According to P.W. Anderson, a Noble laureate in physics and the author of the famous Science paper "More is different", branches of science can be viewed as a hierarchy in which one discipline has to obey the laws of another, more fundamental one: chemistry -- for instance -- is grounded in physics or social sciences in psychology. But knowing the more primal laws does not easily allow us to reconstruct the phenomena at the higher level of the hierarchy. Qualitatively new laws emerge.

Whether the gap of emergent complexity can be bridged and a discipline moved from the level of an effective theory to a fundamental theory, depends on the stage of development of theoretical tools. Until very recently, cognitive studies were basically the domain of humanities, involving first psychology, then moving towards neurobiological and medical studies. Recent explosion of experimental techniques enabling to capture gigantic sets of physical measurements of brain activity at large spatial and temporal resolutions converts cognitive research towards quantitative empirical methodology.

Two factors turned out to be crucial for this advent of brain research: development of experimental tools allowing massive measurements and acquisition of neurophysiological data (dense array EEG, functional MRI, MEG) and construction of supercomputers capable of simulation of large-scale neuronal systems. Both factors have triggered rapid need of development of new techniques and algorithms for analysis of huge sets of data, unravelling hidden correlations and dynamics and filtering signals from noise.

Human brain is by all means one of the most complex systems in Nature. It is therefore tempting to apply successful tools of theory of complex systems in order to test this description when confronted with neural/behavioural experimental data. This process involves mathematics (catastrophe theory and non-linear dynamical systems, networks and graphs theories, information theory) and physics (deterministic chaos, non-equilibrium thermodynamics, statistical physics). Strengthened by successful applications of the theory of complex systems in understanding self-organization phenomena in various domains, like economic and social sciences, genetics, systems biology, transportation and telecommunication systems, such an approach promises therefore that cognitive processes, organization of the human brain and emergence of consciousness will be one day understood at the fundamental level.

The main aim of the grant is thus to apply selected tools of theory of complex systems to the analysis of fluctuations of large sets of data measured in dense-array EEG, in order to understand, also at the quantitative level, the processes involved in committing errors and the brain's resting state. So far, studies on error detection have focused mostly on the time window following the execution of an incorrect response. Moreover, the conventional method used is based on the averaging of short time-window segments, that does not allow for an efficient determination of small changes occurring between subsequent presentations of the stimulus. Therefore, by applying advanced techniques of signal fluctuations analysis, as used in the theory of complex systems, we would like to develop methods for analysing directionality, causality and delays of information transfer in functional networks active during resting state; in the behavioural experiment we would like to unravel answer to the question whether the level of correctness in response can be determined at the stage of decision-selection, preceding an action, i.e. in the time between appearance of a stimulus and a subject responding to it.

With this approach it will be possible to determine dynamics and variations of cognitive and emotional processes at the level of bioelectrical brain activity in the shortest possible time intervals following exposition to a stimulus. Delineation of potential differences between the incorrect and correct responses at the stage of decision-making, can be further used as a basis for the design of dedicated brain-computer systems, able to assess the possibility of human error during the tasks and thus aimed to support the work of operators of critical systems (e.g., medical emergency services, pilots or machine operators).