Dynamics of neural networks with different motif distributions

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The aim of this research is to find links between topological network measures and network dynamics.
In this initial study we have compared the dynamics of two networks with different motif distributions and have analysed the dynamics of the networks before and after a stimulus is applied.

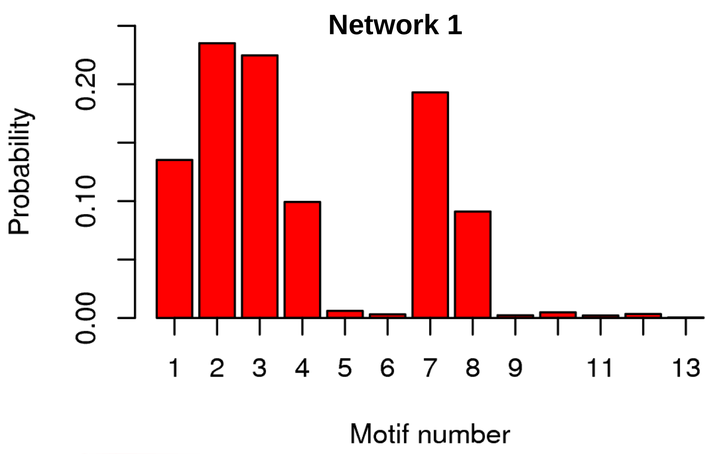
Random Recurrent Neural Networks (RRNNs)
We used RRNNs [2] to model the dynamics of the network:

- RRNNs use a simple model of neurons, each neuron is a single value
- Neurons are linked in a recurrent manner (the network is cyclic)
- Synaptic weights are taken from a random distribution
- A random stimulus is then applied to the network in a constant manner.

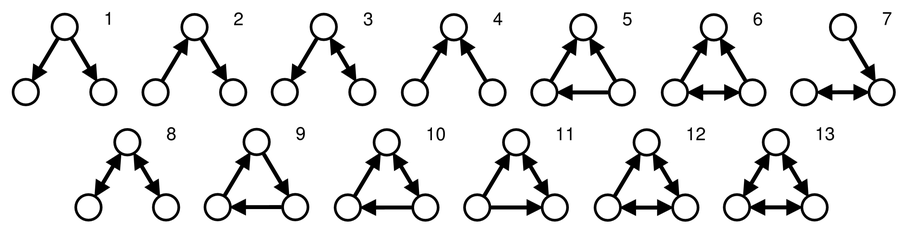
Different methods to apply stimuli to the networks

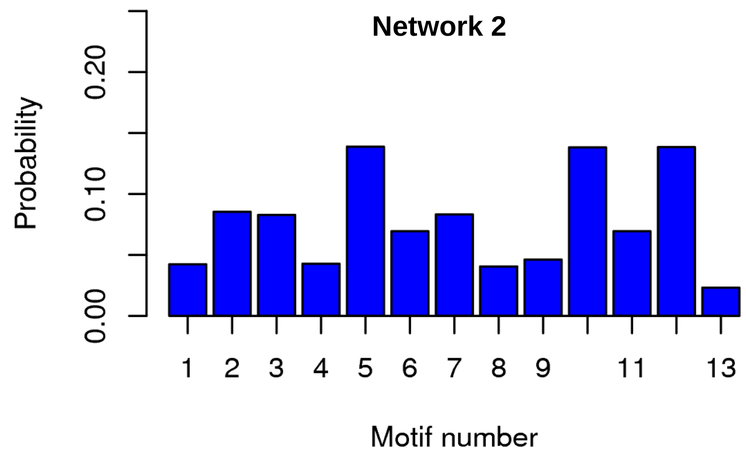
- all : each neuron was given an influence
- least x connected : the x neurons with the least outgoing connections are given an influence
- most x connected : the x neurons with the least outgoing connections are given an influence

