A compartmental biophysical simulation of mechanisms for a persistent firing buffer that is based on intrinsic currents of entorhinal pyramidal cells

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A persistent firing buffer is necessary for episodic learning, since synaptic potentiation requires repeated presentation of sequence data, and since the time intervals between the presentation of successive stimuli are often too great for spike timing dependent potentiation. In prior work (Koene & Hasselmo, 2003, 2006), we proposed mechanisms for a persistent firing buffer that depends on an intrinsic after-depolarizing membrane currrent, based on the one first proposed by Lisman & Idiart (1995). Integrate-and-fire simulations in a system context have been encouraging.

Here, we evaluate biophysical plausibility if the buffer model depends on the after-depolarization observed in pyramidal cells of layer II of the entorhinal cortex (Klink & Alonso, 1997) and in neocortical pyramidal cells (Andrade, 1991). We implement the buffer model, using four individual electrical compartments for each pyramidal cell: cell body, axon, basal dendrites and apical dendrite. We simulate after-depolarizing currents with a range of parameter values that are realistic for pyramidal cells in neocortex, and as measured for pyramidal cells in entorhinal cortex (Fransen et al., 2002).

We show that buffer function may be achieved in the following ways: Rhythmic reactivation of buffered spikes can be governed by the time constant of the after-depolarizing response, or rhythmic reactivation may be governed by the combined after-depolarizing and after-hyperpolarizing responses. If after-depolarization saturates, then the effect of after-hyperpolarization combined with the saturated after-depolarization can reactivate spikes at theta frequency. A similar mechanism is examined if after-depolarization does not saturate, in which case that response may be paired with a non-saturating after-hyperpolarizing response.

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