

VILNIUS UNIVERSITY

Donatas Noreika

TEMPORAL FEATURES OF BINOCULAR RIVALRY AND PERCEPTION OF  
AMBIGUOUS FIGURES

Summary of doctoral dissertation

Social sciences, psychology (06 S)

Vilnius, 2010

The dissertation was prepared in 2006 – 2010 at Vilnius University

**Scientific supervisor:**

prof. habil. dr. Henrikas Vaitkevičius (Vilnius University, social sciences, psychology, 06S)

The dissertation will be defended in the council of psychological science at Vilnius University:

**Chairman:**

prof. dr. Albinas Bagdonas – (Vilnius University, social sciences, psychology, 06S)

**Members:**

assoc. prof. dr. Dalia Bagdžiūnienė (Vilnius University, social sciences, psychology, 06S)

prof. habil. dr. Algis-Povilas Bertulis-Čerkelis (Lithuanian University of Health Sciences, biomedical sciences, biophysics – 02B)

doc. dr. Aušra Daugirdienė (Vilnius Pedagogical University, social sciences, psychology – 06S)

prof. dr. Osvaldas Rukšėnas (Vilnius University, biomedical sciences, biophysics – 02B)

**Opponents:**

doc. dr. Vaclovas Martišius (Vytautas Magnus University, social sciences, psychology – 06S)

dr. Alvydas Šoliūnas (Vilnius University, biomedical sciences, biology – 01B)

The official defence of the dissertation will take place at the public session of the Council of Psychology Science in the Conference Hall of the Faculty of Philosophy of Vilnius University (room No. 201) at 2 p.m. on December 17, 2010.

Address: Universiteto str. 9/1, Vilnius, LT-01513

The summary of the dissertation was sent out on \_\_\_\_\_

The dissertation is available at the library of Vilnius University

VILNIAUS UNIVERSITETAS

Donatas Noreika

AKIŲ KONKURENCIJOS IR DVIPRASMIŲ FIGŪRŲ SUVOKIMO LAIKINĖS  
SAVYBĖS

Daktaro disertacijos santrauka

Socialiniai mokslai, psichologija (06 S)

Vilnius, 2010

Disertacija rengta 2006 – 2010 metais Vilniaus universitete

**Mokslinis vadovas:**

prof. habil. dr. Henrikas Petras Vaitkevičius (Vilniaus universitetas, socialiniai mokslai, psichologija – 06 S)

Disertacija bus ginama Vilniaus universiteto psichologijos krypties taryboje:

**Pirmininkas:**

prof. dr. Albinas Bagdonas – tarybos pirmininkas (Vilniaus universitetas, socialiniai mokslai, psichologija – 06S)

**Nariai:**

doc. dr. Dalia Bagdžiūnienė (Vilniaus universitetas, socialiniai mokslai, psichologija – 06S).

prof. habil. dr. Algis-Povilas Bertulis-Čerkelis (Lietuvos sveikatos mokslų universitetas, biomedicinos mokslai, biofizika – 02B).

doc. dr. Aušra Daugirdienė (Vilniaus pedagoginis universitetas, socialiniai mokslai, psichologija – 06S).

prof. dr. Osvaldas Rukšėnas (Vilniaus universitetas, biomedicinos mokslai, biofizika – 02B).

**Oponentai:**

doc. dr. Vaclovas Martišius (Vytauto Didžiojo universitetas, socialiniai mokslai, psichologija – 06S).

dr. Alvydas Šoliūnas (Vilniaus universitetas, biomedicinos mokslai, biologija – 01B).

Disertacija bus ginama viešame psichologijos mokslo krypties tarybos posėdyje, kuris įvyks 2010 m. gruodžio 17 d. 14 val. Vilniaus universiteto Filosofijos fakulteto konferencijų salėje (201 aud.). Adresas: Universiteto g. 9/1, Vilnius, LT-01513

Disertacijos santrauka išsiuntinėta \_\_\_\_\_

Disertaciją galima peržiūrėti Vilniaus universiteto bibliotekoje

## INTRODUCTION

### **The research problem and scientific novelty of the study**

Bistable (multistable) perception is a phenomenon of cognition when the subjective perception of a person is periodically alternating, while the physical stimulus remains stable. The phenomenon is applied for various research themes in perception and consciousness, and enjoys a growing interest in recent years. Different forms of bistable perception has been described: figure-ground alternations (e.g. vase – faces), apparent 3D objects (e.g. Necker cube), monocular rivalry, binocular rivalry and so on. (Blake, Logothetis, 2002; Osaka et al., 2010). Binocular rivalry and ambiguous figures have been the most popular tool of the studies. Though quite a lot of research has been conducted, the question whether different forms of bistability are based on the same physiological mechanisms is still left open.

Not only bistable perception is interesting on its own right (notice its frequent use in art, e.g. M.C. Escher, S. Dali, various painters of 18<sup>th</sup> century), but it also attracts researchers as a tool for investigation of characteristics of perception. Seeming so striking in bistable perception (like abrupt changes of interpretations), the processes are supposedly common in everyday situations; just they are more vivid and tangible in case of bistability. Some level of ambiguity is common to all sensory stimulation, therefore the reconstruction of a visual scene, based on the pattern of active receptors in retina, is rarely completely unproblematic. Some authors think that eye movements and temporally distributed allocation of visual attention create periodic fluctuations in information processing efficacy, similar to the dominance – suppression cycle observed during bistable perception (Leopold and Logothetis, 1999; Mitchell et al., 2004).

Bistable perception is convenient for investigating various characteristics of perception as its temporal dynamics are responsive to even small changes in stimulus attributes. Even if minor aspects of physical stimulation are altered (i.e., decreased illumination, shortened presentation time, transference of the stimulus from the centre of the retina to the periphery etc.), we will notice changes in easily detectable characteristics of perception (e.g. lengthening of the average dominance time of one of the interpretations) (Blake, Logothetis, 2002). Due to this aspect, bistable perception is often used for exploring various aspects of perception.

Along with giving insights about fundamental principles of vision, the mechanisms of bistable perception are also applicable for creating devices for stereovision, vision prosthesis and diagnosing diseases (Pachidis, Lygouras, 2005; Miller et al., 2010). The phenomenon of binocular rivalry is important for creating transparent or semi-transparent monitors (Patterson et

al., 2007). The results of binocular rivalry research help to construct the monitors in such a way that the possibility of binocular rivalry occurrence would be reduced, as binocular rivalry may prevent seeing important parts of visual images either at the monitor, or in a visual scene.

Bistable perception is an example of sought-after cognitive situations, giving aid to objectively differentiate conscious perception from the physical stimulation. Although the physical stimulation is constant, the subjective perception is unceasingly alternating between available interpretations. It is possible to trace this alternation in a precise way, for example by means of giving the subject an instruction to push separate buttons while seeing one and the other interpretation. At the same time, brain imaging methods might be used to trace changes in brain activation, which are possibly correlating with the times of button presses. This possibility is the reason why bistable perception is often used for researching neural correlates of consciousness.