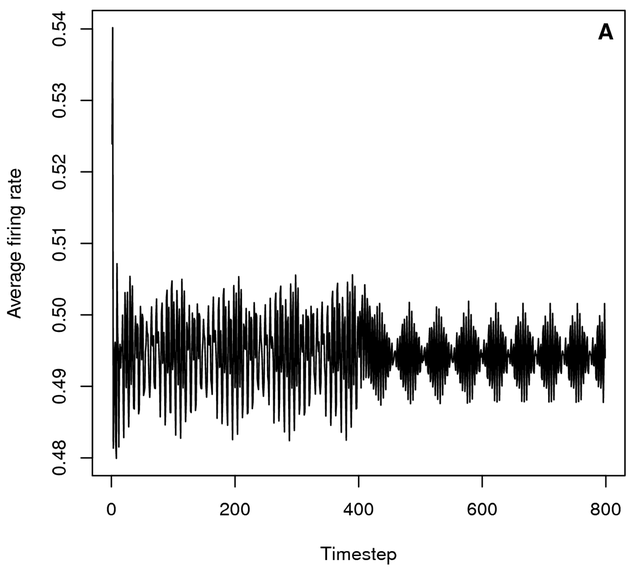
where x = 20,50,100. Each test was performed for 10 different sets of synaptic weights, and each with 10 random seeds for the stimuli. Each network had 250 nodes.



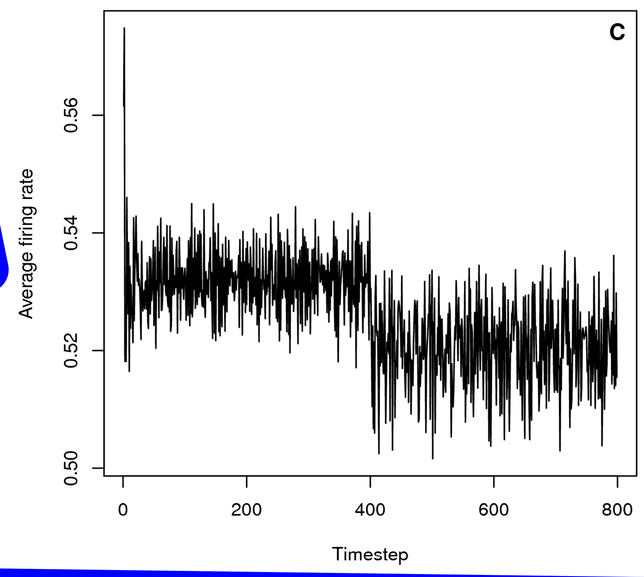
3-node motifs are small networks that can be found within larger networks. Here we have generated two networks with different motif distributions. The networks were generated using the SN model [1].



