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Cross-talk and transitions between multiple environments in an attractor neural network model of the hippocampus

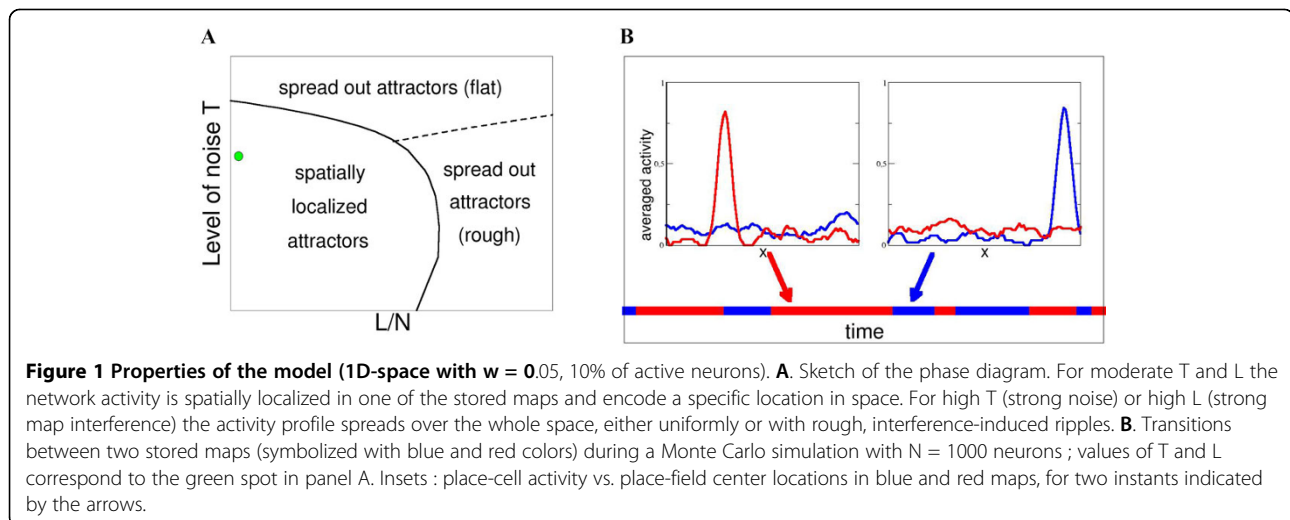
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From Twenty Second Annual Computational Neuroscience Meeting: CNS*2013
Paris, France. 13-18 July 2013

Place cells are neurons in the hippocampus whose activity depends on the animal's location in space and are therefore thought to be crucial for spatial representation [1]. Based on the assumption that CA3 works as an attractor neural network [2] models have shown that spatially-localized attractors, corresponding to different 'environments' or 'spatial maps', can be encoded in one network [2,3]. Transitions and cross-talks between attractors coding for different maps remain, however, poorly understood.

Motivated by a recent experiment showing bistability between competing spatial representations, paced by

theta waves [4] we propose a recurrent model network, whose synaptic connections J_{ij} sum up contributions coming from all the environments according to : 1. The contribution to J_{ij} due to an environment vanish when the centers of the place fields of cells i & j are further away than some cut-off distance w ; 2. Place fields are randomly remapped from one environment to the other. Using tools and concepts from the statistical physics of disordered systems we have solved the model and show that the network can be in one of three regimes, depending on the level of noise in the neural dynamics, T , and the number of environments, L (Figure 1A). In particular,



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we have found the maximal values of T and L (given the other parameters of the model e.g. the number of place cells, the average firing rate, ...) such that, spatially-localized and environment-specific activity is possible. In addition we have observed the presence of spontaneous, i.e. in the absence of external input, dynamical transitions from the activity localized in one map to the activity representative of another environment (Figure 1B). Those transitions are strongly reminiscent of those experimentally observed in [4]. The statistical features of the transitions and their dependence on the parameters of the model can be understood in great analytical details.

Published: 8 July 2013

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doi:10.1186/1471-2202-14-S1-O15

Cite this article as: Rosay and Monasson: Cross-talk and transitions between multiple environments in an attractor neural network model of the hippocampus. *BMC Neuroscience* 2013 **14**(Suppl 1):O15.

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