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The balance of synaptic conductances in shaping hippocampal population rhythms

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A central feature of the hippocampus is its rich tapestry of population oscillations as revealed by electroecephalogrpahic (EEG) recordings. These myriad forms of population activities are related to various behavioural states. For example, during slow wave sleep and awake immobility, the rodent hippocampus exhibits two dominant EEG rhythms, iregular activities with dominant frequencies of 2–3 Hz and intermittent sharp waves. These EEG activities have been implicated in memory-related signal processes. As these population activities primarily rely on CA3 network activities, a sound knowledge regarding the balance between excitatory and inhibitory activities in the CA3 circuit is the key to understanding their generation.

Using thick slices of adult mice, we have produced an in vitro model that is capable of exhibiting either spontaneous rhythmic field potentials (SRFPs, 1–4 Hz) alone or SRFPs together with sharp wave like events [1,2]. We study the balance of synaptic conductances that may underlie these population activities. Our approach is to use the VmD method [3] to investigate the excitation/inhibition balance in individual hippocampal CA3 neurons.

Our results show that 1.) there is a global inhibitory dominance for all the neurons in slices exhibiting SRFPs alone and with sharp wave like events, in accordance with the fact that the SRFPs are inhibitory in nature. 2.) The inhibitory hegemony lessens by a significant degree for neurons in the slices having both sharp wave like events and SRFPs. This sheds light on the importance of increased excitatory inputs in sharp wave generation. 3.) There is a significant disparity in excitation/inhibition balance between pyramidal cells and interneurons, with the pyramidal cells generally receiving a lower ratio of inhibitory inputs. This difference in excitation/inhibition balance probably underscores the possible inhomogeneity of the neural network. These results provide insights not only on the balance of synaptic conductances conducive to hippocampal rhythm generation, but also on the prospective wirings of the structure itself. These insights can in turn be used to constrain computational network models that simulate rhythm generation in the hippocampus.

References

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