Bistable perception is a common illustration of the rhythmic (cyclic) nature of cognitive processes: although the physical stimulus remains constant, the interpretation of the visual images alternates every few seconds. The causes of these cyclical alternations are not agreed upon. The cyclical nature of neuron activity in millisecond range, however, is quite widely described. There are refractory periods in the activity cycle of neurons, and the bursts of separate neurons are inter-adjusted for synchronicity, and these processes cause cyclical fluctuations of activity in the brain. Supposedly, the synchronization of separate neuronal ensembles is an important or even the main mechanism for combining the perceived objects into wholes (Sauve, 1999; Nikolaev et al., 2010).

Although in theoretical models bistable perception is often associated with millisecond-order cyclical processes in the nervous system (Tong et al., 1998; Shpiro et al., 2007), there are not many experimental inquiries to directly connect those processes and the alternations of bistable perception. Should there be experimental proofs of a direct link between cyclical fluctuations of sensitivity in the nervous system and the cycles of bistable perception, it could contribute a lot to understanding of the mechanism and functional significance of both process groups.

A number of theoretical models have been proposed to explain the mechanism of bistable perception; yet, none of them is widely accepted (Freeman, 2005; Koene, 2006; Laing, Carson, 2002; Moreno-Bote et al, 2007; Stollenwerk, Bode, 2003 et al.). An experiment to explore the influence of millisecond-order processes upon the dominance phases of bistable perception would help to evaluate the theoretical models and provide insight on how the

rhythmic process is involved in bistable perception.

The matter under investigation is closely linked to the problem of discrete vs. continuous perception. The theory of discrete perception holds that perception occurs not evenly, but in steps. Bistable perception is a nice example to illustrate that perception may sometimes be not continuous, but to abruptly reverse every few seconds. If the theory of discrete perception is correct, the periods of bistable perception may be multiples of the smallest perceptual units (“perceptual quanta”). This hypothesis could be tested by an experiment, with stimuli presented in discrete time moments rather than continuously, and with the presentation duration systematically changing. This type of inquiry would contribute to arriving at an answer whether the periods of bistable perception are composed of smaller discrete units.

### **The aim of the study**

To assess the influence of the flashing rate of the stimuli on the temporal dynamics of binocular rivalry and perception of ambiguous figures.

### **The objectives of the study**

1. To create a method that could enable to present two independently controlled flashing stimuli to the left and to the right eye of a subject.
2. To establish if there is dependence between binocular rivalry dominance duration and the flashing rate of the stimuli.
3. To compare the temporal dynamics of binocular rivalry when counter-phase and in-phase (synchronous) stimuli are presented.
4. To explore the influence of flashing rate of the stimuli on the temporal dynamics of ambiguous figure perception.
5. To examine the temporal stability of mean dominance durations in several minutes, an hour and several days.

### **Thesis defended**

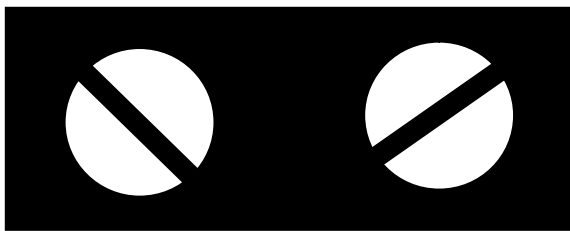
1. The technical equipment and software that were created for the study enable to present the stimuli with a precision of 5  $\mu$ s, which makes it a suitable method for investigating the temporal features of binocular rivalry and ambiguous figure perception.
2. Mean dominance durations of binocular rivalry differ in a significant way if measured while presenting flashing stimuli of various rates. The number of dominance duration

extremums in the 7 – 11 ms interval differs significantly from the number of extremums in other intervals (4 – 6 ms and 12 – 30 ms).

3. Instability is common to binocular rivalry dominance durations, i.e. the values of dominance durations fluctuate within 1 – 2 s if measured at different moments within several minutes, one hour and several days.
4. More than one factor governs changes of mean dominance durations of binocular rivalry.

## THEORETICAL BACKGROUND

Binocular rivalry is a phenomenon of perception when the conscious perception is continually switching between two different images, presented to the left and to the right eye (Fig. 1).

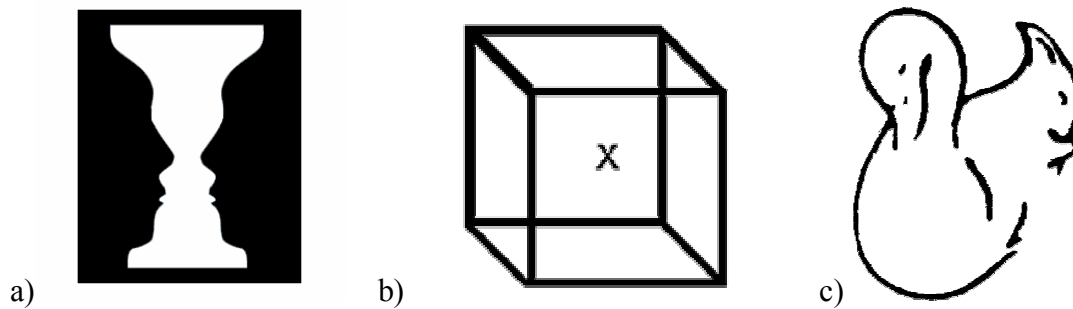


**Fig. 1.** An example of binocular rivalry stimuli. The left stimulus is presented to the left eye, the right one – to the right.

The phenomenon of binocular rivalry occurs when the corresponding sites of the left eye's and right eye's retina receives incompatible images. In contrast to the situation of common vision, the images start to seemingly rival between themselves: the viewer sees one image at a time, and then the perception switches to the other image, and this sequence of events repeats for as long as one continues to look.

Ambiguous figures are images with two (or more) equally possible interpretations (Fig. 2). In this case, identical images are presented to both eyes, but possible interpretations of the viewed image rival between themselves.





**Fig. 2.** Examples of ambiguous figures. a) Rubin's vase – faces; b) the Necker cube; c) swan – squirrel. While viewing the images for prolonged durations, one sees either one or the other interpretation, and the interpretations steadily change each other.

It is still under debate, whether binocular rivalry and perception of ambiguous figures are governed by the same neuronal mechanisms. Most often, binocular rivalry is explained similarly as are other forms of bistability, yet a few other factors may play a role in this case, like predominance of one of the hemispheres, faculties of spatial vision et al. (Blake, Logothetis, 2002; Sterzer et al., 2009).

