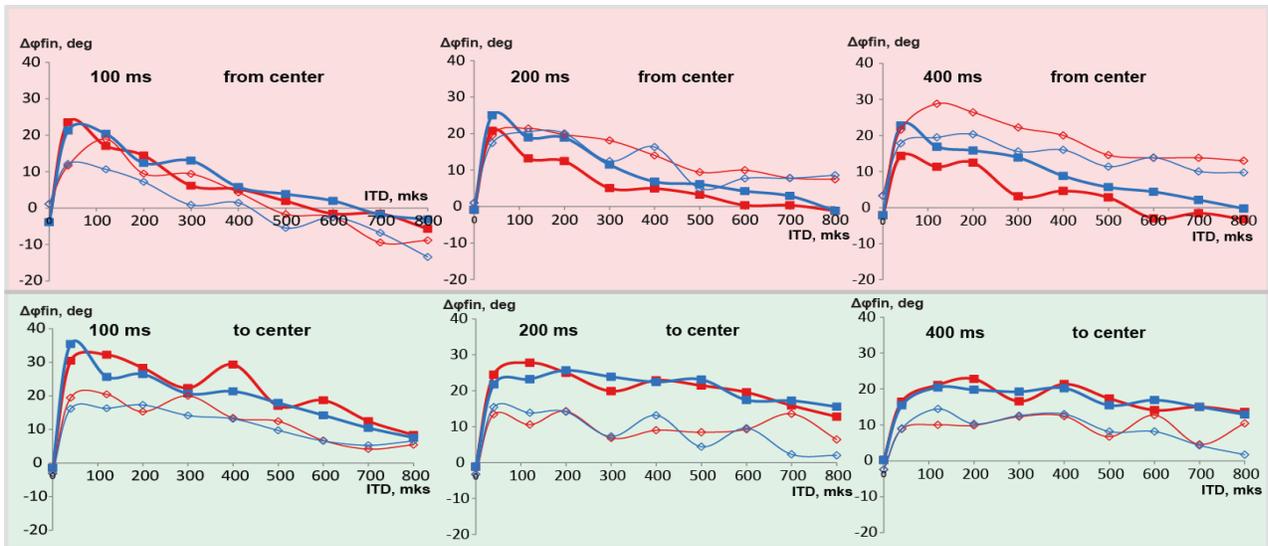


Fig. 4. Displacement of the perceived Motion offset position ( $\Delta\phi_{fin}$ ).

General designations are the same as in Fig.2.

displacement differently depended on the motion parameters in the two groups of subjects.

If perceived trajectory length of the Moving stimulus was less than  $2^\circ$  it was considered as perceptually stationary. The percentage of moving stimuli perceived as stationary depended on

the motion distance and duration. Both groups of subjects exhibited equal percentage of moving stimuli perceived as stationary. Only 30-35% of central stationary stimuli employed in all Motion sessions were perceived as stationary. Amongst Moving stimuli with onset or offset ITD = 40  $\mu$ s, about 15-25% were perceived as stationary. This proportion decreased with ITD value and the trajectory length, correspondingly. It rarely exceeded 5% for Moving stimuli with onset or offset ITD > 200  $\mu$ s. Percentage of Moving stimuli perceived as Stationary didn't differ between stimuli durations 200 and 400 ms, but it could be up to 5% higher for the 100 ms duration.

The number of reversals of the perceived motion direction (relative to the actual one) changed as a function of motion distance for the stimuli moving from the periphery to the center (Fig.5, lower panel). For stimuli moving in the opposite direction, it didn't change with distance and duration (Fig. 5, upper panel).

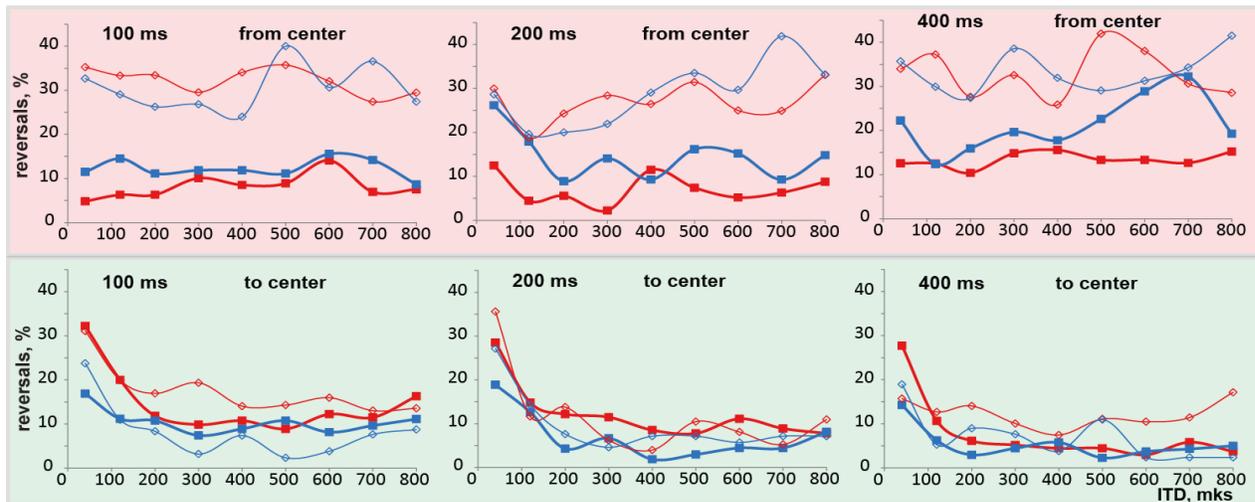


Fig. 5. Percentage of Reversals.

General designations are the same as in Fig.2.

## Conclusion

The observed differences may be related to specialization and dynamic interaction of the right and the left hemisphere of the brain during localization of a moving sound source.

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# Chromatic accentuation in Dyslexia: Useful implications for effective assistive technology

Pinna B.<sup>1</sup>, Shelepin E. Yu.,<sup>2</sup>, Deiana K.<sup>1</sup>

<sup>1</sup> Dept. of Humanities & Social Sciences, Univ. of Sassari, Italy

<sup>2</sup> I. P. Pavlov Institute of Physiology, Russian Academy of Sciences, SPb, Russia  
email: [baingio@uniss.it](mailto:baingio@uniss.it)

*According to Gestalt psychologists, color is considered a less effective attribute if compared to shape and luminance. Aim of this work is to determine the role played by color and how it can influence visual organization and in particular how it affects the process of reading and word recognition in dyslexics and normal readers. Several stimuli were created in order to prove the role of chromatic accentuation in different conditions and 20 dyslexic subjects between 7 and 10 years old and 20 others subjects of the same age from a control group were tested. Shortly, with this study, we have demonstrated that chromatic accentuation, indeed affects grouping and consequently reading time, easiness and comprehension, furthermore it improves reading in developmental dyslexia. For this reason with this work we wish to promote new methods of using color in information design for the improvement of reading easiness and text comprehension.*

## Introduction

### The problem of perceptual organization

The problem of perceptual organization is to understand why we perceive a world articulated in objects such as people, cities, houses, words and trees, and not a world of scattered differences of luminance colors, ages and bars.

Well-known ‘principles of grouping’: such as proximity, similarity, good continuation, closure, convexity, exhaustiveness, symmetry, Prägnanz and past experience resulted from Wertheimer’s [1, 2] studies, whereas Rubin [3] specified rules of figure-ground organization such as surroundedness, size, orientation, contrast, symmetry, convexity, and parallelism.

### The principle of similarity

The inner local organization of the small squares of Fig. 1 in rows (a) or columns (b) is due to the Gestalt grouping principle of similarity stating that, all else being equal, the most similar elements (in color, brightness, size, empty/filled, shapes, etc.) are grouped together.

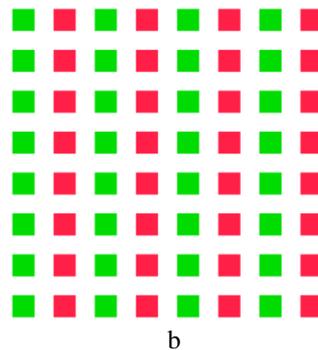
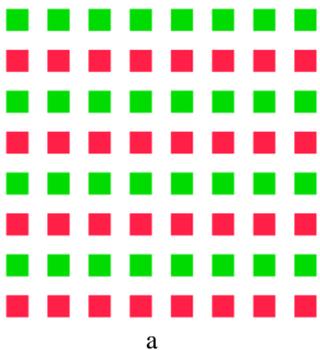


Fig. 1. The similarity principle groups the small squares in rows (a) and columns (b).

### Color, Wholeness, Fragmentation and Dyslexia

The main purpose of this work is to explore how color can influence visual organization and, by means of it, further processes such as reading and visual

word recognition both in normal readers and dyslexics. In fact, by involving cognitive and metacognitive domains, color permits exploration of broader issues concerning perception (Pinna

& Deiana 2014), memory, knowledge, representation and learning, where color can more clearly express its biological advantages for humans. Color enhances wholeness, and also it causes fragmentation, when it is applied contrariwise. Therefore, to understand the role of chromatic accentuation we use color either as a whole or as a fragmentation tool, hence, operating synergistically or against some grouping principles and similarity attributes. According to this, color is expected to affect grouping and other visual processes related to the phenomenal wholeness involved in reading and word recognition.

### The technique of chromatic accentuation

Our technique can be scientifically relevant for the following main reasons. (i) To understand the role of color in perceptual grouping and figure-ground segregation. (ii) To determine psychophysically the role of color in influencing processes at a higher level, like reading and word recognition. (iii) To test cognitive processes during color vision efficiencies. (iv) To test the magnocellular theory of developmental dyslexia. As a matter of fact, reading needs the acquisition of good orthographic skills to recognize the visual form of words, essential elements to access their meaning directly. Reading also needs good phonological skills to pronounce unfamiliar words using knowledge of letter sound and conversion rules. Indeed, in dyslexics, the development of the visual magnocellular system is defective: development of the magnocellular layers of the dyslexic lateral geniculate nucleus (LGN) is abnormal, their motion sensitivity is reduced and in many dyslexics there is an unsteady binocular fixation, thus, poor visual localization, especially on the left side (left neglect).

### General Methods

#### Subjects

The subjects were children between the ages of 7 and 10 years. Two groups were recruited from schools, from therapists and teachers. 20 control subjects with normal reading and writing skills were compared with 20 dyslexic subjects. Stimuli. The text used as a stimulus was the well known “The war of ghosts” (in Italian) by Bartlett (1932). A non-word condition was also used by mixing randomly the sequence of syllable. Five different equiluminant colors were used: brown, blue, green, purple and red. Four chromatic conditions were used (see Fig. 2): (i) monochromatic –the entire text could be of only one (green) of the 5 colors; (ii) word –each word was of a different color; (iii) syllable – each syllable was of a different color from the adjacent one; (iv) letter – each letter was of a different color.

OnenighttwoyoungmenfromEgulacwentdowntotherivertohuntseals  
ndwhiletheywerethereitbecamefoggyandcalm.Thentheheardwar-c  
ries,andtheythought:"Maybethisisawar-party".Theyescapedtothes  
ore,andhidbehindalog.Nowcanoescameup,andtheyheardthenoiseof  
paddles,andsawonecanoecominguptoem.Therewerefivemeninthe  
canoe,andtheysaid:"Whathoudoyouthink?Wewishtotakeyoualong.Wear  
egoinguptherivertomakewaronthepeople."Oneoftheyoungmensaid,"  
lhavenoarrows.""Arrowsareinthecanoe,"heysaid."Iwillnotgoalong.I  
mightbekilled.Myrelativesdonotknowwherelhavegone.Butyou,"hesa

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canoe,andtheysaid:"Whathoudoyouthink?Wewishtotakeyoualong.Wear  
egoinguptherivertomakewaronthepeople."Oneoftheyoungmensaid,"  
lhavenoarrows.""Arrowsareinthecanoe,"heysaid."Iwillnotgoalong.I  
mightbekilled.Myrelativesdonotknowwherelhavegone.Butyou,"hesa

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ndwhiletheywerethereitbecamefoggyandcalm.Thentheheardwar-c  
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canoe,andtheysaid:"Whathoudoyouthink?Wewishtotakeyoualong.Wear  
egoinguptherivertomakewaronthepeople."Oneoftheyoungmensaid,"  
lhavenoarrows.""Arrowsareinthecanoe,"heysaid."Iwillnotgoalong.I  
mightbekilled.Myrelativesdonotknowwherelhavegone.Butyou,"hesa

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paddles,andsawonecanoecominguptoem.Therewerefivemeninthe  
canoe,andtheysaid:"Whathoudoyouthink?Wewishtotakeyoualong.Wear  
egoinguptherivertomakewaronthepeople."Oneoftheyoungmensaid,"  
lhavenoarrows.""Arrowsareinthecanoe,"heysaid."Iwillnotgoalong.I  
mightbekilled.Myrelativesdonotknowwherelhavegone.Butyou,"hesa

Fig. 2. Examples (translated in English) of some conditions used (please test the role of color in influencing the reading easiness, the wholeness and fragmentation role).

### Procedure

The tasks of one group of 10n and 10d subjects were (i) to read the texts as clearly as possible in a loud voice (reading task), (ii) to scale (in percent) the reading easiness of the stimuli used in each experiment (scaling task), and (iii) to

answer a multiple-choice reading comprehension test related to the text (comprehension task). Reading time and number of errors in both reading and comprehension tasks were computed. Furthermore, a second group of 10n and 10d subjects was asked to scale (0-10) the four chromatic conditions according to the following subjective and qualitative impressions and feelings: reading speed, accuracy, weariness, easiness, effort, comprehension, clarity, discomfort. The chromatic variations were combined with word-non word conditions and with 0 or 1 blank inter-word separation.

## Results

The main results of our experiments are summarized in the graphs, shown on the Fig. 3 and in the online channel of SPCN 2016 (<https://f1000research.com/posters/5-1754>). Similar differences between normal and dyslexic readers were also obtained in all the qualitative impressions studied.

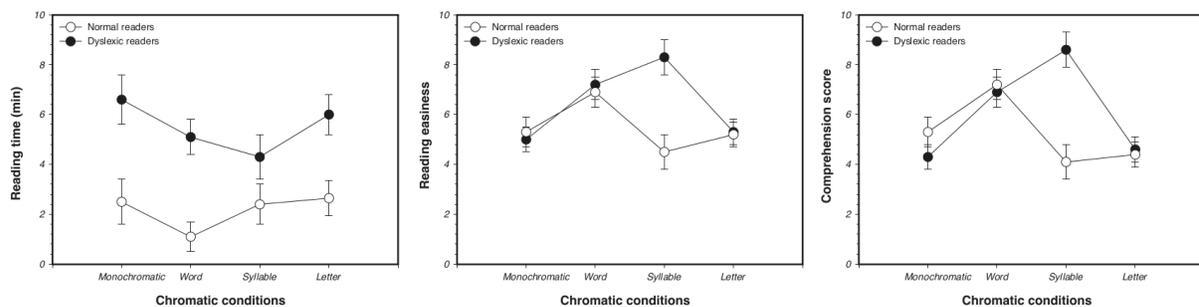


Fig. 3. Main results

## Conclusions

### Chromatic accentuation in dyslexia

Our results demonstrate that color strongly influences grouping and, as a consequence, reading time, easiness and comprehension. These processes are related to the fact that they imply whole and part-whole organization. Moreover, chromatic accentuation of a text improves reading in developmental dyslexia. In detail, in developmental dyslexia there may be heightened development of parvocellular systems that underlie their holistic, 'seeing the whole picture' starting from single chromatic parcelled-out elements. In conclusion, we promoted new methods of using color in information design allowing the improvement of reading easiness and text comprehension. Useful implications for effective assistive technology to be incorporated in recent devices such as E-readers and I-Pads can be derived.

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# Spatial memory: the accuracy of allocentric and egocentric spatial representations

Saveleva O.<sup>1</sup>, Zacharkin D.<sup>1</sup>, Menshikova G.<sup>1</sup>

<sup>1</sup> *Department of Physiology, Lomonosov Moscow State University, Moscow, Russia*  
*email: SavelevaPsy@gmail.com*

It has been proposed the existence of two types of spatial representations to successfully code the localization of objects: egocentric and allocentric. The first one specifies spatial information with respect to the observer's position and the second – to relative positions between objects. In our study we investigated the accuracy of both spatial representations using the CAVE virtual reality technology. The results showed the egocentric representations (the front view) were more accurate than allocentric ones (left and above views) and the representations “the left” were less accurate than “the above” ones.

## Introduction

Efficacy constructing of mental images depends on many psychological factors, including correct space perceiving. Therefore, understanding the mechanisms of spatial memory is a fundamental problem. There are two types of storage and reproduction of spatial information can be distinguished: a) location relative positions between objects and b) location relative to the observer. The first type is called allocentric, while the second - egocentric. It is assumed that both types of representation of the surroundings at the same time operate in the task of spatial orientation and navigation. Some tasks demand the representation presented in egocentric coordinates (arm motion control, to sit on a chair), whereas other tasks demand the representation in allocentric coordinates (to go distance from point A to point B). The main feature of allocentric representations is that they are do not depending of the observation point. Their formation depends on many factors, which could lead to mistakes in space mapping. Primary processing of visual information from the light-sensitive surface of the eyes retinas based on the analysis of 2D projection images of 3D objects on a 2D surface of retina. It is assumed that 3D images of the objects constructed thru the foundations of projective transformations and displays basic spatial properties of objects and their relative positions. The current experiments let to propose a parallel model of spatial information processing in egocentric and allocentric coordinate systems. [1]. The ratio of deposits of egocentric allocentric blocks depends the task. Today many questions about allocentric and egocentric representations and poorly studied.

There are several methods of assessing the spatial abilities. For example the intelligence test Amthauer (to identify the three-dimensional spatial figure, showed in the plane). Time is limited. Or a series of Raven matrices (evaluates the spatial ability using the figures in the horizontal and vertical directions). These methods use 2D images. We planned to use 3D scenes. This type of study is rather difficult to carry out under normal laboratory conditions, because it is need the presentation of 3D stimulation, the control of the time of presentation, as well as to develop methods for the detection of violations of the identification of objects and their localization. To overcome these problems, we choose one of the modern technologies for the presentation of stimulation. Virtual reality (VR) systems are actively used in psychological research and showed the efficiency.[3] To complicate the the processes of formation of egocentric and allocentric representations we decided to use thevection illusion (of self-motion of the body). In our studies it was shown that this illusion initiated using virtual reality systems [2].

The goal of our research was to study the memorizing and reproducing processes of spatial representations in egocentric and allocentric systems in the working memory.

The hypothesis of our study. The formation of egocentric and allocentric spatial representations actively implemented in the working memory. The accuracy of formation depends on a time-limited processes in working memory. Egocentric representation are primary formed in the beginning of processing spatial information, that is why its formation and reproduction will be less susceptible to distortion. In contrast, distortion in the reproduction more abstract allocentric representations are stronger, because they are formed later in the limited processing time convinienses in the working memory. These disorders can manifest in reducing the accuracy of identification of objects of the scene, as well as in reducing the encoding and decoding its localization.

## Methods

36 participants (18 male) at the ages from 18 to 46 with normal or corrected to normal eyesight took part in the experiment.

### Stimulation Virtual

Six virtual scenes were constructed consisted of 7 objects located in different 3D positions (Fig. 1). Three of them presented in conditions of vection illusion.

**Apparatus** The virtual environment was presented using Barco Ispace 4 CAVE system, consisted of four screens, integrated into a cubic room with three walls and a floor. The software application was written in Virtools 4.0 environment.



Fig. 1. CAVE virtual reality system.

**Procedure** The participant's task was to remember the scene and then to reproduce objects in a virtual space from three imagined viewer's positions: 1) the front view (as if they would view the scene from the original view point), 2) the left one (the scene viewed from the left) and 3) the above one (viewed from above). To complete the task the participants chose objects from the object's library and located them in a virtual space using flystick. During the execution object's coordinates were recorded. The accuracy of identification and localization was calculated for each of three imagined viewer's positions.

### Results

The results showed the egocentric representations (the front view) were more accurate than allocentric ones (left and above views) and the representations "the left" were

less accurate than "the above" ones.

The task of reproducing localization of objects by changing the mental observation points used allocentric representation of the scene. Our results confirm previous data that the reproducing of a scene is worsening with increasing angle of view seeing: the more a mental perspective different from that under which the scene memorized, then less accuracy.

## Conclusion

Results showed that participants successfully reproduce representation of egocentric perspective, compared with the tasks to reproduce the scene in allocentric coordinates.

The findings reveal fundamental laws of coding spatial information in a person's working memory and show the role of scene observation conditions for an adequate formation allocentric representations.

Established and proven method we evaluate the success of the formation of spatial memory in a dysmotility body using virtual reality can be used to the further study of spatial memory in an ecologically valid conditions.

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## Contextual effects on auditory discrimination of moving sounds

Shestopalova L. B.<sup>1</sup>, Petropavlovskaya E. A.<sup>1</sup>, Semenova V. V.<sup>1</sup>, Vaitulevich S. Ph.<sup>1</sup>,  
Nikitin N. I.<sup>1</sup>

<sup>1</sup> I. P. Pavlov Institute of Physiology, Russian Academy of Sciences, SPb, Russia

email: shestolido@mail.ru

The study focused at the effect of stimulus context on active and passive discrimination of moving sound signals. Different contexts were created by reversing the role of standard and deviant stimuli in the odd-ball blocks. Three types of stimuli were used as standards or deviants: stationary midline noises and two patterns of sound motion produced by linear or abrupt changes of interaural time differences. In passive listening conditions (the sound stimuli ignored), auditory event-related potentials (ERPs) were recorded and mismatch negativity potentials (MMNs) were obtained. Active discrimination of sound motion was measured by hit rate (percent of correct responses), false alarm rate and reaction time.

The influence of the stimulus context on active and passive discrimination of the moving sound stimuli manifested itself as effect of deviance direction. The hit rate and MMN amplitude were higher when the deviant moved faster than the standard. MMN magnitude was more responsive to the velocity of sound motion than the hit rate and false alarm rate. The psychophysical measurements of active motion discrimination in the reversed contexts suggest that smooth and abrupt sound motion may be subsumed under the same perceptual category of 'moving sounds', whereas the stationary stimuli form another perceptual category.

## Introduction

The distinctive feature of sound stimulation is that it evolves in time, and each incoming sound is embedded in the current auditory context. Contextual effects on the discrimination of the relevant signal in the continuous acoustic input formed by concurrently active sound sources represent an important aspect of the auditory scene analysis in humans. An advantageous approach to

investigate auditory context effects involves so-called “oddball reversals” in which the rarely and frequently presented signals (“deviants” and “standards”) change their roles in different experimental blocks. It is crucially important that in the reversed-oddball paradigm the acoustical differences between deviant and standard stimuli do not change during the context reversals. The present study investigates the effect of stimulus context on active and passive discrimination of moving sound signals in the parallel behavioral and MMN experiments.

## **Methods**

All stimuli were binaurally presented low-frequency noise bursts (bandwidth 100–1300 Hz); their duration was 200 ms, apart from 10 ms fade-in/fade-out fronts smoothed by the cosine function. The stimuli of 96 kHz sampling rate were delivered through the 24-digit sound board GINA 24 (96 kHz, Echo Audio, USA). Three types of stimuli were used as standards or deviants in different blocks: stationary midline noises (Cent) and two patterns of sound motion (Slow and Fast) produced by linear or abrupt changes of interaural time differences (ITDs). The Slow and Fast stimuli travelled to the left/right from the head midline over the angular distance determined by  $ITD=200 \mu s$ . The stimuli were presented dichotically through the insert earphones ER-2 to the subjects seated in a sound-proof chamber.

*Behavioral study.* The experiment included 6 types of the oddball blocks. In each block one of the three stimuli (Cent, Slow or Fast) was used as standard and the other served as deviant. In the cent-standard blocks the direction of deviant motion was randomized. In the slow- or fast-standard blocks, the Fast or Slow deviants shifted in the same direction as standards. All blocks consisted of 210 standards and 40 deviants, so the stimulus probabilities were 0.84 and 0.16 for the standards and deviants, respectively. The onset-to-onset interval was 1s, therefore a single block was about 4 min long.

Nine healthy adult listeners performed the active discrimination task. They were asked to press a button when they heard a deviant which moved faster or slower than the standard. The level of performance was measured by hit rate (percent of correct responses) and false alarm rate, along with reaction time.

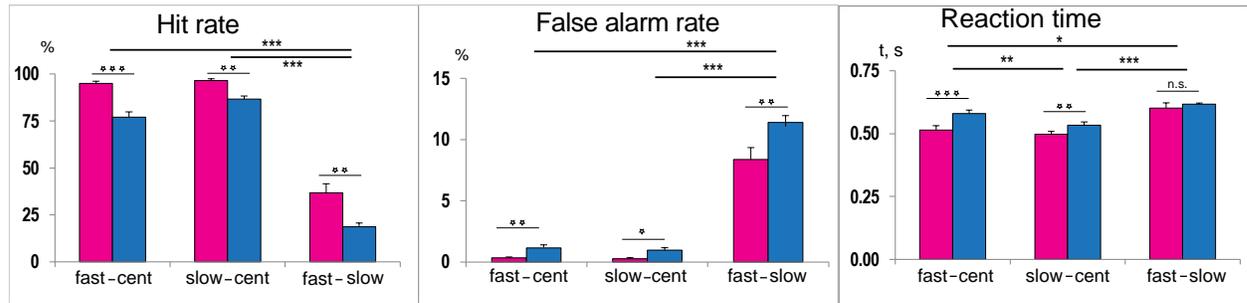
*MMN study.* The EEG was recorded in the oddball blocks with the same sound stimuli as the behavioral study. In each block, one of the three stimuli (Cent, Slow or Fast) served as standard while the other two were used as deviants. In other blocks, the standards and deviants were reversed. Each block contained 420 standards and 80 deviants presented in a pseudorandom order with 1 s onset-to-onset interval, therefore a single block was about 8 min long. In the cent-standard blocks, 40 Slow deviants and 40 Fast deviants shifted in the same direction either leftward or rightward from the head midline. In the slow-standard blocks, 40 Fast deviants shifted in the same direction as standards and 40 Cent deviants were located at the head midline. In the fast-standard blocks, 40 Slow deviants shifted in the same direction as standards and 40 Cent deviants were located at the head midline. The corresponding stimulus probabilities were 0.84, 0.08 and 0.08 for the standard and for two types of deviants, respectively.

Eight healthy adult listeners participated in the MMN study. Four of them took part in the behavioral experiment as well. Each MMN block was presented 6–7 times on different days to each subject, so that minimum 240 deviants were presented for each experimental condition. The blocks were balanced across the directions of sound displacement. Each experimental session consisted of 7–8 blocks presented with short breaks and lasted about 1.5 h.

The MMNs were calculated according to the “same-stimulus” method, that is, by subtracting the ERP for the same stimulus when it was presented as standard in one block, from when it was presented as deviant in another block.

## Results and Discussion

**Behavioral study.** The results of the psychophysical measurements are given in Fig.1. The higher hit rates and lower false alarm rates and reaction times were obtained when the deviants moved faster than the standards.



■ Deviant moves faster      ■ Standard moves faster

Fig.1. Results of the active sound discrimination task. The pairs of red and blue bars represent the opposite oddball configurations corresponding to different contexts. Within each pair, the red bar shows the deviant that moves faster relative to the standard context, and the blue bar shows the opposite combination. Horizontal lines with diamonds or asterisks indicate the significant differences yielded by the repeated measures ANOVA:

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

The psychophysical measurements of active motion discrimination in the reversed contexts suggest that slow and fast sound motion may be subsumed under the same perceptual category of ‘moving sounds’, whereas the stationary stimuli form a separate perceptual category.

**MMN study.** Grand-average ERPs elicited by cent, slow and fast standards and by the Cent, Slow and Fast deviants are shown in Fig.2.

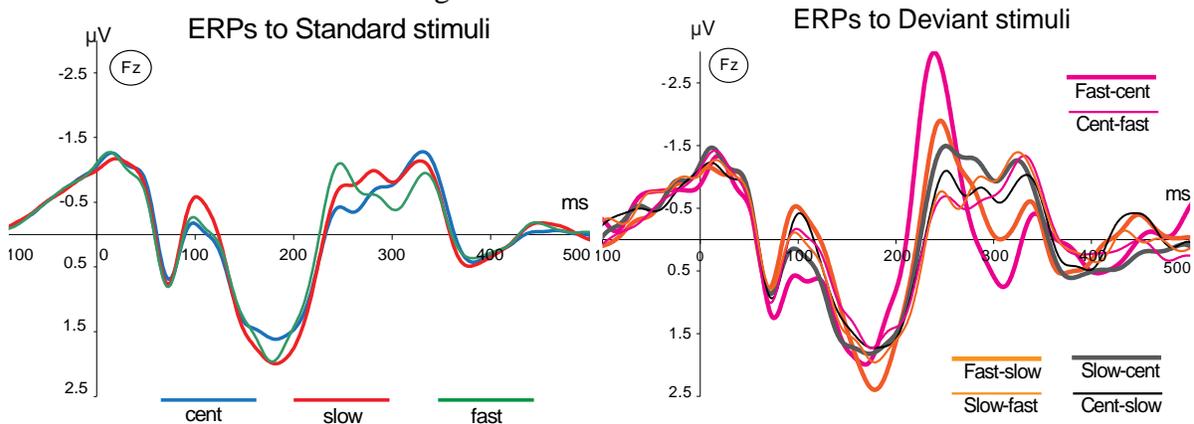


Fig.2. Grand-average ERPs elicited by standards and deviants. Left panel: ERPs to cent, slow and fast standards. Right panel: ERPs to Cent, Slow and Fast deviants presented in the context of cent, slow and fast standards.

