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Non-additive coupling enables stable propagation of synchronous spiking in purely random networks

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Precise timing of spikes and synchronization in the millisecond range has been experimentally observed in different neuronal systems. Their occurrence correlates with external stimuli and is thus considered a key feature of neural computation. The dynamical origin of precise and coordinated spike timing, however, is not well understood. Here we show in a modeling study that synchronous spiking activity of subgroups can persist and propagate in purely random networks if we take into account the non-additive nature of dendritic input integration that was recently uncovered experimentally. We find a transition to stable propagation of synchronized spiking: For additive coupling and at low strength of non-additivity, synchronous spiking dies out; above a critical strength, stable propagation of a group of synchronized spikes becomes possible. We derive a map giving the average future size of a synchronous group in terms of the current group size. For networks with homogeneous parameters the map can be obtained analytically and reveals that the discontinuous transition found is due to a tangent bifurcation at a critical strength of non-additivity. We discuss the mechanism underlying this transition and its consequences for networks with inhomogeneous parameters and additional external noise. Prominent 'synfire-chain' models for the stable propagation of synchronous activity in cortical networks require the existence of feed-forward structures that are superimposed on otherwise randomly connected local cortical circuits. It is unclear, however, whether feed-forward structures actually exist in such local circuits. Our study suggests that additional structural features of the network connectivity may not be required for the propagation of synchronous spiking activity if synaptic interactions exhibit non-additive dendritic integration.