Influence of inhibitory circuits on the frequency tuning of mitral cells

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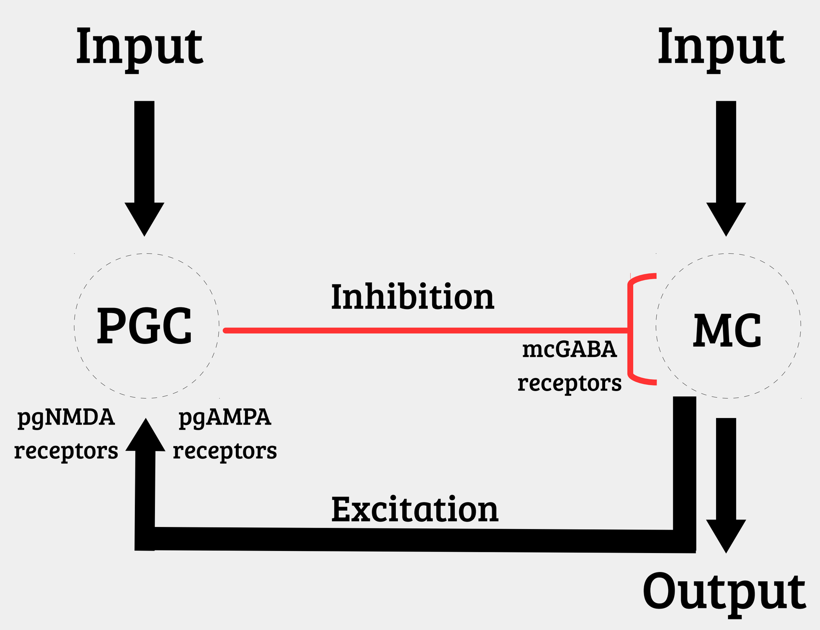
Motivation

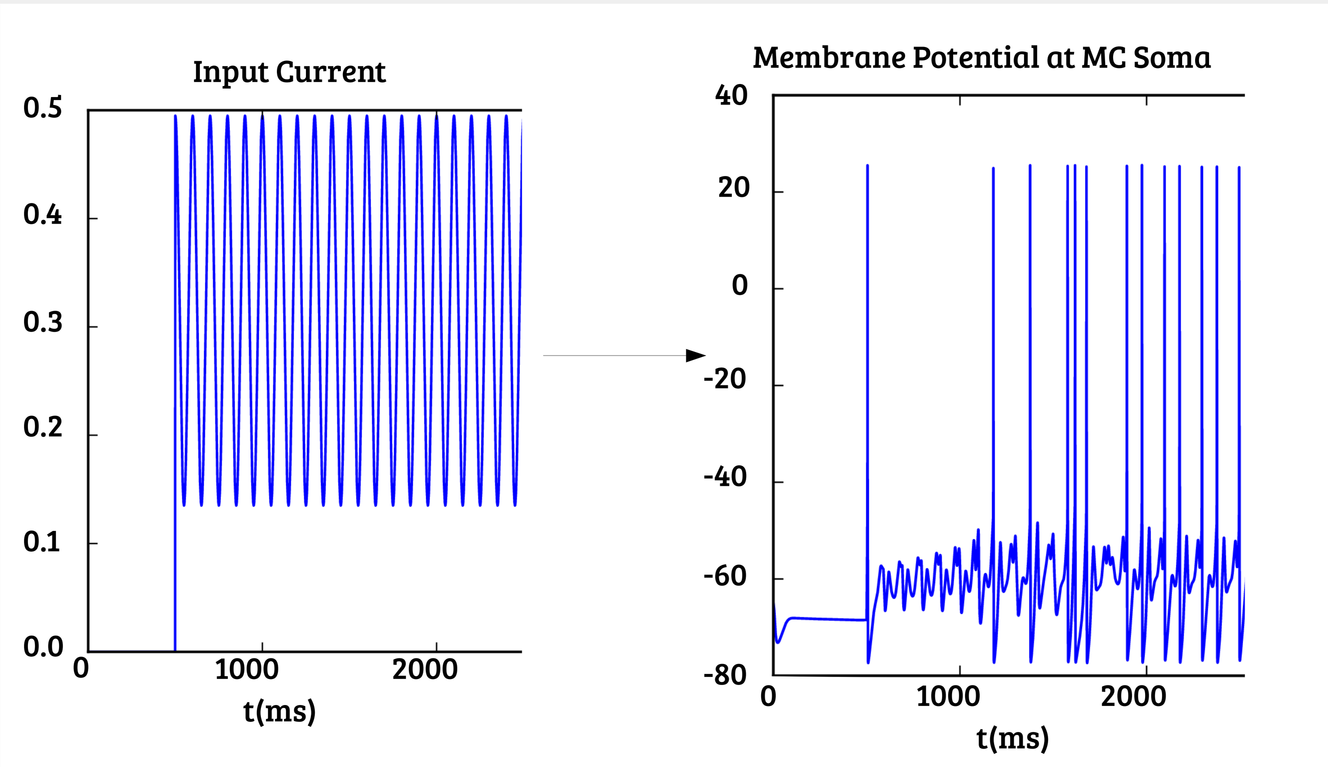
The olfactory bulb (OB) is responsible for receiving, processing and relaying olfactory information (odours). Naturalistic odour stimuli have a rich temporal structure, caused by turbulent airflow. Recent studies show that this structure contains information about the olfactory scene [2, 5]. It has been suggested that animals might exploit this structure and extract information [3]. Some of this information may lie in the frequency content of the stimuli [5], therefore we studied input frequency dependent responses of mitral cells (MCs) in the 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 (periglomerular cells), focusing on recurrent and feed - forward inhibition in the glomerular layer.