Responses to the three standards (left panel) differed both in the N1P2 amplitudes and also in the negative component peaking at around 250 ms. The post-hocs of the repeated measures ANOVA with Standard (cent, slow, fast) showed that the largest N1P2 component was elicited by the slow motion ( $p < 0.05$ ). In the latency range of 225–275ms the highest negativity was elicited by fast

motion ( $p < 0.05$ ). Responses to deviants (Fig. 2, right panel) demonstrated enhanced negativities in the time interval of 200–300 ms. The largest negativities were produced by Fast deviants in both cent- and slow-standard contexts.

The difference waveforms obtained at Fz recording site are shown in Fig. 3.

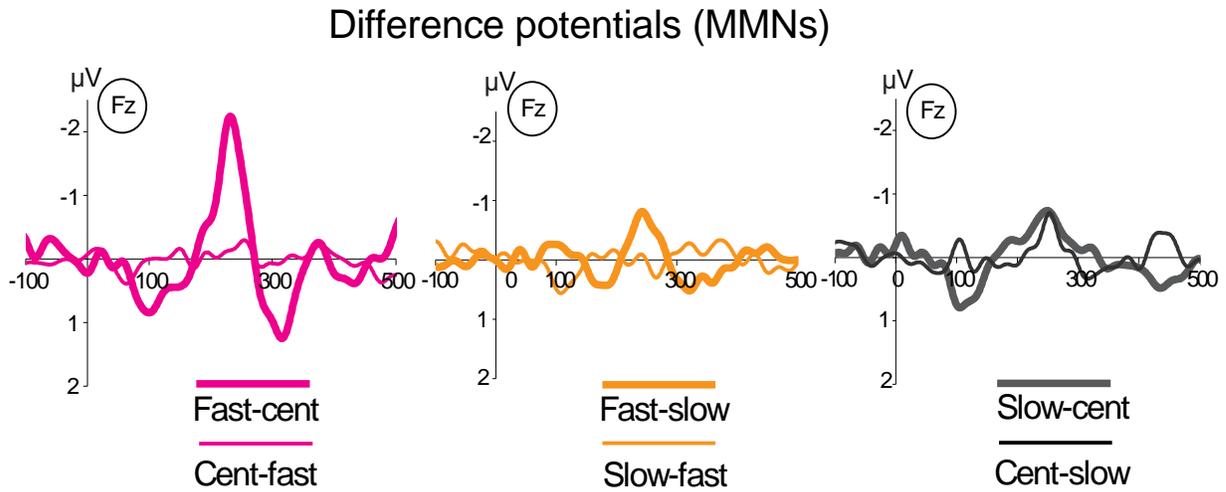


Fig. 3. Grand-average Fz MMN waveforms obtained in the reversed oddball blocks.

Across-subject grand mean MMN amplitudes are shown in Fig. 4. MMN amplitudes were strongly affected by the reversals of the standard-deviant configurations. This effect can be explained in

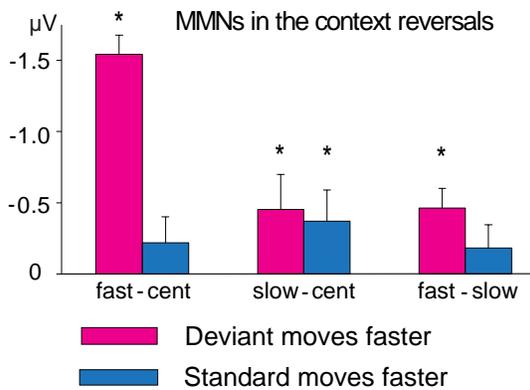


Fig. 4. Mean Fz MMN amplitudes for opposite oddball contexts. Asterisks indicate significant MMNs ( $p < 0.05$ ).

terms of sound velocities. The three standard-deviant configurations that yielded the largest MMNs (Fast/cent, Fast/slow and Slow/cent) may be regarded as velocity increments (as the deviants moved faster than the standards) and the other three (Cent/slow, Cent/fast and Slow/fast) as velocity decrements. The effect of configuration reversal on the MMN amplitude can be attributed to the previously described effect of the direction of deviance for duration MMN [1, 7, 8, 10] and for frequency MMN [4, 5, 8]. According to these findings, the amplitude of MMN elicited by an increment in certain acoustical dimension (increment MMN) may be

higher than that elicited by a decrement in the same dimension (decrement MMN). It can be argued that Fast/cent and Fast/slow MMNs were produced by velocity increments while the reversed combinations (Cent/fast and Slow/fast) represented velocity decrements, and therefore elicited lower MMNs. In the case of Slow/cent and Cent/slow MMNs, the magnitude of deviance increment/decrement ( $113^\circ/s$ ) was likely to be too low for the effect of the deviance direction to become apparent.

Further support for this interpretation is provided by considering repetitive stimulation with standards during an oddball paradigm as a prolonged exposure to adaptor sounds which may induce auditory motion aftereffects [2, 3, 6, 9]. Motion aftereffect dependence on the velocity may

lead to the context reversal effect also being dependent on stimulus velocity. Exposure to the fast standards may cause processes of selective adaptation of neural populations with wide spatial receptive fields tuned to various ITD values (including zero ITD) along with motion-sensitive units. Higher velocity of adaptor would result in stronger adaptation, which was probably reflected in the decrease of the standard ERPs elicited by fast stimulus in the current study. So, the presentation of the fast standards would have caused maximal motion aftereffects and reduced MMNs.

## Conclusions

The main finding of this study is that the hit rate and MMN amplitude were higher when the deviants moved faster than the standards. Preattentive discrimination of fast and slow sound motion and stationary sound sources indexed by MMN was highly dependent on the stimulus context. The contextual effects on active and passive discrimination of the moving sound stimuli manifested itself as the effect of deviance direction: the moving deviant stimuli were easier detected when they were embedded in slower contexts. MMN magnitude was more responsive to the velocity of sound motion than the hit rate and false alarm rate.

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## **THE VISUAL AND OLFACTORY SIGNS OF NEURODEGENERATIVE DISEASES**

Zamaro A.<sup>1</sup>, Stukach Yu.<sup>1</sup>, Panakhova E. N.<sup>2</sup>, Pashkevich S.<sup>1</sup>, Gashimova U.<sup>2</sup>, Kuznetsova T.<sup>1</sup>,  
Kulchitsky V.<sup>1</sup>

<sup>1</sup>*Interdepartmental Research Center for Artificial Intelligence, National Academy of Sciences, Minsk, Belarus;*

<sup>2</sup>*Institute of Physiology of National Academy of Sciences of Azerbaijan*  
*email: vladi@fizio.bas-net.by*

In experiments on Wistar rats (n = 8) the hypothesis is verified of the existence of a correlation between the development of neurodestructive processes in the brain and the appearance of symptoms in the early stages of lesions of various parts of the olfactory analyzer. The design work is based on the identification of the structural and functional markers of destructive phenomena in the brain after unilateral destruction of neurons in the anterior olfactory nucleus via the neurotoxin (150 µM L-glutamic acid, 100 nl). Local destruction of the anterior olfactory nucleus accompanied by diffuse destruction of cholinergic neurons in the neocortex and the emergence in the early postoperative period of impaired visual-spatial control of motor responses and memory processes. The model propose in the embodiment as early markers experimental analysis neurodestructive processes in the brain which are associated with impaired visual-spatial memory and reactions.

Keywords: visual reaction; destruction; anterior olfactory nucleus; cholinergic neurons of the cortex; neurodegenerative processes.

### **Introduction**

Every year more and more attention is paid to neurodegenerative processes, like as Alzheimer's disease, Parkinson's disease, Huntington's disease, Pick's disease [1-3]. They are characterized by slowly progressive loss of certain groups of nerve cells and increasing atrophy of the relevant brain and / or spinal cord. Such pathological processes are accompanied by the gradual weakening of the control of mental, somatic and visceral functions of the body. The threat lies for the person in an irreversible development of neurodegenerative processes. The plastic properties of the brain mask developing defects of the brain for a long time, but decompensation of central control of the functions in the organism occurs at a certain stage of development of the disease [1, 4-6]. Unfortunately, radical treatments for most neurodegenerative diseases are absent in the later stage of development of the pathological process. Currently, the pathological process can't be completely stopped or reversed. But symptomatic treatment is palliative, and often leads to side effects and the development of complications. Thus, the social and clinical significance of the problem is obvious.

The solution can be early diagnosis of pathological process when a certain part of neurons have already died, and the characteristic signs of the disease aren't observed. It's advisable to find these early signs of disease in experimental and applied research. Biological markers can help with the diagnosis of latent neurodegenerative process, for example, in the development of autoimmune diseases of the brain [3]. Early diagnosis can prevent the progression of the disease at an early stage.

The significance of the olfactory analyzer disputed poorly for the formation of cognitive function in the conjunction with a new cortex. The connection is known between the functional state of the olfactory analyzer and the intensity of apoptotic processes in the subcortical regions of the brain (the development of Parkinson's disease), or in the frontal regions of the brain and the hippocampus

(Alzheimer's disease) [4]. And the change in the perception of the light system is one of recognized marker of Alzheimer's disease.

The destruction of the relationship between the olfactory analyzer and other parts of the brain became the aim of this research.

Hypothesis is based on the well-known postulates on the relationship of various analyzers. There is a connection between the visual and olfactory analyzers. The violation of this communication affects cognitive functions and alters the behavior.

### **Methods and Design.**

In experiments the Wistar's line rats (n=8) were used with weighing 210-250g. All animals were randomly divided into two groups. The animals from group A (n = 4) were given an injection of anesthesia (ketamine-acepromazine-xylazine as 55.6, 5.5, and 1.1 respectively, ip.). The animals from group B (n = 4) underwent anesthesia and craniotomy. Anesthetized animals were fixed in the stereotaxy and a burr hole was modeled with using boron-creating machine (1.5 mm lateral to the midline, 3.2mm caudal to bregma). Chemical destruction of the anterior olfactory nucleus (AON) was conducted with using Hamilton syringe to a depth of 7.8 mm from the surface of the brain injected 100 nl solution of 150  $\mu$ M L-glutamic acid. Thereafter, the soft tissues were sutured. The olfactory test reveals olfactory threshold of rats at different stages of the experiment [5]. The olfactory test was performed as well as 1, 2, 5, 7 days after destruction AON. A combination of attractor (sunflower oil) and retractor (cinnamon essential oil at different concentrations) was used. 7 samples were used in the test: I - pure sunflower oil; II – 0.005 ml of essential oil to 4.995 ml of sunflower oil; III – 0.025 ml of essential oil to 4.975 ml of sunflower oil; IV – 0.05 ml of essential oil of 4.95 ml of sunflower oil; V – 0.25 ml of essential oil of cinnamon by 4.75 mL of sunflower oil; VI – 0.5 ml of essential oil of cinnamon 4.5 ml sunflower oil; VII - pure essential oil of cinnamon.

In the process of testing solutions were used with increasing concentrations of cinnamon essential oil. For the experiment the rats were placed in a clean plastic box with a ceramic plate, and odor (at first- 10 minutes and a subsequent - 2 minutes) Then, a piece of filter paper (with 3x4 cm size) impregnated with oil solution was placed on a ceramic plate. The stopwatch was stopped when the rat began to lick or chew the paper. Thereafter the bait was removed and the new piece of paper was placed with the more concentrated solution of cinnamon essential oil. If the animal sniffed the bait but didn't lick for 3 minutes, more concentrated sample wasn't offered. The test is completed. Both groups of rats were tested in the simplified water Morris maze (length 70 cm, width 50 cm, height 40 cm) [6]. A circular platform was located in a corner (10 cm in diameter, 1.5-2 cm over the water) with a water temperature of 28-30°C. The training was conducted before operation for two days. Rat was taken from the base of the tail and was lowered to the opposite corner of the platform. This rat could freely explore the space. The stopwatch was stopped when the rat climbed on the platform, after which it was allowed to stay on for 20 seconds. Each animal were given 5 attempts at intervals of 60 seconds. Test in simplified Morris maze was performed on the first and the fifth day after operation. This platform has been hidden under water for 1.5-2.0 cm. The animals were allowed one attempt to find the platform, and measured the time of the detection. On the seventh day after surgery the task of finding the platform was complicated. The start point was modified to the other corner. Other details were unchanged.

Distribution of cells containing acetylcholinesterase in cerebral cortex was performed using histochemical method. The mean and the standard error of the mean (SEM) were calculated according to the results of the olfactory and swimming tests.

## Results and Discussion.

The obtained data in the olfactory test represent the following results. The means weren't statistically different before and after the «sham» operation in group A ( $3.75 \pm 1.03$  and  $4.0 \pm 1.15$ , respectively). Number of positive samples reacting with them (licking or biting paper) grew on the second day after the chemical destruction of the olfactory tract pathways ( $6.75 \pm 0.25$ ) compared with the number of positive samples before surgery ( $3.75 \pm 0.65$ ) in Group B. Thus, in group B, three rats of the four showed positive reactions to the paper, soaked in pure essential oils of cinnamon, on the second day after the operation. Thus, even a unilateral violation of the flow of signals from the olfactory bulb cells to the structures of the olfactory cortex is accompanied by violation of the perception of odors and control of animal behavior.

Morris maze testing with clear water showed that time for searching the platform has increased on the second day after surgery ( $21.75 \pm 11.43$  s) unlike before the destruction of the olfactory tract area ( $6.50 \pm 1.19$  s) of animals in the group B. Time for the search platform was  $12.50 \pm 3.80$  s on the fifth day after the operation in Group B, and it was also higher by preoperative time. In group A (non-destructive) search time amounted to  $6.00 \pm 0.91$  s to operational procedures (anesthesia),  $5.25 \pm 1.03$  with on the second day and  $7.50 \pm 1.04$  with on the fifth day after the procedure. On the 7th day after the operation test was carried out in a simplified maze Morris with colored water (with milk) and changing the position of the starting point. The time to find the platform increased ( $16.25 \pm 4.29$  in Group A, a, c  $9.25 \pm 2.07$  in the group B) unlike preoperative levels ( $6.00 \pm 0.91$  in Group A to, with  $6.50 \pm 1.19$  in Group B). The explanation of this effect requires further experiments.

There were several destructive processes in organelles of cells containing acetylcholinesterase in an analysis of slices of the cerebral cortex via histochemical methods. Sharp decrease of stained cells amount in the hemisphere at the side of chemical destruction of anterior olfactory nucleus was established. Defragmented neurons and their processes were found in the frontal and occipital regions of the brain slices after staining for acetylcholinesterase.

Thus, the experimental unilateral deafferentation of olfactory analyzer in the system at the level of the relay structures of the brain is accompanied by violation of spatio-visual orientation of the animals and the emergence of new crust in nerve and glial cells destroyed organelles containing acetylcholinesterase. The destruction of cholinergic neurons is one of the hallmarks of Alzheimer's disease and other neurodestructive processes. Consequently, there is established the relationship between the structural markers of destructive processes in the brain and the functional markers of developing diseases of higher cortical functions.

## Conclusions

1. Violation of the transmission signals from the olfactory bulb to other parts of the brain after the unilateral destruction of signaling is accompanied by increasing in olfactory threshold, and, as a consequence, reducing of olfactory sensitivity.
2. The visual-spatial orientation of the rats is broken after this the destruction of the anterior olfactory nucleus in the Water Morris test.
3. Violation of olfactory and visual-spatial orientation of the rats after unilateral destruction cells from the anterior olfactory nucleus is associated with the destructive processes in the frontal regions of the brain, especially in the cells and their processes which are containing acetylcholinesterase.

4. These results carefully draw an analogy between the destructive events that occur at the level of the olfactory and visual systems, the processes in the frontal cortex. This processes can be associated with processes in Alzheimer's disease.

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## Neurobiological mechanisms of social punishment

Zinchenko O. O.<sup>1</sup>, Klucharev V. A.<sup>1</sup>

<sup>1</sup> Centre for Cognition and Decsion Making, Department of Psychology, National Research University Higher School of Economics, Moscow, Russia

*email: ozinchenko@hse.ru*

Human societies crucially depend on social norms that specify appropriate actions in various situation. The effect of norms on collective behavior can break down if norm violations are not sanctioned. Social punishment is a form of behavior to enforce social norm compliance that relies on two key brain region: the “mentalizing network” (right temporo-parietal junction – rTPJ) evaluating individual responsibility and the “central-executive network” (right dorsolateral prefrontal cortex – rDLPFC) determining the final decision to punish norm violators. Here we further investigate the role of the brain network – rDLPFC-rTPJ – in third-party punishment. We used transcranial direct-current stimulation (tDCS) to disrupt the rDLPFC-rTPJ network of healthy subjects while they performed the Dictator Game. Our results suggests that the frequency of third-party punishment increased after the tDCS of the rDLPFC-rTPJ. To the best of our knowledge, this is the first study demonstrating the effect of simultaneous tDCS of the rDLPFC and rTPJ on the third-party punishment. We also show that personality traits modulate the effect of tDCS on the third-party punishment.

## Introduction

Cooperation in human societies is greatly affected by social norms. Furthermore, people are often willing to punish norm violations at a substantial personal cost [3]. People feel sympathy/empathy with the victim of norm violations [4] and experience strong negative affect that leads them to punish the offender [2]. The punishment could arise in two main forms: second-party punishment and third-party punishment. Second-party punishment is when you punish someone who defected you; third-party punishment is when you punish someone who defected someone. The third-party punishment is particularly puzzling for the theory of

cooperation because of a persistent people's tendency to punish unfair behavior, even though they do not perceive direct harm from the unfair person.

It has been shown that the right dorsolateral prefrontal cortex (DLPFC) is causally involved in decisions to enforce social norms [1, 6, 8]. For example, inhibition of the right DLPFC by repetitive transcranial magnetic stimulation (rTMS) increased the frequency of third-party punishment during the Dictator Game [6]. Anodal transcranial direct-current stimulation (tDCS) applied to the right DLPFC increased sanction-induced norm compliance (in trials when punishment is possible) and decreased sanction-independent norm compliance (in trials when no punishment is possible) [1]. Thus, the right DLPFC is important for a control of selfish motives. Importantly, social sanctions may also be driven by in-group favoritism and out-group hostility – by so-called “parochialism”. Baumgartner and colleagues [8] demonstrated that rTMS of the temporo-parietal junction (rTPJ) reduced “parochial” third-party punishment. Overall, the fMRI findings suggest that two brain regions play a key role in third-party decisions to punish unfair players: (a) the “mentalizing network” involved in the inference of mental states of other people and the “central-executive network” determining appropriate punishment of norm violators [5].

Here we test the hypothesis that a decision to punish in a third-party punishment paradigm depends on the activity of the entire rDLPFC-rTPJ network. We also measured personality traits, such as Interpersonal Reactivity Index [7, 9] and “Dirty Dozen” questionnaires [10,11], to uncover individual traits mediating of third-party punishment.

## Methods

We used offline 15-min tDCS to disrupt the rDLPFC-rTPJ network in healthy subjects while they performed the Dictator Game. We recruited sixteen native Russian subjects (9 females, mean age = 23±4) who participated in three experimental sessions with a one week break. The game was played by Player 1 (the dictator) and Player 2 (the recipient). Our participants were assigned to the role of a third party (Player 3): they observed monetary units (MU) distributed by Player 1. In an attempt to make the game more social photos of Player 1 and Player 2 were present on the screen during the task. The pictures of Players 1&2 were preselected and semi-randomised to keep facial features similar. Subjects were not informed that decisions of Players 1 were preprogramed.

Every round, Player 1 received an endowment of 40 MU and split them with Player 2 (40/0, 35/5, 30/10, etc.). Participants (Player 3) were endowed with 20 MU in each round, but could punish Player 1 by decreasing her payoff by 0-18 MU. Each MU was multiplied by 2 and deducted from the budget of Player 1. The instructions stated that participants are able to deduct MU from Player 1's budget to decrease her final outcome (1MU = 0.25 Russian rubles, the final budget was paid as an additional monetary bonus at the end of the experiment).

During three weekly sessions we applied tDCS (within-subject design) simultaneously to rDLPFC and rTPJ using one of three stimulation protocols: *Condition N1*, anodal tDCS of the right DLPFC and cathodal tDCS of the right TPJ; *Condition N2*, cathodal tDCS of the right DLPFC and anodal tDCS of the right TPJ; and *Condition N3*, a sham stimulation of the right DLPFC and TPJ. We counterbalanced tDCS stimulation conditions across subjects.

Additionally, we estimated the perspective-taking of the subjects by measuring their ability to make the inference of mental states of others, their emotional distress using Interpersonal Reactivity Index [7,9], machiavellianism and narcissism using Dirty Dozen Questionnaire [10,11].

## Results

Repeated-Measures ANOVA revealed a near-significant difference of third-party punishment in

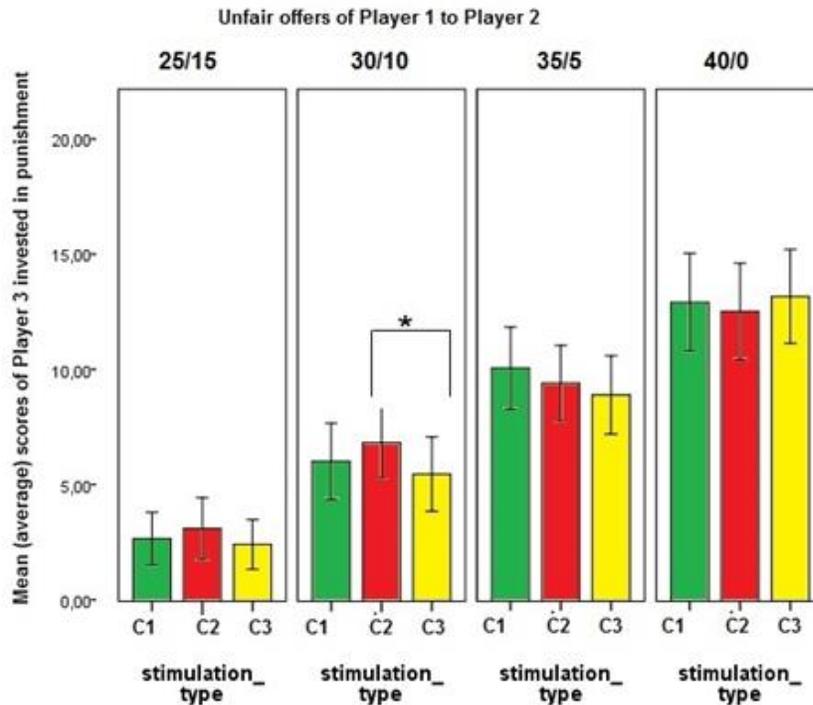


Fig.1. Mean (average) punishment (MU) used by Player 3 (participant) to punish Player 1 (the dictator) for unfair offers.

C1 – Condition 1, C2 – Condition 2, C3 – Condition 3.

Post-hoc analysis revealed significant increase of punishment of slightly unfair offers 30/10 under anodal rTPJ – cathodal rDLPFC tDCS (Condition 2) as compared to the control Condition 3 (\* $p < 0.05$ ).

*Conditions N1* and *Conditions N2* as compared to the control *Conditions N3*:  $F = 2.675$ ,  $p = .059$ . Importantly, when the individual level of perspective-taking was included to ANOVA as a covariate, the general effect of tDCS reached the level of statistical significance:  $F = 3,279$ ,  $p = .03$ . Post-hoc analysis revealed that the observed increase of the third-party punishment in *Condition N2* is significant only for trials with the slightly unfair Player 1's offer – 30/10 ( $p = .02$ , Bonferroni corrected) – *Condition N2*\*offer (Figure 1).

### Conclusion

To the best of our knowledge, this is the first study demonstrating the effect of the simultaneous tDCS of the rDLPFC and rTPJ on the frequency of third-party punishment during Dictator Game. Our results show that the effect of tDCS third-party punishment of norm violators is modulated by individual differences in perspective-taking – the reported tendency to spontaneously adopt the psychological point of view of others in everyday life.

### Acknowledgements

The study is funded by the Russian Academic Excellence Project '5-100'.

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# Abstracts of the Symposium

## **Precedence Effect for Moving Sounds in the Horizontal Plane**

Agaeva M. Yu., Petropavlovskaja E. A.  
I.P. Pavlov Institute of Physiology, St.Petersburg, Russia

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 two moving signals. The first signal was the direct signal (lead) and the other was the delayed (lag). Sound source movement was created by successive switching of 10 loudspeakers. The path length of the lead and lag movement was  $34^{\circ}$ . The lead moved leftward in the right hemisphere (from  $34^{\circ}$  to  $0^{\circ}$ ) and the lag moved leftward in the left hemisphere (from  $-52^{\circ}$  to  $-86^{\circ}$ ). The duration of the lead and the lag was 1s. Lead-lag delays ranged from 1 to 40 ms (onset-to-onset interval). The listeners indicated the location of the beginning and the end of the lag. The results suggest that at short delays (up to 18 ms), the lead strongly dominates the localization of the lag signal. All listeners indicated that they perceived one location near the lead, regardless of instructions. At the longest delays two distinct sounds were perceived. The average value of the echo thresholds in eight subjects was 9.6 ms.

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## **Localization of the Lagged Moving Sound in the Precedence Effect Paradigm**

Agaeva M. Yu., Petropavlovskaja E. A.  
I.P. Pavlov Institute of Physiology, St.Petersburg, Russia

In reverberant environment, humans are able to localize sound source. The auditory system assigns greater weight to the direct sound (lead) than to the later-arriving sound (lag). In this study, sound localization was studied for moving lag in the lead-lag paradigm with stationary lead, compared to the localization of the single moving sound. Lead-lag delays ranged from 1 to 40 ms. Testing was conducted in the free field. The lead was located at azimuth  $15^{\circ}$  (in the right hemisphere). The lag moved from the lead in the left hemisphere (from  $-52^{\circ}$  to  $-86^{\circ}$ ). Subjects were asked to point at the beginning and the end of the lag motion trajectory. Results indicate that at short delays (up to 9 ms) the lead strongly dominates sound localization, suggesting precedence effect. At delays from 9 to 18 ms subjects pointed either to the lead or to the lag. At longer delays all listeners perceived two sounds and pointed only the lag trajectory. The length of the lag motion trajectory decreased relative the single stimulus, suggesting the masking effect. Perceived starting point shifted toward the left ear depending on the delay, which means that the masking mainly affected the initial part of the trajectory.

Supported by grant RFBR 14-04-01282.

## **Laboratory of light-matter coupling in nanostructures, ITMO University, Saint Petersburg**

Alodjants A. P.  
Laboratory of light-matter coupling in nanostructures, ITMO University, Saint Petersburg

In my talk I will review current quantum technologies directed to creation of long lived macroscopic (coherent) states in various quantum physical systems which are convenient lasers, Bose-Einstein condensates occurring in atoms and in solid state physical systems. The

"Schrodinger cat" and Einstein-Podolsky-Rosen paradoxes are discussed in the framework of creation of entangled states between such a systems and quantum states of consciousness relevant to observer. Some experimental possibilities for verification by using quantum biology methods are discussed as well.

Keywords: coherent states, Bose-Einstein condensates, Schrodinger cat, quantum consciousness

### **Optical tissue clearing as a method to assess prenatal organization of human cortical plate in three dimensions.**

Andreeva D. D., Zykin P. A.

Saint Petersburg State University, St. Petersburg, Russia

Optical tissue clearing as a method to assess prenatal organization of human cortical plate in three dimensions.

The marginal zone plays an important role in the corticogenesis, including secreting of reelin by Cajal-Retzius cells (CRC). There is still a controversy about the number of CRC morphotypes present in the cortical plate. Recent publications propose that diversity of morphotypes could be explained by simple difference in the cutting plane. To confirm this idea we need to model CRC with all it's processes which stretch up to 0,5 mm. Such thick slices possesses a challenge to both immunohistochemistry (IHC) and microscopy.

Recently two optical clearing methods compatible with multiple rounds of immunofluorescence staining are appeared - CLARITY and SWITCH. CLARITY is based on protein cross-linking with acrylamide hydrogel followed by selective lipids removal. It provides good antibody penetration for IHC and less light scattering for thick sections (>0.5 mm) and even tissue blocks. SWITCH is a newer method based on glutaraldehyde cross-linking with proteins providing even better antibody penetration. Visualization of such thick sections could be made on the existing two-photon microscope or on specialized selected-plane illumination microscope.

Thus, CLARITY and SWITCH are perspective methods for total Cajal-Retzius cell reconstruction.

### **Functional human brain mapping as a basement for some neurointerfaces.**

Blagovechensky E. D.

Centre for Cognition and Decision Making, National Research University Higher School of Economics, Moscow, Russia; Laboratory of Neuroscience and Molecular Pharmacology, Institute of Translational Biomedicine, Saint Petersburg State University, Russian Federation

We are trying to connect special activity of the brain area with the external action and predict it. This is the basement of some popular types of the brain-computer interfaces (BCI). But the question: do we have stability in the brain to use it as a driven signal for neurointerfaces? To check that one can use TMS as a probe for stable response for stable activation of the neuronal populations. But the result shows the high variability. Also the state of the brain can be modulated by external environment – for example by the mirror neurons system. Conclusions: One of the problems with BCI based on the functional human brain mapping is high variability of the brain activity even in very specific brain areas.

## **Spectral and phase correlation of EEG bursts ensemble: wavelet analysis**

Bozhokin S. V., Suslova I. B.

Peter the Great Saint-Petersburg Polytechnic University

We modeled electroencephalogram (EEG) activity bursts as a superposition of elementary non-stationary signals. Using the technique of continuous wavelet transform (CWT) and spectral integrals analysis, we calculated a set of new quantitative parameters characterizing the time variation of spectral properties of each burst and the ensemble of bursts [1-3]. We developed a new algorithm to detect instantaneous phase correlation of nonstationary EEG signals from different brain leads. The method is based on the CWT with adaptive Morlet mother wavelet that allows the change of spectral and temporal resolution. We considered the difference of straightened phases of wavelet images as phase correlation indicator. The procedure does not require time averaging. We tested the approach by calculating phase correlation in time of two EEG signals. This approach can be effective in the coherent study of time-dependent processes in physics and biology, such as EEG waves propagating in the cerebral cortex, including phase correlation of EEG bursts, and evoked potentials arising in response to sensory stimulation.

