

# An integrate and fire model of minicolumns in prefrontal cortex explains selective firing of neurons during goal-directed behavior

Randal A. Koene & M.E. Hasselmo  
Boston University, Boston, MA  
Department of Psychology Center for Memory and Brain,  
and Program in Neuroscience

May 19, 2004

Simulations replicated results in a visual go/no-go conditioned stimulus task (W.Schultz *et al.*, *Cerebral Cortex*, 2000), in which monkeys were randomly given three visual stimuli: 1. Rewarded movement stimulus; specific movement is rewarded. 2. Rewarded non-movement; refraining from specific movement is rewarded. 3. Unrewarded movement; movement is required without reward and the trial is repeated unless the monkey performs the movement.

In the prefrontal cortex model, sensory input states and motor actions are represented by individual cortical minicolumns with integrate and fire neurons. And spike timing dependent synaptic plasticity encodes transitions between the states and actions on sparse intercolumnar connections and dense intracolumnar connections. The spike timing needed for plasticity is provided by a short-term memory based on persistent firing that is achieved by intrinsic membrane currents. An associative spread of activity from the goal representation enables retrieval of a learned sequence of states and actions, so that a goal-directed action is selected for the current state. Encoding and retrieval take place in distinct phases of network oscillations. The model corresponds to a biological implementation of reinforcement learning.

The model predicts neural firing that is selective for a specific trial and specific to cue, action or reward, closely resembling activity recorded by W.Schultz *et al.* in orbitofrontal neurons. The functions of neurons in the model offer explanations for their selective activity. And additional specific responses not identified by W.Schultz *et al.* were found. Supported by NIMH DA16454, MH60013, MH61492 and MH60450.