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A dynamical model of epilepsy in a plastic neuronal network

In this work we explore the parameter dependence of self-organization scenarios taking place in a neuronal network model equipped with activity-dependent synaptic plasticity [1]. We identify several distinct stationary states as well as parameter regions in which two or more states are unstable and the system displays spontaneous dynamic transitions between them. Such transitions take place recurrently, in various patterns, and involve abrupt reorganization of functional connectivity with simultaneous appearance of new oscillatory behavior. For selected parameter regions the pattern of transitions suggestively resembles stereotypical seizure-like events that reproduce some important pathophysiological features of epilepsy. These include: a pronounced peak in neuronal activity accompanied by hypersynchronization during the events and long, irregular inter-event intervals. We also demonstrate transient "pre-seizure states", a feature which has been recently identified by nonlinear EEG analysis in some forms of epilepsy [2]. Our model suggests a novel hypothesis for the still poorly understood basic mechanisms of epilepsy and seizure generation. We discuss the biological plausibility and bio-medical implications of our findings and outline some possible interpretations in the context of phase transitions and complex systems theory.

References

[1] Izhikevich EM, Polychronization: Computation With Spikes, Neural Comput. (2006) 18:245-282.

[2] Le van Quyen M et al., Characterizing Neurodynamic Changes Before Seizures, J Clin Neurophysiol. (2001) 18(3):191-208.