Influence of inhibitory circuits in the olfactory bulb on the frequency tuning of mitral cells

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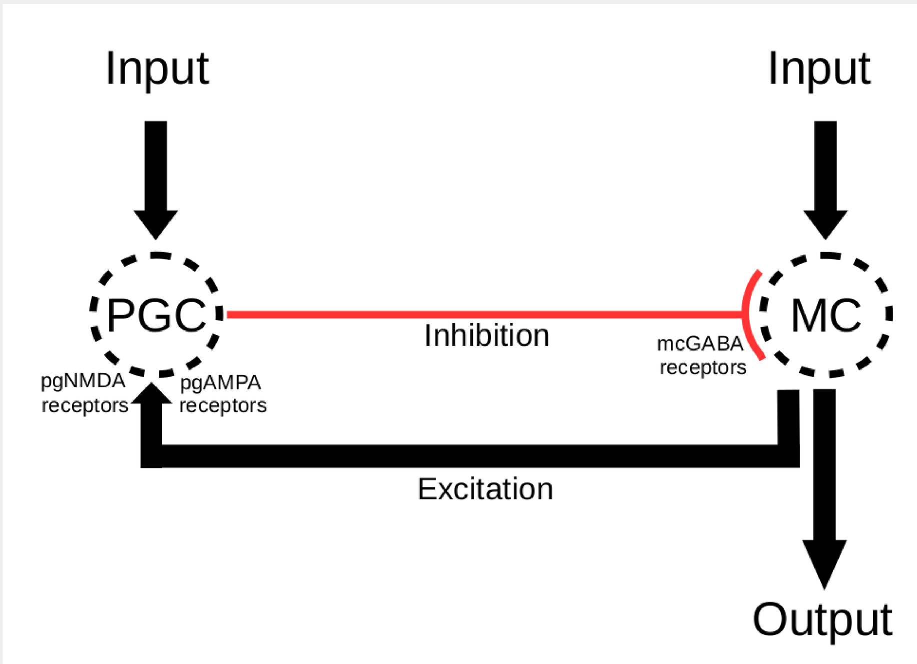
Motivation

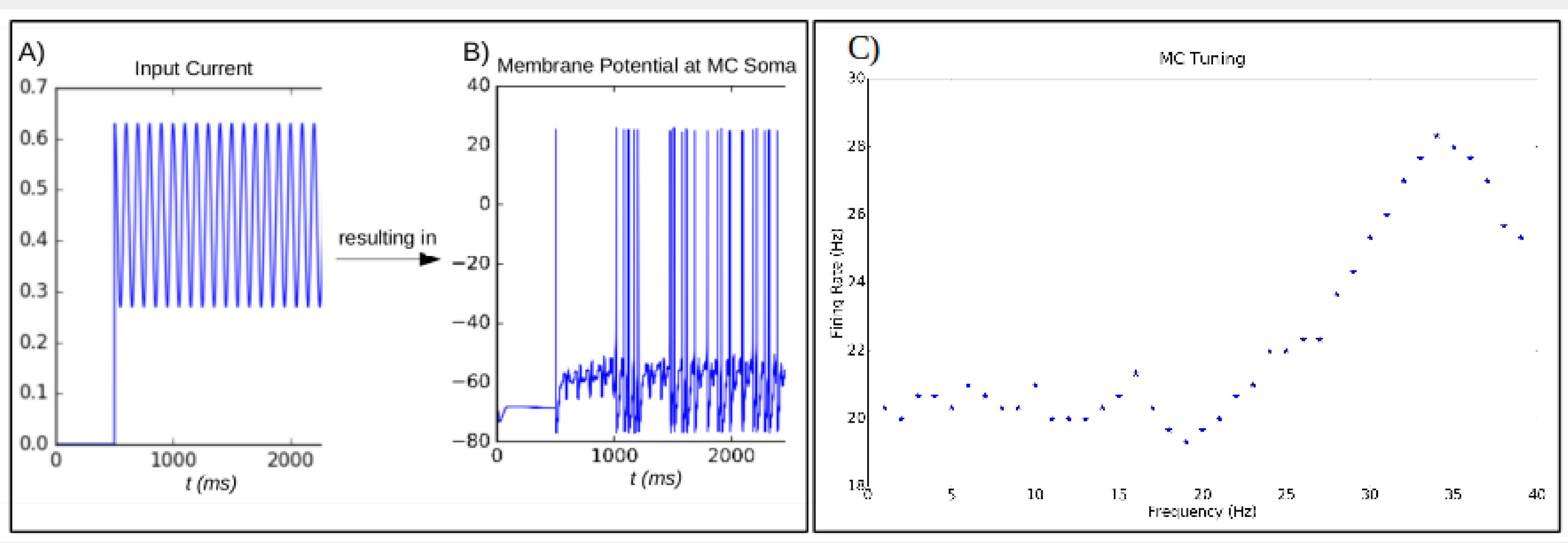
The olfactory bulb (OB) in mammals is responsible for receiving, processing and relaying olfactory information (odours). Naturalistic odour stimuli have a rich temporal structure, caused by turbulent airflow. Recent studies show that this structure contains information about the olfactory scene, for example the distance to an odour source [1, 2]. Furthermore, it has been suggested that animals might exploit this structure and extract this information in order to find odour sources [3]. As some of this information may lie in the frequency content of the stimuli [2], we studied input frequency dependent responses of mitral cells (MCs) in the olfactory bulb (OB). Specifically, we investigated whether MCs show frequency tuning and, if they do, how different components of the glomerular layer circuitry shape and determine the tuning.