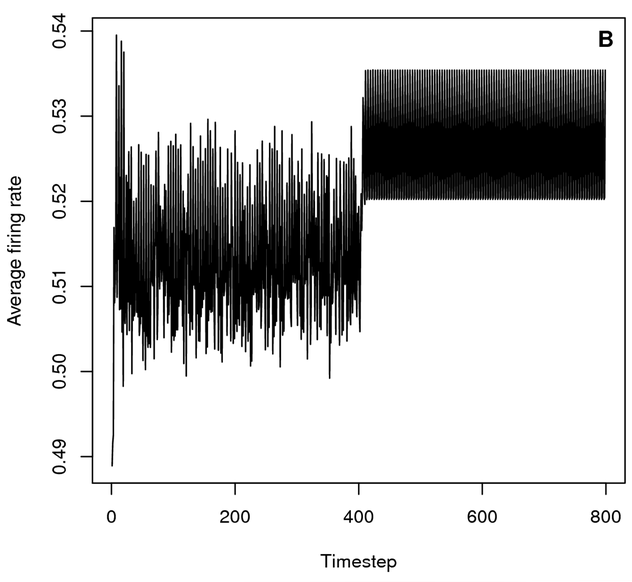




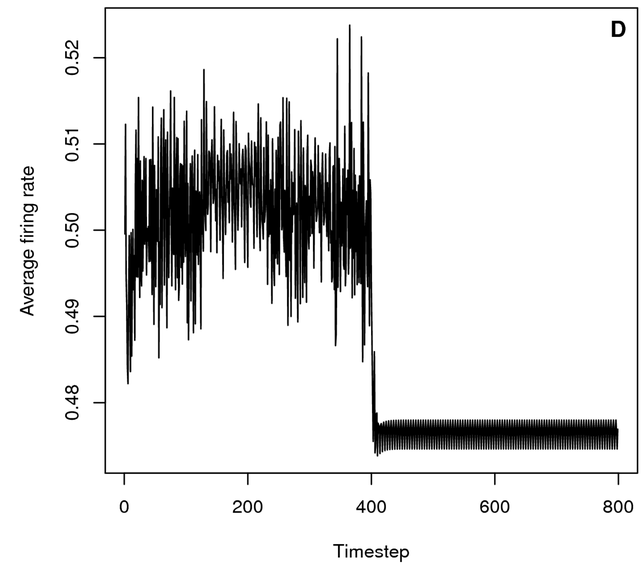
Network 1 is occasionally regular before any stimuli is applied to it. Here the stimulus is being applied to the 20 least connected nodes.



Network 2 was never regular before a stimuli was applied, and was more likely to still not be regular after the stimuli was applied. Here the stimulus is being applied to the 100 most connected nodes.



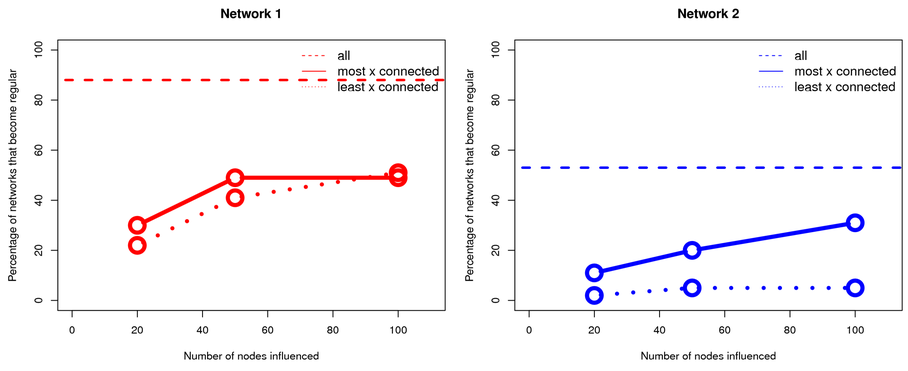
In network 1, when a stimuli is applied to the 100 least connected nodes or 50 most connected nodes, then about half of the time the dynamics become regular. As more nodes are chosen then the number of networks that become regular increase until the 88% of networks that become regular when all nodes are given the stimulus is reached. Here a stimulus is being applied to the 20 most connected nodes.



Here network 2 is again having an influence applied to the 100 most connected nodes. This network can have regular dynamics, but this is much less frequent than with network 1.

Number of times the dynamics became regular from 100 trials.

	All	Least 20	Least 50	Least 100	Most 20	Most 50	Most 100
Network 1	88	22	41	51	30	49	49
Network 2	53	2	5	5	11	20	31



Conclusions
There are great differences between the dynamics of the two networks, with network 1 having regular dynamics more often than network 2.

The motif distribution is not the only topological measure that differs between the two networks; the different degree distributions and cluster coefficients should be taken into account.

These results agree with those already present in the literature [3], that networks with densely linked groups of neurons, such as network 2, have more complex dynamics.

[1] P. Frisco, Network model with structured nodes, Physics Review E (PRE), 84, (2), 2011, 021931
[2] Siri, B.; Berry, H. & Quoy, M. Topological and dynamical structures induced by Hebbian learning in random neural networks International Conference on Complex Systems, Boston, 2006
[3] Sporns, O.; Tononi, G. & Edelman, G. Theoretical Neuroanatomy: Relating Anatomical and Functional Connectivity in Graphs and Cortical Connection Matrices Cerebral Cortex, 10, (2), 2000