Influence of inhibitory circuits on the frequency tuning of mitral cells

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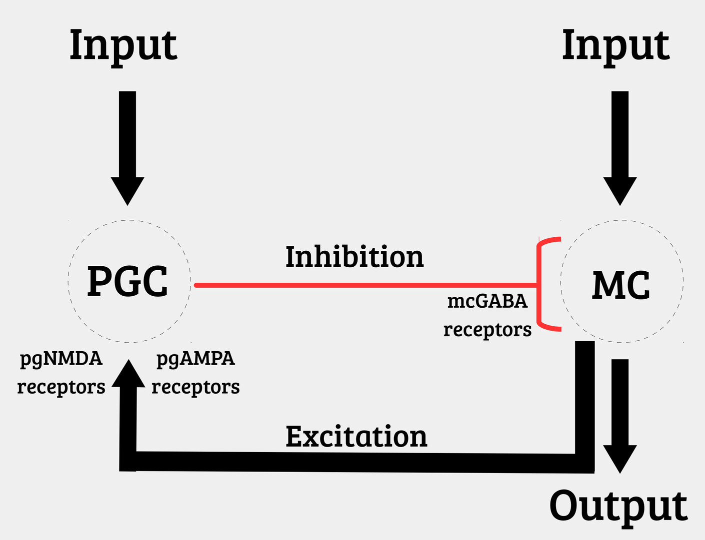
Introduction

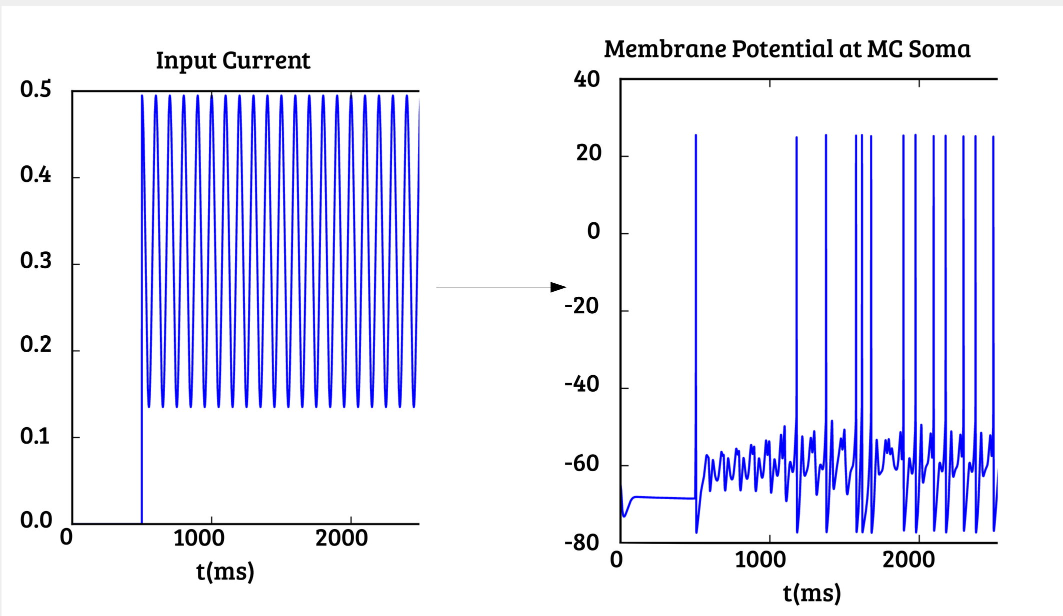
- Recent studies show that the structure of odour stimuli contains information about the olfactory scene [2, 5].
- We investigated whether mitral cells (MCs) in the OB show frequency tuning and, if they do, how different components of the glomerular layer circuitry shape and determine the tuning.

Model



- We 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



- We 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.

