Death and rebirth of neural activity in sparse inhibitory networks

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Inhibition is a key aspect of neural dynamics playing a fundamental role for the emergence of neural rhythms and the implementation of various information coding strategies. Inhibitory populations are present in several brain structures, and the comprehension of their dynamics is strategical for the understanding of neural processing. In this talk, we clarify the mechanisms underlying a general phenomenon present in pulse-coupled heterogeneous inhibitory networks: inhibition can induce not only suppression of neural activity, as expected, but can also promote neural re-activation. In particular, for globally coupled systems, the number of firing neurons monotonically reduces upon increasing the strength of inhibition (neuronal death). However, the random pruning of connections is able to reverse the action of inhibition, i.e. in a random sparse network a sufficiently strong synaptic strength can surprisingly promote, rather than depress, the activity of neurons (neuronal rebirth). Thus, the number of firing neurons reaches a minimum value at some intermediate synaptic strength. We show that this minimum signals a transition from a regime dominated by neurons with a higher firing activity to a phase where all neurons are effectively sub-threshold and their irregular firing is driven by current fluctuations [1]. We explain the origin of the transition by deriving a mean field formulation of the problem able to provide the fraction of active neurons as well as the first two moments of their firing statistics [2]. The introduction of a synaptic time scale does not modify the main aspects of the reported phenomenon. However, for sufficiently slow synapses the transition becomes dramatic, and the system passes from a perfectly regular evolution to irregular bursting dynamics. In this latter regime the model provides predictions consistent with experimental findings for a specific class of neurons, namely the medium spiny neurons in the striatum.

References

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