Keywords: wavelet, brain activity bursts, instantaneous phase correlation

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## **Characteristics of visual processing in preschool children with typical and atypical development**

Cherenkova L. V., Sokolova L. V.

St. Petersburg National University, St. Petersburg, 199034 Russia

We investigated the specificity of functioning of the two visual processing channels – magno- and parvocellular- in solving the problem of recognition of visual objects in preschool children with typical and atypical development of 4-6 years.

In children with typical development of different age and sex were established age and gender differences in the processing within the magno- and parvocellular channels of visual system.

Reduced effectiveness of the magnocellular channel as the lower and the upper levels of the visual system was observed in all children with atypical development, regardless of the child's neurological status. However, the degree of weakening of the processing of visual information independent of the severity of the neurological disorders that were detected when comparing groups of children with different levels of general speech disorders.

Reduced effectiveness of the parvocellular channel on the lower and upper levels of the visual system was inherent only in children with autism spectrum disorder accompanied by mental retardation, and depended on the degree of autism spectrum disorders. Such deficit could determine a violation of setting mechanisms for processing information coming at parvocellular channels and mechanisms of integration of all the selected attributes of visual objects into a global image, resulting in a lack of ability to recognize visual objects, regardless of their transformations.

Keywords: visual perception, integral image, mental retardation, autism.

## **Biophysically detailed modeling of visual cortex in terms of neuronal populations**

Chizhov A. V.

Ioffe Institute, Saint-Petersburg, Russia

Primary vision is experimentally studied in slices and in vivo, by electrophysiological recordings and optical imaging. Description of the experimental results in the frames of a mathematical model is a challenging problem. We have developed an efficient mathematical model able to provide a biophysically-detailed description of the data in terms of activity of neuronal populations interacting within the primary visual cortex. The model considers as a single unit a population of regular or fast spiking Hodgkin-Huxley-like neurons of similar neurons receiving a common input and an individual noise. The dynamics of such statistical ensemble is quite precisely described by a conductance-based refractory density (CBRD) approach. Basing on CBRD, a complex model of a cortical network as a layered heterogeneous continuum has been constructed. The model reproduces a set of known experimental intracellular and optical recordings in the primary visual cortex of cats and monkeys. In particular, it reproduces the effects of orientation and direction tuning, sustained locking of a stimulus and apparent motion.

The work has been supported by the Russian Foundation for Basic Research with the grant 15-04-06234a

Keywords: visual cortex, population activity, mathematical model

## **Neural mechanisms of choice-induced preference change: EEG study**

Colosio M.<sup>1</sup>, Shestakova A. N.<sup>1</sup>, Nikulin V.<sup>1,2</sup>, Novikov N.<sup>1</sup> and Klucharev V. A.<sup>1</sup>

<sup>1</sup>Centre for Cognition and Decision Making, Department of Psychology, National Research University Higher School of Economics, Moscow, Russian Federation

<sup>2</sup>Neurophysics Group, Department of Neurology, Charité Universitätsmedizin Berlin, Campus Benjamin Franklin, Hindenburgdamm 30, Berlin, Germany

**Objective:** According to cognitive dissonance (CD) theory (Festinger, 1957), when a person has to select between two items that are equally attractive, the mere act of choosing one item induces a preference change. Therefore, the chosen item is evaluated more positively and the rejected item more negatively – this is so called a post-decisional re-evaluation of the alternatives. Recent neuroimaging studies suggested a critical role of the medial prefrontal cortex (mPFC) in postdecisional spreading of alternatives (see Izuma 2013, for a review). Here, we used electroencephalography (EEG) to further investigate the role of the mPFC in CD.

**Methods:** During an EEG session 45 right-handed hungry subjects performed a modified version of the free-choice paradigm (Izuma et al., 2010), in which subjects were initially asked to rate their preference for food items. Next, subjects made choices between pairs of foods which varied systematically so that choices were sometimes made between two equally preferred foods (Self-Difficult trials), and other times between a highly preferred food and an undesirable food (Self-Easy trial). Next, subjects were asked to rate the original set of food items again to detect post-decisional spreading of preferences. Subjects also participated in two control conditions (Computer trials, Post-ex choices). Besides, participants underwent the Eriksen Flanker task.

**Results:** Our behavioral result clearly demonstrated the post-decisional spreading of alternatives, i.e. items that were rejected during Self-Difficult trials were rated significantly more negatively than items rejected during Self-Easy trials. Importantly, event-related potentials (ERPs) and source localization analysis showed a stronger negative fronto-central ERP in Self-Difficult trials, similar to classic error-related negativity (ERN) component recorded during the Eriksen Flanker task.

Additionally, time-frequency analysis demonstrated a stronger enhancement of occipital theta activity and stronger alpha suppression during Self-Difficult trails than during Self-Easy trials.

Conclusion: ERN has been previously associated with incorrect responses and general performance monitoring mechanism (Young et al. 2004). Our results showed a similarity between CD-related ERP and ERN. Source analysis demonstrated that both CD-related ERP and ERN are generated within the mPFC. Altogether, our results strongly suggest that CD is reflected in the activity of the mPFC as a part of the general performance-monitoring circuitry.

This work was supported by Russian Science Foundation (Project 14-18-02522)

### **Signal Processing in MRI: new challenges with ultra-high field 7T scanners**

Costagli M., Invited

IMAGO7, Laboratory of Medical Physics and Biotechnologies for Magnetic Resonance, Stella Maris Hospital, Pisa, Italy

The first part of this lecture will review the basic principles of magnetic resonance (MR) and the wealth of different imaging contrasts that can be achieved to investigate, in vivo, the human brain anatomy and function. The impact of recently introduced MR systems operating at ultra-high magnetic field ( $\geq 7T$ ), with their advantages and their still open challenges, will also be described. The boost in signal-to-noise ratio (SNR) offered by MR systems operating at 7T and beyond comes, in fact, at a price: the use of higher radiofrequencies, hence shorter wavelengths, raises challenges of spatial homogeneity in the images, as well as issues related to specific absorption rate (SAR) and patient safety.

The second part of the lecture will focus on the vast diversity of signal/image processing and analysis techniques that are used in MRI, including parallel imaging, motion correction, tissue segmentation, and functional mapping. In particular, a wide range of experimental designs and statistical approaches for mapping the activity of the human brain in response to a particular task or during “resting state” will be described.

The last part of this lecture will present a few examples of image processing and analysis in experiments conducted on high field MR scanners.

### **Perception patterns of static and dynamic texts: An experimental study of Russian**

Dobrego A.; Petrova T.

Saint Petersburg State University, St.Petersburg, Russia

The present study is one of the first eye-tracking experiment on Russian language material, checking out if the text style is among the readability categories and if it influences the effect of reading perspective. Two text types were used: a static text (descriptive sentences) and a dynamic text (sequence of events following swiftly on one another). In Experiment participants (32 native speakers of Russian) read six texts of the same length written in a different style, presented randomly and retold them afterwards. The following measurements were considered: IA first fixation duration, IA dwell time. Retelling the texts was additionally used to collect data on text comprehension and accessibility. The readability of the texts was checked on the special website <http://ru.readability.io/>, where 5 readability formulas adapted for the Russian language were used. Findings demonstrated significant differences between perception of the texts of different types. The results indicate that there is a certain tendency to read a static text longer than dynamic.

Dynamic texts are easier to retell than static texts (significant differences in the length of the retellings and mentioning the key words). The results of checking the texts by readability formulas are correlated with eye tracking data and retellings.

The research was supported by grant № 14-18-02135 of Russian Science Foundation

Keywords: eye-tracking, readability, static and dynamic texts, Russian

### **Comparative analysis of visometry results obtained with optometric chart and image projector**

Doktorova T. A., Koskin S. A., Kovalskaya A. A.

Department of ophthalmology; S. M. Kirov Military Medical Academy, Saint-Petersburg

Visual acuity research is one of the major methods of visual functions estimation.

There are compared visometry results received by Golovin-Sivtsev chart and image projector at different distances using different optotypes.

70 people (140 eyes) aged 17-82 years ( $46,7 \pm 2,7$ ) participated in the research: 34 males and 36 females with the visual acuity 0,01-2,0. They were divided into three groups with different visual acuity: 1.0-2.0, 0.1-0.9 and 0.01-0.09. Letter optotypes and Landolt rings were demonstrated at standard conditions using distances 1.5, 3.0 and 5.0 m. The data were averaged and compared.

Significant deviations were observed even in the case of average indexes matching. The first group had statistically reliable differences, the second didn't have it and the third had overstatement of indicators at 1.5 and 3.0 m.

Conclusions: Visual acuity at different distances may depend on patient refraction. Equal distances using optometric charts and image projectors in different examination rooms recommended.

Keywords: Visual acuity, optometric charts, image projector

### **Development of modern two-photon microscope in use of neuroscience**

Doronin M., Popov A.

Institute of Neuroscience, Nizhny Novgorod State University, Nizhny Novgorod, Russia

Two-photon microscopy is one of the most useful methods for neuroscientists. This may be explained by the fact that this technique allows obtaining 3D images of tissues due to the laser focus change that is possible because of a substantially greater penetration depth on the main wavelength into biological tissues. Self-developed microscopy system provides a possibility to service it and modify the structure of the microscope depending on a highly specialized experimental design and scientific goals. Our article may be regarded as a quick reference for laboratory staff who are wishing to develop their own microscopy system for self-service, modernize the system and save the lab budget.

### **Simulation of upright body position in human on unstable support**

Dubovsky V. A., Rubakhova V. M., Savchenko V. V., Pashkevich S. G.

Joint Institute of Mechanical Engineering of the National Academy of Sciences of Belarus & Institute of Physiology of the National Academy of Sciences of Belarus

At the heart of the development of human locomotor functions methods and tools and their improvement in relation to such areas as medical rehabilitation, athletic training, professional selection and training of professionally important qualities of "man-machine" system operators,

underlies new knowledge about the neurophysiologic mechanisms of human locomotor control, which level is currently still not sufficiently high. In this respect, there is a need to construct mathematical models to investigate the various aspects of human motor control.

The report presents a model of human body upright position maintaining on stabilometrical platform with unstable footplate of the balancing type, based on the human body representation in the form of inverted pendulum, and neural structures of the central nervous system, stabilizing the upright position of the body - in the form of PID-controller with feedback body inversion from the upright position. Simulation of human upright body position maintaining on unstable stabilometrical plate was implemented in Matlab 7 using Simulink package. Check of goodness fit of the developed mathematical model to the real process of human upright position maintaining on an unstable supporting surface was carried out by comparing of the simulation results with the results of experimental study of the process of human upright position maintaining on the pilot stabilometric system sample of the balancing type. The comparison showed the qualitative similarity and quantitative proximity of simulation results and experimental data.

Keywords: "man-machine" system, stabilometrical platform, human locomotor control

### **Network connectivity in cryptogenic epilepsy**

Efimtsev A. Yu.<sup>1</sup>, Bazilevich S. N.<sup>3</sup>, Fokin V. A.<sup>1</sup>, Sokolov A. V.<sup>1</sup>, Trufanov G. E.<sup>1</sup>, Harauzov A. K.<sup>2</sup>, Shelepin Yu. E.<sup>2</sup>, Vasiljev P. P.<sup>2</sup>

<sup>1</sup> North-West Federal Medical Research Centre n.a. V.A. Almazov, Saint-Petersburg

<sup>2</sup> Pavlov Institute of Physiology Russian Academy of Sciences, Saint-Petersburg

<sup>3</sup> Military Medical Academy n.a. S.M. Kirov, Saint-Petersburg

atralf@mail.ru, falcon.and@mail.ru

**Introduction.** Resting state functional MRI offers a unique information, allowing to define functional processes, that don't depend on execution of any task and take place in a non-working brain.

The primary purpose of this study was to find out if any changes of brain regions functional interaction present in patients with cryptogenic temporal lobe epilepsy during seizure-free period. **Materials and Methods.** 30 patients with epilepsy (20 men, 10 women) and 17 healthy controls (10 men, 7 women) underwent magnetic resonance imaging on 3.0T MR scanner. All patients have had different cognitive complaints even in seizure-free periods. The illness duration was 3 to 6 years and Middle age – 25 years. The study included clinical-laboratory tests, EEG and magnetic resonance imaging (resting-state fMRI). For statistical analysis we applied a toolbox for SPM – CONN – which is used to establish functional connectivity of a human brain. We used seed-driven analysis.

**Results.** The result of ROI to ROI analyses depicts presence of functional connections between different brain regions. We've choose Medial Prefrontal Cortex as a seed ROI, because it is considered to be a part of Default Mode Network. DMN is known to be one of main resting state networks. MPFC is normally linked with most general functional brain areas.

The strength of FCs correlates with spot size. There are stronger positive FC with Posterior Cingulum, mentioned above, including BA23, BA31 with left hemisphere accent. Taking into consideration that all patients had seizure activity focus in left Temporal Lobe, you can notice weaker negative FC in general, absence of negative FC in Primary Somatosensory (BA2), Primary Auditory Cortex (BA.42-R), Insular Cortex (BA.13-L), Fusiform gyrus (BA.37-L). Weaker positive FC with Anterior prefrontal Cortex (BA10) and Orbitofrontal Area (BA11) in right

hemisphere, which belong to association cortex, and may result in cognitive, behavioral, and emotional consequences arising. Right Inferior Parietal Lobe, Right Lateral Parietal Cortex connections are weaker too. Note less significant connections with Temporal Areas (Inferior and Middle Temporal gyri) in patient group.

Conclusions. 1. Talking about pathogenesis of cryptogenic epilepsy, this pattern of activity may suggest that these two systems operate in an opposing mode in the human brain. Taking into attention weakened influence of right hemisphere parietal and frontal structures (these are sort of brake-system of the brain) and strengthen influence of Posterior Cingulum in left hemisphere, we may hypothesize about brain activity disbalance, and it results in uncontrolled seizure-distribution. 2. Epilepsy is a symptom rather than the cause of brain dysfunction. Our small research showed the evidence of functional connections disbalance between frontal lobes structures exactly and other regions in general. And it correlates well with presence of cognitive problems in patients. Frontal cortex connectome is only a part (big one though) of global connectivity, which has to be explored in a large population of each subtype of epilepsy to establish general patterns of illness manifestation. So the trigger, starting seizure in patients with CGE, may be not an exact structure but a whole complex system of connections which does not function properly.

Supported by Russian Science Foundation (№14-15-00918).

### **Virtual technologies in medical visualization.**

Fokin V. A., Efimtsev A. Yu.

North-West Federal Medical Research Centre n.a. V.A. Almazov, Saint-Petersburg

Assessment of visual analyzer functional state is important for practical medicine. During examination of visual acuity and visual fields a lot of significant difficulties may occur. Methods and modalities used for conventional assessment are subjective and based on patient's answers which do not always reflect the real condition of visual analyzer. In this article the modern conceptions of objective assessment of visual analyzer functional state using functional magnetic resonance imaging are regarded. It was found that the performance of functional magnetic resonance imaging in various pathological conditions, allows not only to assess the organization and functional specialization of the visual cortex of the brain, but also to draw conclusions about the relationship between the areas of the visual cortex and specific cognitive functions. However, functional magnetic resonance imaging does not allow determining the cortical mechanisms at the level of individual neurons. Now comparative studies conducted in healthy volunteers and patients with pathological changes help to judge the functional organization of the cerebral cortex. In general, functional magnetic resonance imaging is an objective, safe and non-invasive method of modern neurovisualization and it can be successfully used in clinical ophthalmology. Supported by Russian Science Foundation (№14-15-00918).

## **Approaches to the development of automatic segmentation method MRI-images**

Frolova E.

St.Petersburg National Research University of Information Technologies, Mechanics and Optics

This article deals with the problem of distinguishing the boundaries of various structures at postprocessing of biomedical images. Approaches to the development of automatic segmentation methods for a variety of structural and functional studies of the brain. Particular attention is paid to algorithms used in real time for image segmentation of magnetic resonance imaging. We describe the most common methods of segmentation of MRI images, different accuracy, complexity, and other parameters.

## **Evaluation of emotional expressions viewers**

Golubov A.

St.Petersburg State University of Film and Television

With the evolution of television and Internet began to appear more and more audiovisual information is available to the end user. In the modern world of information overload, people do not have time to perform the whole flow, to highlight relevant and interesting content for yourself. Thus, systematic semantic metadata provide valuable information to the user. They can allow him to choose a program according to the nature of the emotional impact on the person that will interest people from his group. The aim of this work is to study the emotional expression of the user when viewing audiovisual programs, and development of a method for the automatic creation of such responses for the enrichment of semantic metadata.

## **MEG correlates of internalization of social influence.**

Gorin A.<sup>1</sup>, Zubarev I.<sup>3</sup>, Shestakova A. N.<sup>1</sup>, Ossadtchi A.<sup>1,2</sup> and Klucharev V. A.<sup>1</sup>

<sup>1</sup>Centre for Cognition and Decision Making, National Research University Higher School of Economics, Russian Federation.

<sup>2</sup>Laboratory of Control of Complex Systems, Institute of problems of mechanical engineering, Russian Academy of Sciences, St. Petersburg, Russian Federation

<sup>3</sup>Department of Neuroscience and Biomedical Engineering, Aalto University, Espoo, Finland

Social psychology has robustly demonstrated the strong social influence of group opinions on those of individuals. Previously, it was difficult to distinguish a true change of opinion evoked by social influence from mere public compliance. A recent fMRI study (Zaki et al., 2011) suggested that social conformity indeed changes subjective values as indicated by long-lasting changes of the activity in the orbitofrontal cortex and striatum (Zaki et al., 2011). In the present study, we used a paradigm in which participants' initial judgments about the trustworthiness of faces were open to the social influence of group opinion (Campbell-Meiklejohn et al., 2012). Participants rated the trustworthiness of faces, and, after each rating, they were informed of the "average group rating" assigned to the face by a large group of people. The MEG signal was recorded with a 306-channel Elekta Neuromag system (n = 15) 30 min after the exposure to the group (normative) opinion.

We compared evoked responses to faces that were previously rated similarly both by a subject and a group (no-conflict trials) with evoked responses to faces that were rated differently (conflict trials). In the sensor space, we found a significant difference at the centroparietal sites: a cluster-

corrected permutation test both for magnetometers ( $p = 0.028$ ) and gradiometers ( $p = 0.002$ ). Source analysis demonstrated the significant difference between conflict and no-conflict trials bilaterally in the posterior medial cortex: left precuneus:  $p = 0.03$ ; right precuneus:  $p = 0.01$ . Our MEG results suggest that activity of the precuneus encodes long-lasting effects of social influence. This study was funded by the Russian Academic Excellence Project '5-100'.

### **Motion performance of sound images with various rhythmic structures**

Gvozdeva A. P., Andreeva I. G.

Sechenov Institute of Evolutionary Physiology and Biochemistry RAS

The sound of the footsteps of man and animals, communication signals including speech have an interrupted quasi-periodic structure, but the study of their perception focuses on continuous sound images. The goals of the present study are to 1) determine the perceptual boundary between continuous and interrupted motion for various rhythms; 2) investigate the auditory adaptation to two types of motion. The monotonic increase in the thresholds of perception of continuous and interrupted motion in the period of rhythmic structure were revealed, the thresholds for the pause between the noise bursts reduced with increase in their duration in range of 5 to 100 ms. With a minimum sound duration that is necessary to determine the direction of motion, the judgment on sound motion continuity was available. After the adaptation to the continuous approach of sound images an auditory aftereffect was observed, which is manifested in the judgments on a continuously moving sound images, and after the adaptation to the interrupted approach the aftereffect was received only for interrupted moving sound images. In accordance with hypothesis about the mechanisms of auditory motion aftereffects, it may indicate the presence of neural structures selectively responsive to the movement of a certain quality.

The work is supported by RFBR (grant № 15-04-02816).

Keywords: motion perception, spatial hearing, psychophysics

### **Approaches to the development of human brain mapping methods.**

Kiryackova T.

St.Petersburg National Research University of Information Technologies, Mechanics and Optics

Работа посвящена картированию анатомических структур головного мозга человека на основе данных нейровизуализации, что является важной и значимой проблемой для понимания принципов функционирования головного мозга. Картирование головного мозга играет ключевую роль в изучении фундаментальных механизмов работы мозга и когнитивных функций в норме и патологии и относится к группе задач, решаемых в области приоритетного направления «Нейротехнологии и когнитивные исследования».

Keywords: Картирование головного мозга, МРТ, нейротехнологии, атлас, карта.

## **Acoustic stimuli duration and the development of muscle fatigue**

Knyazeva V., Aleksandrov A. A.

Saint Petersburg State University, St.Petersburg, Russia

In the present study we examined the effect of acoustic stimuli recognition task in the oddball paradigm (related and unrelated to mismatch negativity generation) on the fatigue development. It was shown previously that short stimuli did not induce mismatch negativity but can be discriminated efficiently in the active oddball paradigm. Our experiment consisted of four experimental conditions: the simple reaction task and the stimuli recognition task (oddball paradigm) of 50 ms stimuli and simple reaction task and oddball paradigm of 15 ms stimuli. In each condition, a participant responded to each target acoustic stimulus by squeezing a handgrip dynamometer. We found the significantly higher rates of fatigue development in the 15 ms stimuli simple reaction task and in both oddball paradigms compared to the 50 ms stimuli simple reaction task. Our results demonstrated that the fatigue development was enhanced related to the voluntary (15 ms stimuli simple reaction task and 15 ms stimuli oddball paradigm) and involuntary (50 ms stimuli oddball paradigm) attention activation compared to the paradigm with minimal attention attraction (50 ms stimuli simple reaction task).

The work was supported by the Russian Foundation for Humanities (project # 15-06-10806).

Keywords: mismatch negativity, muscle fatigue, oddball paradigm, attention

## **Insect models of higher vertebrates behavior**

Knyazev A. N., Shchekanov E. E.

Sechenov Institute of Evolutionary Physiology and Biochemistry, Russian Academy of Sciences, St. Petersburg, Russia

How are behavioral mechanisms working? The answer is impossible without analyzing the operation of “sensory input”. Many such data were gathered on insects regarding visual, chemical and acoustic communication. Unlike previous studies traditionally performed on separate sensory organs, we have applied an integral approach to explore the auditory system of insects (crickets). The goal was to investigate the relationship of neural and hormonal regulation of interaction of distant mechanoreceptor systems (DMRS) - the cercal and tympanal ones - within an integer sensory complex. A working hypothesis of “dynamic neuroendocrine integration” was formulated which describes probable mechanisms of DMRS complex operation, character and change of interrelationships of evolutionary “young” and “old” DMRS with integrative systems, dynamics of regulation of these interrelationships during acoustic communication in different periods of male and female ontogeny, the role of neural and endocrine regulation in these processes. It was shown that to perceive sounds insects use different elements of DMRS working in far and near sound field: tympanal organs to detect pressure waves and cercal organs to detect medium particles displacement. This hypothesis may hold true for insect sensory systems of other modalities and for sensory systems and communication mechanisms in chordates, including vertebrates and man.

## **Anisotropy in visual apparent motion**

Kolbanov V. V.

I. P. Pavlov First Medical University, St.Petersburg, Russia;

It is well known that two spatially separate light flashes with time delay may be visible as two simultaneous, alone moving and two successive objects.

Visual phenomenon of apparent motion ( $\beta$ -motion) was investigated monocularly and binocularly in 20 men. Distance between light sources was  $6^\circ$  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  $12-18^\circ$  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.

## **Review of data-smashing processing principle**

Konoplev Y. Y.

Human Brain Institute of the Russian Academy of Sciences

Data smashing method is based on the new principle for estimating the similarity between the sources of arbitrary data streams. Data smashing doesn't use any domain knowledge nor learning but the efficient is comparable to the specialized algorithms and heuristics devised by domain experts. The key point observation underlying the method is that all quantitative data streams have corresponding anti-streams, which in spite of being non-unique, are tied to the stream's unique statistical structure. The review is inspired by the I.Chattopadhyay and H. Lipson article "Data smashing: uncovering lurking order in data" published in "Interface" in 2014.

## **The study of market anomalies on the basis of the Efficient Market Hypothesis (EMH), and Fractal Market Hypothesis (FMH)**

Korableva O. N.<sup>1,2,3</sup>, Kalimullina O. V.<sup>3</sup>

<sup>1</sup>International Centre of Economics and Business Development; <sup>2</sup>St.Petersburg State Economic University; <sup>3</sup>Head of the International laboratory "Management, system modeling and information technologies in the economy" ITMO University St. Petersburg, Russian Federation

Irrational behavior of investors, which is not consistent with the traditional regulatory economic theory, is the result of the functioning of the neural networks of the brain. This irrational behavior is embodied in the so-called market anomalies ("calendar anomalies", "price anomalies", etc.). In turn, market anomalies confirm the fractal structure of financial markets and prove the existence of long-term memory of the financial markets. Since the markets have long-term memory, the past price behavior affects their future value. Most of the standard analysis of the market suggests that the market process is stochastic and price fluctuations in time in an efficient market are random and do not depend on events and news. Thereby for several years, a number of scientists as an

alternative to the efficient market hypothesis (EMH) support the fractal market hypothesis (FMH). EMH is imperfect because statistically deterministic linear systems provide a small degree of freedom, which significantly reduces their ability to adapt. The FMH financial markets can be viewed as analog to the neural networks of the brain, and fractals. Assuming that investors' decisions can be predicted based on the analysis of information impact on various neurons (fractals), the opening of the corresponding neural mechanism breaks new ground in understanding the nature of investors behavior in financial markets. In this regard, market anomalies should be the subject of further research based on a joint analysis of FMH and classical EMH.

Keywords: Efficient Market Hypothesis (EMH), Fractal Market Hypothesis (FMH), financial markets, market anomalies, neural networks

### **Vection illusion in virtual reality**

Kovalev A.

Lomonosov Moscow State University

Illusory self-motion (vection) describes the sensation of ego-motion induced by viewing moving stimuli in the absence of physical movement. This experiment investigated whether visually induced circular vection is changed if rotational velocities of 20, 40 or 60 o/s of stimuli are used. The vection illusion was evoked by the rotating opto-kinetic drum with black and white stripes in CAVE virtual reality system. 16 participants with healthy vestibular systems took part in this study. Several dependent measures were obtained: vection onset latencies, vection intensity, Simulator Sickness Questionnaire (SSQ) scores to evaluate motion sickness. Subjects passively observed rotating stimulation and pressed the button to indicate the vection appearance. We also used the eye tracking to examine parameters of opto-kinetic nystagmus (OKN) during vection perception. Results showed that onset latencies were significantly shorter, intensity ratings and SSQ scores were significantly higher for velocity of 60 o/s. We analyzed durations of OKN slow phases in period of 10 seconds after pressing a button. It was found that for velocity of 60 o/s slow phases were shorter in these periods compared to other time periods of eye movement recording. Herewith such significant differences were not revealed in dependent measures for other rotational velocities.

Keywords: vection, virtual reality, eye tracking

### **Objective visual acuity measurement by infrared videoculography**

Kovalskaya A. A., Koskin S. A., Shelepin Yu. E., Pronin S. V., Harauzov A. K., Vakhrameeva O. A.

Department of Ophthalmology, S. M. Kirov Military Medical Academy, Saint-Petersburg

We investigate efficacy of infrared videoculography to determine correlation between subjective and objective visual acuities. This study included 150 eyes of 75 volunteers. Objective visual acuity was defined by the smallest size stripe that evoked the optokinetic nystagmus (OKN) response using induction method, or by size of static image stopping OKN using suppression method. Eye movements were recorded by infrared videoculography. Subjects were grouped according to subjective visual acuity, and mean objective visual acuities were compared with those of the subjective one. There was a statistically significant correlation in group with subjective visual acuity from 0.01 to 0.1 between subjective and objective visual acuities, with both induction ( $R = 0.98$ ,  $P > 0.05$ ) and suppression ( $R = 0.87$ ,  $P > 0.05$ ) methods. There was also a statistically

significant correlation in group with subjective visual acuity from 0.2 to 1.0 between subjective and objective visual acuities, with both induction ( $R = 0.78$ ,  $P > 0.05$ ) and suppression ( $R = 0.96$ ,  $P > 0.05$ ) methods. The developed objective visometry method using infrared videooculography based on OKN induction is more informative for visual acuity in the range of 0.01 to 0.1 and based on OKN suppression – in range of from 0.2 to 1.0.

Keywords: optokinetic nystagmus, visual acuity, infrared videooculography, malingering

### **Interaction with a self-avatar while perceiving a mismatch between visual and proprioception information in virtual environments**

Krasilshchikova N. O., Menshikova G. Y.  
Lomonosov MSU

Various studies have proved that the consistency of information within modalities would affect Presence Effect in virtual environments (Slater, 2003). We investigated the subject's respond to a mismatch between visual and proprioception information while perceiving a self-avatar. The CAVE virtual reality system and the embodiment technology were used to create interaction with a self-avatar. The experiment consisted of two parts. In the first part the participants were asked to carry out body movements that were exactly copied by their own avatar displayed in front of them. The exercises should be repeated a number of times for 3 minutes to persuade the participants of being embodied in their own avatar. In the second part the participants could perceive the discrepancy between their own body movements and movements of the avatar. The physiological reactions (summary EMG activities) were recorded during the performance to measure the degree of interaction between the participant and her/his own avatar. The results showed that EMG activities were significantly higher while perceiving a mismatch between visual and proprioception information. Our data may be used to improve the measure of Presence Effect in virtual environments.

The study was funded by Russian Scientific Fund project № 15-18-00109.