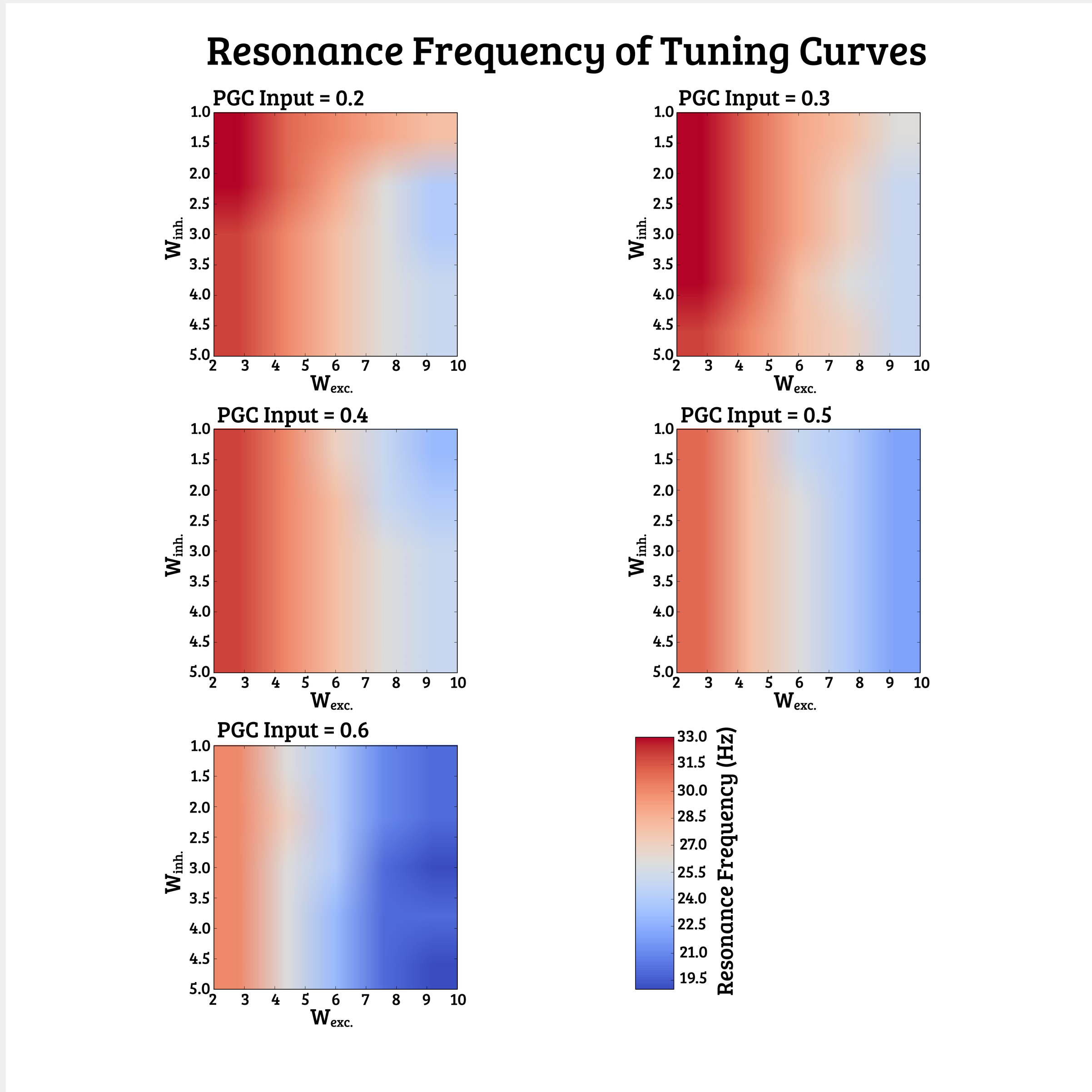
Parameter	Iteration Values
PGC Input Strength (i·c)	0.2 0.3 0.4 0.5 0.6
MC - PGC excitation strength (W_{exc})	2.0 4.0 6.0 8.0 10.0
PGC - MC inhibition strength (W_{inh})	1.0 2.0 3.0 4.0 5.0
Frequency (f)	1.0, 2.0, 3.0, ... , 40.0

- 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 4), measured as:

