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Intense synaptic activity between mitral and granule cells leads to precise spike timing during gamma oscillations in the olfactory bulb

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The olfactory bulb is the first neuronal relay transmitting olfactory stimuli to higher level cortical neural circuits. During a sniff, at the end of the inspiration, the olfactory bulb local field potential (LFP) oscillates at the gamma frequency range (40–60 Hz) [1]. Those oscillations are generated by dendrodendritic synapses between mitral and granule cells [2]. Mitral cells, the principal neurons, activate the granule cells wich in turn inhibit them. With this interplay, mitral cell action potentials occur at a preferential phase of the LFP cycle [2]. The timing of mitral cells action potentials is known to be precise during local field oscillations [3]. This is not the case when mitral cells are individually activated with a slowly varying input current, similar to the one produced by an olfactory stimulation [4]. How do synaptic interactions between mitral and granule cells affect the mitral cell spike timing precision within an LFP cycle?

We developed a simple olfactory bulb model based on biological data. This model is composed of mitral cells receiving excitatory inputs from receptor neurons within olfactory glomeruli. The mitral cells then activate granule cells via fast glutamate excitatory synapses and granules cells inhibit them via fast inhibitory GABAergic synapses. This study focuses on the relation between mitral-granule connectivity and mitral cell activity.

With a slow varying input, our model exhibits gamma oscillations. Those oscillations shape the mitral cell discharges into action potential waves. At each cycle, the firing of a particular mitral cell depends on the strength of its excitatory input and on the amount of synaptic inhibitory events received from granule cells. We show that the synaptic connectivity between mitral and granule cells controls the amount of received inhibition and, that a large number of received synaptic events enhances spike timing precision in mitral cells during successive oscillations.

This study suggests that the density of connection between mitral and granule cells plays a significant role in the precision of firing times encoding the olfactory stimulus. To have a precise and reliable activity during repeated and similar stimulations, mitral cells must receive a sufficiently high number of inhibitory events during the gamma oscillation. This high inhibitory synaptic activity is supported by a dense synaptic connectivity.

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