Influence of inhibitory circuits on the frequency tuning of mitral cells

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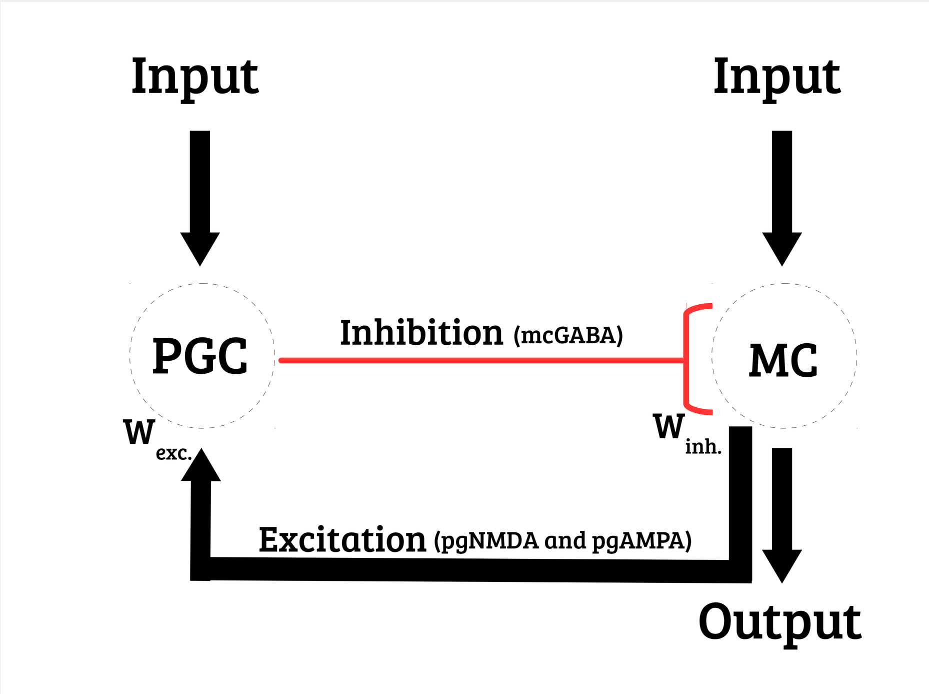
Introduction

Recent studies show that the structure of odour stimuli contains information about the olfactory scene [2, 4]. We investigated whether mitral cells (MCs) in the olfactory bulb (OB) can 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 [3]).
- Modeled MC-PGC (periglomerular cells), focusing on recurrent and feed - forward inhibition in the glomerular layer.

Method

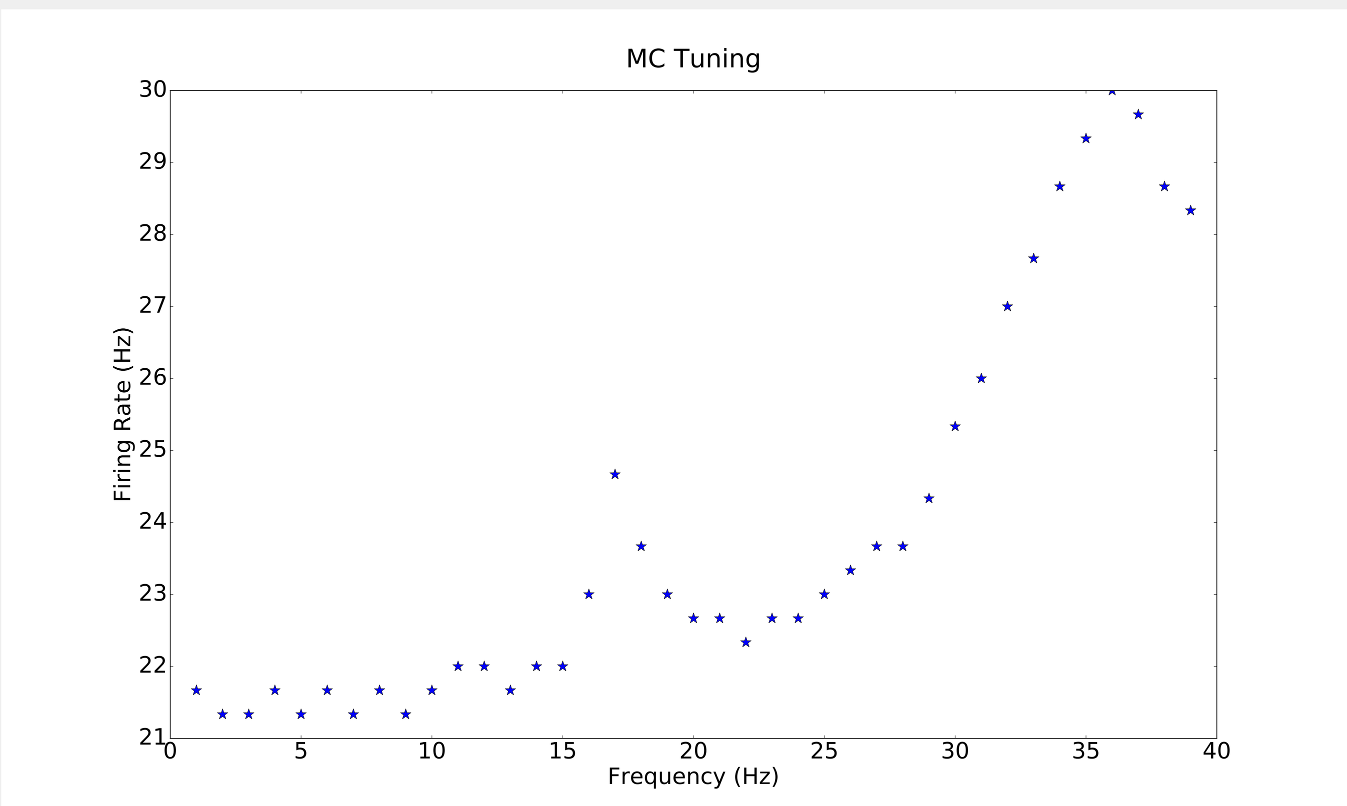
- Parameter combinations: PGC input strength, MC-PGC excitation strength and PGC-MC inhibition strength.
- We used sinusoidal currents of varying frequencies as input, using the equation:

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

- Where c = 0.45nA (strength of input to MC) and φ = 0 (phase).
- PGC input is defined as i·c, where i is the PGC input factor.

Parameter	Iteration Values
PGC Input Factor (i)	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

- Constructed frequency tuning curves and then extracted the peak resonance frequency.

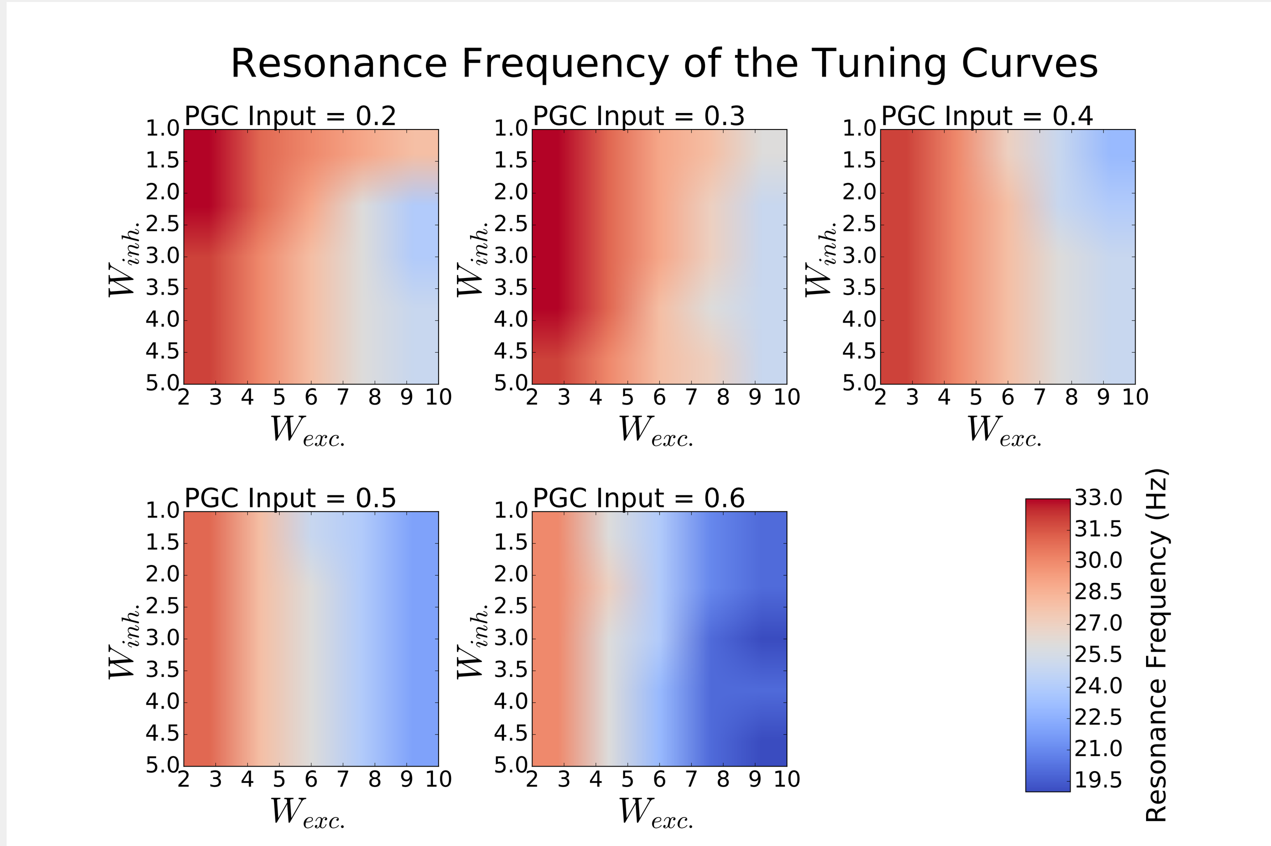


- Extracted the resonance strength of the tuning Q, measured as:

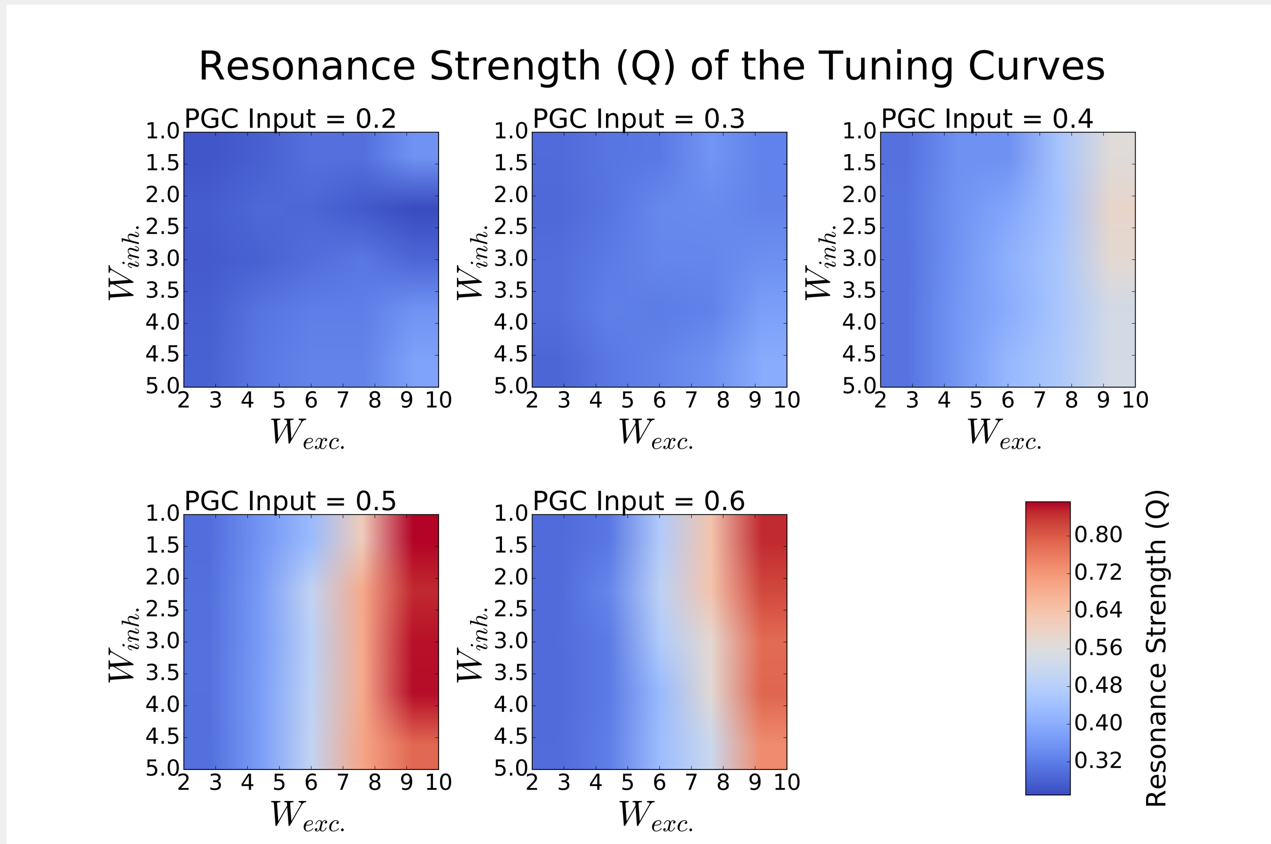
$$Q = \frac{(F_{max} - F_{min})}{\langle F \rangle}$$

- F_{max} and F_{min} are maximum and minimum firing rate.
- <F> 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.
- In a large region of the parameter space, resonance was stronger than the intrinsic resonance of the MC (i.e. without the inhibitory circuitry), for which Q = 0.26.

Conclusion

- Our results suggest that MCs can show frequency tuning in the presence of sufficiently strong excitatory connections between MCs and PGCs, which provide feedback inhibition to the MCs.
- 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.

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References

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