Binocular rivalry and ambiguous figure perception may be considered as examples of *discrete* perception. Rather than shifting gradually, the perception totally transforms every few seconds in these cases. Although the physical stimulus stays the same, the subject sees either one or the other interpretation of the image, and the other interpretation may be totally “out of existence” at that time. The perception vacillates every few seconds and although some transitional waves exist, mediating the transition from one interpretation to the other (Wilson et al., 2001), the transitional period lasts only a part of a second, and during the rest of the time, the subject sees one of the images, totally not seeing the other. This aspect interrelates bistable perception with wider problems of discrete perception and temporally uneven effectiveness of information processing in the nervous system.

Neuronal refractory periods and synchronization of the activity of separate neuronal ensembles make information processing in the nervous system temporally uneven. If the perceived information is presented at a moment when the nervous system is ready to process it, the processing will be immediate and effective. These changes in the efficacy of information processing are in the order of milliseconds and therefore it is hard to investigate it. The temporal resolution of the contemporary brain imaging methods is usually not sufficient for a precise record of the neuronal processing fluctuations. One of the possible ways to investigate the millisecond-order fluctuations of information processing is to present *periodical* stimuli with

exactly controlled flashing rate and to assess whether the flashing rate influences the efficacy of information processing. There are not many experiments in which millisecond-order periodic stimuli would be used, and the findings of the studies are contradictory (van Boxtel et al., 2008; Logothetis et al, 1996; Brascamp et al., 2007; Knapen et al., 2007).

Considering the relevance of this type of a study and the results of the conducted experiments, we constructed equipment, enabling to present visual stimuli, flashing in millisecond-range, and examined, whether the flashing rate of the stimuli effects the dominance durations of binocular rivalry and ambiguous stimulus perception.

## METHODS

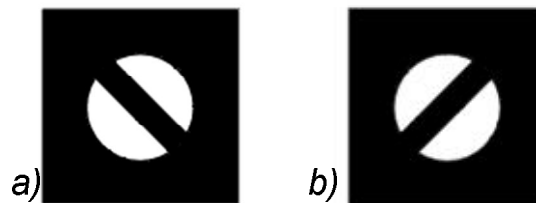
### Subjects

6 male subjects took part in the experiments, mean age – 34.3 y., standard deviation – 15,38, vision normal or corrected to normal. The subjects were staff workers or students at the Psychophysiology laboratory at Vilnius University and had at least minimal experience of taking part in psychophysical experiments.

### Stimuli

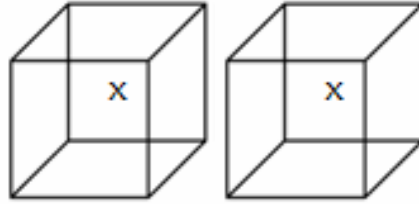
Two types of stimuli were used in the experiments: for binocular rivalry experiments – two round stimuli of different configurations and for ambiguous figure experiments – the Necker cube. A special projector was constructed to present the stimuli in such a way, that, although projected to each eye separately, the stimuli would be seen in one place in space.

In binocular rivalry experiments two different stimuli ( $1.7^\circ$  in diameter), were presented separately to each eye (Fig. 3). The stimuli were composed of black bars ( $0.6^\circ$  in width, tilt  $\pm 45^\circ$ ), intersecting white circles (brightness –  $0.2 \text{ cd/m}^2$ ). The contrast was 0.9.



**Fig. 3.** Binocular rivalry stimuli: a) image, presented to the right eye; b) image, presented to the left eye.

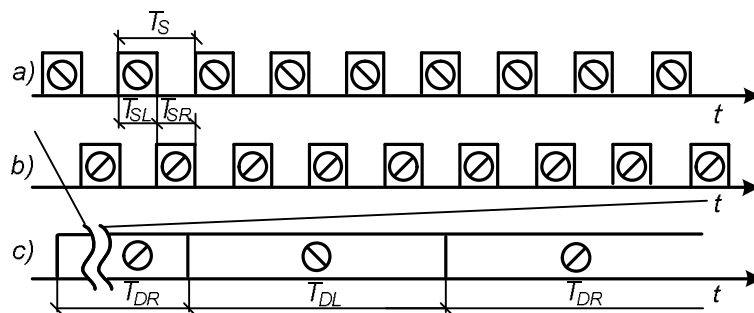
In the Necker cube experiments the same two images of a 3D cube were presented to both eyes, image size 4,91 degrees of visual angle, brightness 0,2 cd/m<sup>2</sup> (Fig. 4).



**Fig. 4.** Stimuli of the ambiguous figure experiment. The left stimulus was presented to the left eye, the right stimulus – to the right eye (the stimuli identical). The cross – a mark for eye fixation.

### The temporal layout for presentation of the stimuli

The stimuli were presented either continually alight, or flashed at a given frequency. The time diagram of the stimuli is presented in Fig. 5. Counter-phase (alternate) presentation is illustrated in the figure. Stimuli were presented in such a way in experiments 1, 3 and 4. The second stimulus is moved in half a phase (one flash duration of a stimulus) from the first stimulus. In experiment 2 the stimuli were presented in phase (synchronously). In all experiments the duration of a pause was equal to the flash duration of a stimulus, moreover, the pause duration and the flash duration were equal for both stimuli (i.e. when changing the flashing rate of one stimulus, the rate of the second stimulus was changed respectively).



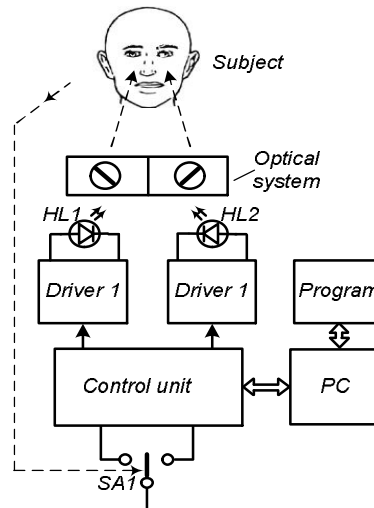
**Fig. 5.** Diagram explaining the process of presenting and perception of the stimuli:  $T_{SL}$ ,  $T_{SR}$  – flash duration of the stimuli, projected to the left and to the right eye ( $T_{SL} = T_{SR}$ );  $T_S = T_{SL} + T_{SR}$  – period of the flashing stimulus;  $T_{DL}$ ,  $T_{DR}$  – time periods when the subject perceived the stimuli, presented to the left and to the right eye.

In experiments 1, 2 (binocular rivalry) and 3 (the Necker cube) we used these flash durations (for more comfortable notation we used flash durations in ms and not flashing rates (Hz) for coding): without flash, 5 ms, 7 ms, 10 ms, 12 ms, 15 ms, 17 ms, 20 ms, 25 ms and 30

ms. In experiment 4 we used stimuli from a narrower interval – 4 through 20 ms, changing the flash durations in 1 ms step (17 flash durations altogether). The flash duration in each session was constant, and the order of presenting flash durations was random in all experiments.