Method



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

$$y(t) = c \cdot \sin(2 \cdot \pi \cdot ft + \varphi) + 0.18$$

- Where strength of input to MC (c) = 0.45nA and phase (φ) = 0.

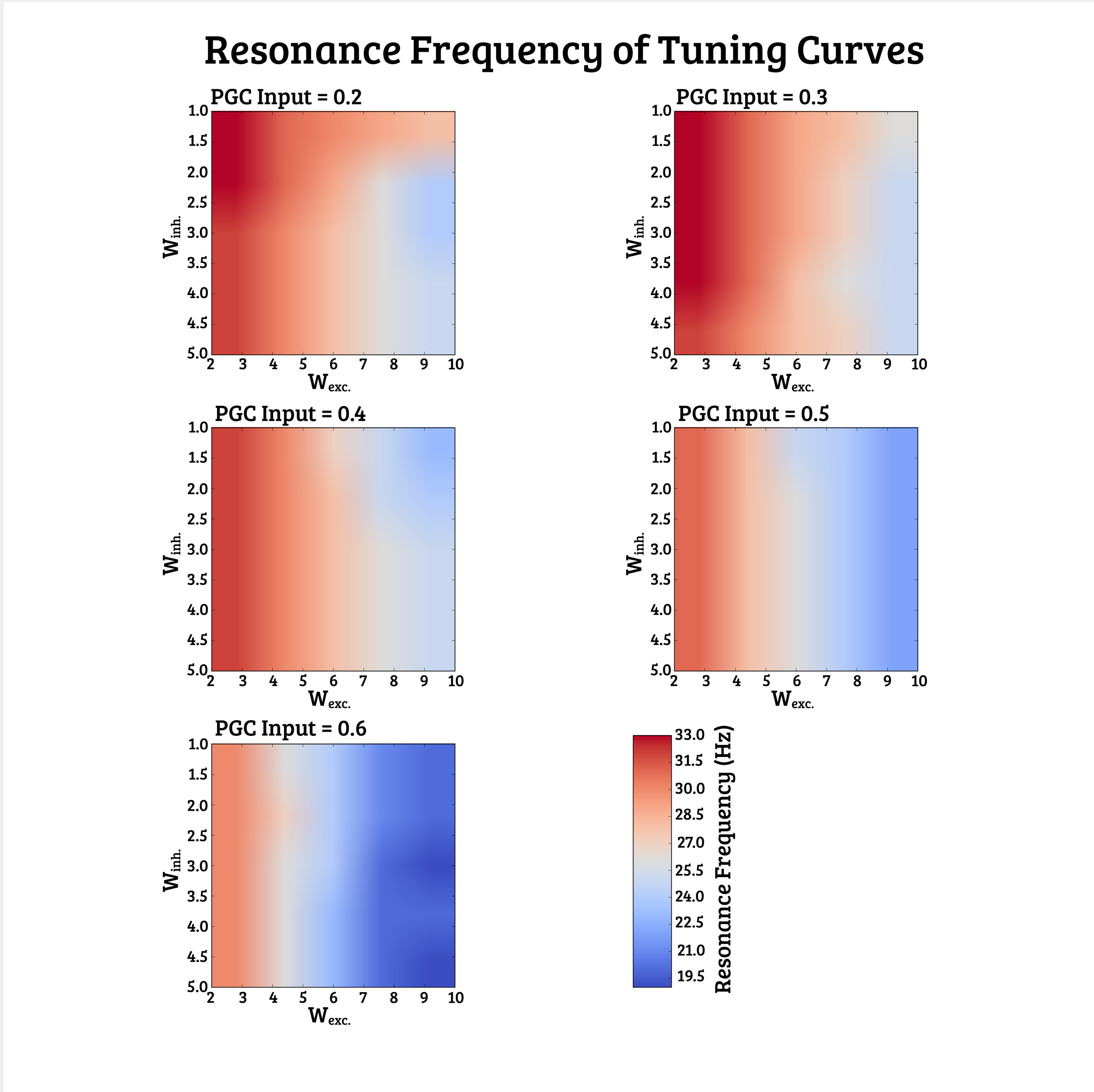
Parameter	Iteration Values
PGC Input Strength (i·c)	0.2 0.3 0.4 0.5 0.6
MC - PGC excitation strength (W_{exc})	2.0 4.0 6.0 8.0 10.0
PGC - MC inhibition strength (W_{inh})	1.0 2.0 3.0 4.0 5.0
Frequency (f)	1.0, 2.0, 3.0, ... , 40.0

