Delay-imposed structure on the network dynamics of oscillators

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Abstract

The spatial structure of the brain is represented with tracts between different nodes. Due to the transmission speeds via these tracts, the overall dynamics of the brain is influenced by time-delays. Empirical data from the brain suggests that the tract lengths and thereafter the time delays follow a bimodal distribution. To study their influence on the dynamics, we introduce the Kuramoto model with link-dependent delays. We analyse three different network topologies with same distribution of the delays. In the first model, the distribution is completely random, while in the other two it imposes a structure in the network, dividing it into subpopulations. We observe that even when both subpopulations have identical distribution of natural frequencies and inter- and intra- population couplings, the subpopulations may still split in clusters that have different order parameters. In summary, large-scale brain networks are characterized by the functionally important presence of many signal transmission delays, which have systematic effects upon the global network synchronization behavior. We introduce spatio-temporal decomposition of the connectivity and demonstrate its capacity to explain various synchronization and clustering behaviors. These can be controlled by varying the spatial distribution for the discrete time delays. Our findings unveil the critical importance to the mean-field brain dynamics of its spatial dimension.

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