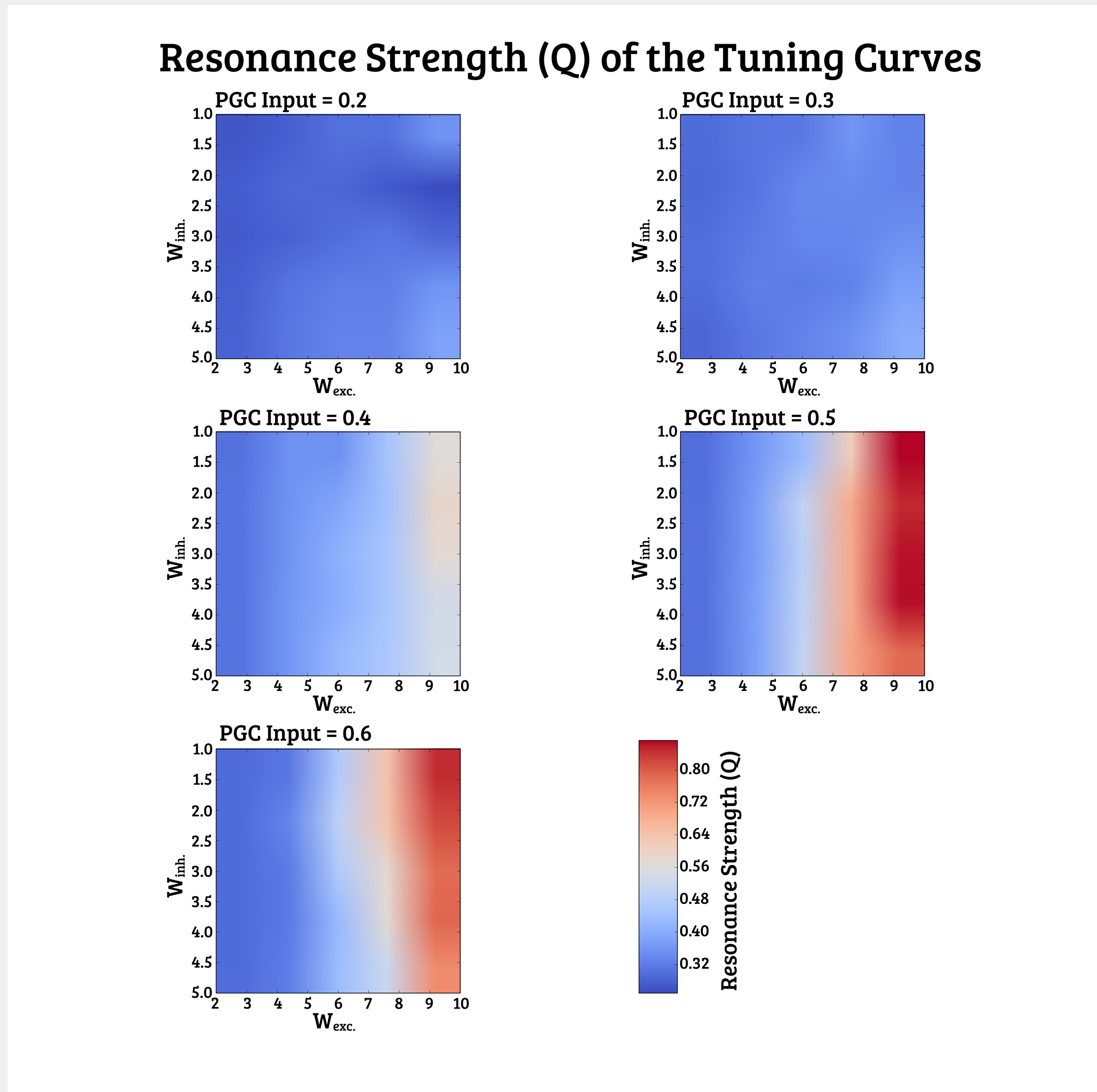
$$Q = \frac{(F_{max} - F_{min})}{\langle F \rangle}$$

- 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.

Conclusion

- 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] Jorge N Brea, Leslie M Kay, and Nancy J Kopell. Biophysical model for gamma rhythms in the olfactory bulb via subthreshold oscillations. Proceedings of the National Academy of Sciences, 106(51):21954--21959, 2009.[2] Antonio Celani, Emmanuel Villermaux, and Massimo Vergassola. Odor landscapes in turbulent environments. Physical Review X, 4(4):041015, 2014.[3] Vincent Jacob, Christelle Monsempès, Jean-Pierre Rospars, Jean-Baptiste Masson, and Philippe Lucas. Olfactory coding in the turbulent realm. PLoS computational biology, 13(12):e1005870, 2017.[4] Guoshi Li and Thomas A Cleland. A two-layer biophysical model of cholinergic neuromodulation in olfactory bulb. Journal of Neuroscience, 33(7):3037--3058, 2013.[5] Michael Schmuker, Viktor Bahr, and Ramón Huerta. Exploiting plume structure to decode gas source distance using metal-oxide gas sensors. Sensors and Actuators B: Chemical, 235:636--646, 2016.

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