### The apparatus

The functional architecture of the experimental apparatus is presented in Fig. 6. The stimuli are presented with the help of high luminance LW3C type light diodes HL1 and HL2, controlled by drivers 1 and 2. The diodes emit light impulses of stable amplitude (accuracy more than 5  $\mu$ s). The commanding impulses are transmitted to the drivers 1 and 2 from the control unit, which generates the impulses according to the computer program signals, transmitted through a LPT port. The devices register time when the subject pushes the switch (SA1) and calculates the perception duration  $T_{DL}$  or  $T_{DR}$  respectively.



**Fig. 6.** Structural diagram of the experimental apparatus: HL1, HL2 – light diodes; PC– personal computer; SA1– switch

A computer program, operating in real time (in DOS OS) and written in C language operated the device. The program sends series of impulses to the control unit and registers responses of the subject. The program guarantees formation of the impulses and registration of the responses with the accuracy of 1  $\mu$ s.

### Procedure

The experiment took place in a completely darkened room. Before each experiment the subject adapted to darkness for 3 min. Then the subject observed the images generated by the stereo projector and indicated which stimulus he was seeing by pushing a switch. A session of

the experiment with one randomly chosen flash duration lasted 3 min. (around 50 switches were performed during that time). A 1 min. break followed each session, after which the experiment continued with another flash duration. 10 sessions (17 in experiment 4) with different flash durations were performed in such a way. Every subject repeated the experiment 2 - 6 times (at different days), and the results were averaged separately for each subject, according to the corresponding measuring sessions (flash durations).

### **Data analysis**

The subjects were instructed to hold the button pressed while perceiving one of the stimuli (Fig. 3 (a)) and to hold the button released while seeing the other stimulus (Fig. 3 (b)). The computer program recorded the absolute time of every press and release of the switch, and computed the duration of every press and release. The press and release durations were treated as dominance durations of one and the other stimuli respectively. The mean dominance durations of the stimulus presented to each eye for every flash duration were computed. As mean dominance durations and the profile of the curve differed individually in a significant way, the data of separate subjects were not averaged and the analysis with individual data was performed instead. We were more interested in the differences of dominance durations, but not in the absolute values, so we standardized the absolute dominance duration values with respect to the average of each eye: we counted  $\Delta T = T - T_{\text{VID}}$ , where  $\Delta T$  – difference of the mean dominance duration;  $T$  – mean dominance duration, of a given flash duration;  $T_{\text{VID}}$  – mean dominance duration of the eye, counted by summing all the flash durations results for that eye ( $T_{\text{VID}}$  is counted separately for each eye). We specified mean dominance duration as a function of the stimulus flash duration. The profile of the curve was analyzed, looking for statistically significant differences among mean dominance durations, registered while presenting stimuli of different flash durations.

We tested the fit of the curve with the Kolmogorov-Smirnov test and found that in most cases the distribution of the data does not satisfy the criteria of the normal distribution. We used the nonparametric Mann-Whitney test for the independent samples to compare the means of dominance durations.

For analyzing rates of dominance duration maximums and minimums in different ranges of the function, we performed extremum analysis of the function. We defined extremum as a point, where the variation (direction) of the function changes its sign (minimum: from – to +; maximum: from + to -). If the neighbouring points of the extremum did not differ in statistically

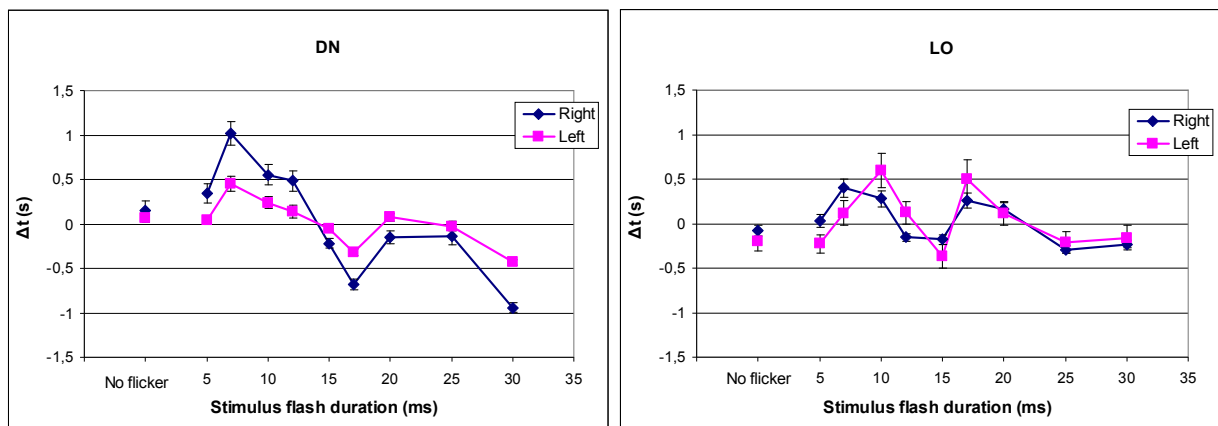
significant way from one of the extremums, we also ascribed them to extremums. Outside (marginal) points of the curve were ascribed to extremums according to the function's change of its sign from the closest extremum (from one side). We tested the equality of proportions of the extremums using nonparametric Cochran's Q test.

Looking for factors that could possibly explain the distribution of the mean dominance durations, we have performed factor analysis. We used both absolute values and differences from the mean dominance durations of an eye for the analysis, examining how individual differences affect the values. We counted data from all the participants for factor analysis.

Analysing the possibility of cyclical repetition of the dominance durations in each session, we used autocorrelation analysis.

## MAIN RESULTS

The results of the experiment demonstrated that mean dominance durations, measured while presenting stimuli of different flash durations, differ in a significant way (Fig. 7).