Model



- Used a model of the OB (modified from [4]).
- Modeled MC - PGC, focusing on recurrent and feed - forward inhibition in the glomerular layer.

Method

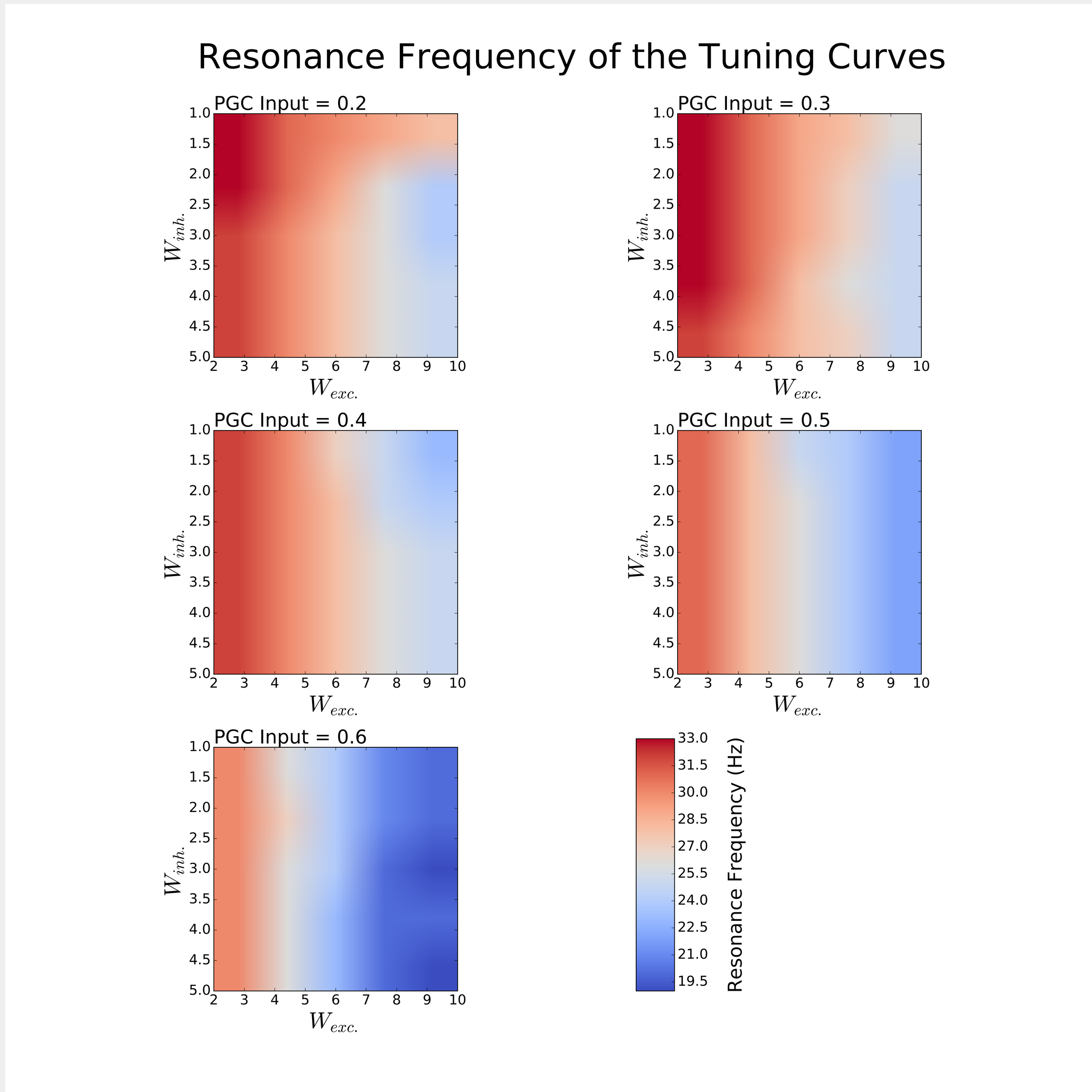


- Used sinusoidal currents of varying frequencies as input, using the equation:

$$y(t) = csin(2\pi ft + \varphi) + 0.18. \quad (1)$$

- Phase $(\varphi) = 0$ and strength of input to MC $(c) = 0.45nA$.
- PGC input strength was adjusted by multiplying $0.45nA$ by the values: $0.2, 0.3, 0.4, 0.5$ and 0.6.
- MC - PGC excitation strength varied using W_{exc} values: $2.0, 4.0, 6.0, 8.0$ and 10.0.
- PGC - MC inhibition strength varied using W_{inh} values: $1.0, 2.0, 3.0, 4.0$ and 5.0.
- Frequency (f) of input ranged between 1.0Hz and 40.0Hz (with step size 1.0).
- Parameter combinations: PGC input strength, MC - PGC excitation strength and PGC - MC inhibition strength.
- Constructed frequency tuning curves