Keywords: Virtual reality, Avatar, Presence Effect, Mismatch of sensory signals

### **Relationship between eye movements and the geometry of the fovea**

Lamminpiya A. M.<sup>1</sup>, Moiseenko G. A.<sup>1</sup>, Vakhrameeva O. A.<sup>1</sup>, Sukhinin M. V.<sup>2</sup>, Shelepin Yu. E.<sup>1</sup>

<sup>1</sup> Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia

<sup>2</sup> Kirov Military Medical Academy, St. Petersburg, Russia

The experiment involved 13 subjects with normal visual acuity. The average age of the participants was 30.2 years (from 21 to 35 years). To obtain the quantitative characteristics of the fovea structure, the method of optical coherence tomography of the retina, which is common in the ophthalmological practice, was applied. We used this method to determine the individual anatomic features of the retina structure, such as fovea and foveola diameter. Each subject was to read 15 brief text fragments, which were given using an LED monitor with a screen resolution of  $1920 \times 1080$ . During the investigation, eye movements and eye parameters were recorded by eye-tracking system.

We have shown that there is a relationship between individual characteristics of eye movements and the features of the shape of the foveolar area. There is a negative correlation between the fovea diameter and fixation duration. A larger fovea diameter seems to provide a wider capture of

fragments of image (a text in the case under consideration), which is directly reflected on the duration of fixation: in this case, the eye receives and transfers the necessary information on a stimulus in less time. Therefore, the fovea size also indirectly influences the number of characters captured by eye per fixation: a larger diameter skips more information. This make it possible to assess the influence of the geometry of the foveolar area on the parameters of eye movements, since the visual acuity is maximal due to the highest density of receptors here. Supported by Russian Science Foundation (№14-15-00918).

### **Design and analysis of large semantic networks.**

Lebedeva T., Kostyuchenko E.

Tomsk State University of Control Systems and Radioelectronics

A study of the possibility of subject area isolating, based on the connectivity of its concepts is presented. Graph of links between articles for "Space" category of russian wikipedia was created. Graph is presented as lists of nodes and links. Algorithm of finding areas of high connectivity in semantic networks:

- First node is the subject area;
- The program looks at the list of links and find all nodes associated with it;
- Determine the ratio of the link number for candidate to the subject area to the size of the subject area. If this ratio is greater than a set threshold, then the node candidate is added to the subject area, and the algorithm proceeds to the next candidate, in other case - is ignored;
- When all the candidates will be tested, the algorithm proceeds to remove the nodes of subject area whose connection ratio is less than the set threshold.

Algorithm is work before subject area stabilization.

The algorithm was approbated on test graphs. Testing on the real fragment of Wikipedia on the basis of three cycles showed the correctness of the algorithm. However, to obtain a final assessment there is need for its optimization for better speed.

The work is fulfilled with the support of the Ministry of Education and Science of the Russian Federation within the limits of the base part of the state task for TUSUR on 2015-2016 (the project No 3657).

Keywords: semantic network, graph, subject area

### **Mechanisms of Active and Passive Perception of 3D Virtual Environments**

Lesnikova A.<sup>1,2</sup>, Pronin S. V.<sup>2</sup>

<sup>1</sup>Saint Petersburg State University, <sup>2</sup>Pavlov's Institute of Physiology of the Russian Academy of Sciences

3D virtual environments are one of the most promising courses of the modern technological development. 3D virtual environments have moved beyond a recreational use and are gaining popularity among scientists, doctors, the military etc. One of the worst obstacles for their spreading and development is the fact that stereoscopic technologies cause visual fatigue and discomfort. The goal of our research was investigating visual fatigue during active and passive perception of 3D virtual environments. The aims of the research included investigating characteristics of the visual activity during active and passive perception of 3D virtual environments, measuring the

degree of visual fatigue after active and passive perception and inquiring into the factors of visual fatigue after the use of stereoscopic technologies. The methods we used included eye tracker measurements, a visual acuity test, a stereoscopic vision test and a written survey about subjective feeling of visual discomfort and fatigue.

During our research we found eye movement differences between active and passive perception of 3D virtual environments and measured differences between the stereoscopic depth before and after watching 3D content. We have made a number of important conclusions. First, strategies of eye movements are different for active and passive 3D perception. Second, both active and passive perception of 3D virtual environments increase stereoscopic depth perception. Third, the data we've got do not show a correlation between low binocular vision and difference in visual acuity between the left and the right eyes, on the one hand, and visual discomfort and eye fatigue, on the other.

One of the important results we got was understanding that the stereoscopic depth of vision had increased, not decreased, as it had been expected due to the visual fatigue, after 2 hours of 3D watching. We hypothesize that what we observed was a kind of eye training and the adaptation of the visual system to the mechanisms of 3D virtual technologies. Further research could shed light on the nature of the phenomenon we observed and could foster development of 3D virtual technologies that will be both safe and comfortable for the human eyes.

Keywords: virtual environments, 3D, eye fatigue

### **Eye-tracking's comparison research of planar and volumetric images' perception among art orientation's students**

Lomtatidze O., Alekseeva A., Kolezneva I.

Ural Federal University (UrFU), Ural state academy of architecture and arts (USAAA)

The purpose of this scientific research is to compare the features of planar and volumetric images' perception made by students from Academy of architecture and arts. Photos of the architectural model and the drawing of hall's space were used as stimulus. The assessment of visual perception of students was carried out by eye-tracking - SMIREN 500 in the Laboratory of psychophysiology and psychophysics, UrFU, on the sample of 21 students-architects. The thermal cards of perception were composed taking into account the duration and frequency of fixations on the allocated details of images. During the perception of both visual stimuli tested-persons are focused on the same objects, in spite of this, the structure of perception is differed. During the perception of the photo of the architectural model, the attention is concentrated on holistic objects. During the perception of the photo of drawing of hall's space, the attention is concentrated on lines and contours of objects, the attention zones are also going on lines of borders of space (joints of walls and a ceiling). The analysis of the obtained data of perception of planar and volumetric images allows assuming that students use two various strategy of perception of objects.

Keywords: Strategy of perception, Eye-tracking, Planar and volumetric images,

## **Eye movements during recognition of facial expression of contradictory photo portraits**

Luniakova E., Ganizada J.

Lomonosov Moscow State University

Recognition of facial expressions of normal and composite photo portraits was studied. Two images of the same person – one posing neutrality and the other displaying one of basic emotional expressions (anger, fear, disgust, happiness, or sadness) were combined to construct a composite photo. Eye region from one photo was pasted in the same place of the other photo. Three sets of images were used in experiment: “A” (normal photos), “B” (composite photos with neutral eyes on the emotional face), and “C” (composite photos with emotional eyes on the neutral face).

The results show no significant differences between images “A” and “B” in expression recognition and in proportion of fixations on the various internal parts of the faces, except fear expression. A fearful face with neutral eyes was not perceived as fearful; a rate of fixations on the eyes region increased. Facial expressions on images “C” were described as “concentration”, “contempt”, “distrust”, rarely as “neutral expression”, and never as the same basic emotions which were posed on the original photo portraits. Dwell time and fixation rate on eyes area increased, on the other internal parts of the face significantly decreased for all composite photos with emotional eyes on the neutral face.

Keywords: eye movements, facial expression recognition

## **An effect of the type of title on perception of photographs: An eye tracking study**

Luniakova E., Pakhomova O.

Lomonosov Moscow State University

An influence of preceding verbal information on eye movement’s parameters during the perception of photographs was studied.

24 images eliciting different emotions (12 pleasant and 12 unpleasant) – landscapes, still-lives and social scenes – were presented to 82 participants. Four types of titles were created for every photo. The titles differed in emotional tone (positive or negative) and semantic (abstract or specific). The specific title contained a noun naming one of the depicted objects in the image. A region of a picture where the object was located was set as target area of interests (AOI) in analysis. A number of fixations, total fixation’s duration in AOIs, a number of saccades and total saccades amplitude during perception of the photographs were analyzed.

The results show that participants tend to estimate images preceded by inconsistent titles (pleasant image with negative title and vice versa) as more neutral than preceded by coherent title or presented without any title. Total saccades amplitude during perception of the photos with inconsistent titles is longer. A number of fixations and total fixation’s duration in AOIs are significantly higher in “specific title” than in “abstract title” conditions. So, preceding title could affect oculomotor activity during image perception.

Keywords: picture perception, eye movements

## **The Speech Analysis Methods**

Lyakso E., Frolova O., Grigorev A., Sokolova V., Yarotskaya K., Sapojnikov A.  
Saint Petersburg State University, St.Petersburg, Russia

The production of spoken language involves three major levels of processing: conceptualization, formulation, and articulation. The level of articulation allows evaluating speech intelligibility, the emotional state of the speaker, identifies the speaker's voice, to reveal irregularities in the articulation in the oral cavity. Spectrographic method provides information about the vibrations of the vocal cords (fundamental frequency or pitch values) and articulation in the oral cavity (formants frequencies). The movements of articulation can be registration via articulogramma. At the same time this method quite complete to the healthy adults. Glottographic method is used for analysis of vocal folds vibration. The spectrographic method is non-invasive. This method could be taken in clinic and for child speech studies. For example: spectrographic analysis of early infants vocalizations reveals the combination of voice features specific for neurological disease: percent of noise spectrum in the vocalizations, duration of vocalizations and the pauses between the phonations, the pitch values and amplitude modulation coefficient. The vowels acoustic features - duration, pitch, formant frequencies and its amplitude, effect of coarticulation let us show the dynamics of child's articulation mastering. Such speech disorders as dysarthria require a special approach, but for non-specific speech disorders accompanying atypical development (ex. autism spectrum disorders - ASD) acoustic parameters which can form the basis of bio-markers for early diagnosis of ASD. Analysis of grammar and pragmatic of speech, electroencephalography, and EP are taken for consideration for asses of child's psychophysiological status and speech structures maturity. Complex analysis of child psychophysiological features and speech on different levels is important for early diagnosis of developmental risk.

The work was supported by RFBR (grants 16-06-00024a; 15-06-07852a).

## **Modeling convolutional neural network for text detection task**

Malakhova E. Yu., Shelepin Yu. E.  
Pavlov Institute of physiology, RAS

In recent psychophysiological studies natural stimuli like video or images are commonly used. While measuring and analyzing subject's reaction on the presented stimuli it is essential to pay attention to properties of natural images. Textual content in natural scenes can provide important information about environment for human subjects. Therefore posteriori or a priori analysis of stimuli can be useful for research purposes.

Recent most popular approaches for text detection on images include low-level feature processing, such as Stroke Width Transform and Optical character recognition, and higher level feature processing using Convolution Neural Networks (CNN). The image is often pre-processed with slicing window technique in order to obtain multiple subregions and pass them through the network. Here we propose a different approach for differentiation between text and non-text images and for text-heavy region detection. This model is implemented with a Convolutional Neural Network, which generates a saliency map based on probability of observing text in an image region. Then the candidate regions can be extracted to perform additional classification task and text recognition. We evaluate the proposed algorithm on a dataset of natural images in a variety of scenarios. Detection performance is compared to the existing state-of-the-art algorithms.

Supported by Russian Science Foundation (№14-15-00918).

Keywords: deep learning, cnn, text recognition, image processing

## **Training Deep Neural Network for Accurate Age and Gender Recognition on Small Set of Data**

Malashin R. O., Anisimov N. A.  
ITMO University, Vavilov State Optical Institute

Recent works have shown that deep convolutional neural networks (DCNN) trained on 26,000 images provide state-of-the-art solution for automatic age and gender recognition by means of image analysis. In this work we fine-tuned DCNN learned on ImageNet dataset and have achieved good accuracy using only 2000 training images. We show that further increase of size of training data will not give significant increase in recognition rate. We have studied several aspects of weights transferring, including neural network architectures and importance of usage of non-linear activation functions in fine-tuned layers. We argue that the results show that high-level features formed inside deep neural networks (that are learned on large amount of data) have good generalization capabilities in terms of object invariance.

Keywords: neural network, age, gender recognition

## **Postprocessing analysis of MRI.**

Marusina M., Krivykh A.  
ITMO University, St. Petersburg, Russia

One of the main problems within post processing of brain MRI images is the segmentation of different structures which provides the necessary data for structural and functional researches. Carried out the analysis of the different image processing algorithms and available software that capable to carry out automatic segmentation of brain structures. Presented segmentation results by using algorithms based on the method marker controlled watershed based on the method of thresholding the images and based on methods that use graph theory. Analyzed correctness of the applied methods of segmentation. Carried out the assessment of the possibility of creating fractal express-analysis for the presence of focal masses in the studied tissues and developed recommendations for its use.

## **Influence of lexical context on mismatch negativity elicited by pseudowords processing**

Memetova K., Aleksandrov A. A., Stankevich L.  
Saint Petersburg State University, St.Petersburg, Russia

The present study is designed to establish how lexical context influences the MMN latency and amplitude when the pseudowords are presented. The ERPs were recorded according to the multi-deviant passive odd-ball paradigm by using only pseudowords (control condition) or pseudowords and words with different lexical frequencies (lexical context). We found the generation of different MMN patterns when the same pseudoword was presented in different

contexts. The pseudoword presented in context with another pseudowords demonstrated the smaller amplitude and the bigger MMN latency. Whereas the same pseudoword presented in context with words led to the significantly enhanced amplitude and the decreased latency of MMN. It is supposed that the pseudoword presented in context with words is perceived as conceptually different stimulus leading to the significantly enhanced MMN.

Moreover, the hypothesis of lexical frequency influence on MMN has been supported. We found that the presentation of a high-frequency word led to the significantly more pronounced MMN response relative to a low-frequency one (Aleksandrov A.A. et al.). The high-frequency words also evoked the earlier response, indicating more rapid access to a frequently used lexical entry. We hypothesize that different amounts of activation depend on the words lexical representation strength.

The work was supported by the Russian Foundation for Humanities (project # 15-06-10806) Aleksandrov A.A., Memetova K.S., Stankevich L.N., Uplisova K.O. Lexical frequency influence on MMN: an ERP-study in Russian language. Rossiiskii fiziologicheskii zhurnal imeni I.M. Sechenova / Rossiiskaia akademiia nauk. 2016 (in press).

Keywords: ERP, pseudowords, words frequency, MMN.

### **Influence of image size on localization areas of decision-making in classification tasks**

Moiseenko G. A., Pronin S. V., Chikhman V. N., Shelepin Yu. E.

Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia

The aim of this study was to investigate how the images size effect on the decision-making areas localization in tasks of classification image of animate and inanimate nature.

The study involved 35 healthy volunteers between the ages of 22 to 35 years with normal or corrected to normal vision glasses. The method of cognitive evoked potentials was conducted two experiments. In the 1st series of experiments with a distance of 1.5 m from the subject's eyes to the monitor on the monitor screen were presented images of objects animate and inanimate nature, filtered at high and low spatial frequencies using wavelet filtering. In the 2nd series of experiments at the limit of resolution of the visual system from a distance of 5 m from the subject's eyes to the screen of the monitor subjects were presented not filtered images of objects animate and inanimate nature. In the 1st series of experiments, the angular size of the objects images on the screen - 3 ang. deg, in the 2nd series - 0.4 ang. deg. In both series of images is presented on the monitor binocular. The Instruction to subjects was to classify images to animate and inanimate objects. Time of images presentation was 100 ms with an interval of 1 second. Register evoked potentials was carried out by the scheme 10-20 with referential ear electrodes.

The role of regions in the temporal objects classification and confirmed their role in objects images recognition of invariant to their size.

Keywords: decision-making, classification images, images recognition, invariance

Supported by Russian Science Foundation (№14-15-00918).

### **The case 'automobile' in the logics of neurotechnologies**

Monakhov F.

Saint-Petersburg State University

A development of automobile industry provoked the massive changes in the lives of humans. In the course of a bit more than a century the automobile industry has become one of the leading branches of mechanic engineering. Since it has been hi-tech industry, the automobile industry provides impulses for the development of an industry of vehicle components, iron and non-ferrous industry, and of different industrial branches, such as chemical, electro-technical, glass, electronics, and light industries. At the same time, it provides the demand for the various research and opens the way for practical implementation of the newest technologies.

The emergence and expansion of the term automobility has become possible also because of the transformation of the comprehension of the concept of ‘corporality’. In the scopes of this term, the usage of every object or instrument, which augment perceptual, sensory, physical, physiological and other human capacities, are interpreted on the level of discursive practices as ‘supplementing’ the body. In the everyday life, drivers, pilots, and various operative specialists over some technical devices say that they ‘feel’ their machines, and even merge with it.

The development of the concept of corporality – undertaken by the eminent representatives of the French intellectual school, such as Michael Foucault, Roland Barthes, Maurice Merleau-Ponty, Gilles Deleuze, Jean-Luc Nancy – was problematized by the process of increasing intensity and complexity of the way of interactions of human with artificial objects and instruments, which has led to the new problem of some kind of hybrid systems, such as, for instance, the car-driver – which is considered by the modern sociologists as the hybrid manufacturing embracing the human knowledge, human will, and also cars, roads, and road signs.

The following task has become the strategic trend of modern automobile production – the creation of artificial systems of car driving, which uses the methods of processing diverse signals and information, including visual. All these allow sustaining the parameters of car moving actually without a driver. These are the sustaining of the given speed (cruise control), electronic stability program, the ensuing the safe distance from other members of the traffic, geolocation, etc. The usage of neurotechnologies opens a perspective of real embodiment of the concept of corporality.  
Keywords: Automobiles. Neural science.

## **Modern Education in the Context of Neurotechnologies**

Monakhov V., Orlov V.

Saint-Petersburg State University

The rising interest to the perspective opportunities of neurotechnologies – which usually signify the wide conglomerate of diverse technological solutions, all built on the basis of the principles of functioning of the neural system, – induce us to analyze and to reconsider the methods practiced within the systems of modern education.

The achievements in the fields of knowledge, which are connected to studying human as biological creature, propel us to elaborate a new understanding of interactions his biological and social factors that define the human nature and his behavioral algorithms. The progress of modern neuroscience and cognitive studies, dynamic growth of informational, transporting and other technologies change the qualitative characteristics of human environment in the most radical way. Besides, they form the new demands to the basic abilities, skills and habits, which human should develop in himself with the support of educational institutions. These institutions possess the vast set of instruments of the most modern educational technologies that could aid the process of re-educating modern human.

The current stage of the scientific and technological revolution that we are living in now can be described by the following characteristics, such as the lavish increase of the sizes of informational streams, the increasing speed of the informational flow, constant renewing of different forms of social communication, the increase of presence of the machines almost in all the fields of science and human activities, and the mammoth expansion of virtual reality. At the same time, the channeling structure of informational stream, which today’s human needs to comprehend, also undergoes changes. First of all, the informational stream is getting increased that comes in in the form of visual and audial signals; it is related to the development of multimedia sources of

informational transfer. As the result, the habits of analytical reading and writing undergoes the process of erosion, which demands for the universities to add special methodical events to their curriculums, which would effectively rectify this ‘disease’ that already reached the massive part among the graduates of modern schools.

Because of that, the interest of educational institutions to the achievements of neurophysiology – just as to the other fields of neurosciences and related technologies – becomes entirely understandable. In fact, this field of knowledge occupies more and more prominent place among human sciences. In turn, the representatives of neurosciences and cognitive studies would find much appealing for them in the modern educational systems, especially those that value the methods of natural teaching. These are, for instance, the system of liberal education – and the educational model of liberal arts & sciences.

Keywords: neurotechnologies. Liberal education. Human body

### **The impact of spatial-frequency filtering to recognize of stimuli in healthy subjects and patients with schizophrenia (psychophysical and electrophysiological methods of investigation).**

Murav'ova S.<sup>1</sup>, Moiseenko G. A.<sup>1</sup>, Pronina M.<sup>2</sup>, Pronin S. V.<sup>1</sup>, Shelepin E. Yu.<sup>1</sup>, Shelepin Yu. E.<sup>1</sup>

<sup>1</sup>Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia

<sup>2</sup>N.P. Bechtereva Institute of the Human Brain RAS, Saint-Petersburg,

These electrophysiological and psychophysical studies, we conducted on a group of healthy subjects 18-30 years old. The work consisted of 3 stages. The first stage: electrophysiological (measuring cognitive visual evoked potentials) and psychophysical research (measurement of contrast sensitivity) to spatial stimuli and images of objects that are processed using wavelet filters for the low and high spatial frequencies. The second stage was the impact on the visual system of subjects by presenting of virtual environment (10 stimulations). The task of the observers included a careful review of spatial images (stimulation of magno-system) and the individual objects on the monitor (stimulation of parvo-system). The third stage was the repeated measurement of cognitive visual evoked potentials and contrast sensitivity. The analysis of amplitude of the components of cognitive VEP and analysis of contrast sensitivity out before and after stimulation was conducted. We can conclude that in healthy subjects virtual environment improved the efficiency of magno- and parvo-system.

Supported by Russian Science Foundation (№14-15-00918).

Keywords: vision, cognitive visual evoked potentials, contrast sensitivity, magno- and parvo-system, virtual environment

### **Evaluation of deep features for global visual localization**

Nedoshivina L., Peterson M.

ITMO University

Visual localization is a crucial problem for mobile robots. Recent works on content-based image retrieval show that one can effectively match images using a global descriptor constructed on the base of convolutional neural network features. Here we evaluate this approach in application to the global localization problem, where a robot should determine its location by matching the current image of the environment with key frames in the map. Adjacent images in the set of key frames of the environment map has relatively low content variation, so it's interesting to examine the ability to construct distinguishable descriptors using deep features in such case.

We've also compared deep features based descriptors with more classic methods, such as aggregation of local features into the histogram of visual words. Conducted experiments have shown that descriptors on the base of deep features provide high matching success rate and is inferior to histograms of visual words with spatial pyramid matching kernel. Moreover, deep features based descriptors have shown greater resistance to occlusion and distortions, indicating its applicability to global visual localization.

Keywords: convolutional neural network, visual localization

### **Developing brain and hypoxia**

Otellin V. A., Invited

Pavlov Institute Physiology Russian Academy of Sciences (St. Petersburg)

The study of brain development, the formation of its structures and functions in ontogeny is dictated both by the logic of the development of basic research and clinical demands. Hypoxia different genesis and intensity is a frequent event in the ontogeny and can lead to the formation of pathology. This report will be given information about the brain responses of rats in the perinatal period, the effect of normobaric hypoxia (models mature and premature human pregnancy). The nature and severity of the structural changes to a large extent depend on the phase of brain development (critical periods of development), some morphogenetic processes. In the pre-implantation period of hypoxia causes the death of the embryo or the formation of deformities. In postimplantation period takes place the formation of abnormal structures of the brain, changing their architectonic and cellular composition that combines with disabilities in learning, motivation and emotional problems and pain sensitivity. The neonatal period in human and laboratory mammals characterized by ongoing processes of structural and functional development of the brain. Hypoxia at this time in the neocortex and hippocampus leads to a slowing of neuronal differentiation and synaptogenesis, selective death of pyramidal neurons, formation of protein-synthesizing apparatus of violations in all cell types. All of these disorders affect the structural and functional characteristics of the adult animal brain. Our findings open the way pharmacological correction.

The work is supported by grant number RNF 16-15-10272

### **To amygdalar control of perceptive function of visual system**

Panakhova E. N., Hashimova U. F., Rzayeva-Ismailova N. M.

Institute of Physiology named after Academician Abdulla Garayev, Baku, Azerbaijan

Intersystemal integration of Visual System (VS) with emosiogenic brain structions which perceptive and cognitive processes are based on, are the important link in the disclosing the principles of functionalsystem providing the realization of behavior. The important role in formation of visual-controlled purposeful behavior belongs to amygdala which provides monitoring and assessment of biological importance of visual signal. Amygdalaectomy results in disturbance in the psychonervous memorialization processes and identification of the images accompanied by abnormalities in the behavior adequacy, while destruction of visual- amygdalar connections causes development of neurodegenerative diseases (Alzheimer's disease and others) in which loss of perceptive and cognitive functions is noticed. The stimulation of Basolateral or Corticomедial Amygdala (which are in opponant connections) discovered their selective action on VS structures [1, 2]. Each section has a dual effect (inhibitory and stimulating) on parvocellular

and magnocellular pathways. The organization of neuronal networks and mechanism of the realization of the effect of Amygdala on all levels of VS points that it can be realized by direct or oligosynaptic pathways through Hypothalamus, Pulvinar or Colliculus Superior (Fig. 1).

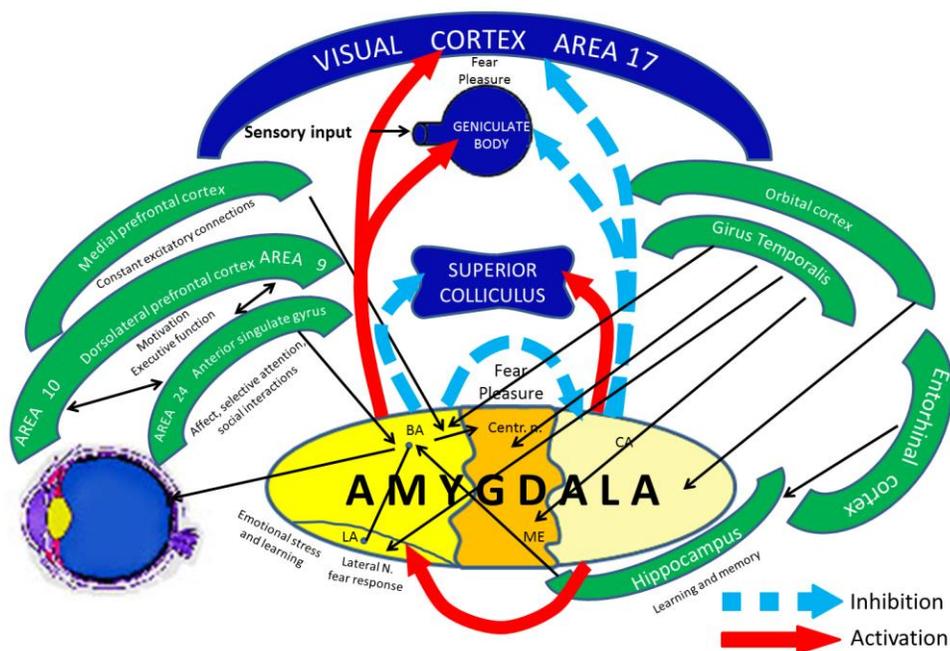


Fig. 1. Neuronal network of intrastructure connections between visual system and amygdala

An opposite character of multidirectional polyfunctional effect of Basolateral and Corticomedial Amygdala on Visual Cortex, Geniculate body and Colliculus Superior has been revealed. Basolateral Amygdala increases the actualization of information in the Cortex, while Corticomedial, in opposite, exerts inhibitory effect on its realization through parvocellular pathway.

Keywords: Visual System, Amygdala, parvocellular, magnocellular pathways

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## Regulation of neuronal excitability and network behaviour by extracellular GABA

Pavlov I., Invited

UCL Institute of Neurology, London

GABA is the main inhibitory neurotransmitter in the brain and in addition to its role in fast synaptic neurotransmission also exerts a diffuse action through activation of extrasynaptic GABA receptors. The physiological role of this slower form of signaling has recently attracted considerable attention. It has been described in many brain regions ranging from cortical areas to subcortical structures and has been implicated in the variety of cognitive processes as well as in the pathophysiology of several neurological disorders. Here I will introduce the concept of tonic

inhibition and will discuss how this form of non-synaptic signaling may impact on synaptic physiology, single cell neuronal output, and how it may be involved in the modulation of neural network dynamics. I will further describe a novel GABA receptor-independent mechanism through which ambient GABA can suppress glutamatergic signalling through activation of GABA transporters in astrocytes. This form of inhibition may contribute to the detection and homeostatic regulation of network activity by astroglia.

This work is supported by The Worshipful Company of Pewterers and Epilepsy Research UK.

### **Videoculographie as a method for measurement of human visual analyzer function.**

Perminova S. M.<sup>1</sup>, Shelepin E. Yu.<sup>2</sup>, Shelepin Yu. E.<sup>2</sup>

<sup>1</sup> Saint Petersburg State University, Saint-Petersburg

<sup>2</sup> I.P. Pavlov Institute of Physiology RAS, Saint-Petersburg

Метод визуализации зрительной функции – видеоокулография – до сих пор не стандартизован, несмотря на большой период исследований. Необходимо конкретизировать параметры, которые используются в качестве метрики движения глаз, а также способы представления этих данных и методы их интерпретации. Мы исследовали окуломоторную функцию человека, т.е. установили соответствие движений глаз траектории движущегося объекта у здоровых людей. В работе установлено, что чем больше частота и меньше размах движущегося предмета, тем сложнее здоровому человеку следить за этим предметом, это проявляется увеличением количества отклонений (саккад) от заданных параметров.

Supported by Russian Science Foundation (№14-15-00918).

### **Human Brain Functional Asymmetry and Moving Sound Localization**

Petrovavlovskaja E. A., Shestopalova L. B., Shkurko A. A., Semenova V. V., Nikitin N. I.

I.P. Pavlov Institute of Physiology, St.Petersburg, Russia

Functional asymmetry is a basic property of the human brain which affects motor, sensory and cognitive processes. There is a lot of evidence that in right-handed people right hemisphere of the brain is better fitted for the spatial information processing, regardless of the sensory modalities. The ability to localize short stationary and moving sounds under dichotic stimulation was tested in 9 right-handers and 7 left-handers. The stimuli were white noise bursts of 100, 200 and 400 ms duration with constant or linearly changing interaural time differences (ITD).

Both groups of subjects had symmetrical subjective acoustic space and equal percentage of moving stimuli perceived as stationary. In the right-handed subjects, the stationary stimuli of similar ITDs were lateralized further from the head midline. This suggests that the functional asymmetry affects subjective acoustic space metrics. The subjective onset position of moving stimuli was shifted further in the direction of motion in right-handers than in left-handers. The offset position shift differently depended on the motion parameters in two groups of subjects. The observed differences are related to specialization and dynamic interaction of the right and left hemispheres of the brain during the localization of a moving sound source.

## **Recognition of verbal and nonverbal stimuli: the effect of familiarity**

Podvigina D. N., Prokopenya V. K.