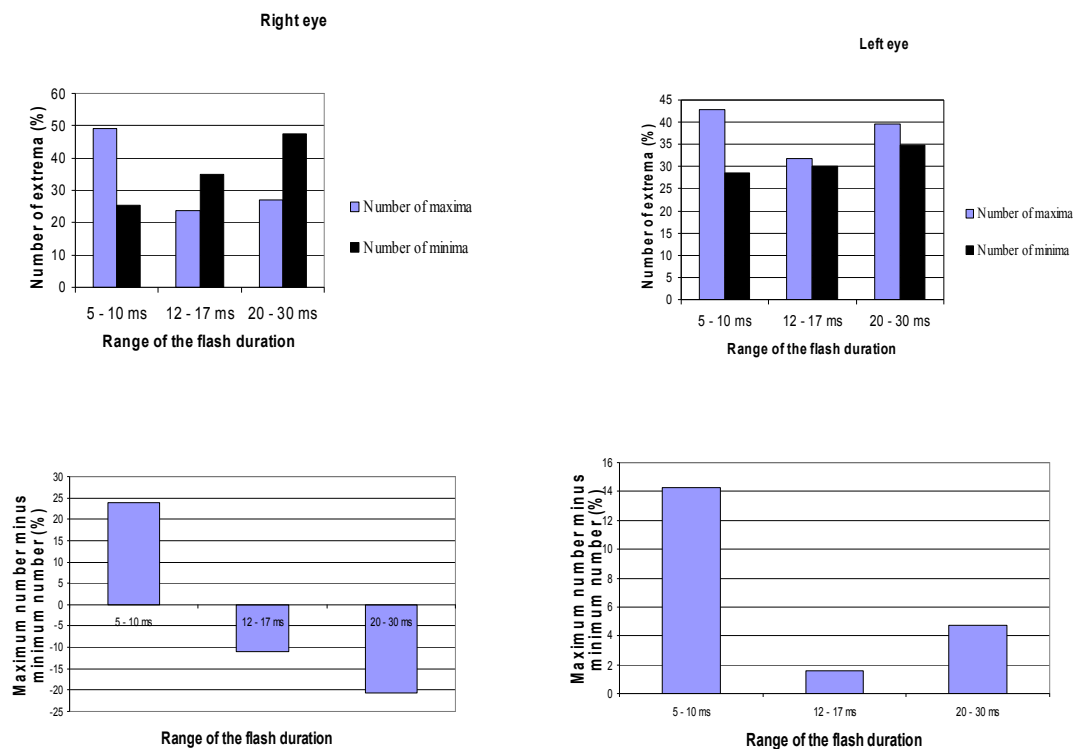


**Fig. 7.** Experimental results with the counter-phase stimulus presentation. Standardized mean dominance durations of 2 subjects. X axis – stimulus flash duration (ms), Y axis ( $\Delta t$  (s)) – standardized mean dominance duration (s). The Y-axis zero point denotes the mean dominance duration of each eye, computed by summing all flash durations of the eye. Data of individual subjects is presented in separate graphs. The vertical bars denote standard error of the mean.

The experimental results confirmed the hypothesis, that mean dominance durations, as a function of stimulus flash durations has distinct extrema. Fig. 7 shows that the dependence of mean dominance duration on stimulus flash duration is not a monotonic function. Mean

dominance durations, measured while presenting stimuli of different flash durations, differ in a significant way, though the profile of the curve is different for individual subjects. The total mean dominance duration also differs individually. The mean dominance duration differs individually within the range of 1 – 2 s.

For analyzing rates of dominance duration maxima and minima in different ranges of the function, we performed extremum analysis of the function. Fig. 8 demonstrates extremum rates, obtained by dividing the examined range into intervals of 3 flash durations in each. The extremum numbers obtained from 21 experiments (6 subjects).



**Fig. 8.** Comparison of extremum numbers, obtained while presenting stimuli of different flash durations, in intervals of 3 flash durations. Data from 21 experiment (6 subjects). a) number of extrema, obtained while presenting stimuli of different flash durations (in percent). b) Differences of maxima and minima in the given intervals; every column is obtained by subtracting number of minima from the number of maxima.

It is obvious from Fig. 8 that the distribution of extremums in different ranges is not equal (Cochran's Q  $p = 0.005 < 0,05$ ). Although the examined intervals were not equal in length, because of the different distances between the examined flash durations, this preliminary data is sufficient to see the pronounced differences among some of the ranges. Maximums predominate in the range of short flash durations (5 – 10 ms). In the middle interval of the examined range (12 – 17 ms) there are fewer extremums and no clear predominance of either maximums or minimums is vivid. In the interval of 20 – 30 ms the tendencies differ for the left

and in the right eye. Minimums are more frequent in the right eye and maximums in the left.

The factor analysis showed that there are at least four distinct factors, governing changes of mean dominance durations of binocular rivalry. Additional research is needed to discover what these factors are. We speculate that eye movements are one of the possible factors calling to address.

When the stimuli were presented in phase (synchronously; experiment 2), pronounced differences between mean dominance durations, measured while presenting different flash durations, were also recorded. In the data of the right eye the distribution of dominance duration extremums were similar to that found in experiment 1: maximums predominate in the 5 – 10 ms range, the number of maximums and minimums is similar in 12 – 17 ms range and more minimums are found in the 20 – 30 ms range. In the left-eye data, the interval of 12 – 17 ms differed in experiments 1 and 2 – in experiment 2 more maximums were found in that interval.

In experiment 3 we used ambiguous figures (the Necker cube) to examine the influence of stimulus flash durations on mean dominance duration. In most cases the absolute values of dominance durations in these experiments were larger than that found in binocular rivalry experiments. Also the interval with predominance of maximums was moved to the side of longer flash durations (7 – 11 ms in the case of binocular rivalry and 12 – 17 ms or 20 – 30 ms (depending of the eye) in the case of ambiguous figures).

Additional experiments with repeatedly presented non-flashing (continuous) stimuli showed that mean dominance durations of binocular rivalry have a characteristic of temporal instability, i.e. measured at different moments during several minutes, an hour and several days, the values of mean dominance durations fluctuate within the range of 1 – 2 s. Further experiments would help to evaluate the extent and causes of this fluctuation in a systematic manner.

## CONCLUSIONS

1. The constructed technical equipment and software secures more than 5  $\mu$ s precision of stimulus presentation and is suitable for investigating temporal characteristics of binocular rivalry and ambiguous figures.
2. When the 4 – 30 ms flash duration stimuli flash in counter-phase, significant differences in mean dominance durations of binocular rivalry are observed. Maximums of dominance durations are most frequent in the 7 – 11 ms flash duration range. Periodicity



is characteristic to the intervals of maximum and minimum predominance – the same tendency or either maximums or minimums to dominate repeats itself every 4 – 6 ms.

3. When the stimuli are presented in phase (synchronously), the tendency or the extremum distribution in the right-eye data is similar to that found in the case of counter-phase stimuli: maximums predominate in the 5 – 10 ms range (46,7 %), the number of maximums and minimums is similar in 12 – 17 ms range (33 ir 31 %), and more minimums are found in the 20 – 30 ms range (46,7 %). In the left-eye data, contrary to the counter-phase experiment, more maximums are found in the 12 – 17 ms interval (31,1 %).
4. With ambiguous-figure stimuli, the absolute values of mean dominance durations are 0,5 – 2 s larger than that found in binocular rivalry experiments. The interval with predominance of maximums is moved towards longer flash durations in case of ambiguous-figure perception: 7 – 11 ms in the case of binocular rivalry and 12 – 17 ms or 20 – 30 ms, depending on the eye, in the case of ambiguous figures.
5. Instability is common to binocular rivalry dominance durations, i.e. the values of dominance durations fluctuate within 1 – 2 s range when measured at different moments within several minutes, one hour and several days.
6. More than one factor determines changes of mean dominance durations of binocular rivalry.