Results



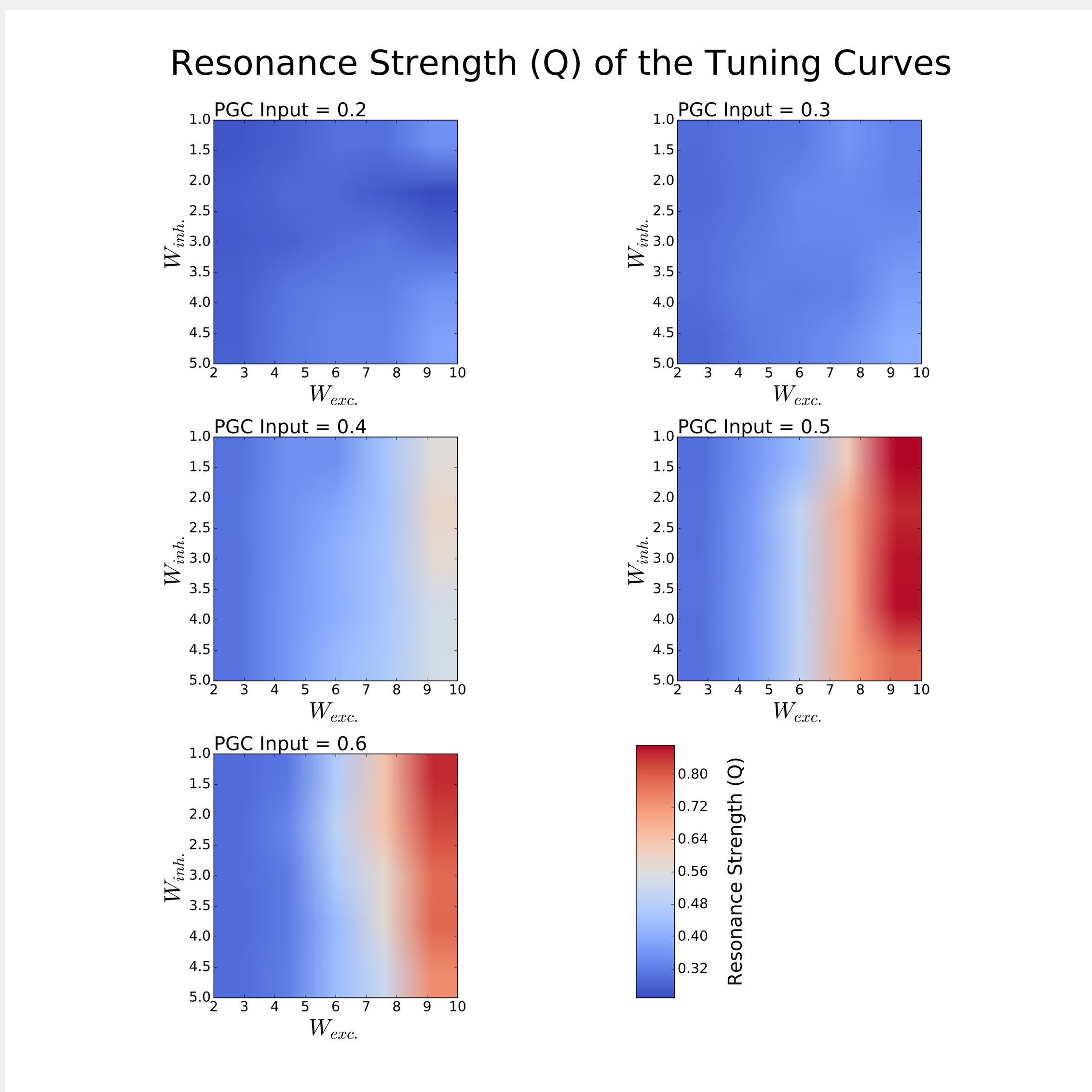
- Resonance frequency decreased as the excitation of the PGC increased (both from input and the MC).
- Strength of PGC inhibition onto the MC did not have a strong effect.
- Resonance strength increased with the strength of the excitatory connection, when the PGC received sufficient external input from olfactory stimuli.

Discussion

- Extracted the peak resonance frequency and the strength of the tuning Q, measured as:

$$Q = \frac{(F_{max} - F_{min})}{< F >} \quad (2)$$

- F_{max} and F_{min} is maximum and minimum firing rate.
- $< F >$ is mean firing rate over all measured frequencies.



- Results suggest that the MC can indeed show frequency tuning.
- this depends on the strength of the excitatory synaptic input to the PGC, which provide inhibitory input to the MC.

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