Pavlov Institute of Physiology, Russian Academy of Sciences; Saint Petersburg State University

Face and word recognition is crucial for social communication. A number of studies suggested that stimuli of these types are processed separately, considering their specific features result in left-lateralization for verbal and right-lateralization for nonverbal stimuli. We suggested that EEG patterns accompanying recognition of words and faces would be modulated by stimulus familiarity as well as by its type. We recorded EEG in 29 subjects presented with 80 complex stimuli – words superimposed on face images, - combining familiar and unfamiliar faces and words in equal parts. The general task was to judge stimulus familiarity: in one part of the experiment the instruction was to classify the faces as familiar or unfamiliar (with the words unattended), in another part – to classify the words the same way. The results demonstrated a strong familiarity effect, with unfamiliar stimuli (both faces and words) eliciting significantly more negative response (N250) in frontal areas than familiar ones. We also found the effect of instruction (attention to faces or to words) more pronounced over the left-hemisphere electrodes, showing greater response (N400 wave) in word-task condition as compared to face-task condition.

Supported by Russian Science Foundation, project No 14-18-02135

Keywords: Cognitive science, ERP, verbal and nonverbal pattern recognition, face perception

## **Changes in amplitude of components of cognitive evoked potentials from patients with schizophrenia after presenting of virtual environment**

Pnevskaya A.<sup>1</sup>, Murav`eva S.<sup>2</sup>, Novik D.<sup>3</sup>, Ivanova L.<sup>3</sup>, Shelepin Yu. E.<sup>2</sup>

<sup>1</sup>Pediatric Medical University, Saint-Petersburg; <sup>2</sup>I.P. Pavlov Institute of Physiology RAS, Saint-Petersburg; <sup>3</sup> Peter the Great Polytechnic University, Saint-Petersburg

These electrophysiological and psychophysical studies, we conducted on a group of patients with paranoid form of schizophrenia, disease duration 1 - 5 years. The aim of the research was to define the impact on the visual system of patients by presenting of virtual environment. The work consisted of measurements of cognitive visual evoked potentials and contrast sensitivity to spatial stimuli and images of objects that are processed using wavelet filters for the low (magnosystem) and high (parvosystem) spatial frequencies. The result of the study showed a significant decrease in the amplitude of the N170 (P170) component in occipital, central and frontal areas upon presentation of images, filtered by high spatial frequencies compared to the control group. These data were correlated with these measurements of contrast sensitivity: there was a significant decrease in the high spatial frequencies. After a course of visual stimulation there was a significant increase in the amplitude of the N170 (P170) component and contrast sensitivity at high spatial frequencies. The research showed that there has been a dysfunction of the parvosystem in patients with schizophrenia, and the virtual environment improved the efficiency of this system.

Supported by Russian Science Foundation (№14-15-00918).

## **The art and consumers with mental disorders.**

Pronin S. V., Shelepin Yu. E., Shoshina I.

Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia

Statistical properties of the natural visual scenes are the fundamental base for the structural–functional organization of the visual system. Works of art, as well as ordinary simple drawings, are a reflection of the surrounding medium; therefore, it can be expected that the main statistical characteristics of such images will be close to those for natural scenes. But from the other hand the statistical characteristics of drawings made by different people reflect their internal emotional, esthetic, cultural tradition of the person and mental health. So the drawings work as projective tests reflects the consumers archetype and may be different in compare the normal observers and patients with mental disorders.

The aim of our work was to investigate defects of visual perception and decision making, in normal consumers and patients with schizophrenia and the style of face are the do, independently of their skills in art. There are the numerous studies of visual deficit of contrast sensitivity, space perception, local and global analysis of the scene accompanying schizophrenia. Image processing of well-known paintings demonstrate more contrast in particular part of spatial frequency spectrum in different paints. There are not less than two groups of patients with change in low and at higher spatial frequency range. The resulting data are regarded as evidence of dysfunction of the global analysis of the images by patient with schizophrenia. We demonstrate the increase of the internal noise level in the visual system of these consumers.

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## **Changes in components of event-related potentials from patients with schizophrenia after presenting of virtual environment**

Pronina M. V.,<sup>1</sup> Murav`eva S.V.<sup>2</sup>, Poliakov Y. I.<sup>1</sup>, Ponomarev V. A.<sup>1</sup>, Kropotov J. D.<sup>1</sup>, Shelepin Yu. E.<sup>2</sup>

<sup>1</sup> N.P. Bechtereva Institute of the Human Brain RAS, Saint-Petersburg

<sup>2</sup> I.P. Pavlov Institute of Physiology RAS, Saint-Petersburg

Event-related potentials are widely used for studying disturbances in cognitive functions in patients with psychiatric disorders. Recently a new mathematical method of blind source separation based on the statistics of the second order was adapted for separating ERPs signals in order to pick out activity from different brain sources, which reflect different operations including stages of sensory processing, decision making and action realization. In the present study EEG from 8 adult patients with schizophrenia was recorded before and after presenting of virtual environment. During the recording patients performed visual cued Go/NoGo task with four categories of trials: animal-animal (probe Go), animal-plant (probe NoGo), plant-plant (Ignore) and plant-human (Novel). Participants were instructed to press the button as quickly as possible after Go probes and don't press after other types of stimuli.

Applying of the method of blind source separation to ERPs data allowed picking out 6 latent components which described 97% of the registered signal. According to the time course and topography, two of them reflect stages of visual processing and the rest are connected with cognitive operations. Localization of the components' sources was determined by means of sLORETA. We found significant ( $p < 0.05$ ) changes in components, which are generated in the parietal, premotor and orbitofrontal cortex and reflect cognitive operations of action engagement, execution and evaluation.

Supported by Russian Science Foundation (№14-15-00918).

## **The potential power of media to enhance cognition: The tacit components of human perception in mediated worlds**

Reiner M., Invited

Technion – Israel Institute of Technology, Haifa, Israel

Media has evolved to provide new ways to interact with reality. Novel interfaces of virtual/augmented worlds, trick our brain into perceiving mediated reality as physical, engaging our perceptual system into an immersive experience of a captivating emotional and bodily rollercoaster. VR/AR bring new exciting cinematic presence, enhanced game experience, immersive journalism, rehabilitation and a whole range of medical applications. Can we implant cues to enhance the human affective and cognitive experience? Can we enhance the emotional response to an event in a VR cinema? Enhance perception in an immersive journalistic report? Enhance memory, spatial intelligence, problem solving in a learning V/AR environment? Is it feasible to enhance the motor rehabilitation of a patient after stroke? Cues and processes that have never existed in the physical reality, can be implanted in the V/AR. There is a need to identify the cues that will activate the brain mechanisms that correlate with enhanced cognition. This talk will describe results of studies on enhanced cognition processes. In general, we asked participants to perform tasks in a multimodal virtual reality, while being connected to an EEG system. Our results correlate optimal performance, VR stimuli and brain mechanisms. Three examples will be described on enhanced: social communication, neuro-rehabilitation after stroke, and finally a BCI (Brain Computer –Interface) system in Virtual Reality.

## **The impact of avatar's ethnic appearance on proxemic behavior**

Saveleva O. A., Zacharkin D. V., Menshikova G. Ya.

Lomonosov MSU

It has been shown that the rules of social interactions between human and avatars in virtual environments are similar to interactions in the real world (Yee et al., 2007). Our aim was to study participant's proxemic behavior during the social interaction with avatars of different ethnic appearance. We constructed three virtual scenes. In each scene a group of avatars of the same ethnic appearance stood in the center of a living room. The virtual scenes were presented using the CAVE virtual reality system. The participants were asked to go around each avatar and remember all the details of its appearance. During the execution participant's body movements were recorded. Then participants answered the questions about the details of avatar's appearance and filled out questionnaires assessing their presence effect (IPQ) and ethnic attitudes (IAT). The results showed the shorter interpersonal distances with avatars of the same ethnic appearance. It was also revealed that questionnaire's scores were in good agreement with behavioral characteristics while performing the memory task.

The study was funded by Russian Scientific Fund project № 15-18-00109.

Keywords: virtual avatar, ethnic appearance, proxemic, interpersonal distance

## **Spatial memory: the accuracy of allocentric and egocentric spatial representations**

Saveleva O. A., Zacharkin D. V., Menshikova G. Ya.  
Lomonosov MSU

It has been proposed the existence of two types of spatial representations to successfully code the localization of objects: egocentric and allocentric. The first one specifies spatial information with respect to the observer's position and the second – to relative positions between objects. In our study we investigated the accuracy of both spatial representations using the CAVE virtual reality technology. Six virtual scenes were constructed consisted of 7 objects located in different 3D positions. The participant's task was to remember the scene and then to reproduce objects in a virtual space from three imagined viewer's positions: 1) the front view (as if they would view the scene from the original view point), 2) the left one (the scene viewed from the left) and 3) the above one (viewed from above). To complete the task the participants chose objects from the object's library and located them in a virtual space using flystick. During the execution object's coordinates were recorded. The accuracy of identification and localization was calculated for each of three imagined viewer's positions. The results showed the egocentric representations (the front view) were more accurate than allocentric ones (left and above views) and the representations "the left" were less accurate than "the above" ones.

The study was funded by Russian Scientific Fund project № 15-18-00109.

Keywords: spatial representations, egocentric, allocentric, virtual reality

## **Violation of reading ability at high visual acuity after surgery for idiopathic macular hole.**

Sdobnikova S. V., Sdobnikova L. E., Makhotin S. S.  
Helmholtz Institute of Eye Diseases, Moscow, Russia

Idiopathic macular hole (IMO) is an acquired through retinal defect in the center of the macular region, which occurs as a result of tangential traction and is accompanied by a significant decrease in vision, and the appearance of metamorphopsia and central scotoma. To date, the IMO is the most frequent indication for transsiliary vitrectomy, during which the internal limiting membrane is removed (ILM peeling), which is the basement membrane of Muller cells whose nuclei are located in the inner nuclear layer of the retina. In 95% of cases IMO closing occurs with the restoration of the normal architectonics of the retina, but a significant number of patients after macular surgery IMO at high visual acuity / close (0.5 to 1.0) have difficulties in reading (dyslexia). Some patients have complaints of dyslexia so distinct that the ability to read is completely absent. The aim is to examine the discrepancy between the high visual acuity, obtained in the postoperative period, and functional results.

## **A filter bank for suppression of speech signals**

Shayakhmetkyzy D.<sup>1</sup>, Altay E. A.<sup>2</sup>,

<sup>1</sup>Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics

<sup>2</sup>Kazakh National Research Technical University after K.I.Satpayev, Almaty, Kazakhstan,

Actuality: The processing of speech signals and systems working with the voice signals are now becoming more common in applications where it is an effective and convenient way to manage and share information with technical devices. Development of algorithm filtering of voice signals is an important task that requires the creation of effective methods of information processing.

The purpose of this work is the development and research of speech treatment algorithm designed to enhance perceptual quality of speech signals, exposed to acoustic noise and distortion.

Method: apply the theoretical and experimental research methods. Theoretical studies are based on a comparative analysis of various methods of treatment of a speech signal from acoustic noise and signal distortions, the choice among the methods considered most appropriate, as well as the implementation of the method chosen in practice. Experimental studies are realized by MatLAB / Simulink and Adobe Audition software.

Conclusion: We conducted research and analysis of speech signals for further processing of the signal from the noise and disturbance. The source of the speech signal recorded intrinsic noise on tape. As noise in the speech signal has been introduced experimentally pink noise in the program Adobe Audition. To filter notch filter (Band stop filter) and a low-pass filter has been selected (Low pass filter). The result was a purified signal.

### **Anti-interference processing electrocardiosignals**

Shayakhmetkyzy D.<sup>1</sup>, Altay E. A.<sup>2</sup>, Koishibayev D. N.<sup>2</sup>

<sup>1</sup>Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics

<sup>2</sup>Kazakh National Research Technical University after K.I.Satpayev, Almaty, Kazakhstan,

Actuality: In recent decades, actively developing pre-treatment technology of biological signals, enabling the identification of the functional state of the organism (FSO) person at an early stage of the disease. Chance of a number of deviations and borderline states, which do not appear in the form of contrasting characteristics. This may be different initial cardiac anomalies. In such cases, especially important methods to identify minor deviations from normal cardio.

The purpose is to study the interference suppression algorithm and identification of the main components – the teeth, segment and ECG intervals.

Currently we have developed a variety of algorithms for solving the problem, but most of them have a definite drawback - when passing through the block filter useful signal loses its shape, the noise increases, which leads to a shift of the main components of the ECG, and reduces the accuracy of the identification of cardio. In order to eliminate this drawback, the bank offered cascading filters.

Basic provisions of the research: The paper considers the filter bank to suppress electrocardiosignal interference, which consists of a low-frequency, high frequency and notch filter. For interference suppression and identification of the main cardiographic complex filter bank is designed. The amplitude-frequency characteristics and phase frequency characteristics for filter synthesis.

The main result: cardio analysis were spend and identified the main components of cardio. Calculated statistical parameters, the degree of deviation of the signal is within the confidence interval of  $\pm \sigma$ . The results of the standard deviation and the signal / noise ratio shows improvement in the quality and accuracy of cardio. The effectiveness of this algorithm is 99.86%.

## **The Insight and pattern recognition threshold**

Shelepin K. Yu.<sup>1,2</sup>, Zhukova (Borachuk) O. V.<sup>3</sup>, Vasiljev P. P.<sup>3</sup>

<sup>1</sup>St Petersburg State University, Russia

<sup>2</sup>Neuro iconic & Neuro mechanic Ltd. Russia

<sup>3</sup>Pavlov Institute of Physiology

The Insight phenomenon in our work is discussed as a part of the Gestalt psychology. According to our approach, consists just in formulation (mental modeling) the new relationships which permit to solve the problem. The changes of relationships depends on the restructuring, usually evoked by sudden perceptual transformation of the parts of a context.

The modelling of insight is an old problem. The well-known 9 dot matrix model of Insight strongly depends on the instruction we give to an observer and his/her internal strength to follow the instruction. If participant strongly follow instruction “connect the dots” it make impossible solving of the problem if this instruction will not be broken mentally by participant. Surprise - the solving is essay to most participants if instruction includes the words “pass the dots, by the line”.

The next insight model is next Gestalt perceptual effect grouping of dots in the matrix – perceiving the lines or the columns in dot matrix– as well is related to the task but much less. It works automatically like the perception of ambiguous figures, and so can't be a model of Insight.

Both traditional models for experimental insight demonstration, the 9 dot matrix test and ambiguous columns versus line in dot matrix effect strongly depend on recombination process. On the contrary to recombination approach, we proposed to investigate and measure the insight as the threshold process. This permits us to resolve only one of many mechanisms of Insight but very important. Water level in Archimedes bath is a wonderful example of importance of the threshold measurements in solving insight problem.

This experiments can be provide by measuring the threshold of figures minimal completeness, or maximal incompleteness, but sufficient for this figurer cognition. To achieve this aim of our work we use computer version of Golin Test [1]. This is well-known method of measuring the perception thresholds of fragmented images. We explore it for solving the problem of evaluating the characteristics of insight in a mind. We operate the optical properties of incomplete images and measure the psychophysical recognition thresholds of this test objects. This is necessary conditions for the appearance of visual insight.

The emotional part of insight – the age-effect is very important to clarify the threshold as insight. The emotion reaction was estimated by conventional subjective tests and by objective measurement of physiological emotional reaction by measuring eye movements, pupil size, and provide the EEG and EMG recordings. The architecture of the neural networks and brain area interconnection

ensure the appearance of insight that is considered using results of fMRI and EEG measurements we provide.

The threshold of incomplete image recognition in noisy background is supported by subjective reaction (aga-effect) and physiological measurements which demonstrate a statistically significant emotional response after decision. The visibility of 20 % of test image is enough to mental integrate visible fragments into whole objects independently that 80 % are invisible. This effect of visibility is correlated with general Pareto principle [1] and is impaired at schizophrenia patients [2].

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## **Human brain. Internal noise and decision making.**

Shelepin Yu. E.

I. P. Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg

Two approaches to the description of brain functioning during the solution of image perception by consumers are considered: studies of the perception of the statistical properties of global whole images and studies of the perception of images in terms of local higher-order informative features. These approaches describe two different neuronal nets of the human brain used for image recognition. Local higher-order informative features are used by the brain as additional sources of information about the image. The role of this source increases on learning a given alphabet of stimuli. In accordance with a matched filtration model, the images of the texture, object and scene are perceived as a whole structure, or a part depended on the task. This description of a whole gestalt is compared with a reference gestalt which is stored in memory and selected using the selective attention mechanism. At the primary filtration step and the matched filtration step, the recognition thresholds of images reflect the processes of extracting the signal from noise. The personal limiting factor is internal noise of the consumer's brain. It is measured as equivalent. The tests we develop to measure internal noise during the last 20 years we used as a differential tool for the diagnosis of diverse cognitive impairments. The development of methods of digitally synthesizing and processing images has made it possible to create test images that selectively activate various neuronal net activity of the visual system. The methods of neuroiconic, for preparing images – stimulus and for neuroimaging. The goal of this study is the spatiotemporal localization (mapping) of the neuronal net of the consumers brain, involved in making decisions concerning the task such as pattern recognition of textures, shape of objects, faces, scenes. It is established that a subject's reaction time correlates with the degree of ordering of the textures, image complexity, personality (had participant musical education an experience or not) and with the latency of the late components of the induced potentials in the frontal cortex controlling response. Mapping of the brain by the method of functional magnetic-resonance tomography showed that the activity of the brain in the process of making decisions involving recognition occurs in the frontal cortex of the human brain. The concept of the real efficiency of the human visual system, by means of which a comparison is made between the efficiency of the functioning of the human visual system and a model of it when images of test objects on which noise is superimposed are to be recognized. Based on experimental studies, it is shown that the real efficiency of the visual system is close to unity for a wide range of solvable problems. We pointed that the real efficiency of the visual system is lower for people with mental disorders than for healthy consumers. The limiting factor is internal noise, different by its sources for local and global analysis of the scene.

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## **Neurotechnology for consumers.**

Shelepin Yu. E.

P. Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia

The object and natural scene recognition in conditions of uncertainty is important part of the visual information processing. There are the interesting aspects of the relationship of verbal and non-verbal objects and scene description. The neural network architecture that provides the perception of verbal and nonverbal signals has the common part in the frontal lobe. This means that the study of the semantic structure of the language and the semantics of images gives, on the one hand, the

ability to understand the mode of processing and presentation of information in the human brain, the construction pattern of the world, and on the other hand, human neural network architecture and its activity is way for modern technology of artificial intelligent devices. This knowledge allows us to predict the perception and activities in different environments of the consumers ensure that it is correct. The restructuring of neural networks is possible even in the primary visual cortex. Current data in common with the key ideas of the time due to neural networks, made by Boris Babkin in 1904 in the world's first thesis on higher nervous activity. Boris Babkin was I.P. Pavlov and V.M. Bekhterev student, and later the teacher of Donald Hebb and thus almost all of the North American school of neural networks investigation and his ideas of temporal connection are crucial for neuronal net technology. Understanding the neural network tuning principles is important in building architecture neuromorphic processes that ensure the synthesis of new knowledge and new technologies create decision in transport, military, economic and social control. These same technologies to restore the patient's brain are keys to open different brain functions.

Now we have created neuromorphic hardware-software complex for the human mental restoration of functional disorders and injuries. These is brain fitness which combine visual stimulation and intensive motor activity for the patients in virtual environments with the strong image processing based on the visual system properties of the patient. Important is constructing scenarios and algorithms with different priorities and aim for optimal decisions under uncertainty conditions by normal consumers and patients.

Supported by Russian Science Foundation (№14-15-00918).

### **The Fastest or The Slowest? Contextual effects on moving sound discrimination**

Shestopalova L. B., Petropavlovskaja E. A., Semenova V. V., Vaitulevich S. Ph., Nikitin N. I.  
I.P. Pavlov Institute of Physiology, St.Petersburg, Russia

The study focused at the effect of stimulus context on active and passive discrimination of moving sound signals. Different contexts were created by reversing the role of standard and deviant stimuli in the odd-ball blocks. Three types of stimuli were used as standards or deviants: stationary midline noises and two patterns of sound motion produced by linear or abrupt changes of interaural time differences. In passive listening conditions (the sound stimuli ignored), auditory event-related potentials (ERPs) were recorded and mismatch negativity potentials (MMNs) were obtained. Active discrimination of sound motion was measured by hit rate (percent of correct responses), false alarm rate and reaction time.

The influence of the stimulus context on active and passive discrimination of the moving sound stimuli manifested itself as effect of deviance direction. The hit rate and MMN amplitude were higher when the deviant moved faster than the standard. MMN magnitude was more responsive to the velocity of sound motion than the hit rate and false alarm rate. The psychophysical measurements of active motion discrimination in the reversed contexts suggest that smooth and abrupt sound motion may be subsumed under the same perceptual category of 'moving sounds', whereas the stationary stimuli form another perceptual category.

## **The mechanisms of global and local image analysis in schizophrenia**

Shoshina I. I.<sup>1</sup>, Shelepin Yu. E.<sup>2</sup>, Konkina S. A.<sup>1</sup>, Sergienko R. A.<sup>1</sup>

<sup>1</sup>Siberian Federal University, Krasnoyarsk, Russia

<sup>2</sup>I.P. Pavlov Institute of Physiology, Russian Academy of Science, Russia, St.-Petersburg

The purpose of the study is to examine of the mechanisms of global and local analysis, features of their interaction and the role of interaction to ensure the integrity of perception in the task of recognition using fragmented images on model of schizophrenia. Objects of the research are 24 mentally healthy persons and 54 patients with schizophrenia. We use Gollin test. It was found that patients with schizophrenia require more contour fragments to recognize the object, than healthy subjects. Individuals with first-episode schizophrenia require fewer fragments for recognition of the object contour than the chronically ill, as well as patients with paroxysmal type of the disease compared with patients with a continuous type of the disease. The results of the study certify the dysfunction of mechanisms of recognition of fragmented figures in schizophrenia, that is, mechanisms for building a complete image. Based on the theory of spatial-frequency filtering in the visual system, these mechanisms are mechanisms of global and local analysis. Thus, we have demonstrated dysfunction of the mechanisms of global and local analysis at the highest levels of information processing, showed that the severity of these disorders depends on the clinical picture and the type of the disease.

Supported by Russian Science Foundation (№14-15-00918).

Keywords: global and local analysis, schizophrenia, Gollin-test, visual dysfunction

## **Postural reactions occurred as a result of listening of approaching and withdrawing footstep sounds**

Smirnova V. A.<sup>1</sup>, Andreeva I. G.<sup>1</sup>, Bobrova E. V.<sup>2</sup>, Gvozdeva A. P.<sup>1</sup>, Antifeev I. E.<sup>3</sup>

<sup>1</sup>Sechenov Institute of Evolutionary Physiology and Biochemistry RAS, St. Petersburg, Russia;

<sup>2</sup>Pavlov Institute of Physiology RAS, St. Petersburg, Russia,

<sup>3</sup>Institute for Analytical Instrumentation RAS, St. Petersburg, Russia

Motion perception is a multimodal process, since motion stimulation in one modality leads to adaptive perceptual changes in other sensory systems including vestibular and proprioceptive modalities. We had previously reported changes of posture evoked by moving sound images, but natural motion sounds are known to be more effective for sensory adaptation. The aim of our study was to show postural reactions to approaching and withdrawing steps sounds. Recordings of approaching, withdrawing and in-place (control condition) footsteps sounds were played back through the headphones during 45 s to 8 humans with closed eyes. For moving steps an increase of trajectory lengths of a centre of pressure (COP) in the sagittal plane was observed during and after the stimulation in comparison with its length before the stimulation. For in-place steps the value was increased only after their listening. Listening to stimuli of all the types induced a backward COP shift during second part of their presentation. A postural motion aftereffect manifested in the significant increase of body sway after sound stimulation what was revealed in the increase of the COP trajectory length and its standard deviations. The work is supported by RFBR (grant № 15-04-02816).

Keywords: auditory motion, footstep sound, postural reaction, multimodal interaction, motion aftereffect

## **Searching for visual features driving face neurons in the higher visual cortex, inferior temporal cortex, in macaque monkeys**

Tanifuji M., Invited

Lab for Integrative Neural Systems, RIKEN, Tokyo, Japan

We recognize objects in an invariant manner across large variations in views, position, photometric conditions, and some deformation in their shapes. This is not trivial behavioral property because there is an enormous number of objects belonging to the same category, and typically larger differences in retinal images arise from variations of an object than from different objects in the same category.

In our brain, there is accumulated evidence that objects are represented by combination of neurons each encoding a visual feature less complex than complete objects in inferior temporal (IT) cortex (Desimone, et al., 1984; Tanaka, et al., 1991; Tsunoda, et al., 2001; Yamane, et al., 2006; Brincat and Connor, 2004; Freiwald, et al., 2009). Thus, one hypothetical framework for invariant object recognition is that various appearances of an object are represented separately from other objects in the visual feature space in IT cortex (DiCarlo and Cox, 2007). In support, Hung and colleagues recorded neuronal responses to objects with various sizes and positions from monkey IT cortex, and found that these objects were well separated in the neural response space (Hung, et al., 2005). Other studies suggested that view invariant representation of faces is achieved by population responses of neurons in the most anterior part of IT cortex (Freiwald and Tsao, 2010; Dubois, Berker, and Tsao, 2015). However, we still do not understand general property of visual features critical for making object representation invariant. There was an attempt to address this question for position invariance, but our understanding is still very limited (Rust and DiCarlo, 2010).

Identification of visual features detected by IT neurons is essentially crucial for fundamental understanding of invariant object representation. Previously, one approach was to simplify the best object stimulus and found the simplest and efficient visual feature that activated individual neurons (Desimone, et al., 1984; Tanaka, et al., 1991). More recently, responses of IT neurons to a parameterized artificial stimulus set were recorded and critical parameters to explain responses to these stimuli were explored (Brincat and Connor, 2004). Although these studies gave insights into visual features encoded by IT neurons, they are not sufficient to address object representation in the visual feature space. Description of visual features was qualitative in the former approach, and it is difficult to put real world objects in their parameterized space in the latter approach. Identification of the visual features has been left behind because of lack of appropriate approaches for feature identification.

In the present study, we proposed a novel method to identify features of IT neurons where description is quantitative and therefore would make possible to address object representation in the feature space. The target was neurons in a face selective region in anterior IT cortex (Sato, et al., 2013). In this approach, we searched for the features in the subset of regions in natural images. Because of following reasons, we considered that this strategy was reasonable. First, since IT cortex is essentially dedicated to object vision in natural scenes, it is reasonable to search for the features in natural images although natural images construct only a small subset of possible images. Second, at the level of intermediate complexity of visual features that IT neurons represent, the features could be general across objects including faces and non-faces, at least if the subset includes sufficiently large number of elements (Tanaka, et al., 1991; Tsunoda, et al., 2001). As a result, we found image fragments that explained up to 67 % of the variance (on average, 45 %) in object responses of IT neurons. To our best knowledge, there is no other studies that quantitatively searched for visual features that explained object responses for IT neurons. In V1 and V4, a study

where response property was characterized by spectral receptive field showed that correlation coefficients between neuronal object responses and predicted responses from their model were 0.32 and 0.37 in V4 and V1, respectively (David, et al., 2006). The correlation coefficient in our study was 0.82 (on average, 0.68), and thus the performance of our methods is remarkably high even compared with a reasonable approach in earlier visual areas.

These image fragments were characterized by specific arrangements of local feature elements of orientations and colors. Some of these features detected local parts of faces but others detect global face configurations. The feature description enables us to predict responses to arbitrary objects. We found in simulations that the identified features accounted for physiologically observed properties of IT cells, such as view tuning and responses to mirror symmetric faces.

### **Machineries for forming center and periphery of receptive fields in monkey anterior inferior temporal cortex**

Tanifuji M., Invited

Lab for Integrative Neural Systems, RIKEN, Tokyo, Japan

A remarkable aspect of object recognition is that we recognize a few objects embedded in a cluttered environment in our daily life. To recognize these objects unambiguously, it would be advantageous to have receptive fields (RFs) as small as the target objects. On the other hand, explanation of translational invariance in object recognition requires RFs to be large.

In inferior temporal (IT) cortex of macaque monkeys, previous studies have shown that IT neurons have large RFs (ex, Op de Beeck and Vogels, 2000 and Kobatake and Tanaka, 1994). For example, one of the studies with monkeys performing a fixation task showed the mean size of RFs to be as large as 10.3 degree (Op de Beeck and Vogels, 2000). On the other hand, a study reported that RF can be as small as 2.6 degree when monkeys performed a task to recognize a small stimulus presented near the fixation point (DiCarlo and Maunsell, 2003).

Based on these findings, we hypothesized that IT neurons have large RFs in a default mode, such as RFs observed in monkeys with fixation tasks, and that the default mode RFs can be modulated by task demands. Modulation of the default mode RFs may be critical for explaining object recognition in a cluttered environment.

In order to examine this hypothesis, we investigated neural circuit mechanisms along the ventral visual pathway to form large default RFs and modulation of RFs with spatial attention. We found (1) that central part of a RF of anterior IT neurons was processed significantly faster than peripheral part, (2) this difference in processing latency did not depend on spatial attention, but (3) that magnitudes of responses at different locations in RFs were modulated depending on the location of spatial attention. To test whether these properties arose before visual information reaching anterior IT cortex, we examined latency and modulation by spatial attention in V4 neurons having their RFs in peripheral locations and in the center of the visual field. As a result, we found that differences in latency and attentional modulation of magnitude were not observed in V4 neurons. Thus, default mode processing of objects in visual field center and of objects in peripheral visual field use different machineries in areas between V4 and anterior IT (potentially, area TEO), and attention modulates output gain of the machineries.

