Chaos versus Noise as drivers of Multistability in Neural Networks

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Multi-stable behavior of neural networks is actively being studied as a landmark of ongoing cerebral activity, reported in both fMRI and EEG/MEG recordings. It is thought to be important as a mechanism for dealing with sensory novelty and to allow for an efficient coding of information in an ever-changing surrounding environment. This occurs when, in the absence of stimulus, a system does not settle on a specific attractor but rather shows a continuous jumping between different partially synchronized states. Many advances have been made in understanding how network topology, connection delays and noise can contribute to build this dynamic. Little or no attention, however, has been paid to the difference between chaotic and stochastic influences on the switching between different network states. Neural dynamics is characterized by high-dimensional non-linear interactions (leading to chaotic behavior) as well as the random behavior of some of their components (that introduces stochastic dynamics or noise). Understanding how chaos and noise can shape different aspects of network dynamics is still an outstanding effort.
We are studying multi-stability in networks of conductance-based neurons with chaotic behavior, connected in a small-world topology. We have already shown that, in deterministic simulations, the networks show multi-stable dynamics in a certain range of global connectivity strength [1]. In the present work, we are characterizing the multi-stable dynamics when the networks are, in addition to chaotic, subject to stochastic influences. Stochasticity is added in the form of multiplicative noise, added to the dynamics of ion channels to resemble channel noise. To characterize multi-stability, we calculate the Functional Connectivity Dynamics (FCD) matrix [2] by comparing the Functional connectivity (FC) matrices of a time course, that describe the pair-wise phase synchronies in a moving window fashion.
Our results show that in most cases noise abolishes the multi-stable behavior that is evoked by chaos in the network, resulting in more heterogenous synchronization patterns unless the network is fully synchronized by a strong coupling. In networks composed of non-chaotic oscillators and at intermediate values of coupling, noise can induce multi-stability in an otherwise synchronized, non-chaotic network. Finally, performing the analysis at two different time scales we found evidence suggesting that noise induces the appearance of short-lived synchronized states. Our current efforts are focused on quantifying the dynamics of the itinerancy in and out of the synchronized state and on studying the effect of different network topologies in this behavior.

References

[1] K. Xu, J.P. Maidana, S. Castro, P. Orio (2018) Is chaos making a difference? Synchronization transitions in networks of chaotic and non-chaotic neurons. *Submitted, under review*.

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