INTERMITTENCY DURING BISTABLE VISUAL PERCEPTION OF AMBIGUOUS IMAGES

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Abstract
Present paper is devoted to the study of intermittency during the perception of bistable Necker cube image being a good example of an ambiguous object. Design of experiment allowing to measure characteristics of intermittency in the process of bistable visual perception was created. Distributions of time intervals lengths corresponding to the periods of left-oriented cube or right-oriented cube observation have been obtained. In a large range of durations distribution of time intervals of observation one of the projections of the Necker cube obeys the exponential law. Cognitive noise level of participants of the experiments has been estimated. The greater the intensity of cognitive noise is, the more frequently the changes of the bistable image projections occur in the perception of the subjects and, accordingly, the shorter the average time of observation of each projection is in the intermittent dynamics of ambiguous image perception. It was also shown that for different values of intensity I of cube edges the difference between more probable duration of observation of the left projection and of the right one increases with the increasing or decreasing of I with regard to I = 0.5.

Key words
Intermittency, visual perception, bistability, Necker cube.

1 Introduction

At the present time the study of human brain arouse the great interest of investigators from different areas of science. An intensive progress in developing of methods of experimental investigation and mathematical approaches leads to increasing of interdisciplinary publications during last years [Hramov et al., 2015; Leopold and Logothetis, 1999; Blake and Logothetis, 2002] . It should be noted that at the end of the XX century the most part of human consciousness studies were connected with its psychological aspects, but at the present time it is mainly the field of interests of neuroscience which has combined tools of mathematics, physics and nonlinear dynamics with the neurophysiological and biological view on the processes in the brain neuronal structures. Visual perception and attendant cognitive processes were often studied using ambiguous images (bistable objects) [Hramov et al., 2015; Leopold and Logothetis, 1999; Blake and Logothetis, 2002; Pisarchik, Jaimes-Reategui, Magallon-Garcia and Castillo-Morales, 2014; Runnova et al., 2016; Grubov et al., 2016]. The perception of bistable images is one of interesting tasks allowing to understand many different aspects of visual perception and objects recognition. The mechanism of image recognition does not well understood yet, but it is known that the perception is the result of processes in distributed network of occipital, parietal and frontal areas of cortex [Tong, Meng and Blake, 2006]. There is a hypothesis that switchings in the perception of ambiguous object concern with the inner noise being inherent for neural cells [Huguet, Rinzel and Hupe, 2014; Moreno-Bote, Rinzel and Rubin, 2007; Heekeren, Marrett and Ungerleider, 2008; Wilson, 2003] and arising due to the neuronal spikes. Thus, noise plays crucial role both in the process of ambiguous images perception and in other cases of making decision. An intermittency implies the presence of two or more types of behaviour in the system dynamics which alternates with each other [Pisarchik, Jaimes-Reategui, Magallon-Garcia and Castillo-Morales, 2014; Koronovskii and Hramov, 2008; Campos-Mejía et al., 2015; Hramov and Koronovskii, 2005; Hramov, Koronovskii, Kurovskaya and Moskalenko, 2011; Hramov, Koronovskii, Kurovskaya and Boccaletti, 2006; Manneville and Pomeau, 1980; Hramov et al., 2006; Hramov et al., 2007]. Thus, one can consider bistable visual perception as a process of recognition of intermittent patterns, being the projections of ambiguous image. Present paper is devoted to the study of intermittency during the perception of Necker cube image being a good example of an ambiguous object.

2 Design of experiment

Unsymmetrical Necker cube shown in Fig. 1 was used as ambiguous image in our experiments. The contrast of the three middle lines centered in the left middle corner was used as one of the control parameter I. The intensity of the three middle lines centered in the right corner was set to $(1 - I)$, and the intensity of the six visible outer cube edges was fixed to 1. Zero value of the control parameter corresponds to the left-oriented cube and if I is equal to 1 observer will see the right-oriented cube. For another values of control parameter there will be spontaneous alternations between these two projections of Necker cube in the process of its visual perception.

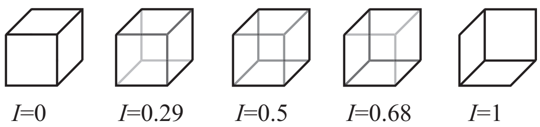

Figure 1. Unsymmetrical Necker cube. Necker cubes with limit and middle values of I are shown

Necker cube image was placed in the middle of the computer screen on the wight background. The bistable visual perception of the Necker cube image was explained to and really seen by all participants. Subjects were instructed to press left or right keys on the control panel each time their perception of the cube changed. The experiment consists of several runs of 5 min each. The runs were interrupted by breaks of a lengths freely chosen by the subjects, thus minimizing tiring effects [Merk and Schnakenberg, 2002; Grubov et al., 2016]. The duration of each period at constant perception was computed from the time interval between two successive keystrokes. Total time of experiment was about 50 minutes for each cube.

3 Results of experimental investigations

Results of the analysis of experimental data are shown in figures below. Figure 2 demonstrates typical distributions of time interval lengths corresponding to the left and right projections of Necker cube for two subjects (A and B) being investigated in the experiment. In the frames the length of time intervals spent in a constant perception state is plotted versus number of the occurrences.

