SPIKING REGIMES IN MODEL NETWORKS OF HIPPOCAMPAL PERSISTENT FIRING NEURONS

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Rapid persistent firing is thought to be the neural correlate of short-term memory maintenance [1], in which transient stimuli must be preserved during long delay periods outlasting them. Therefore, the brain structures commonly involved in working memory tasks, including the hippocampus, must possess the necessary substrates for the generation and maintenance of elevated persistent activity. Various synaptic mechanisms underlying mnemonic persistent firing have been suggested by neuroscientists. The common view is that networks with specific topologies, such as recurrent excitatory connections, depend on strong local excitation for the generation of long-lasting neuronal activity and rhythmic oscillations [2]. However, it has been shown that memory can also be encoded in brain regions which do not display such topologies, such as the CA1 area of the hippocampus [3]. These regions display similar activation patterns, and must therefore rely on mechanisms which are independent of topology and connectivity, such as intrinsic cellular properties. Among these are the ionic currents mediated by calcium-activated non-specific (CAN) ion channels, which seem to be a valid candidate for rhythm generators in hippocampal networks.

Our work investigates the different patterns of activity displayed by model networks of hippocampal CAN-equipped persistent firing neurons. The neuron model is based on the Hodgkin-Huxley formalism for increased biological plausibility. We show that synchronized patterns elicited by a transient ($250\,ms$) stimulus can be maintained solely by CAN currents, without the need for strong recurrent connections. In addition, such a CAN-network exhibits three main types of firing regimes depending on the value of the connection weights – a slow regime with firing rates $6\,Hz < f < 18\,Hz$, a bursting regime, and a fast gamma regime with firing rates $f > 40\,Hz$. These results are in accordance with in vitro recordings of hippocampal slice preparations [4], and provide a possible explanation for the generation and maintenance of memory-related oscillatory activity in different frequency bands, within the hippocampus.

References

[1] J. Fuster and G. E. Alexander, "Neuron Activity Related to Short-Term Memory," *Science*, vol. 173, pp. 652–654, Aug. 1971.

[2] X.-J. Wang, "Synaptic reverberation underlying mnemonic persistent activity," *Trends in neurosciences*, vol. 24, pp. 455–63, Aug. 2001.

[3] D. G. Amaral, "Emerging principles of intrinsic hippocampal organization," *Current opinion in neurobiology*, vol. 3, pp. 225–229, 1993.

[4] B. Knauer, A. Jochems, M. J. Valero-Aracama, and M. Yoshida, "Long-lasting intrinsic persistent firing in rat CA1 pyramidal cells: a possible mechanism for active maintenance of memory," *Hippocampus*, vol. 23, pp. 820–31, Sept. 2013.