## **Adam Smith and Greed as a Sentiment**

Taylor J.  
Saint-Petersburg State University

Utilitarian philosophy influenced Adam Smith 's notion of greed in *The Theory of Moral Sentiments* (1759). Smith (1723-1790) said that greed was a sentiment. It was the evil opposite of pity. Pity was also a sentiment, and pity was the source of benevolence or generosity. He took this whole theory of sentiments from his teacher Francis Hutcheson (1694-1747) who in turn took it from the third earl of Shaftesbury (1671-1713), a major English philosopher. Since greed was a sentiment, it was therefore not subject to voluntary restraint because, as Shaftesbury said, sentiment was an impulse, a medical condition, and it was rooted in the balance or temper of the four humors, earth, air, fire, and water. Smith's famous "invisible hand" was a corollary concept: it was an involuntary natural phenomenon similar to sentiment. "The invisible hand" in other words was an involuntary natural restraint on greed, similar to pity, and it was therefore another example of Smith's dependence on utilitarian philosophy.

Keywords: Adam Smith. Greed. Sentiment

## **Three ways to relate consciousness and quantum mechanics**

Terekhovich V.  
Saint Petersburg University, Institute of Philosophy

All of the ways to relate the laws of quantum mechanics with the phenomenon of human consciousness can be divided into three types. The first way provides the consciousness of the observer with a special place in the measurement. However, consciousness should not possess any quantum properties to explain the quantum paradoxes. Consciousness must be something external that connects quantum and classical phenomena. The second way borrows the models and formalisms from quantum physics to describe an activity of the human brain. It is based on a number of analogies between the manifestations of consciousness and behavior of quantum objects. A simple transfer of the quantum models and properties of quantum objects to consciousness faces a number of difficulties. The third way concentrates on the search for general principles of the human brain and quantum phenomena. I will consider two directions of this. One of them is related to the justification of the metaphysical principle of free will inherent in varying degrees in consciousness and quantum objects (the theorems of free will). Another direction investigates the general principles of creating, exchange and processing of information in the quantum theory and the theory of consciousness.

Keywords: quantum mechanics, consciousness, human brain, information

## **Comparison of singular photons detection sensitivity in human retinal receptive field and in artificial photodetectors matrixes.**

Tibilov A. S.<sup>1</sup>, Nesterov V.<sup>2</sup>, Shelepin Yu. E.<sup>3</sup>

<sup>1</sup>Vavilov State Optical Institute, St. Petersburg, Russia,

<sup>2</sup>AO SILAR,

<sup>3</sup>Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia

Проведена теоретическая оценка чувствительности адаптированной к темноте сетчатки при предъявлении в качестве стимула слабых световых вспышек точечного источника. Полученный результат экстраполирован на произвольное малоугловое изображение для определения предельной яркости, регистрируемой на сетчатке. Полученные результаты сравниваются с возможностями современных охлаждаемых ПЗС приёмников с умножением (EMCCD). Оказалось, что при одинаковой вероятности ложных сигналов сетчатка обеспечивает ту же предельную яркость, что и матрица EMCCD, но несколько уступает ей по предельной энергии регистрируемой точечной вспышки.

## **Measuring of the fovea and foveola using line scans and 3D Macular scans obtained with spectral domain optical coherent tomography.**

Vakhrameeva O. A.<sup>1</sup>, Moiseenko G. A.<sup>1</sup>, Maltsev D. S.<sup>2</sup>, Sukhinin M. V.<sup>2</sup>, Koskin S. A.<sup>2</sup>

<sup>1</sup>Pavlov Institute of Physiology, Russian Academy of Sciences.

<sup>2</sup>Department of ophthalmology; S. M. Kirov Military Medical Academy, St. Petersburg, Russia

The fovea and foveola sizes vary, depending on the method of measurements. Some of the methods investigates functional characteristics to detect the size of the fovea, foveola and other regions of macula. The other methods are morphological. In practical medicine researchers usually need to detect key objects of the retina, like fovea, blood vessels, optic disk to locate changes of the retina related to a particular disease on surface for further treatment. For this purpose they usually use the fundus images. In this research we used line scans and 3D Macular scans to obtain the image of the macula region. We measured diameters of the fovea and foveola regions and compared these characteristics with performance of human in different tasks. We showed, that anatomical characteristics of the fovea (fovea and foveolar diameters) affect recognition of the small objects. This dependence has been approved using electrophysiological methods. Supported by Russian Science Foundation (№14-15-00918).

## **Mathematical model of the visual system. Vizeotopiya, field of vision – retina – V1.**

Vargin P. S.

JSC Television scientific research institute, Moscow, Russia

Приведены результаты моделирования отображения поля зрения на первичную зрительную кору головного мозга. Используются результаты работ E.L. Schwartz'a и др. по комплексному отображению, такого рода, с целью получения цветных двумерных деформированных плоских изображений, соответствующих корковым образам. При восприятии окружающей среды, в зрительной системе человека происходит последовательное отображение трехмерной картины внешнего мира в серию двумерных изображений различной природы, которое можно назвать зрительным циклом. Цикл

начинается с проецирования оптического изображения на сетчатку глаза и заканчивается проекцией трехмерного зрительного представления на внешний мир.

При математическом моделировании зрительного цикла, отдельные его фазы могут представляться блоками, допускающими совершенствование в процессе биологических исследований. Математическая модель позволяет производить отображения с пропуском отдельных фаз цикла или их упрощением, или даже изменением, в зависимости от частной и общей целей моделирования. Общая цель моделирования – наглядность.

Особое место при моделировании отводится восприятию цвета, наряду с восприятием формы объектов наблюдения.

При моделировании восприятия формы, различают визиотопию и ретинотопию. Первая позволяет избежать анализа геометрических искажений, свойственных оптической системе глаза.

При отображении поля зрения на первичную зрительную кору головного мозга возникают сильные искажения формы поля зрения, как из-за изменения плотности волокон зрительного нерва по сетчатке глаза, так и из-за складчатого характера коры. Если растянуть кору на плоскости, уничтожая складки, можно хорошо описать визиотопию клин-дипольной моделью Эрика Шварца.

Модификации этой модели использовал Кристофер Тайлер для анализа отображения данных функциональной магнито-резонансной томографии зрительной коры.

Особый интерес представляет моделирование отображения поля зрения на первичную зрительную кору головного мозга, с целью получения цветных двумерных деформированных плоских изображений, соответствующих корковым образам.

Наша модель позволяет получить статический или динамический образ любого предъявляемого зрительного стимула на V1 в полном или контурном виде.

Keywords: Поле зрения кора визиотопия

### **Biophysically detailed model of direction selectivity of visual cortex, based on population approach**

Yakimova E.<sup>1</sup>, Chizhov A. V.<sup>2,3</sup>, Smirnova E.<sup>2</sup>

<sup>1</sup>Pavlov Institute of Physiology, Russian Academy of Sciences;

<sup>2</sup>Ioffe Institute,

<sup>3</sup>Sechenov Institute of Evolutionary Physiology and Biochemistry of RAS. St. Petersburg, Russia.

Biophysically detailed description of the mechanisms of orientation and direction selectivity of visual cortex neurons is still in development. We have incorporated a simplified, filter-based description of retino-thalamic visual signal processing including a mechanism of direction selectivity into the detailed, conductance-based description of neuronal population activity of the primary visual cortex. Our simulations of the cortical response to moving gratings have verified that the mechanism based on asymmetrical projections of lagged and non-lagged thalamic neurons to the cortex provides the direction selectivity in an extent consistent with experimental evidences, and that the biophysical model realistically reproduces such characteristics of the visual cortex activity as membrane potential, firing rate, synaptic conductances etc. The proposed model is to be further compared in detail with experimental data obtained in slices and in vivo.

Keywords: visual cortex, LGN, direction selectivity, population model

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## **Hemispheric and frequency-dependent effects from transcranial alternating current stimulation modulates risk-taking**

Yaple Z. A.<sup>1</sup>, Feurra M.<sup>1,2</sup>, Martinez-Saito M.<sup>1</sup>, Shestakova A. N.<sup>1</sup>, Klucharev V. A.<sup>1,2</sup>

<sup>1</sup> Centre for Cognition and Decision Making, National Research University Higher School of Economics, Moscow, 109316, Russian Federation.

<sup>2</sup> Department of Psychology, National Research University Higher School of Economics, Moscow, 109316, Russian Federation

In this study, we investigated the effect of transcranial alternating current stimulation (tACS) of the dorsolateral prefrontal cortex (DLPFC) on risk-taking and cognitive control. Stimulation was delivered online at 5, 10, 20, and 40 Hz on the left and right DLPFC while subjects performed a modified task-switching paradigm. The task allowed subjects to choose between risky and certain options associated with potential gains or losses while simultaneously measuring the cognitive control component of decision making. Our results revealed a frequency- and hemisphere-specific effect of 20Hz tACS of the left DLPFC that significantly increased risk-taking. This evidence suggests a modulatory role of 20 Hz neural oscillations at the left DLPFC in risk-taking.

This study was funded by the Russian Academic Excellence Project '5-100'.

Cognitive control, risky decision making, framing effect, task-switching

## **Computational model of the second-order visual channels**

Yavna D. V., Babenko V. V.

Southern Federal University

The aim of our research is to create the computational model of visual second-order channels which independently detect spatial modulations of contrast, orientation, or spatial frequency in static visual scenes. The reason to create the model is the psychophysical and psychophysiological data that support an assumption of the human second-order channel specificity. The advantage of the model is similarity with natural neural structures.

Our model is based on the classical "filter-rectify-filter" scheme, which explains the second-order feature detection. In order to provide the specificity to modulation dimension, the contrast normalization mechanism was added to channels detecting the orientation and frequency modulations [Kingdom et al., 2003], and the input of inhibitory subfields of the second order mechanism was altered [Babenko, Yavna, 2009].

While the excitatory subfield is formed by the inputs from the first-order filters tuned to the certain orientation and spatial frequency band, inhibitory subfields receive signals from the elements with different orientation and frequency tunings in our model.

The model can be useful for solving some of the image and video processing tasks such as segmentation, feature extraction, and data compression.

This work was financially supported by the Ministry of education and science of Russia (Agreement No 1741).

## **Disorientation of rats after destruction of anterior olfactory nucleus**

Zamaro A., Stukach Y, Pashkevich S., Kulchitsky V.

Interdepartmental Research Center for Artificial Intelligence, National Academy of Sciences of Belarus, Minsk, Belarus

White rats (n=8) were tested in simplified Morris water maze twice with one week break. Craniotomy was performed under ketamine-xylazine-acepromazine anesthesia after reflex establishment in 4 rats (group 1) from the right side (3.2 mm rostral to Bregma, 1.5 mm lateral to midline). 100 nL of 100  $\mu$ M glutamic acid solution were introduced to 7.2 mm depth using nanoliter pump. Rats from second group (n=4) suffered only anesthesia and craniotomy. Rats were tested again in simplified Morris water maze in 1 and 5 days after the operation. The increase of escape latency was established in rats with destroyed neurons of caudal parts of anterior olfactory nucleus. The site of water test start has been changed in 10 days after the operation. Paradoxical reaction was noticed: escape latency in rats with destroyed cells of anterior olfactory nucleus was shorter than the one in rats with intact brain. All the rats were decapitated in two weeks after the operation. Distribution of cells containing acetylcholinesterase in cerebral cortex was performed using histochemical method. Sharp decrease of stained cells amount in the area of right (at the side of chemical destruction) hemisphere was established compared to left hemisphere and to ones of rats with undamaged anterior olfactory nucleus.

Keywords: Morris test, behavior, orientation, destruction, anterior olfactory nucleus

## **An fMRI study of brain activation in a visual adaptation task to the features of facial expression**

Zhukova (Borachuk) O. V.<sup>1</sup>, Shelepin Yu. E.<sup>1,2</sup>, Harauzov A. K.<sup>2</sup>, Vasiljev P. P.<sup>2</sup>, Vershinina E. A.<sup>2</sup>

<sup>1</sup>St. Petersburg State University (St. Petersburg, Russia);

<sup>2</sup>Pavlov Institute of Physiology Russian Academy of Sciences (St. Petersburg, Russia)

The research is the study of brain activation in a visual adaptation task to the features of facial expression. In the first paradigm, one group of subjects was presented one and the same image of the virtual human face, and in the second paradigm one group of subjects was presented 36 different virtual human faces. Subjects were receiving the same two instructions: to determine the turn of the virtual face in the image (left/right) and to rate the emotion (joy/sadness). Spatial mapping of activated brain areas was conducted by the BOLD method of functional magnetic resonance tomography. The results showed that in the conditions of the constantly repeating presentation of the different face images one and the same image of virtual human face brain activity t increases in the second half of the experiment, and on the contrary, in the conditions of constantly repeating presentation of the one and the same face image brain activity decreases. The study shows that in a high probability of repetition of stimuli (presentation of the same face image) the level of blood flow in the second half of the study significantly reduces in almost all areas relating to the face detection network.

The study was performed as part of the financing of the research project "Psychophysiological and neurolinguistic aspects of verbal and nonverbal patterns of the recognition process" the Russian Science Foundation project № 14-18-0213.

Keywords: Adaptation, facial expression, fMRI, decision-making

## **fMRI research of the decision making process in uncertain condition.**

Zhukova (Borachuk) O. V.

Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia

Рассмотрены особенности принятия решения в условиях различной степени неопределенности. Использовали нейтральные (оптотипы – матрицы с различной степенью упорядоченности элементов Габора) и эмоционально значимые (оптоклоны – синтезированные лица) стимулы. Для оценки реакций мозга на стимулы использовали психофизические методы измерения и функциональную магнитно-резонансную томографию. Показаны разные режимы работы нейронных ансамблей мозга в зависимости от степени неопределенности сигнала. Выявлено, что баланс критериев при принятии решений осуществляется при помощи оппонентного механизма взаимодействия разных нейронных структур, аналогично тем оппонентным механизмам, которые известны в первичных структурах зрительной системы. При этом, "ошибки" восприятия в максимально неопределенных сигналах, например, при восприятии лица в близких к белому шуму структурах, не содержащих изображения оптоклонов, имеют важное экологическое значение.

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## **The role of the temporo-parietal junction and dorsolateral prefrontal cortex in third-party punishment of norm violations**

Zinchenko O. O.<sup>1</sup>, Klucharev V. A.<sup>1</sup>

<sup>1</sup>Centre for Cognition and Decision Making, Department of Psychology, National Research University Higher School of Economics, Moscow, Russian Federation,

Cooperation in human societies is greatly affected by social norms. Furthermore, people are often willing to punish norm violations at a substantial personal cost (Fehr and Fischbacher, 2004). It has been found that the right dorsolateral prefrontal cortex (rDLPFC) and right temporo-parietal junction (rTPJ) is causally involved in decisions to enforce social norms (Brune et al., 2012; Ruff et al., 2013, Baumgartner et al., 2014). Here we test the hypothesis that a decision to punish in a third-party punishment paradigm depends on the activity of the entire rDLPFC-rTPJ network.

To check our hypothesis, we used transcranial direct-current stimulation (tDCS) to disrupt the rDLPFC-rTPJ network in healthy subjects while they performed the Dictator Game. Additionally, we estimated the moral attitudes (Kolberg-Gilligan model) of subjects by measuring their understanding of the conventions/rules of a society. During separate sessions (within-subject design), we applied tDCS simultaneously to rDLPFC and rTPJ using three stimulation protocols: Condition N1, cathodal tDCS of the right DLPFC and anodal tDCS of the right TPJ; Condition N2, anodal tDCS of the right DLPFC and cathodal tDCS of the right TPJ; and Condition N3, a sham stimulation of the right DLPFC and TPJ. Our pilot study suggests that the frequency of third-party punishment near-significantly increased in Conditions N1 and N2 as compared to the control, Condition N3 (sham). Importantly, when moral attitudes were taken as a covariate, the effect of tDCS reached the level of significance.

Keywords: social norm enforcement, social punishment, tDCS, DLPFC, TPJ

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# Materials of the Satellite workshop for undergraduate and graduate students

## “Digital and informational technologies in electronic media industry (June 29-July 1)”

### 3D Camera For Depth Sensing and Motion Tracking,

Andreev Dmitry

Несмотря на невероятные достижения в области визуальных технологий, которые способны эмулировать достаточно большую степень функций человеческого мозга, компьютеры не способны воссоздать расчёты зрительной коры человека, и одним из важнейших инструментов который им ещё предстоит освоить это восприятие глубины.

У данной камеры датчик глубины основан на пассивном стереоскопе, выводящим видео с синхронизированными правым и левым видеопотоками. Графический процессор этой камеры вычисляет карту глубины из видео в режиме реального времени от программного обеспечения.

Двойные датчики на передней части устройства передают две видеозаписи высокой чёткости на программное обеспечение, которое затем сравнивает изображения соединяя их для получения полной карты глубины каждого объекта.

Карта глубины.

Карта глубины представляет собой двумерное одноканальное изображение, содержащее информацию о расстоянии от плоскости сенсора до объектов сцены. В некотором смысле это значение координаты  $z$  (координаты  $x$  и  $y$  в данном случае относятся к плоскости сенсора).

Получение карт глубины возможно несколькими способами:

- 1) Из имеющейся трехмерной модели сцены;
- 2) По паре стереоизображений;
- 3) С помощью специализированных сенсоров.

Каждый способ имеет свои достоинства и недостатки. В прикладных задачах актуальны последние два способа. Получение карты глубины по паре стереоизображений не требует дополнительного оборудования, но во многих случаях не дает желаемого результата.

Идея, лежащая в основе построения карты глубины по стереопаре очень проста. Для каждой точки на одном изображении выполняется поиск парной ей точки на другом изображении. А по паре соответствующих точек можно выполнить триангуляцию и определить координаты их прообраза в трехмерном пространстве. Зная трехмерные координаты прообраза, глубина вычисляется, как расстояние до плоскости камеры.

Одна из главных проблем специализированных сенсоров заключается в том, что большинство сенсоров не работает с поверхностями стекла или жидкости. Хорошим примером такого сенсора является Microsoft Kinect. К сожалению, данные, получаемые с сенсора, как правило, содержат некоторые дефекты, такие как неравномерные карая и поверхности объектов, области неправильно измеренных значений глубины для некоторых типов материалов.

Объектом исследования являются методы и алгоритмы предобработки карты глубины изображений. Целью работы является уменьшение погрешности определения расстояния от объектов сцены до камеры сенсора за счет обработки изображения карты глубины с целью подавления шума и восстановления утраченных участков карты глубин.

**Future models for live event broadcasting (Analytical review on the basis of IBC2015 papers),**  
Balakireva Elizaveta

В век информационных технологий нельзя не стремиться к чему-то новому, это касается и трансляции крупных мероприятий в прямом эфире. В своем докладе я хочу показать, что телевидение уже давно перешло ступень обыкновенной передачи изображения и звука на расстоянии. Сегодня – каждый зритель может получить уникальный опыт общения с экраном: VR-технологии, второй экран, конвергенция СМИ на разных платформах, камеры с обзором 360\*. Всё это и многое другое может сегодня дать нам современная технология ведения прямых трансляций. «Почувствуй то, что можешь только видеть» - вот девиз, которому должны следовать современные производители телевидения. На примере международных Игр Содружества (Commonwealth Games) 2014, я расскажу о современных методах трансляции, таких как:

- Панорамное исследование
- Живой взгляд 360\*
- Высокая частотность кадров
- Онлайн 4G – трансляция

Чтобы достичь максимального качества трансляции звука и изображения, нужно помнить о совместимости продукта и спроса на него, в этом ключе будут рассмотрены вопросы совместимости:

- Существующие форматы
- Выбор протокола доставки
- Потокое вещание
- Синхронизация
- Авто-конфигурация
- Безопасность

Live-трансляции будущего дадут каждому зрителю уникальный опыт, который станет достойной заменой живому мероприятию. Возможно, что через несколько лет, мы сможем пользоваться современными методами трансляций мобильно и повседневно. Нужно стремиться к будущему в телевидении, и возможно, оно настанет уже завтра.

**Avatar-based sign language interpretation for weather forecast and other tv programs (for example, Korea) (Analytical review on the basis of IBC2015 papers),**  
Dzhafarova Giulshan

Благодаря цифровому телевидению (DTV), субтитры и сурдоперевод стали доступной услугой для глухонемых людей в большинстве стран. Однако сурдоперевод не только требует определенных затрат, но и занимает некоторое пространство на экране телевизора. К примеру, в Корее сурдоперевод почти не предусмотрен. Он занимает 5% от всего вещания. Даже, если в программе есть интерпретация на языке жестов, глухонемые зрители зачастую не успевают уловить суть, так как действия быстро сменяются.

2. Корейские разработчики предложили систему, которая переводит закрытые заголовки программ прогноза погоды в KSL (корейский язык жестов) и представляет это с помощью 3D-анимации аватара. Переведенные данные отправляются с помощью Интернета на персональный компьютер (ПК) и мобильные устройства для отображения соответствующего анимированного сурдоперевода.

3. В словаре KSL имеется около 12000 слов. Трудно построить KSL-словарь и захватить движения для всех

этих слов. Поэтому были проанализированы прогнозы погоды в течение последних трех лет. После некоторой обработки прогнозных сценариев, слова были распределены по частям речи.

4. Синонимы переводятся на тот же язык жестов. Например, "дом", "корпус" и «обитель» являются синонимами, и все должны быть показаны как один жест.

5. Для визуализации переведенных кодов языка жестов, должна быть построена база данных движения.

Можно сделать движения путем редактирования каждого ключевого кадра, но был сделан захват движений настоящего человека. К тому же к существующим 2700 жестам для повседневной жизни, было добавлено 500 слов, посвященных прогнозам погоды в студии.

6. Части тела и движения рук объединили в программном обеспечении MotionBuilder.

7. Для приложений использовался движок Unity3D.

Система, предложенная в данной работе, создает язык анимации 3D, путем перевода закрытых титров в DTV. Для того чтобы найти частоту повторяемости каждого слова, были проанализированы прогнозы погоды, которые выходили на протяжении трех лет.

### **Ready for 8k UHD TV Broadcasting in Japan (Analytical review on the basis of IBC2015 papers), Jitina Maria**

Преимуществом 8K UHD TV является большее покрытие углового поля зрения телезрителя для большего ощущения присутствия и реалистичности происходящего на экране.

2. Подготовка UHD TV средств и оборудования охватывает широкий спектр задач от производства контента до производства средств воспроизведения, передачи и приёма.

3. Множество телезрителей сможет увидеть трансляции Олимпийских и Паралимпийских игр в 4K и 8K разрешении у себя дома. Уже сейчас японские потребители активно скупают UHD телевизоры, ведь уже сейчас в Японии доступен телевизионный контент в разрешении 4K.

4. Внедрение технологий UHD TV для широкого коммерческого пользования приведёт к разработке новых, более экономичных, средств приёма телевизионного сигнала, а так же к разработке новых способов сжатия информации.

5. На данный момент так же изучается, как 8K видео может быть использовано в других сферах помимо телевизионного вещания, включая медицину, образование и так далее.

#### **Перевод основных терминов и словосочетаний на английский язык**

1. The advantage of 8K UHD TV is complete filling of the view field to increase sense of presence and sense of realness.

2. Preparing UHD TV facilities and equipment covering a range of objectives from content production to play-out, transmission, and reception.

3. Many viewers will be able to see the broadcast of the Tokyo 2020 Olympic and Paralympic Games in 4K and 8K resolution at home. Already, Japanese consumers are actively buying UHD TVs. Television content in 4K resolution is already available in Japan.

4. Implementation of UHD TV technologies for a wide commercial use will lead to the development of new, more efficient, means of reception of a television signal, as well as to working-out new methods of data compression.

5. Now NHK is studying how 8K can be used in a variety of areas besides broadcasting, including medicine, education and so on.

### **Building of 3D model of video object based on for the minimum number of still images, Zabelin Dmitry**

1. Исследование и анализ методов построения трехмерной модели по фотоизображениям. К данным методам и программам относятся: Autodesk Remake, 3dfZephyr, Insight3d, Basel Face Model, Vocord FaceControl 3D. Определение минимального количества изображений, по которым перечисленные программы и технологии способны построить трехмерную модель. Алгоритм разработанного решения поставленной задачи состоит из следующих пунктов:

2. Загрузка изображения человеческого лица.

3. Сопоставление уже готовых landmark для 3DM модели и вычисленных с фотоизображения.
4. Наложение изображения на трехмерный меш человеческого лица, созданный технологией Basel Face Model.
5. Вывод полученных результатов на экран.
6. Анализ результатов. Дополнительные исследования связанные с изучением зависимости разрешения фотоизображения и получившегося результата.
7. Построение 3d-модели – Building a 3d- model.

### **Visual Radio Production for Sport Events (Analytical review on the basis of IBC2015 papers), Ivanova Diana**

Большинство современных радиоприемных устройств, таких как автомобили, смартфоны включают в себя цветной экран и интегрируют цифровое, гибридное или веб-радио. С помощью этих функций, вместе с аудио могут быть переданы и снимки с места событий.

ЕВU / Евровидение добавили визуализацию для спортивных мероприятий, проходящих в режиме реального времени. Содержимое представляет собой сигнал с результатами состязаний, фотографии с места событий и комментарии, которые вещатели могут использовать на своих радио или веб-платформах. Многие вещатели распространили сигнал либо на DAB / DAB + 1 либо на RadioDNS2 или разместили слайд-шоу на своих веб-сайтах. В этом докладе вкратце описано как платформа усваивает и обрабатывает информацию, и как производит слайды, готовые для вещания широкому кругу слушателей.

Live raw data – необработанная информация

Content production – производство содержимого

Scalable platform – масштабируемая платформа

Processing ingested content – обработка полученного содержимого

Open messaging communication - открытая система обмена сообщениями

### **Application of augmented reality in film-making process**

Karnachkova Yulia

В наши дни технологию дополненной реальности можно применять в разных сферах деятельности, таких как: дизайн, видеоигры, конструкторские разработки и т.д. В данной работе будет рассмотрено применение дополненной реальности непосредственно при съемке фильмов, мероприятий в прямом эфире, а также при монтаже уже отснятого материала. К примеру, компания ICEreality и строительная компания DIRTT создали платформу дополненной реальности, которая позволяет человеку ходить и строить объекты в виртуальной реальности, но видеть их в физическом окружении самого здания. Данную технологию можно применить при строительстве декораций для фильмов, что существенно упрощает работу, как и актеров, которые смогут увидеть место действия своих героев, так и художников по декорациям, которые простым движением руки смогут построить и визуализировать свою задумку.

Дополненная реальность - augmented reality; Виртуальная реальность - virtual reality.

### **Estimation the emotional state of viewers by facial image**

Korostekov Stepan

Объектом исследования является новый способ получения семантических метаданных аудиовизуального контента. Этот способ основывается на распознавании эмоционального профиля зрителя программой FaceReader во время просмотра кинофильма. Цель данной работы заключается

в нахождении корреляции между семантическими метаданными, полученными с помощью программы FaceReader, и прогнозами, составленными профессиональными аналитиками для одного и того же кинофильма. В результате экспериментов была обнаружена прямая связь между семантическими метаданными, полученными в автоматическом режиме, и составленными вручную аналитиками. Предполагаемый подход к получению семантических метаданных позволит создавать различные версии компактных представлений кинофильмов для разных групп зрителей.  
Semantic Metadata, audiovisual content, emotional profile

### **Graphic analyzers of sound data**

Mirzaianova Svetlana

Graphic analysis of the audio data has a long history. This began with the invention of the optical sound recording on film. Scientists began to analyze how the recorded sound associated with an image on film. In this paper I want to consider various methods of representation of audio data in graphical form. The primary analysis conducted by the graphs in the time and frequency domains. But there are also other, more specific ways of presenting audio data. The choice of method depends on the problem to be solved. Currently graphical analysis of the audio data is a good helper when creating high-quality audio recordings for different areas: film, music, radio. In addition, it is used in speech recognition systems serving for user identification and building security systems. Modern software spectrum analyzers can display a lot of frequency parameters and characteristics, revealing the sound quality of audio systems. However, to use these data, it is possible only with the understanding of acoustic mechanisms behind the irregularities on the charts, and using the right tools to address them.

### **Securing the digital home**

Mikhailova Daria

Представьте, что возвращаясь вечером с работы и подъезжая к своему дому, ворота автоматически открываются перед вами, свет в прихожей сам загорается, кондиционер поддерживает комфортную температуру в комнате, умный пылесос только что пропылесосил кухню, а ваш ужин автоматически разогрелся в микроволновой печи. Звучит как научная фантастика. Однако благодаря таким феноменам как Умный дом (Digital Home) и Интернет вещей (IoT, Internet of Things) все это уже воплощается в реальность.

С каждым годом наши современные «крепости» все больше оснащаются интеллектуальными девайсами, гаджетами, датчиками, автоматизированными системами и пр. Смарт-телевизоры, интеллектуальные кондиционеры, самостоятельные работающие пылесосы, умные холодильники, стиральные и посудомоечные машины, «общающиеся» между собой по WiFi. Все это - примеры уже существующих устройств IoT, заполняющих Умные дома. Однако сколько еще нереализованных и перспективных идей, например, холодильник, самостоятельно заказывающий закончившиеся продукты питания в магазинах.

С развитием технологий IoT и Digital Home жизнь пользователя с одной стороны значительно упростилась, с другой – ему пришлось столкнуться с новыми, ранее неизвестными проблемами.

Среди достоинств Умного дома следует отметить его экономичность (экономия электроэнергии, воды), надежную систему видеонаблюдения, пожарную и охранную сигнализации, а также общую комфортную атмосферу для потребителя и экономии его времени на повседневные домашние дела. По данным исследований около 30% потребителей уже имеют или планируют приобрести домашние смарт-устройства IoT в ближайшее время. Однако с какими трудностями и проблемами им скорее всего предстоит столкнуться?

