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Presentation Abstract

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Title: Models of neural networks of spiking neurons performing complex cognitive tasks

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Abstract: The recorded neural activity is highly variable and heterogeneous, especially in areas like the prefrontal cortex that are believed to be important for high cognitive functions. The activity varies across time and from trial to trial and shows selectivity to sensory stimuli, the intended actions and the animal decisions, the rule in effect and the context in which the task is performed. Interestingly, often the neural activity is selective to combinations of these different aspects of the task (mixed selectivity). We recently showed that the observed richness and diversity of neural responses play an important role in context dependent tasks, in particular when the same event leads to the activation of a population of neurons in one context, and to its inactivation in another. The selectivity to conjunctions of events and mental states is obtained naturally by randomly connected

neurons (RCNs). The number of needed RCNs to solve these context dependent tasks is surprisingly small and scales linearly with the complexity of the task. Here we extend our previous work to more realistic models of neural networks of spiking neurons with realistic synapses. The task is solved by defining a set of mental states, each representing a particular action or a disposition to behavior. Every event induces a transition to a different mental state that depends on both the event and previous mental states. Each mental state is an attractor of the neural dynamics represented by a pattern of reverberating activity. The neural network is composed of three populations of recurrently connected neurons, (1) excitatory neurons representing the inner mental states project their activity with synapses of random weight to a (2) pool of excitatory neurons implementing the mixed selective neurons and finally (3) a pool of inhibitory neurons. The synapses to the neurons of the first population are plastic and they are determined as follows: we assume that the neurons generate Poisson spike trains at the frequency that represents a particular mental state. We then tune the synaptic weights generating the recurrent input, so that we reproduce the firing rate of the Poisson spike trains. We follow a similar procedure for the event driven transitions. The NMDA component of the recurrent synaptic input plays an important role, as in decision making neural circuits (Wang 2003). The important aspects of the NMDA component are the slow dynamics that stabilizes the collective neural dynamics, and the non-linear response to the frequency of pre-synaptic spikes, due to saturation of the receptors. Such non-linearity causes the effective firing rate to saturate already at the operating frequency of the neurons.

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