## **REFERENCES**

1. Blake R., Logothetis N. K. Visual Competition // *Nature Reviews Neuroscience*, 2002, vol.3. P. 1-11.
2. Brascamp J.W., Knapen T.H.J., Kanai R., van Ee R., van den Berg A.V. Flash suppression and flash facilitation in binocular rivalry // *Journal of Vision*, 2007, vol. 7(12). P. 1-12.
3. Freeman A.W. Multistage Model for Binocular Rivalry // *Journal of Neurophysiology*, 2005, vol. 94, p. 4412-4420.
4. Knapen T.H.J., Paffen C., Kanai R., van Ee R. Stimulus flash alters interocular grouping during binocular rivalry // *Vision Research*, 2007, vol. 47. P. 1-7.
5. Koene A. R. A model for perceptual averaging and stochastic bistable behavior and the role of voluntary control // *Neural Computation*, 2006, vol.18. P. 3069-3096.

6. Laing C.R., Carson C.C. A spiking neuron model for binocular rivalry // *Journal of Computational Neuroscience*, 2002, vol.12 P. 39-53.
7. Leopold D. A., Logothetis N.K. Multistable phenomena: changing views in perception // *Trends in cognitive science*, 1999, vol. 3(7).P. 254–264.
8. Mitchel J.F., Stoner G.R., Reynolds J.H. Object-based attention determines dominance in binocular rivalry // *Nature*, 2004, vol. 429. P. 410-413.
9. Logothetis N.K., Leopold D.A., Sheinberg D.L. What is rivalling during binocular rivalry? // *Nature*, 1996, vol. 380. P. 621-624.
10. Miller S. M., Hansell N.K., Ngo T.T., Liu G.B., Pettigrew J. D., Martin N. G., Wright M.J. Genetic contribution to individual variation in binocular rivalry rate // *PNAS*, 2010 Vol. 107, P. 2664-2668.
11. Moreno-Bote R., Rinzel J., Rubin N. Noise-Induced Alternations in an Attractor Network Model of Perceptual Bistability // *Journal of Neurophysiology*, 2007, vol. 98, P. 1125-1139.
12. Nikolaev A.R., Gepshtein S., Gong P., van Leeuwen C. Duration of coherence intervals in electrical brain activity in perceptual organization // *Cerebral cortex*, 2010, vol. 20. P. 365-382.
13. Osaka N., Matsuyoshi D., Ikeda T., Osaka M. Implied motion because of instability in Hokusai Manga activates the human motion-sensitive extrastriate visual cortex: an fMRI study of the impact of visual art // *Neuroreport*, 2010, vol. 10. P. 264-7.
14. Pachidis T.P., Lygouras J.N. Pseudo-Stereo Vision System: A Detailed Study // *Journal of Intelligent and Robotic Systems*, 2005, Vol. 42. P. 135-167.
15. Patterson R., Winterbottom M., Pierce B., Fox R. Bicolor rivalry and head-worn displays // *Human factors*, 2007, vol. 49(6). P. 1083-1096.
16. Sauve K. Gamma-band synchronous oscillations: recent evidence regarding their functional significance // *Consciousness and cognition*, 1999, vol. 8. P. 213-224.
17. Shpiro A., Curtu R., Rinzel J., Rubin N. Dynamical Characteristics Common to Neuronal Competition Models // *Journal of Neurophysiology*, 2007, vol. 97. P. 462-473.
18. Sterzer P., Kleinschmidt A., Rees G. The neural bases of multistable perception // *Trends in cognitive sciences*, 2009, vol. 13(7). P. 310-318.
19. Stollenwerk L., Bode M. Lateral neural model of binocular rivalry // *Neural Computation*, 2003, vol.15. P. 2863-2882.
20. Tong F., Nakayama K., Vaughan J. T., Kanwisher N. Binocular rivalry and visual

- awareness in human extrastriate cortex // *Neuron*, 1998, vol. 21. P. 753–759.
21. van Boxtel J.J.A., Alais D., Erkelens C.J., van Ee R. The role of temporally coarse form processing during binocular rivalry. *PLoS ONE* 3(1): e1429, 2008.
22. Wilson H. R., Blake R., Lee S.H. Dynamics of travelling waves in visual perception // *Nature*, 2001, vol. 412. P. 907–910.

## REZIUMÉ

Akių konkurencija ir dviprasmių figūrų suvokimas yra dvi iš daugelio nestabilaus (alteruojančio) suvokimo formų. Nestabilus suvokimas – tai pažinimo reiškinys, kai subjektyvus suvokiamas vaizdas ar garsas periodiškai kinta, fiziniam stimuliui išliekant pastoviam. Pastaraisiais metais šis reiškinys sulaukia vis daugiau tyrėjų dėmesio, nes yra pritaikomas įvairioms suvokimo ir sąmonės savybėms tirti. Nors atlikta nemažai tyrimų, iki šiol nėra aišku, ar įvairios nestabilaus suvokimo formos yra pagrįstos tais pačiais fiziologiniais mechanizmais.

Nors akių konkurencijos ir dviprasmių figūrų suvokimas paprastai yra siejamas su milisekundžių eilės informacijos apdorojimo procesų netolygumais nervų sistemoje, trūksta tyrimų, bandančių tiesiogiai sieti šiuos du procesų tipus. Jei tyrimais pavyktų patvirtinti tiesioginį ryšį tarp cikliško jautrumo svyravimų nervų sistemoje ir nestabilaus suvokimo ciklų, tai padėtų geriau suprasti nestabilaus suvokimo veikimo mechanizmą ir nervų sistemos jautrumo svyravimų funkcinę reikšmę.

Dėl neuronų darbo refrakcinių periodų ir atskirų neuronų grupių sinchronizacijos, informacijos apdorojimas nervų sistemoje nėra tolygus. Jei suvokiama informacija yra pateikiama tokiu momentu, kai nervų sistema yra pasirengusi ją apdoroti, apdorojimo efektyvumas bus didesnis. Šie informacijos apdorojimo netolygumai yra milisekundžių eilės, todėl tiksliau juos ištirti yra labai sudėtinga. Dabartinių smegenų vaizdavimo metodų laikinės rezoliucijos paprastai neužtenka, kad būtų galima tiksliai fiksuoti minimuosius neuronų darbo netolygumus. Vienas iš galimų būdų tirti milisekundžių eilės informacijos apdorojimo netolygumus yra pateikti *periodinius* stimulus su tiksliai kontroliuojamu dažniu, ir žiūrėti, ar stimulų mirksėjimo dažnis veikia informacijos apdorojimo efektyvumą. Tyrimų, kuriuose būtų pateikiami milisekundžių eilės periodiniai stimulai, ir nagrinėjama stimulų mirksėjimo dažnio įtaka, yra nedaug, ir jų rezultatai yra prieštaringi.

Atsižvelgdami į tokio pobūdžio tyrimų aktualumą ir iki šiol atliktų šios srities tyrimų

rezultatus, sukūrėme specialią įrangą, leidžiančią pateikti dideliu dažniu mirksinčius stimulus nepriklausomai į vieną ir kitą akį, ir tyrėme, ar stimulų mirksėjimo dažnis lemia akių konkurencijos ir dviprasmių figūrų suvokimo dominavimo trukmę.

