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Decision-Making Model and Experimental Study of the Influence of Stochastic Processes on Cognitive Brain Ability

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The perception of ambiguous images [1, 2] is just one, but a very exciting task among an enormous number of open problems which appeared during recent intensive brain studies. Visual perception was often studied through perceptual alternations while observing ambiguous images [3, 4], although perceptual alternations were also described for other modalities [4]. This phenomenon is also tightly connected with the problem of the categorical perception [17]. Though the underlying mechanism of image recognition is not yet well understood, the metastable visual perception is known to engage a distributed network of occipital, parietal and frontal cortical areas [5]. The generally accepted concept that throws light on this phenomenon involves noise inherent to neural brain cells activity, whose origin may be explained as the result of random neuron spikes [6]. Internal noise seems to play a crucial role in brain dynamics related to both the perception activity and other brain functions [4–6]. Different manifestations of stochastic processes in brain were extensively studied, including the perception of ambiguous images, in terms of simple stochastic processes like the Wiener process from the viewpoint of statistical properties [3–6]. At the moment, the important problem lies in developing ways to quantitatively measure noise characteristics that can open up plenty of new opportunities both in a study of the brain functionality and a diagnosis of its pathologies.

In the present work, we develop the quantitative theory and propose the experimental technique for measuring noise intensity related to the perception of ambiguous images. Both our theoretical findings and the proposed experimental approach are proved by psychological experiments.

The experimental studies were performed in accordance to the ethical standards. Forty healthy subjects from a group of unpaid volunteers, male and female, between the ages of 20 and 45 with the normal or corrected-to-normal visual acuity participated in the experiments. As an ambiguous image, we used the Necker cube illusion. The contrast of the three middle lines centered in the left middle corner, I∈[0; 1], was considered as a control parameter. During the experiment Necker cube images with different wireframe contrasts, i.e. with the different values of the control parameter I (Fig. 1), were repeatedly showed to a person in a random sequence, with each cube being placed in the middle of a computer screen as black lines on a white background. All participants were well aware about two possible orientations of the Necker cube, and both were really seen by all of them. All participants were instructed to press either the left or the right key on the control panel according to their first visual impression (left-oriented cube (Fig. 1(a)) or right-oriented cube (Fig. 1(e), respectively). Both the image presentation and the recording of personal responses were accomplished with the help of the equipment being a part of Electroencephalograph-recorder Encephalan-EEGR-19/26 (Medicom MTD).

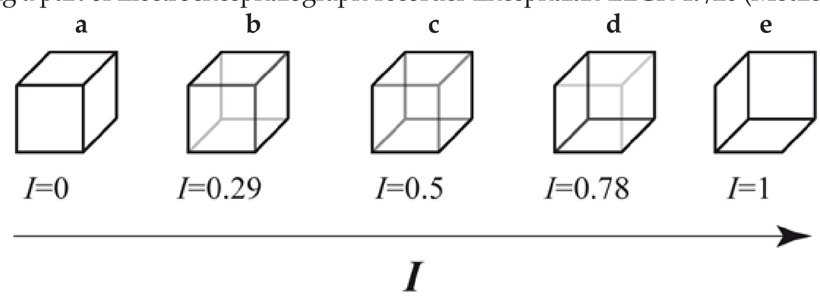

Fig.1. *Examples of distinct Necker cube images with different wireframe contrasts characterized by control parameter I*

Contrary to the traditional approach in our study we mainly focus on the theoretical and quantitative description as well as on the experimental measurement of the concrete relevant factor of the brain activity, namely, on the noise intensity characterizing the stochastic processes in the brain. Based on the methods of statistical physics, we develop a theory which helped us to derive the analytical (not empirical) expression for the experimental data and measure the noise intensity characterizing the stochastic processes in the brain. Also EEG recording volunteers were studied on the wavelet base [7]. Investigations have allowed revealing characteristic patterns for the perception of the Necker cube with different parameter I. The developed theory provides the solid experimentally approved basis for further understanding of brain functionality. We expect that our work will be interesting and useful for scientists carrying out interdisciplinary research at the cutting edge of physics, neurophysiology and medicine.

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Chimeralike States in a Network of Oscillators

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We report chimeralike states in an ensemble of oscillators using a type of global coupling consisting of two components: attractive and repulsive mean-field feedback. We identify the existence of two types of chimeralike states in a bistable Li´enard system; in one type, both the coherent and the incoherent populations are in chaotic states (which we refer to as chaos-chaos chimeralike states) and, in another type, the incoherent population is in periodic state while the coherent population has irregular small oscillation. We find a metastable state in a parameter regime of the Li´enard system where the coherent and noncoherent states migrate in time from one to another subpopulation. The relative size of the incoherent subpopulation, in the chimeralike states, remains almost stable with increasing size of the network. The generality of the coupling configuration in the origin of the chimeralike states is tested, using a second example of bistable system, the van der Pol-Duffing oscillator where the chimeralike states emerge as weakly chaotic in the coherent subpopulation and chaotic in the incoherent subpopulation. Furthermore, we apply the coupling, in a simplified form, to form a network of the chaotic R¨ossler system where both the noncoherent and the coherent subpopulations show chaotic dynamics.

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