Phase Oscillator Networks with Distance-Dependent Delays: How Does Conduction Speed Affect Large-Scale Brain Dynamics?

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Conduction speed of neural signals between brain regions varies with age and degenerative diseases such as multiple sclerosis. In this work, we investigate how changes in conduction speed affect large-scale brain dynamics. We consider coupled phase oscillator models with time delays, where the delays are proportional to the distance between nodes and inversely related to conduction speed. Our study includes network configurations such as a two-node network with a single delay and a ring network with multiple delays. We examine phase-locked states, and find synchronous, asynchronous, splay, and cluster states. Using linear stability analysis, we determine the stability of these states and generate bifurcation diagrams where conduction speed acts as the bifurcation parameter. These diagrams provide insights into what states are stable for different conduction speeds. To further validate our results, we complement our analytical findings with direct simulations of the networks.

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