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# The role of criticality in the structure-function relationship in the human brain

Healthy brains exhibit a rich dynamic repertoire with flexible and diverse spatiotemporal pattern replays across microscopic and macroscopic scales.We hypothesize that the system must operate near a critical regime for the functional repertoire to be fully explored, and flexible dynamics to emerge.To test this hypothesis, we employ a modular Spiking Neuronal Network model, where each group of Leaky Integrate-and-Fire neurons represents a cortical region.A learning rule based on Spike-Timing-Dependent Plasticity (STDP) is used to encode patterns of activations that propagate between modules.The patterns exploit empirical information on the number of white-matter fibers between regions. The model [1] displays two distinct dynamical regimes: an uncorrelated low-rate state and a strongly correlated state, marked by a high Order Parameter value (indicating the similarity of spontaneous activity with one of stored patterns).These regimes are separated by either a first-order or second-order phase transition, depending on the strength of global inhibition and structured connections. When the hysteresis loop shrinks, a continuous phase transition occurs, and it opens up an extended region with high order parameter fluctuations (close a Widom line with maxima of fluctuations).The model predictions are compared with empirical data from magnetoencephalographic (MEG) recordings in healthy adults. We show that the structural-function correlation is maximized when the model is the extended critical regime.Then, the Levenshtein distance is used to quantify the similarity between the sequences of region activations in neural avalanches from both the empirical data and the model simulations.Notably a similar repertoire of sequence is observed in synthetic data and MEG, only when the model operates within the critical extended regime.

[1]The role of criticality in the structure-function relationship in the human brain. M.Angiolelli S.Scarpetta et al. Physical Review Research 2025

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