Во-первых, это довольно высокая цена за умные устройства Интернета вещей. А во-вторых, Умный дом может превратиться в кошмар для безопасности имущества и персональных данных клиента. Каждое подключенное к сети устройство получает и хранит огромное количество личных потребительских данных, тем самым создает угрозу кибератак, ограбления дома или захвата персональных данных с целью шантажа.

Многие производители, работающие на рынке датчиков IoT, уделяют больше внимания дизайну смарт-гаджетов и уменьшению их цены, а вопросы безопасности относят на второй план. Однако, определенно, этим нельзя пренебрегать. Например, если клиент имеет в доме интеллектуальный кондиционер, реагирующий на движения в комнате и соединенный с дверными замками, подвергается серьезному риску взлома жилища, и если устройство будет взломано, грабителям не составит особого труда проникнуть в дом.

Следует помнить, что кибератака Умного дома - это не просто единичный взлом какого-то компьютера или смарт-кондиционера. Как правило, криминальные хакеры сегодня работают в крупных преступных группировках. Если они находят уязвимое место, позволяющее им использовать определенный смарт-телевизор для получения доступа к чему-то, что приносит неплохую прибыль, они не остановятся на доме одного клиента, а начнут атаку против миллионов потребителей, купивших этот смарт-телевизор.

Логично, что пользователей отпугивают возможные риски, угроза безопасности имущества и ненадежность конфиденциальной информации. Это может привести к снижению уровня доверия и уверенности потребителей в технологии IoT.

Для решения этой проблемы следует повышать степень надежности охранных систем Умного дома и устройств IoT. Против кибератак предлагаются такие способы защиты дома как Home Guard (домашняя охрана) и подход attack continuum approach, который не ограничивается безопасностью одного дома, а обеспечивает контроль безопасности Умных домов всей клиентской базы. Система распознает угрозу или ошибку и сообщает в оперативный центр безопасности, откуда их могут быстро заблокировать во всех других сетях клиентов. Такой же подход attack continuum approach используется в настоящее время в крупнейших мировых корпорациях и государственных предприятиях.

Поскольку технологии, сеть интернет, IoT постоянно меняются (чуть ли не каждый день анонсируются девайсы и покупаются в дом все новые и новые гаджеты) становится сложно уследить за современными вредоносными программами и способами кибератак. Можно защитить свою домашнюю сеть и свой Умный дом от вчерашней атаки, но это может не помочь справиться с завтрашней. Поэтому существует необходимость постоянного анализа состояния домашней сети до, во время и после атаки для того, чтобы:

Выявлять подозрительные элементы и блокировать атаки прежде, чем данные и устройства ваших клиентов им подвергнутся

Распознавать и быстро реагировать на атаки, фиксировать их, прежде чем они распространятся на другие устройства вашей сети и ваш контент

Понять, что злоумышленник пытается сделать, и принять быстрые и эффективные меры, чтобы заблокировать атаки во всех сетях ваших других клиентов

В общем, проблема безопасности Умного дома требует решения и уже имеет несколько способов и возможностей такого решения. Технологии Умного дома и Интернета вещей являются в настоящее время довольно перспективными. Можно сказать, что если десять лет назад IoT и Digital Home являлись утопией, то сейчас идет активный процесс внедрения смарт-устройств и технологий в дома продвинутых потребителей. Позитивные прогнозы гласят, что широкое внедрение IoT и превращение наших домов в настоящие умные «космические корабли» уже не за горами и будет постепенно происходить буквально в течение следующих пяти лет.

Перевод основных терминов и словосочетаний на английский язык

Digital or Smart Home - умный дом — система домашних устройств, способных выполнять действия и решать определенные задачи без участия человека.

Internet of Things (IoT) - интернет вещей

## Calculating an angle of rotation of the human head by photo

Petrovskiy Evgeniy

Основой предлагаемой в работе методики является треугольник, составленный по опорным точкам лица человека «Глаза – Рот». Опорные точки ищутся из анализа вертикальных и горизонтальных гистограмм лица человека. Определение максимумов и минимумов предварительно сглаженных гистограмм приводит к нахождению на лице человека местоположений глаз и рта. По координатам центра областей глаз и рта можно построить треугольник. Естественно, что при повороте головы углы треугольника будут меняться, и это свойство используется для оценки угла поворота головы человека. Угол у левого глаза —  $\alpha$ , у правого —  $\beta$  и у середины рта —  $\gamma$ . Идея методики определения угла поворота головы связана с нахождением зависимости между изменением углов треугольника и углом поворота головы человека. Все изменения углов треугольника уникальны и позволяют четко идентифицировать сторону поворота головы. Это очень важный показатель качества предлагаемой модели. Представляя все комбинации углов в единой модели, возможно четко получать реальный угол поворота головы человека относительно направления на источник получения изображений. Предполагая, для простоты, зависимость между точным углом поворота головы и найденным углом треугольника в виде линейной модели  $y = a + bx$ , можно решить задачу нахождения коэффициентов  $a$  и  $b$  методом наименьших квадратов. На основе полученных оценок составляются уравнения, из которых и вычисляется точный угол поворота головы человека.

Угол поворота головы человека – Angle of rotation of the human head; Треугольник «Глаза - Рот» - Triangle «Eyes - Mouth»; Распознавание лиц – Face recognition; Идентификация личности – Personal identification.

## Temporal versus spatial resolution - comparative tests for broadcast sports

Razin Sergey

В данной работе рассмотрены результаты исследования, которое призвано определить, что обеспечивает фактический рост детализации спортивных трансляций – увеличение пространственного разрешения или временного разрешения.

По данным исследования, увеличение временного разрешения улучшает детализацию изображения движущихся объектов гораздо эффективнее, чем увеличение пространственного разрешения. Высокая скорость затвора позволяет захватить значительно больше деталей, чем высокие параметры пространственного разрешения.

Детализация движущихся изображений зависит от резкости объектива, разрешающей способности, размытия изображения (motion blur), шумы и глубины резкости.

Жертвуя временным разрешением ради высокого пространственного разрешения в условиях быстрого движения, мы получаем плохое изображение по сравнению с тем, которое могли получить за счет поддержания частоты кадров.

## The future of recommender systems,

Savenkova Irina

Рекомендательные системы стали неотъемлемой частью нашей жизни. Перечислим несколько примеров, с которыми сталкивались многие из вас: рекомендации людей, которых вы можете знать, а также аудиозаписей и групп, которые могут быть вам интересны во ВКонтакте; рекомендации работодателю резюме, которые больше всего подходят для данной вакансии на hh.ru; рекомендации сопутствующих и часто приобретаемых с данным товаром товаров на Ozon.ru (и многих других сайтах).

Среди кино можно выделить рекомендации фильмов на Кинопоиске, среди аудио – Pandora (служба потокового воспроизведения музыки в Интернете; пользователь медиапроигрывателя Pandora выбирает музыкального исполнителя, после чего система ищет похожие композиции, используя около 400 музыкальных характеристик (например, синкопа, тональность, гармония и т. д.); используя функции «нравится» или «не нравится», слушатель может настроить «радиостанцию» по своему вкусу)). Универсальной системой является Imhonet.ru, дающий рекомендации по фильмам, сериалам, телепередачам, книгам и играм.

В мире регулярно проводятся конференции, либо полностью посвященные рекомендательным системам (например, ACM RecSys), либо включающие их как секцию. В будущем роль рекомендательных систем будет только возрастать в связи с возрастанием стремления к персонализации, усложнением выбора, обусловленным ростом предложения продуктов и услуг, а также в связи с развитием информационных технологий.

Интерес к рекомендательным системам возник благодаря Netflix Prize (открытое соревнование на лучший алгоритм предсказания оценки, которую зритель поставит фильму, на основе предыдущих оценок этого и других зрителей. Соревнование проводил Netflix, крупная компания по аренде DVD (на тот момент). За некоторыми исключениями, участвовать могли все желающие. Главный приз составлял \$1,000,000. Для его получения необходимо было улучшить алгоритм Netflix на 10 %).

В большинстве рекомендательных систем применяется один из двух базовых подходов: контентная и коллаборативная фильтрация. Существуют также и другие подходы (в том числе гибридные). Алгоритм работы контентной фильтрации следующий – товары полностью сравниваются на основании их атрибутов (для фильма это актеры, режиссер, жанр и т.д.), а после чего система задаёт их соответствие. Коллаборативная фильтрация заключается в поиске похожих пользователей – «рекомендации, основанные на пользователях» или поиске похожих продуктов – «рекомендации, основанные на продуктах». В первом случае для построения рекомендаций находятся так называемые «соседи» пользователя, то есть наиболее похожие на него пользователи, предполагается что пользователю понравятся те же объекты, что и «соседям». Во втором случае пользователь характеризуется объектами, которые он просмотрел или оценил. Все объекты-соседи объединяются во множество из которого исключаются объекты, просмотренные или оцененные пользователем. Из оставшегося множества строится топ рекомендаций. При этом подходе в создании рекомендаций участвуют все пользователи, которым понравился тот или иной объект.

Перспективы развития рекомендательных систем обуславливаются развитием таких областей как Big Data (т.к. необходима обработка больших объемов данных), Clouds (т.к. облачные технологии многократно повышают эффективность работы), Data Science (т.к. необходима теоретическая база для разработки алгоритмов анализа данных в целях выявления зависимостей, а также для построения прогноза), Data Mining (используется в частности для кластеризации), Machine Learning (используется в частности для обучения алгоритмов с подкреплением).

Рассмотрим пути дальнейшего развития рекомендательных систем. Во-первых, рекомендательные системы будут интегрированы в «умные» телевизоры, пользователю будут предлагаться интересные ему кинофильмы и передачи, демонстрируемые на телевидении, основываясь на истории просмотра (при совместном использовании телевизора необходимо идентифицировать пользователей).

Во-вторых, сейчас есть возможность давать рекомендации пользователю, учитывая его прошлый опыт просмотра. Но во внимание не берутся такие факторы как текущее местонахождение пользователя, время года, день недели, время суток, которые влияют на вкусы пользователя. Уже сейчас идет работа над созданием систем, которые будут учитывать эти и другие факторы, давая различные рекомендации при их изменении.

В-третьих, на данный момент системы позволяют делать рекомендации для одного человека. В перспективе появится система, которая дает рекомендации определенной группе пользователей (например, когда несколько людей намереваются вместе посмотреть кинофильм, но не могут договориться, какой именно).

В-четвертых, в рекомендательных системах будет активно использоваться технология «второго экрана». Например, пользователь смотрит кулинарное шоу по телевидению, в то же время ему на телефон или планшет приходит рецепт блюда, человек отмечает, интересен ли ему данный рецепт или нет, в результате система формирует список рекомендаций уже по кулинарным блюдам.

В-пятых, будет укрепляться связь виртуальной и реальной жизни человека. Если вернуться к предыдущему примеру, то система может в ответ на одобрение рецепта также предлагать по запросу автоматический поиск и заказ продуктов в супермаркете, опять же основываясь на информации о предпочитаемых пользователем магазинах и текущих ценах в нем, предлагая различные варианты: «экономный выбор», «высококачественный набор», «ближайший к дому» и др. Это тем более вероятно, что некоторые системы уже сейчас позволяют связывать виртуальную и реальную жизнь человека. Например, советуют посмотреть определенный фильм конкретному человеку в кинотеатре. В дальнейшем данная связь будет только усиливаться.

В-шестых, дальнейшее развитие состоит в укреплении человеко-компьютерного взаимодействия. Для этого необходимо получать от пользователя как можно больше информации (что он смотрит, что покупает, в какое время спит и т.д.), причем часть информации можно получать непосредственно, задавая пользователю вопросы о нем самом. Таким образом, можно будет составить точный психологический портрет и рекомендовать человеку именно то, в чем он нуждается. Причем система должна безошибочно определять настроение человека по голосу, мимике и предлагать ему соответствующие фильмы, музыку и т.д.

В-седьмых, развитие речевых анализаторов и применение нечеткой логики позволит обрабатывать запросы вида «хочу посмотреть романтический фильм со счастливым концом» и выдавать пользователю именно те фильмы, которые соответствуют его пожеланиям.

Таким образом, рекомендательные системы прочно укрепились в мире интенсивно развивающихся информационных технологий. И со временем их проникновение в повседневную жизнь будет только усиливаться.

Перевод основных терминов и словосочетаний на английский язык: Recommender systems, Recommendation systems, Content-based filtering, Collaborative filtering, User-based collaborative filtering, Item-based collaborative filtering, Big Data, Data Science, Data Mining, Machine Learning, Clouds, Smart TV, Second Screen, Human-Computer Interaction, Fuzzy logic

## **Flicker image in film and television and digital technologies of dealing with them**

Yudin Semen

Существует множество искажений изображения, которые возникают вследствие его дискретизации по времени. Такими искажениями являются мелькания, стробоскопический-эффект, дробление движущихся изображений др. Мигание изображения – это одно из наиболее заметных и неприятных для глаза искажений.

Целью работы является исследование методов и средств борьбы с миганиями изображения в кино и телевидении.

При анализе причин появления миганий изображения используются положения теории записи и воспроизведения информации (в частности теория дискретизации).

«Мигания изображения» - низкочастотные колебания яркости изображения (причем частота миганий существенно ниже частоты слияния мельканий для зрительного анализатора, например 4 Гц), которые в некоторых случаях могут сопровождаться перемещением по полю кадра темной полосы. Мигания изображения – это одно из наиболее заметных и неприятных для глаза искажений в кино и телевидении, которое может возникнуть еще в процессе съемки в виде изменения яркости последовательных кадров и оно будет видно на изображении независимо от того на каком устройстве отображается фильм (киноэкран, телевизор).

В части исследования эффективности работы существующих плагинов для устранения миганий изображения применяются методы цифровой обработки изображения.

Бороться с миганием изображения позволяет видеоредактор Adobe Premiere Pro с помощью специальных плагинов. Нами были протестированы плагины: Digital Anarchy Flicker Free и BCC Flicker Fixer.

Тестирование Digital Anarchy Flicker Free показало, что он достаточно эффективно борется с миганиями и в том числе с перемещающейся темной полосой, однако был выявлен недостаток Flicker Free – при обработке сцен с быстро движущимися объектами вокруг них возникает смазанный след.

Тестирование BCC Flicker Fixer показало, что он более сложен в управлении, но имеет больше методов борьбы с миганиями, в сравнении с Digital Anarchy Flicker Free. BCC Flicker Fixer достаточно эффективно борется с миганиями и в том числе с перемещающейся темной полосой.

Мигания – flicker. Дискретизация – sampling . Плагин – Plugin.

## **Research of stereo pair parameters and depth perception in VR systems,**

Chafonova Victoria

В настоящее время технологии виртуальной реальности сделали значительный скачок вперед. Виртуальная реальность (англ. Virtual Reality или VR) – это искусственно созданный при помощи компьютерных технологий мир, который передают человеку при помощи его органов чувств: обоняния, осязания, зрения, слуха и др. Технологии виртуальной реальности имитируют реальные воздействия на человека и окружающие его предметы, соблюдая законы физики, либо пренебрегая ими.

Стереоизображение воспринимается объемным благодаря тому, что изображенные объекты стереопары в зависимости от их расположения по глубине сцены имеют различный горизонтальный параллакс (параллакс – взаимное смещение сопряженных точек в изображениях стереопары), а каждый глаз зрителя видит только предназначенное для него сепарированное изображение.

В работе проведены исследования параллаксов и восприятия объемного изображения в искусственно смоделированной виртуальной реальности, и обработанного «под виртуальную реальность», изображения реального мира, используя алгоритмы, разработанные в диссертации.

Исследование выполнено при финансовой поддержке Фонда содействия развитию малых форм предприятий в научно-технической сфере

## **Personal identification by face image**

Shliakhtenko Marina

Как известно, большую часть информации об окружающем мире человек получает с помощью зрения. На данный период времени мощностей современных компьютеров уже хватает для решения хотя бы части задач анализа зрительной информации. Одна из задач такого рода –определение личности работающего за компьютером человека. Это позволит повысить надежность обеспечения прав доступа к информации и одновременно сделать эту процедуру более дружественной по отношению к человеку.

Целью данной бакалаврской работы является написание программы, позволяющей идентифицировать личность по биометрическим признакам лица.

Для достижения поставленной цели необходимо было решить следующие задачи:

- предварительная обработка изображений;
- написание программного кода,

Для выполнения данной работы был использован метод геометрии лица. Преимущество метода в том, что, в отличие от большинства биометрических методов, не требуется дорогостоящее оборудование. При соответствующем оборудовании даже существует возможность распознавания на значительных расстояниях от камеры.

В работе использовался алгоритм поиска лица, разработанный Виолой и Джонсом. На сегодняшний день это самый популярный метод для поиска области лица на изображении, он характеризуется высокой скоростью и эффективностью.

За основу идентификации были взяты признаки лица, которые использует человеческий мозг для сравнения лица. Наименее изменяемыми пропорциями обладает треугольник «глаза-нос».

Полученный алгоритм даёт результат достоверного распознавания личности на 56 изображениях – 76,8%. Это значительно уступает на сегодняшний день многим программам идентификации личности, однако в случае дальнейшей работы над алгоритмом, можно значительно увеличить процент распознавания.

# **Materials of the satellite session of the international conference Laser Optics: “Semiconductor Lasers, Materials and Applications” (June 28-June 30).**

## **Semiconductor laser based optical frequency combs - applications in communications and signal processing**

Delfyett P., Bhooplapur S., Klee A., Sarailou E., Bagnell K.;  
CREOL, The College of Optics & Photonics, Univ. of Central Florida, United States

Optical frequency combs from mode-locked lasers are developed and used for realizing unique functionality for applications in ultra-wide bandwidth communication and signal processing.

## **Novel approach for transverse mode engineering in edge-emitting semiconductor lasers**

Gordeev N. Yu.,<sup>1,2,3</sup> Payusov A. S.,<sup>1,2,3</sup> Shernyakov Yu. M.,<sup>2,3</sup> Mintairov S. A.,<sup>2</sup> Kalyuzhnyy N. A.,<sup>2</sup> Kulagina M. M.,<sup>2</sup> Zhukov A. E.,<sup>3</sup> Maximov M. V.,<sup>2,3</sup>;  
1 – Submicron Heterostructures for Microelectronics, Research Engineering Center RAS, 2 – Ioffe Inst., 3 - St. Petersburg Academic Univ., Russia

We review our novel approach based on coupled large optical cavity (CLOC) structures for effective suppression of high-order transverse modes in edge-emitting lasers with broadened waveguides. We discuss the main principles of the CLOC laser concept and present our recent numerical and experimental results of the laser operation.

## **Wavelength stabilized high-power diode lasers – design, manufacturing and applications**

Sumpf B.; Ferdinand-Braun Inst., Germany

Wavelength stabilized high-power diode lasers are requested light sources in the field of laser based sensor systems. They are used as pump lasers for non-linear frequency conversion, e.g. second harmonic generation, to pump solid state laser devices applied for diagnostic purposes in life sciences and they are applied directly as light sources for absorption or Raman spectroscopy. This paper presents recent developments concerning distributed Bragg reflector (DBR) ridge waveguide (RW) diode lasers for vibrational spectroscopy and high brightness DBR-tapered lasers for non-linear optics. The manufacturing and the electrooptical, spectral, and beam parameters of these devices will be presented together with a compact handheld Raman probe using an implemented dualwavelength DBR-RW diode laser for Shifted Excitation Raman Difference Spectroscopy

## **Integrated butt-coupled membrane laser for Indium Phosphide on Silicon platform**

Pogoretskiy V., Higuera-Rodriguez A., Jiao Y., van der Tol J. J. G. M, Heiss D., Smit M. K.;  
Eindhoven Univ. of Technology, The Netherlands

In this work we present the design and technology development for an integrated butt-coupled membrane laser in the IMOS (Indium Phosphide Membrane on Silicon) platform. Laser is expected to have a small footprint (less than 50  $\mu\text{m}^2$ ), 1 mA threshold current and a direct modulation frequency of 10 GHz.

### **Modulation response of double tunneling-injection quantum dot lasers**

Asryan L. V.; Virginia Polytechnic Inst. and State Univ., United States

The upper limit for the modulation bandwidth in a double tunneling-injection (DTI) quantum dot (QD) laser is discussed. While the maximum bandwidth is the same in DTI and conventional QD lasers, the optimum dc current, at which it is obtained, is lower in a DTI laser. Different factors limiting the modulation bandwidth in a DTI QD laser are also discussed.

### **Integrated mode locked laser systems in semiconductor photonic integrated circuits**

Bente E., Moskalenko V., Latkowski S., Llorens-Revull M., Williams K.;  
Eindhoven Univ. of Technology, Netherlands

The performance of integrated planar waveguide mode locked lasers can be enhanced using the available photonic integration platform technology in indium-phosphide. Extended cavity mode locked oscillators including DBR mirrors and phase modulators can be realized at telecom wavelengths to improve performance and control over the device. Integrated pulse shapers and special amplifiers can be used to improve the output properties further.

### **Mode-locking and Q-switching in 1.06 $\mu\text{m}$ two-sectional QW lasers due to Stark effect**

Buyalo M. S.,<sup>1,2</sup> Gadzhiyev I. M.,<sup>1,2</sup> Il'inskaya N. D.,<sup>1</sup> Usikova A. A.,<sup>1</sup> Nevedomskiy V. N.,<sup>1</sup> Egorov A. Yu.,<sup>2</sup> Portnoi E. L.,<sup>1</sup>;  
1 - Ioffe Inst., 2 - ITMO Univ., Russia

In two section lasers with 3 QWs passive mode-locking and Q-switching are realized. Frequency rate in mode-locking is 75 GHz with time-bandwidth product 0.49. The bleaching mechanism is induced by photocurrent in absorber at high reverse biases.

### **High-energy picosecond optical pulse generation with asymmetric-waveguide diode lasers**

Avrutin E. A.,<sup>1</sup> Ryvkin B. S.,<sup>2,3</sup> Kostamovaara J. T.,<sup>2</sup>;  
1 - Univ. of York, United Kingdom, 2 - Univ. of Oulu, Finland, 3 - Ioffe Inst., Russia

We report recent progress and discuss important issues in the design of gain-switched and combined gain/Q-switched asymmetric waveguide lasers with a large effective spot size for applications ranging from optical range finding (with a prototype system developed) to nonlinear optics. The role of the active layer material, the waveguide design, and the use of saturable absorber in the cavity are discussed.

### **Laser-thyristors as a source of high-power laser pulses with a pulse width of 1-100 ns**

Podoskin A. A.,<sup>1</sup> Soboleva O. S.,<sup>1</sup> Zolotarev V. V.,<sup>1</sup> Veselov D. A.,<sup>1</sup> Pikhin N. A.,<sup>1</sup> Tarasov I. S.,<sup>1</sup> Bagaev T. A.,<sup>2</sup>,  
Ladugin M. A.,<sup>2</sup> Marmalyuk A. A.,<sup>2</sup> Simakov V. A.,<sup>2</sup> Slipchenko S. O.,<sup>1</sup>;  
1 - Ioffe Inst., 2 - Stel'makh Research and Development Inst. «Polyus», Russia

A low-voltage AlGaAs/GaAs/InGaAs laser-thyristor heterostructure has been fabricated in order to have a compact source of high-power laser pulses at 900nm wavelength. Peak powers/pulse width of 55 W/100 ns and 8 W/10 ns from 200 $\mu\text{m}$  aperture and 1W/1ns from 20 $\mu\text{m}$  aperture have been demonstrated.

### **Frequency combs from InAs/InP quantum dash based mode-locked lasers for multi-terabit/s data transmission**

Ramdane A.<sup>1</sup>, Panapakkam V.<sup>1</sup>, Gaimard Q.<sup>1</sup>, Merghem K.<sup>1</sup>, Aubin G.<sup>1</sup>, Chimot N.<sup>2</sup>, Lelarge F.<sup>2</sup>, Vujicic V.<sup>3</sup>, Anthur A.<sup>3</sup>, Zhou R.<sup>3</sup>, Barry L. P.<sup>3</sup>, Marin P.<sup>4</sup>, Kema J. N.<sup>1,4</sup>, Pfeifle J.<sup>4</sup>, Koos C.<sup>4</sup>;

1 - Laboratory for Photonics, CNRS, France, 2 - III-V Lab, Palaiseau, France, 3 - Dublin City Univ., Ireland, 4 - Karlsruhe Inst. of Technology (KIT), Germany

InAs/ InP quantum dash based mode locked lasers are particularly suited for frequency comb generation. Multi-terabit/s data transmission has been achieved using one single chip

### **Dislocations in LD and LED semiconductor heterostructures**

Romanov A. E.<sup>1,2</sup>, Speck J. S.<sup>3</sup>;

1 - ITMO Univ., Russia, 2 - Ioffe Inst., Russia, 3 - UCSB, United States

We discuss misfit dislocations (MDs) and threading dislocations (TDs) in latticemismatched semiconductor heteroepitaxial layers, which are the key structural elements of light-emitting diodes (LEDs) and laser diodes (LDs). Novel approaches to modelling MD formation and TD reduction are considered. The behavior of dislocations in conventional III-V semiconductor compounds as well in polar and semipolar III-nitride heterostructures are reviewed in detail.

### **The most important issues in technology of AlGaInNbased laser diodes and in array**

Leszczynski M.;

TopGaN and Inst. of High Pressure Physics UNIPRESS, Poland

Despite the bright commercial future of nitride LDs, there is a number of technological issues which are being solved, and some of them will be discussed in the presentation.

### **Fractional order of poling period for broadly tunable second harmonic generation**

Fedorova K. A.<sup>1,2</sup>, Sokolovskii G. S.<sup>2</sup>, Bakshaev I. O.<sup>3</sup>, Livshits D. A.<sup>3</sup>, Rafailov E. U.<sup>1</sup>;

1 - Aston Univ., United Kingdom, 2 - Ioffe Inst., Russia, 3 - Innolume GmbH, Germany

We demonstrate the possibility of using a fractional order of poling period of nonlinear crystal waveguides for tunable second harmonic generation. This approach allows for an extension of wavelength coverage in the visible spectral region by frequency doubling in a single nonlinear crystal waveguide.

### **True yellow II-VI/GaAs optically pumped laser structures for microchip laser diode converters**

Sorokin S. V.<sup>1</sup>, Sedova I. V.<sup>1</sup>, Gronin S. V.<sup>1</sup>, Ivanov S. V.<sup>1</sup>, Lutsenko E. V.<sup>2</sup>, Vainilovich A. G.<sup>2</sup>, Yablonskii G. P.<sup>2</sup>;

1 - Ioffe Inst., Russia, 2 - Stepanov Inst. of Physics NASB, Belarus

We report on recent progress in developing true-yellow (570-590nm) lowthreshold (on for microchip laser diode converters).

## **Infrared, green, and blue-violet pulsed lasers based on semiconductor structures pumped by low-energy electron beam**

Zverev M. M.<sup>1</sup>, Gamov N. A.<sup>1</sup>, Zhdanova E. V.<sup>1</sup>, Studionov V. B.<sup>1</sup>, Sedova I. V.<sup>2</sup>, Sorokin S. V.<sup>2</sup>, Gronin S. V.<sup>2</sup>, Ivanov S. V.<sup>2</sup>, Ladugin M. A.<sup>3</sup>, Padalitsa A.<sup>3</sup>, Mazalov A. V.<sup>3</sup>, Kureshov V.<sup>3</sup>, Marmalyuk A. A.<sup>3</sup>;  
1 - Moscow Technological Univ. MIREA, 2 - Ioffe Inst., 3 – RDI Polyus, Russia

Ultimate parameters of infrared, visible and blue-violet electron-beampumped lasers and laser arrays based on II-VI, III-V and III-N semiconductor heterostructures, obtained at electron energy below ~10keV are discussed.

## **Monolithic high-index contrast grating VCSELs**

Gebski M.<sup>1</sup>, Marciniak M.<sup>1</sup>, Dems M.<sup>1</sup>, Lott J. A.<sup>2</sup>, Czyszanowski T.<sup>1</sup>;  
1 - Lodz Univ. of Technology, Poland, 2 - Technical Univ. Berlin, Germany

A new and radically simplified construction of the vertical-cavity surfaceemitting laser (VCSEL) with monolithic high-index contrast grating will be investigated. Instead of hundreds of epitaxial layers as in conventional VCSELs, the proposed design consists of a thin active zone capturing and recombining the carriers positioned between two monolithic cladding layers of p-doped and n-doped material. In these semiconductor lasers the optical feedback is provided by one or two planar monolithic subwavelength gratings etched into the cladding layers on either side of the optical cavity.

## **VCSEL polarization control by rhomboidal selectivelyoxidized current aperture**

Bobrov M. A.<sup>1</sup>, Maleev N. A.<sup>1</sup>, Blokhin S. A.<sup>1</sup>, Kuzmenkov A. G.<sup>1,2</sup>, Vasil'ev A. P.<sup>1,2</sup>, Blokhin A. A.<sup>1</sup>, Kulagina M. M.<sup>1</sup>, Guseva Yu. A.<sup>1</sup>, Troshkov S. I.<sup>1</sup>, Ustinov V. M.<sup>1,2,3</sup>;  
1 – Ioffe Inst., 2 - Submicron Heterostructures for Microelectronics, Research Engineering Center RAS, 3 - Peter the Great St. Petersburg Polytechnic Univ., Russia

The new approach for single-mode (SM) VCSEL polarization control based on rhomboidal selectively-oxidized current aperture combined with intracavity contacts is discussed. MBE-grown VCSELs with aperture size of about 2.5 micron demonstrate lasing at 845-852 nm with SM output power exceeds 1.5 mW, SMSR high than 30 dB, and orthogonal polarization suppression ratio high than 20 dB for temperature of 20-80oC.

## **Progress in high-power VECSELs: from material science to applications**

Guina M.; Tampere Univ. of Technology, Finland

The presentation is focused on reviewing the major recent steps in the development of VECSEL technology. Emphasis is put on advances concerning power scaling, thermal management, and wavelength coverage. Ultimately, an outline of emerging applications in medicine and atom physics, is presented.