### **Tyrimo tikslas**

Ištirti, kaip akių konkurencijos ir dviprasmių figūrų suvokimo laikinę dinamiką veikia pateikiamų stimulų mirksėjimo dažnis.

### **Uždaviniai**

1. Sukurti metodą, padedantį tirti akių konkurencijos ir dviprasmių figūrų suvokimo laikines savybes, pateikiant į vieną ir kitą akis du nepriklausomu dažniu mirksinčius stimulus.
2. Nustatyti, ar egzistuoja akių konkurencijos vidutinės dominavimo trukmės priklausomybė nuo pateikiamų stimulų mirksėjimo dažnio.
3. Palyginti dominavimo trukmių dinamiką pateikiant priešfazėje ir fazėje mirksinčius stimulus.
4. Ištirti stimulų mirksėjimo dažnio įtaką dviprasmių figūrų laikinėms savybėms.
5. Panagrinti akių konkurencijos dominavimo trukmių dinamiką įvairiose laiko skalėse (kelių minučių, valandos ir parų eigoje).

### **Ginamieji teiginiai**

1. Sukurtoji techninė ir programinė įranga užtikrina stimulų pateikimą didesniu negu 5  $\mu$ s tikslumu ir yra tinkama akių konkurencijos ir dviprasmių suvokimo laikinėms savybėms tirti.
2. Pateikiant 4 – 30 ms trukmės dažniu mirksinčius stimulus, fiksuojami reikšmingi skirtumai tarp akių konkurencijos vidutinių dominavimo trukmių. Ekstremumų dažnis 7 – 11 ms intervale reikšmingai skiriasi nuo dažnio kituose intervaluose (4 – 6 ms ir 12 – 30 ms).
3. Akių konkurencijos dominavimo trukmėms būdingas laikinis nestabilumas, t.y. matuojant dominavimo trukmę skirtingais laiko momentais kelių minučių, valandos ir kelių parų eigoje, vidutinių dominavimo trukmių reikšmės svyruoja 1 – 2 s ribose.
4. Akių konkurencijos vidutinės dominavimo trukmės pokyčius lemia daugiau negu vienas faktorius.

## **Metodika**

**Tyrimo dalyviai.** Eksperimentuose savanoriškai dalyvavo 6 vyriškos lyties dalyviai, amžiaus vidurkis – 34,3 m., standartinis nuokrypis – 15,38, rega normali arba pakoreguota iki normalios. Dalyviai buvo Vilniaus universiteto Psichofiziologijos laboratorijos darbuotojai arba studentai ir turėjo bent minimalią dalyvavimo psichofizikiniuose eksperimentuose patirtį.

**Aparatūra ir stimulai.** Mirksintiems akių konkurencijos ir dviprasmių figūrų suvokimo stimulams pateikti buvo sukonstruota speciali aparatūra ir programinė įranga, leidžianti pateikti regimuosius vaizdus didesniu negu 5  $\mu$ s tikslumu. Akių konkurencijos tyrimams naudoti į vieną ir kitą akis pateikiami skirtingos konfigūracijos 1,7° regimojo kampo dydžio apskritimo formos stimulai, dviprasmių figūrų suvokimo tyrimams – Neckerio kubas.

Tyrimo stimulai buvo pateikiami arba ištaisai šviečiantys, arba mirksintys tiksliai užprogramuotu intervalu. Mirksintys stimulai mirksėjo arba priešfazėje (pakaitomis), arba fazėje (synchroniškai), ir tyrėme, ar stimulų mirksėjimo pobūdis turi įtakos suvokimui. Trijuose eksperimentuose tyrimui naudotos tokios stimulo vieno pateikimo trukmės: be mirksėjimo, 5 ms, 7 ms, 10 ms, 12 ms, 15 ms, 17 ms, 20 ms, 25 ms ir 30 ms. Eksperimento eigoje šios trukmės buvo parenkamos atsitiktine tvarka. 4 eksperimente naudoti stimulai iš siauresnio intervalo – nuo 4 ms iki 20 ms, parenkant stimulus kas 1 ms (iš viso 17 stimulo pateikimo dažnių).

**Eksperimento eiga.** Eksperimentas vyko visiškai užtemdytame kambaryje. Iki eksperimento pradžios 3 min. buvo skiriamos adaptacijai tamsoje. Vėliau tyrimo dalyvis stebėjo pateikiamus vaizdus stereoprojektoriuje ir spausdamas mygtuką nurodė, kurį stimulą matė. Matavimo serija su kiekviena atsitiktinai parinkta stimulo pateikimo trukme tęsėsi 3 min. (per šį laiką įvykdavo apie 50 stimulo suvokimo kitimų). Po 1 min pertraukos ji buvo tęsiama su kita atsitiktinai parinkta kita trukme, ir taip vieno eksperimento metu buvo atliekama dešimt (4 eksperimente – 17) matavimo serijų su visomis dominančiomis stimulo pateikimo trukmėmis. Su kiekvienu tiriamuoju toks eksperimentas pakartotas du – šešis kartus (skirtingomis dienomis) ir rezultatai suvidurkinti kiekvienam tiriamajam atskirai pagal atitinkamas matavimo serijas.

**Duomenų tvarkymas.** Kompiuterio programa fiksavo kiekvieno mygtuko nuspaudimo ir atleidimo absoliutų laiką ir apskaičiavo kiekvieno nuspaudimo ir atleidimo trukmę. Buvo skaičiuojama vidutinė kiekvienos akies stimulo dominavimo trukmė esant kiekvienai stimulo pateikimo trukmei. Analizuotas gautos kreivės pobūdis, ieškant statistiškai reikšmingų skirtumų tarp dominavimo laiko reikšmių, užfiksuotų pateikiant skirtingos trukmės stimulus. Dominavimo trukmių maksimumų ir minimumų dažnių skirtinguose funkcijos diapazonuose

analizei, atlikta funkcijos ekstremumų analizė. Tiriant gautų vidurkių pasiskirstymo galimo paaiškinimo bendresniais faktoriais galimybę, atlikta faktorinė analizė. Ieškant ciklinio pasikartojimo galimybių tarp išmatuotų dominavimo trukmių, atlikta autokoreliacinė analizė.

## **Rezultatai**

Eksperimento rezultatai parodė, kad tarp vidutinių dominavimo trukmių, išmatuotų pateikiant skirtingos trukmės stimulus, išryškėja reikšmingi skirtumai, nors tarp tyrimo dalyvių kreivės pobūdis skiriasi. Individualiai labai skiriasi ir bendras dominavimo laiko vidurkis. Vidutinė dominavimo trukmė tarp tyrimo dalyvių svyruoja 2 – 4,5 s ribose.

