Modeling the impact of neuromorphological alterations in Down Syndrome on fast neural oscillations

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Cognitive disorders, including Down Syndrome (DS), are known to present significant morphological alterations in neuron architectural complexity. However, the direct relationship between these neuromorphological alterations and impaired brain function is not fully understood. To address this gap, we propose a novel computational model that accounts for the observed morphological alterations in DS.

The model consists of a cross-sectional layer of the mice motor cortex, composed of 3037 Izhikevich neurons. The network connectivity is obtained by explicitly accounting for two single neuron morphological parameters: the mean dendritic tree radius and the spine density. We obtain these values by fitting neuron data corresponding to three mice models: wild type (WT), transgenic (TgDyrk1A), and trisomic (Ts65Dn). Our results show that the interplay between pyramidal and fast-spiking interneurons produces gamma activity (~40Hz) which is reduced in the pathological models. This finding aligns with experimental observations and validates our computational approach.

Furthermore, we investigate the effect of altered excitation-inhibition balance in our model by analyzing overinhibited networks. Our results indicate that gamma power may be increased or decreased depending on the external input to the network. Finally, we perform a numerical exploration of the morphological parameter space to determine the direct effect of each structural parameter on gamma frequency and power.

Overall, our findings reveal the direct relation between morphology alterations and gamma oscillations impairment in DS. Moreover, this research highlights the potential of computational modeling to unravel the relation between neuron architecture and brain function and ultimately improve our understanding of cognitive disorders.