## **1.3 μm InAs quantum dot semiconductor disk laser**

Blokhin S. A.<sup>1</sup>, Bobrov M. A.<sup>1</sup>, Blokhin A. A.<sup>1</sup>, Kuzmenkov A. G.<sup>1</sup>, Vasil'ev A. P.<sup>1</sup>, Maleev N. A.<sup>1</sup>, Dudelev V. V.<sup>1</sup>, Soboleva K. K.<sup>2</sup>, Sokolovskii G. S.<sup>1</sup>, Rantamäki A.<sup>3</sup>, Okhotnikov O.<sup>3</sup>, Ustinov V. M.<sup>1</sup>;  
1 - Ioffe Inst., Russia, 2 - Peter the Great St.Petersburg Polytechnic Univ., Russia, 3 - Tampere Univ. of Technology, Finland

We report an InAs/InGaAs quantum dot-based optically pumped verticalexternal-cavity surface-emitting laser emitting at 1.3 μm. A fibre-coupled 808 nm laser diode and V-cavity configuration were used. Continuous wave output power over 200 mW is obtained at 7-15°C, which is the highest reported for such type of surface-emitting laser in this wavelength range.

### **A serially-connected two-chip VECSEL for dualwavelength emission**

Zhang F.<sup>1</sup>, Gaafar M.<sup>1</sup>, Möller C.<sup>1</sup>, Stolz W.<sup>1,2</sup>, Koch M.<sup>1</sup>, Rahimi-Iman A.<sup>1</sup>;

1 - Philipps-Univ. Marburg, Germany, 2 - NAsP III/V GmbH, Germany

We present a compact and flexible cavity design for high intracavity powers in dual-wavelength vertical-external-cavity surface-emitting lasers (VECSELs), by serially connecting two different gain chips in one cavity. Such device generates linearly polarized dual-wavelength emission with up to 640 W intracavity power at 10 nm wavelength spacing, which is tunable via a changing of the cavity angles on the chips. Furthermore, in this cavity, type-I second harmonic generation and sum-frequency generation have been performed in a LiNbO<sub>3</sub> crystal.

### **Self-mode-locked semiconductor disk laser**

Rahimi-Iman A.<sup>1</sup>, Gaafar M.<sup>1</sup>, Vaupel M.<sup>1</sup>, Möller C.<sup>1</sup>, Zhang F.<sup>1</sup>, Al-Nakdali D.<sup>1</sup>, Fedorova K. A.<sup>2</sup>, Stolz W.<sup>1,3</sup>, Rafailov E.U.<sup>2</sup>, Koch M.<sup>1</sup>;

1 - Philipps-Univ. Marburg, Germany, 2 - Aston Univ., United Kingdom, 3 - NAsP III/V GmbH, Germany

In the last decade, vertical-external-cavity surface-emitting lasers (VECSELs) have become promising sources of ultrashort laser pulses. While the mode-locked operation has been strongly relying on costly semiconductor saturable-absorber mirrors for many years, new techniques have been found for pulse formation. Mode-locking VECSELs are nowadays not only achievable by using a variety of saturable absorbers, but also by using a saturable-absorber-free technique referred to as self-mode-locking (SML), which is to be highlighted here.

### **Brillouin and Raman scattering in silicon and silicon nitride photonic integrated circuits**

Baets R.; Ghent Univ., Belgium

Silicon photonics has gained considerable momentum as a platform for the on-chip integration of advanced photonic functions on the basis of CMOS technology, especially in the fields of telecom and datacom. Here we report on the use of this platform for photon-phonon interaction in nanophotonic silicon or silicon nitride waveguides. We discuss the first demonstration of Brillouin gain in silicon waveguides as well as Raman spectroscopy taking advantage of silicon nitride photonic circuits.

### **AFM visualization of half-disk WGM laser modes**

Alekseev P. A.<sup>1</sup>, Dunaevskiy M. S.<sup>1,2</sup>, Monakhov A. M.<sup>1</sup>, Dudelev V. V.<sup>1</sup>, Sokolovskii G. S.<sup>1,3</sup>, Baranov A.<sup>4</sup>, Teissier R.<sup>4</sup>;

1 - Ioffe Inst., Russia, 2 - ITMO Univ., Russia, 3 - Peter the Great St. Petersburg Polytechnic Univ., Russia,

4 - Inst. d'Electronique du Sud, France

By means of atomic force microscopy (AFM) the spatial mapping of the laser intensity was performed on the cleavage of the whispering gallery modes (WGM) half-disk laser. The study was carried out in the near- and far-field regime. It showed a strong spatial divergence of different modes in the laser.

### **Compact external cavity laser with photonic crystal cavity reflector**

O'Faolain L.<sup>1,3</sup>, Liles A. A.<sup>1</sup>, Bakoz A. P.<sup>2,3</sup>, Gonzalez-Fernandez A. A.<sup>1</sup>, Hegarty S. P.<sup>2,3</sup>;

1 - Univ. St. Andrews, United Kingdom, 2 - Tyndall National Inst., Ireland, 3 - Cork Inst. of Technology, Ireland

Energy efficient Wavelength Division Multiplexing (WDM) is the key to satisfying the future bandwidth requirements of datacentres. As the silicon photonics platform is regarded the only technology able to meet the required power and cost efficiency levels, the development of silicon photonics compatible narrow

linewidth lasers is now crucial. We discuss the requirements for such laser systems and report the experimental demonstration of an external-cavity hybrid lasers consisting of a III-V Semiconductor Optical Amplifier and Photonic Crystal (PhC) based resonant reflector.

### **Photonic crystal reflector laser**

Bakoz A. P.<sup>1,2</sup>, Liles A. A.<sup>3</sup>, Viktorov E. A.<sup>4,5</sup>, Faolain L. O.<sup>3</sup>, Huyet G.<sup>1,2,4</sup>, Hegarty S. P.<sup>1,2</sup>;

1 - Cork Inst. of Technology, Ireland, 2 - Tyndall National Inst., Ireland, 3 - Univ. St Andrews, United Kingdom, 4 - ITMO Univ., Russia, 5 - Univ. Libre de Bruxelles, Belgium

We describe the lasing characteristics of a semiconductor laser device, utilising a reflective semiconductor amplifier as a combined gain/mirror component, and a high Q photonic crystal reflective filter as the second cavity mirror.

### **Photonic crystal surface emitting lasers – coherent arrays and external feedback**

Taylor R. J. E.<sup>1</sup>, Li G.<sup>2</sup>, Ivanov P.<sup>2</sup>, Childs D. T. D.<sup>2</sup>, Stevens B. J.<sup>3</sup>, Babazadeh N.<sup>2</sup>, Ignatova O.<sup>2</sup>, Nakano Y.<sup>1</sup>, Tanemura T.<sup>1</sup>, Hogg R. A.<sup>2</sup>;

1 - Univ. of Tokyo, Japan, 2 - Univ. of Glasgow, United Kingdom, 3 - Univ. of Sheffield, United Kingdom

Electronic control of coherence in 2D arrays of photonic crystal surface emitting lasers is discussed.

### **Light sheet microscopy for visualising fast biological dynamics in 3D**

Olarte O. E., Andilla J., Licea-Rodriguez J., Artigas D., Loza-Alvarez P.;

ICFO-Inst. de Ciències Fotoniques, The Barcelona Inst. of Science and Technology, Spain

High resolution and fast dynamic visualization in 3D can be achieved by combining light sheet and wavefront coding. This results in a system that allows the light sheet to be positioned at different distances from the focus plane. By scanning the light sheet through the sample, it is possible to produce high resolution volumetric images of living samples at unprecedented speeds.

### **The use of angular momentum of light for characterization of biological tissues**

Bykov A.<sup>1</sup>, Popov A.<sup>1</sup>, Doronin A.<sup>2</sup>, Meglinski I.<sup>1</sup>;

1 - Univ. of Oulu, Finland, 2 – Yale Univ., United States

We investigate the applicability of use of Laguerre-Gaussian laser beams for optical biopsy. In current presentation a Monte Carlo based numerical simulation of complex vector light beams propagating that undergoing anisotropic scattering in turbid tissue-like scattering media will be presented in comparison with the plane wave light beams. Several basic phenomena associated with the anisotropic scattering of the vector light beams in turbid media are discussed, including the mutual influence of light's polarization and its directional awareness during the multiply scattering.

### **Development of a US laser system for the gravitational wave mission LISA**

Camp J., Numata K.;

NASA Goddard Space Flight Center, United States

A highly stable and robust laser system is a key component of the space-based, Gravitational Wave mission LISA architecture. In this talk I will describe our plans to demonstrate a TRL 5 LISA laser system at Goddard Space Flight Center by 2017. The laser system includes a low-noise oscillator followed by a power

amplifier. The oscillator is a low-mass, compact 10 mW External Cavity Laser, consisting of a semiconductor laser coupled to an optical cavity, built by the laser vendor Redfern Integrated Optics. The amplifier is a diode-pumped Yb fiber with 2.5 W output, built at Goddard. I will show noise and reliability data for the full laser system, and describe our plans to reach TRL 5 by 2017.

### **Conical refraction with low-coherent light sources**

Sokolovskii G. S.<sup>1</sup>, Mylnikov V. Yu.<sup>2</sup>, Losev S. N.<sup>1,2</sup>, Fedorova K. A.<sup>3</sup>, Rafailov E. U.<sup>3</sup>;  
1 – Ioffe Inst., Russia, 2 - Peter the Great St. Petersburg Polytechnic Univ., Russia, 3 – Aston Univ., United Kingdom

We report on conical refraction (CR) experiments with low-coherent light sources such as light-emitting diodes (LEDs) that demonstrated different CR patterns. Variation of the pinhole size from 25 to 100  $\mu\text{m}$  reduced the spatial coherence of the LED radiation and resulted in disappearance of the dark Poggendorf ring. This is attributed to the interference nature of the Lloyd's distribution.

### **All semiconductor akinetic swept source for optical coherence tomography**

Chen Z.<sup>1</sup>, Bonesi M.<sup>1</sup>, Sattmann H.<sup>1</sup>, Ginner L.<sup>1</sup>, Leitgeb R.<sup>1</sup>, Hoover E.<sup>2</sup>, Nammari K.<sup>2</sup>, Crawford M.<sup>2</sup>, Ensher J.<sup>2</sup>, Minneman M.<sup>2</sup>, Drexler W.<sup>1</sup>;  
1 - Medical Univ. Vienna, Austria, 2 - Insight Photonic Solutions, Inc., United States

All-semiconductor, all-electronic tunable, akinetic (without any form of movement in the tuning mechanism) compact and cost-effective swept source laser technology is used for demonstrating OCT and OCT angiography at 1550nm and 1300 nm with unprecedented imaging performance.

### **Interband Cascade Lasers for sensing**

Höfling S.<sup>1,2</sup>, Weih R.<sup>1</sup>, Kamp M.<sup>1</sup>;  
1 - Univ. Würzburg, Germany, 2 - Univ. of St Andrews, United Kingdom

The Interband Cascade Laser (ICL) combines the interband transition as in a conventional diode laser with the cascading scheme of a Quantum Cascade Laser. ICLs allow for an external quantum efficiency greater than which is enabled because of the special band alignment of GaInSb/AlAs/InAs-interfaces that separates hole and electron injector and internally feed each cascade with carriers. This makes ICLs a unique with great design flexibility. By changing the InAs layer thickness of the typically used W-shaped quantum well (W-QW) the emission wavelength can be tuned within the entire mid infrared region which is known as the fingerprint region of a variety of industrially relevant molecules. We present our progress achieved in the field of ICL device research.

### **Broadly tunable dual-wavelength InAs/GaAs quantumdot laser for THz generation**

Fedorova K. A.<sup>1,2</sup>, Gorodetsky A. A.<sup>1,3</sup>, Livshits D. A.<sup>4</sup>, Maleev N. A.<sup>2</sup>, Blokhin S. A.<sup>2</sup>, Soboleva K. K.<sup>5</sup>, Ustinov V. M.<sup>6</sup>, Rafailov E. U.<sup>1</sup>;  
1 - Aston Univ., United Kingdom, 2 – Ioffe Inst., Russia, 3 - ITMO Univ., Russia, 4 - Innolume GmbH, Germany, 5 - Peter the Great St. Petersburg Polytechnic Univ., Russia, 6 - Submicron Heterostructures for Microelectronics, Research Engineering Center RAS, Russia

We demonstrate an ultra-compact, room-temperature, continuous-wave, broadly-tunable dual-wavelength InAs/GaAs quantum-dot external-cavity diode laser in the spectral region between 1150nm and 1301nm with maximum output power of 280mW. This laser source generating two modes with tunable differencefrequency (300GHz-30THz) has a great potential to replace commonly used bulky lasers for THz generation in photomixer devices.

### **Generation of intense sub-100 fs pulses from Yb-doped solid-state lasers based on nanostructured semiconductor saturable absorbers**

Major A.; Univ. of Manitoba, Canada

Results on dual action of semiconductor saturable absorber and Kerr-lens mode locking of Yb-ion doped solid-state lasers will be reported. Using both quantumdot and quantum-well nanostructured semiconductor saturable absorbers, the developed approach enabled demonstration of record high performance of Yb:KGW and Yb:CALGO lasers among other Yb-ion materials in sub-100-fs regime with peak powers ranging from >100 kW to >1 MW.

### **Generation of THz radiation in epitaxial InGaAs films on InP substrates of various crystallographic orientations**

Galiev G. B.<sup>1</sup>, Kitaeva G. H.<sup>2</sup>, Klimov E. A.<sup>1</sup>, Kornienko V. V.<sup>2</sup>, Kuznetsov K. A.<sup>2</sup>, Klochkov A. N.<sup>1</sup>, Pushkarev S. S.<sup>1</sup>;

1 - Inst. of Ultrahigh Frequency Semiconductor Electronics RAS, 2 - Moscow State Univ., Russia

We study the THz wave generation by the time-domain spectroscopy method in low-temperature grown InGaAs layers on InP substrates with crystallographic orientations (100) and (411) It was found that the THz wave generation is 3-5 times more effective in the case of (411)A InP substrates as compared to the (100) substrates. In samples grown at high pressure of As<sub>4</sub> generation of THz waves is more effective at low-frequency range less than 200 GHz.

### **Wavelength-swept laser based on semiconductor optical amplifier for dynamic optical fiber sensors**

Yong Jeon M., Woo Park J., Ock Ko M.;

Chungnam National Univ., Republic of Korea

We report two kinds of wavelength-swept lasers based on semiconductor optical amplifier for dynamic optical fiber sensors. The wavelength-swept laser has a linear relationship that exists between wavelength and time. As an application using the wavelength-swept laser for dynamic optical fiber sensors, we measure a dynamic modulation frequency of the applied electric field using a nematic liquid crystal cell. The amplitude modulation frequency is measured up to 2.5 kHz.

### **Directly-modulated lasers monolithically integrated with an optical filter for long-range access network**

Chimot N., Joshi S., Provost J.-G., Mekhazni K., Lelarge F.;

3-5 Lab, a joint laboratory Nokia Bell Labs France, Thales Research and Technology, CEA Leti, France

The future access networks requires to develop key innovative transmitters operating at 10Gb/s around 1550nm and capable of transmitting data in extended reach passive optical networks (>60km). In this contribution, we demonstrate a novel cost-effective transmitter based on the monolithic integration on InP substrate of a directly modulated laser and a ring resonator compatible with the NGPON2 requirements.

### **Light interaction with colloidal photonic crystals: theoretical and experimental studies**

Yurchenko S. O., Gorbunov E. A., Zaytsev K. I.; Bauman Moscow State Technical Univ., Russia

The effects of strong interaction of optical electromagnetic fields with colloidal photonic crystals (PCs) are considered in our talk. We justify the fingerprints of structural light focusing effect (strong localization of light in multiple hot spots, like at usual focusing) by recent results of our theoretical studies and experimental observations using opal colloidal globular photonic crystals.

### **Extreme events in laser systems**

Agüero M.<sup>1</sup>, Bonazzola C.<sup>1</sup>, Kovalsky M.<sup>1</sup>, Hnilo A.<sup>1</sup>, Metayer C.<sup>2</sup>, Tredicce J. R.<sup>2,3</sup>;  
1 - CEILAP, CITEDEF-CONICET, Argentina, 2 - Univ. de la Nouvelle Calédonie, France, 3 - Univ. de Buenos Aires, Argentina

We consider simple laser systems like a laser with modulated phase or modulated losses, a laser with injected signal and a laser with saturable absorber.

### **Slow and Fast Graphene Oxide Photonics**

De La Rue R. M.<sup>1</sup>, Lai C. K.<sup>2</sup>, Lim W. H.<sup>2</sup>, Ahmad H.<sup>2</sup>, Chong W. Y.<sup>2</sup>, Yap Y. K.<sup>3</sup>;  
1 - Univ. of Glasgow, United Kingdom, 2 - Univ. of Malaya, Malaysia, 3 - Heriot-Watt Univ., Malaysia

Graphene oxide is a 2D material that can be used in a variety of applications of photonics - both as a mono-layer and in multi-layer formats. The presentation will explore how the anisotropic material properties of graphene oxide multilayers can be exploited to obtain useful photonic functionality, with response times that can be very fast – but also much slower.

### **High-power 808 nm laser bars (5mm) with wall-plug efficiency more than 67%**

Bagaev T. A., Ladugin M. A., Andreev A. Y., Marmalyuk A. A., Sapozhnikov S. M., Lobintsov A. V.;  
R&D Inst. Polus, Russia

In present paper the device characteristics of the 808 nm laser diodes bars with different waveguides have been compared. It was demonstrated that structures with broad asymmetrical waveguide has higher output power than that with narrow symmetrical waveguide.

### **Spatial current density distribution of «vertical» and «face-up» high-power blue AlGaInN LEDs**

Aladov A. V., Chernyakov A. E., Zakgeim A. L.;  
Submicron Heterostructures for Microelectronics, Research Engineering Center RAS, Russia

This paper studies current spreading, light emission and heat transfer in highpower «vertical» and «face-up» AlGaInN light emitting diodes (LEDs).

### **Frequency stability of miniature quantum magnetometer with laser pumping**

Ermak S. V.<sup>1</sup>, Petrenko M. V.<sup>2</sup>, Semenov V. V.<sup>1</sup>;  
1 - Peter the Great St. Petersburg Polytechnic Univ., 2 - Ioffe Inst., Russia

The experiments performed using the system of two quantum magnetometers with laser pumping showed the possibility of reduction of the light shift influence on frequency stability of the miniature quantum magnetometer.

### **Q-switch in injected quantum dot laser**

Viktorov E. A.<sup>1,2</sup>, Erneux T.<sup>2</sup>, Tykalewicz B.<sup>3,4,5</sup>, Goulding D.<sup>3,4,5</sup>, Hegarty S. P.<sup>3,4,5</sup>, Huyet G.<sup>1,3,4,5</sup>, Dubinkin I. N.<sup>1</sup>, Fedorov N. A.<sup>1</sup>, Kelleher B.<sup>5</sup>;  
1 - ITMO Univ., Russia, 2 - Univ. Libre de Bruxelles, Belgium, 3 - Univ. College Cork, Ireland, 4 - Cork Inst. Of Technology, Ireland, 5 - Tyndall National Inst., Ireland

We report on Q-switched operation in an optically injected quantum dot laser. It results from the ability of the laser to emit simultaneously from the ground state (GS) and first excited state (ES). The injected GS operates as a gate for the ES output.

### **Carbon monoxide concentration measurement on the base of GaInAsSb heterolaser**

Lebiadok Y. V.<sup>1</sup>, Kabanau D. M.<sup>1</sup>, Imenkov A. N.<sup>2</sup>, Yakovlev Y. P.<sup>2</sup>;

1 - SSPA "Optics, Optoelectronics & Laser Technology", Belarus, 2 - Ioffe Inst., Russia

The method of detection of carbon monoxide on the base of laser diode with GaInAsSb quantum active layer and its characteristics are discussed in the report.

### **Modeling a semiconductor quantum dot laser**

Koryukin I. V.; Inst. of Applied Physics RAS, Russia

We analyze the electron-hole asymmetry model of a semiconductor quantum dot laser at different relaxation rates of the transitions between electron and hole levels. It is shown that the model can be simplified when the relaxation between hole levels is much faster than the relaxation between electron levels.

### **Quantum cascade laser grown by MOCVD and operating at 9.7 $\mu\text{m}$**

Ladugin M. A.<sup>1</sup>, Andreev A. Yu.<sup>1</sup>, Bagaev T. A.<sup>1</sup>, Gorlachuk P. V.<sup>1</sup>, Lobintsov A. V.<sup>1</sup>, Marmalyuk A. A.<sup>1</sup>, Padalitsa A. A.<sup>1</sup>, Ryaboshan Yu. L.<sup>1</sup>, Sapozhnikov S. M.<sup>1</sup>, Simakov V. A.<sup>1</sup>, Telegin K. Yu.<sup>1</sup>, Zasavitskii I. I.<sup>2</sup>, Zubov A. N.<sup>2</sup>;

1 - R&D Inst. Polyus, 2 - Lebedev Physical Inst. RAS, Russia

A quantum cascade laser emitting in the spectral range of 9.7  $\mu\text{m}$  at 77 K has been developed. The laser heterostructure based on GaAs/AlGaAs was grown by the MOCVD technology. In the pulsed operation mode, the threshold current density of  $\sim 2 \text{ kA/cm}^2$  and the emission power of above 200 mW have been obtained for the laser of the dimensions of 30 mm x 3 mm.

### **Perforated microring resonators**

Levitskii I. V.<sup>1</sup>, Evtikhiev V. P.<sup>2</sup>;

1 - SHM R&E Center RAS, 2 - Ioffe Inst., Russia

We propose a novel approach to control mode structure of microring resonators using subwavelength hollow core defects. Their influence on mode structure was studied computationally and experimentally.

### **Metamaterial for the second harmonic generation**

Savchenko G. M.<sup>1,2</sup>, Dudelev V. V.<sup>1</sup>, Soboleva K. K.<sup>1,3</sup>, Lundin V. V.<sup>1</sup>, Sakharov A. V.<sup>1</sup>, Deryagin A. G.<sup>1</sup>, Kuchinskii V. I.<sup>1,2</sup>, Averkiev N. S.<sup>1</sup>, Sokolovskii G. S.<sup>1</sup>;

1 - Ioffe Inst., 2 - St. Petersburg Electrotechnical Univ., 3 - Peter the Great St. Petersburg Polytechnic Univ., Russia

We investigate the metamaterial with the structure comprising alternating semiconductor layers with intrinsic and metallic conductivity that can be grown epitaxially. The metamaterial is designed to demonstrate artificially low dispersion of the refractive index for the efficient second harmonic generation.

### **Dynamic model of laser-thyristor based on AlGaAs/ GaAs heterostructure for subnanosecond optical pulse generation**

Soboleva O. S., Podoskin A. A., Yuferev V. S., Pikhtin N. A., Slipchenko S. O., Tarasov I. S.;

Ioffe Inst., Russia

A new approach to high power laser pulse generation based on current switch integrated in to laser heterostructure has been demonstrated. The modeling of various structure designs has been performed and

the possibility of obtaining short (2ns) and high amplitude (16 A) current pulses and generating of highpower (46W) optical pulses in optimized structure has been shown.

### **Dark soliton generation from semiconductor optical amplifier gain medium in ring fiber configuration**

Turtaev S. N.<sup>1</sup>, Chernysheva M. A.<sup>2</sup>, Fedorova K. A.<sup>2</sup>, Gorodetsky A. A.<sup>2</sup>, Rafailov E. U.<sup>2</sup>;

1 - Univ. of Dundee, 2 - Aston Univ., United Kingdom

We have investigated the mode-lock operation from a semiconductor optical amplifier (SOA) gain chip in the ring fibre configuration. At lower pump currents, the laser generates dark soliton pulses both at the fundamental repetition rate of 39 MHz and supports up to the 6th harmonic order corresponding to 234-MHz repetition rate with an output power of ~2.1mW. At higher pump currents, the laser can be switched between the bright, dark and concurrent bright and dark soliton generation regimes.

### **Effect of waveguide design on AlGaInAs/InP laser diode characteristics**

Veselov D. A.<sup>1</sup>, Shashkin I. S.<sup>1</sup>, Ayusheva K. R.<sup>1</sup>, Lyutetskiy A. V.<sup>1</sup>, Pikhtin N. A.<sup>1</sup>, Slipchenko S. O.<sup>1</sup>, Padalitsa A. A.<sup>2</sup>, Ladugin M. A.<sup>2</sup>, Marmalyuk A. A.<sup>2</sup>, Ryaboshtan Yu. L.<sup>2</sup>, Tarasov I. S.<sup>1</sup>;

1 - Ioffe Inst., 2 - JSC Sigm Plus, Russia

1550nm-lasers based on MOCVD-grown heterostructures are investigated. It is determined, that additional barrier layers grown between waveguide and cladding layers block carrier leakage into the cladding layers but results in internal optical loss rise with drive current increase. It is demonstrated that incorporation of barrier layers allows attaining 92% internal quantum efficiency and 3.2W CW RT output optical power.

### **ZnSe-based laser array pumped by electron beam with energy below 6 keV**

Zverev M. M.<sup>1</sup>, Gamov N. A.<sup>1</sup>, Zhdanova E. V.<sup>1</sup>, Studionov V. B.<sup>1</sup>, Sedova I. V.<sup>2</sup>, Sorokin S. V.<sup>2</sup>, Gronin S. V.<sup>2</sup>, Ivanov S. V.<sup>2</sup>;

1 - Moscow Technological Univ. MIREA, 2 - Ioffe Inst., Russia

ZnSe-based laser array pumped by a pulsed electron beam with an energy of 5.6 keV has been studied. Output pulse power up to 180 W per one facet at wavelength of about 548 nm was measured at room-temperature.

### **Theory to optical properties of compound semiconductors for laser applications**

Jandieri K., Wiemer M., Baranovskii S. D.;

Philipps Univ. Marburg, Germany

Using analytical calculations based on the set of rate equations and straightforward Monte Carlo computer simulations we provide theoretical description of the temperature-dependent effects for photoluminescence in Ga(NAsP) and Ga(AsBi) successfully used for optically pumped and for electrically injected lasers. Comparison of the theoretical results with experimental data allows one to determine such decisive material parameters as the concentration of nonradiative centres, the compositional dependence of the band gap, and the energy dependence of the density of localized states in the band tails.

### **Statistical properties of polarization noise in multimode VCSELs**

Chizhevsky V. N.<sup>1</sup>, Maloshtan A. S.<sup>1,2</sup>, Glejm A. V.<sup>2</sup>;

1 - Stepanov Inst. of Physics NASB, Belarus, 2 - ITMO Univ., Russia

We report an experimental study of local and integral statistical properties of polarization noise in multimode VCSELs in broad ranges of the injection current and the laser diode temperature with the aim to find maximal min-entropy of polarization noise used as a source of randomness for the fast random bit generation.

### **Defect visualization and characterization in ZnSe crystals using two-photon confocal microscopy**

Gladilin A. A.<sup>1</sup>, Kalinushkin V. P.<sup>1</sup>, Uvarov O. V.<sup>1</sup>, Gavrischuk E. M.<sup>2</sup>, Timofeeva N. A.<sup>2</sup>, Iconnikov V. B.<sup>2</sup>, Studenikin M. I.<sup>1</sup>, Chapnin V. A.<sup>1</sup>, Ryabova A. V.<sup>1</sup>;

1 - Prokhorov General Physics Inst. RAS, 2 - Devyatykh Inst. of Chemistry of High-Purity Substances RAS, Russia

We have studied the luminescence of extended defects of single-crystalline and polycrystalline ZnSe using two-photon confocal microscopy in the spectral range 450 - 720 nm; we have also investigated the influence of Cr and Fe doping on the defect structure of ZnSe. Maps of luminescence were obtained with micro-scale spatial resolution from the depth reaching 3 mm under the surface.

### **InSb quantum dashes heterostructures in narrow-gap InAs(Sb,P) matrix system**

Moiseev K. D., Romanov V. V., Ivanov E. V., Dement'ev P. A., Sokura L. A., Nevedomsky V. N., Bert N. A.;

Ioffe Inst., Russia

Heterostructures based on the InSb quantum dashes buried into the InAs unipolar matrix exhibited the electroluminescence near 3.62  $\mu\text{m}$  at room temperature. Use of the multi-component InAsSbP matrix layers lattice-matched with the InAs substrate allows to control the matrix surface chemistry and to determine the shape of the deposited nano-islands.

### **Multi-mode dynamics of intracavity OPO pumped by vertical external cavity surface-emitting laser**

Morozov Yu. A.<sup>1</sup>, Kozlovsky V. I.<sup>2</sup>;

1 - Kotel'nikov Inst. of RadioEngineering and Electronics RAS (Saratov Branch), 2 - Lebedev Physical Inst. RAS, Russia

The multi-mode transient dynamics of a singly-resonant intracavity optical parametric oscillator (ICSRO) pumped by a vertical external cavity surface-emitting laser has been numerically analyzed. Nonlinear parametric interaction in the ICSRO was shown to stimulate multi-mode lasing with the intensity dip at a central frequency of emission. The insertion of an etalon makes the device exhibit a single-mode operation.

### **Study of particle drag force in a channel for optical trapping applications**

Poniaev S. A.<sup>1</sup>, Soboleva K. K.<sup>2</sup>, Sobolev A. I.<sup>2</sup>, Sokolovskii G. S.<sup>1</sup>;

1 - Ioffe Inst., 2 - Peter the Great St. Petersburg Polytechnic Univ., Russia

Application of semiconductor light sources for optical trapping and manipulation of micrometer-sized objects for lab-on-a-chip applications requires careful consideration of the drag force acting on a particle moving in a fluid. We present results of numerical simulation of the drag force acting on a micro-particle in a two-wall channel and its dependence on the distance between the particle and the channel wall.

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[+7\(909\) 579-46-24](tel:+7(909)579-46-24)

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