- Parameter combinations: PGC input strength, MC - PGC excitation strength and PGC - MC inhibition strength.
- Constructed frequency tuning curves and then extracted the peak resonance frequency (fig 3).
- Extracted the resonance strength of the tuning Q (fig 3), measured as:

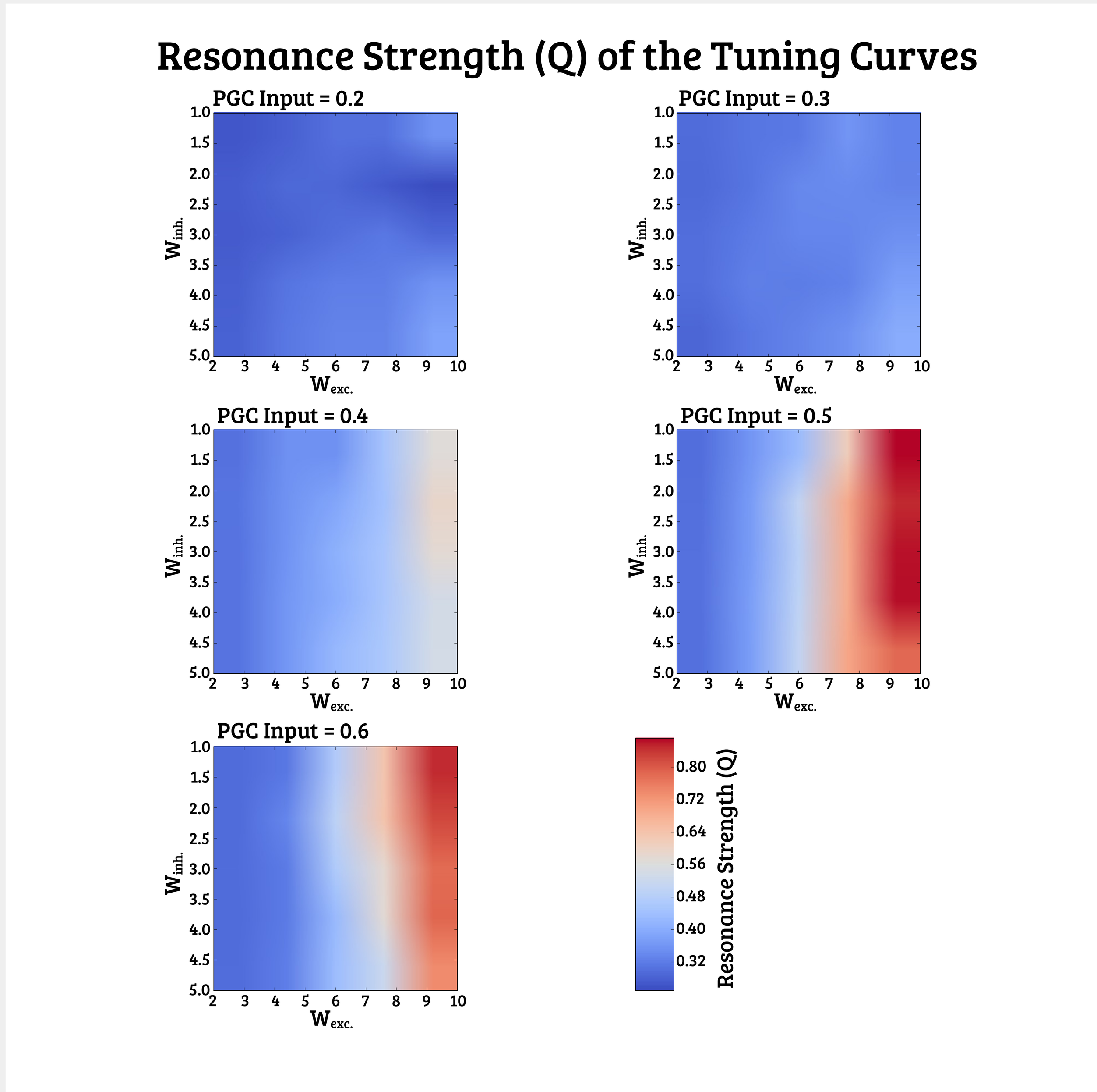
$$Q = \frac{(F_{max} - F_{min})}{\langle F \rangle}$$

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

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.

Discussion

- Results suggest the MC can show frequency tuning.
- Therefore, the OB might be able to detect the frequency composition of signals.
- This could be used for olfactory scene analysis.
- However, we only see tuning in a narrow frequency range.

References

[1] Brea, J. N., Kay, L. M., and Kopell, N. J.
Biophysical model for gamma rhythms in the olfactory bulb via subthreshold oscillations.
Proceedings of the National Academy of Sciences 106, 51 (2009), 21954–21959.

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