Funkcijos ekstremumų analizė parodė, kad ekstremumų pasiskirstymas įvairiuose funkcijos diapazonuose nėra vienodas (Cochran's Q  $p = 0.005 < 0,05$ ). Nors tirtieji intervalai nebuvo lygūs dėl skirtingų atstumų tarp tirtųjų stimulų pateikimo trukmių, jau iš šios preliminarios analizės matyti ryškūs skirtumai tarp kai kurių diapazonų. Esant trumpoms stimulo pateikimo trukmėms (5 – 10 ms) vyrauja maksimumai. Tirtąjo diapazono viduriniajame intervale (12 – 17 ms) ekstremumų skaičius yra mažesnis ir nėra aiškios maksimumų ar minimumų vyravimo tendencijos. 20 – 30 ms intervale dešinės ir kairės akies tendencijos skiriasi. Dešinėje akyje dažniau pasitaiko minimumai, kairėje – maksimumai.

Faktorinė analizė parodė, kad egzistuoja bent keturi stiprūs faktoriai, lemiantys akių konkurencijos vidutinės dominavimo trukmės pokyčius. Tiksliau nustatyti, kokie būtent yra šie faktoriai, reikėtų tolesnių tyrimų.

Kuomet stimuli buvo pateikiami fazėje (antrasis eksperimentas), taip pat nustatyti statistiškai reikšmingi skirtumai tarp kai kurių dominavimo trukmių prie skirtingų stimulų pateikimo trukmių. Dešinės akies duomenyse funkcijos ekstremumų pasiskirstymo tendencija buvo panaši, kaip ir pirmajame eksperimente: 5 – 10 ms intervale vyravo maksimumai, 12 – 17 ms intervale ekstremumų skaičius buvo nedidelis, o 20 – 30 ms intervale daugiau buvo minimumų. Kairės akies duomenyse gana ryškiai tarp pirmojo ir antrojo eksperimentų skyrėsi 12 – 17 ms intervalas – antrajame čia daug dažniau pasitaikė maksimumai.

Trečiajame eksperimente stimulų pateikimo trukmės įtaką vidutinei dominavimo trukmei tyrėme naudodami dviprasmio suvokimo figūrą – Nekerio kubą. Daugeliu atveju absoliučios dominavimo trukmės reikšmės šiame eksperimente buvo didesnės negu bandymuose su akių konkurencija. Taip pat suvokiant dviprasmes figūras intervalas, kuriame dažniausiai pasitaikė maksimumai, buvo pasislinkęs ilgesnių pateikimo trukmių link (7 – 11 ms akių konkurencijos atveju ir 12 – 17 ms ar 20 – 30 ms (priklausomai nuo akies) dviprasmių figūrų atveju).

Papildomi eksperimentai su pakartotinai pateikiamais nemirksinčiais (ištiesai šviečiančiais) stimulais parodė, kad akių konkurencijos vidutinėms dominavimo trukmėms yra būdingas laikinis nestabilumas, t.y. matuojant dominavimo trukmę skirtingais laiko momentais valandos eigoje, vidutinių dominavimo trukmių reikšmės svyruoja 1 – 2 s ribose. Tiksliau įvertinti šio svyravimo mastui ir priežastims reikėtų tolesnių eksperimentų.

### **Išvados**

1. Sukurtoji techninė ir programinė įranga užtikrina stimulų pateikimą didesniu negu 5  $\mu$ s tikslumu ir yra tinkama akių konkurencijos ir dviprasmio suvokimo laikinėms savybėms tirti.
2. Pateikiant 4 – 30 ms trukmės pastoviu dažniu priešfazėje mirksinčius stimulus, fiksuojami reikšmingi skirtumai tarp akių konkurencijos vidutinių dominavimo trukmių. Dominavimo trukmių maksimumai dažniausiai pasitaiko 7 – 11 ms intervale. Maksimumų ir minimumų vyravimo intervalams yra būdingas periodiškumas – vieninga maksimumų ar minimumų vyravimo tendencija kartojasi kas 4 – 6 ms.
3. Pateikiant fazėje mirksinčius stimulus, dešinės akies duomenyse funkcijos ekstremumų pasiskirstymo tendencija yra panaši, kaip ir priešfazėje mirksinčių stimulų atveju: 5 – 10 ms intervale vyrauja maksimumai (46,7 %), 12 – 17 ms intervale maksimumų ir minimumų skaičius yra panašus (33 ir 31 %), o 20 – 30 ms intervale dažnesni minimumai (46,7 %). Kairės akies duomenyse, skirtingai nuo eksperimento priešfazėje, 12 – 17 ms intervale dažniau pasitaiko maksimumai (31,1 %).
4. Suvokiant dviprasmes figūras, absoliučios dominavimo trukmės yra 0,5 – 2 s didesnės negu bandymuose su akių konkurencija. Suvokiant dviprasmes figūras intervalas, kuriame dažniausiai pasitaiko maksimumai, yra pasislinkęs ilgesnių pateikimo trukmių link: 7 – 11 ms akių konkurencijos atveju ir 12 – 17 ms ar 20 – 30 ms, priklausomai nuo akies, dviprasmių figūrų atveju.
5. Akių konkurencijos dominavimo trukmėms būdingas laikinis nestabilumas, t.y. matuojant dominavimo trukmę skirtingais laiko momentais kelių minučių, valandos ir kelių parų eigoje, vidutinių dominavimo trukmių reikšmės svyruoja 1 – 2 s ribose.
6. Akių konkurencijos vidutinę dominavimo trukmę lemia daugiau negu vienas faktorius.

## LIST OF AUTHOR'S PUBLICATIONS

Noreika D., Švegžda A., Stanikūnas R., Vanagas V., Vaitkevičius H. Abiakės konkurencijos reiškinių laikinės charakteristikos // *Psichologija*. 2008, T. 37, P. 7-19.

Noreika D. Regimosios informacijos diskretinimas laike ir jos ryšys su abiakė konkurencija // *Žmogus XXI amžiuje: kas naujo? VI Jaunųjų mokslininkų psichologų konferencija* / [sudarė I. Salialionė, A. Kairys], Vilnius: Vilniaus universiteto leidykla, 2009, P. 7-13.

Noreika D., Vaitkevičius H., Švegžda A., Vanagas V., Stanikūnas R., Bliznikas Z. A Flickering Stimuli Method for Investigating Temporal Features of Binocular Vision // *Electronics and Electrical Engineering*. – Kaunas: Technologija. 2010, No. 7 (103), P. 35-38.

## ABOUT THE AUTHOR

Donatas Noreika finished his bachelor studies in psychology in 2003 and master studies in clinical psychology in 2005, both in Vilnius University. In 2006 he started his doctoral studies in Vilnius university. Since 2004 Donatas actively participated in organizing “The conference of young scientists in psychology” in Vilnius University and other young scientists’ events in Lithuania.

Donatas’ scientific interests include cognitive processes, psychophysiology, mental imagery and psychology of creativity. At the same time he is interested in practical psychology: psychological consulting, group processes, encouraging creativity and interdisciplinary projects.