In the Fig. 3 distributions of time intervals lengths corresponding to the left and right projections of Necker cube for the same subject and several cubes with different intensity of the cubes edges are shown. One can easily see the increase of difference Δt between the most probable values of time of perception for left and right Necker cube projections with the decreasing of parameter I. In addition, when the values of I is less than 0.5 the "left" projection dominates in the visual

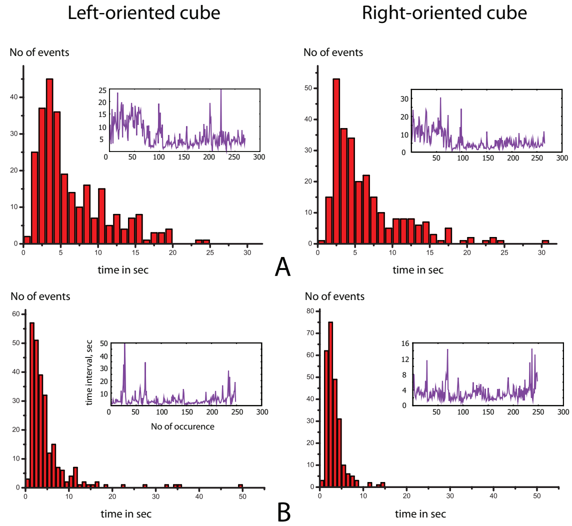

Figure 2. Distributions of time intervals lengths corresponding to the left and right projections of Necker cube with $I = 0.5$ for two subjects (A and B) being investigated in the experiment. In the frames the length of time intervals spent in a constant perception state is plotted versus number of the occurrences

perception, at $I > 0.5$ the maximum of distribution for the "right" projection will account for the time interval value being greater than the maximum value for left-oriented cube distribution. Similar results were demonstrated by other subjects, however, the values of the most probable time of observation of each projection of bistable image differs because of individual characteristics of visual perception, and different levels of cognitive noise of the participants of the experiment.

Figure 4 shows the distributions of the time intervals of observation of the Necker cube left projection with the intensity of the edges $I = 0.29$ obtained for different subjects with different levels of cognitive noise. The y-axis is shown in logarithmical scale. It should be noted that in a large range of durations distribution of time intervals of observation one of the projections of the Necker cube obeys the exponential law, with the slope of the lines approximating the experimental data shown in the figure by points increasing with the increase of the cognitive noise level of subject being investigated in the experiment. The greater the intensity of cognitive noise is, the more frequently the changes of the bistable image projections occur in the perception of the subjects and, accordingly, the shorter the average time of observation of each projection is in the intermittent dynamics of ambiguous image perception.

4 Conclusion

Design of experiment allowing to measure characteristics of intermittency in the process of bistable visual perception was created. Distributions of time intervals lengths corresponding to the periods of left-oriented cube or right-oriented cube observation have been obtained. It was shown that for different values of I the

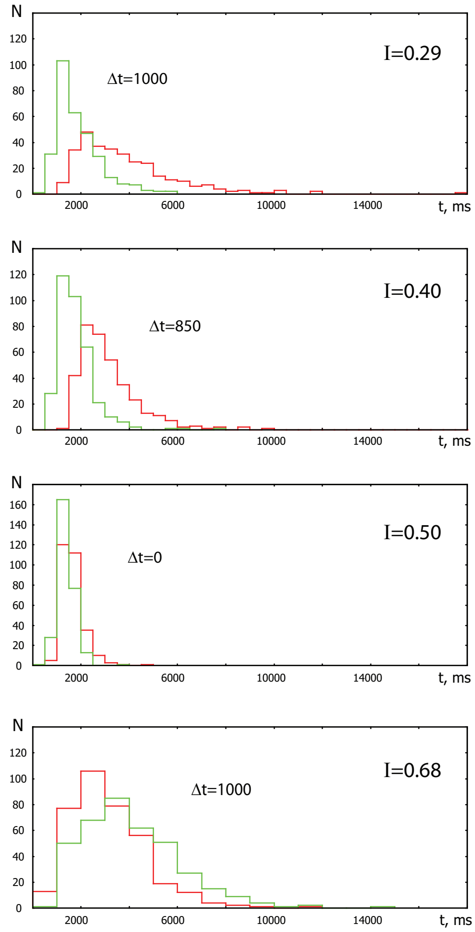

Figure 3. Distributions of time intervals lengths corresponding to the left and right projections of Necker cube for the same subject and several cubes with different intensity of the cubes edges. Δt is the difference between the most probable values of time of perception for left and right Necker cube projections.

difference between more probable duration of observation of the left projection and of the right one increases with the increasing or decreasing I with regard to $I = 0.5$. It was also shown that in a large range of durations distribution of time intervals of observation one of the projections of the Necker cube obeys the exponential law, with the slope of the lines approximating the experimental data increasing with the increase of the cognitive noise level of subject being investigated in the experiment.

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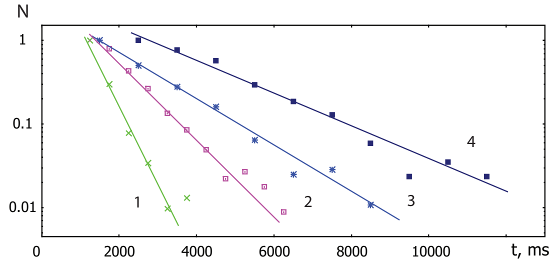

Figure 4. Distributions of time intervals lengths corresponding to the left projection of Necker cube for different subjects and the same cube with intensity of the cubes edges $I = 0.29$. The y-axis is shown in logarithmical scale. Experimental data are shown by points. Lines illustrate corresponding approximations. The higher cognitive noise level subject being investigated in the experiment has, the bigger slope the line approximating experimental data demonstrates.

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