Collective oscillations in the rat barrel-thalamus network

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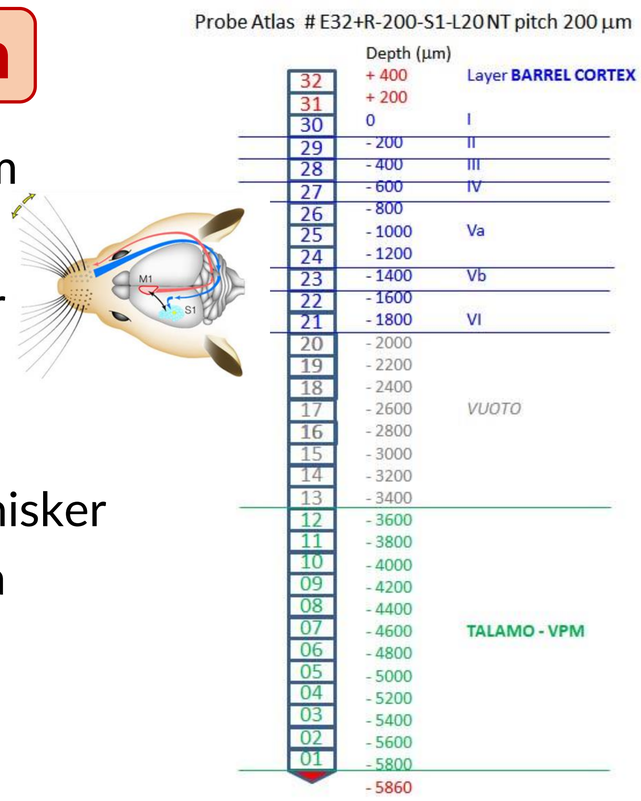
Context

Neural oscillations are often found in mammalian cortical networks, in a **task dependent** way, suggesting their functional role. We here study the rat thalamus-barrel cortex sensory path and its response to whisker stimulation, whose **oscillatory behavior** is poorly studied in the literature.

Experimental paradigm

LFPs and **MUAs** recordings from barrel cortex and thalamus in urethane anesthetized rats after whisker stimulation and during spontaneous activity.

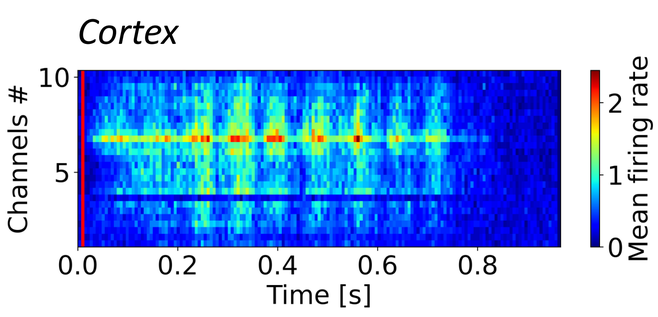
Stimulation paradigm: single whisker stimulations is performed with a piezoelectric actuator.

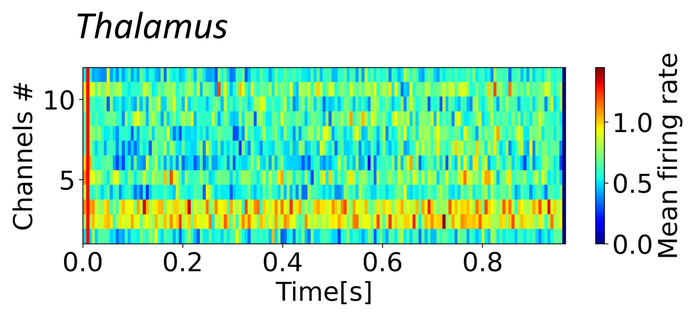


Data analysis

MUAs

Average firing rate across trials: collective oscillations are present in the barrel cortex (NOT in the thalamus) after whisker stimulation.

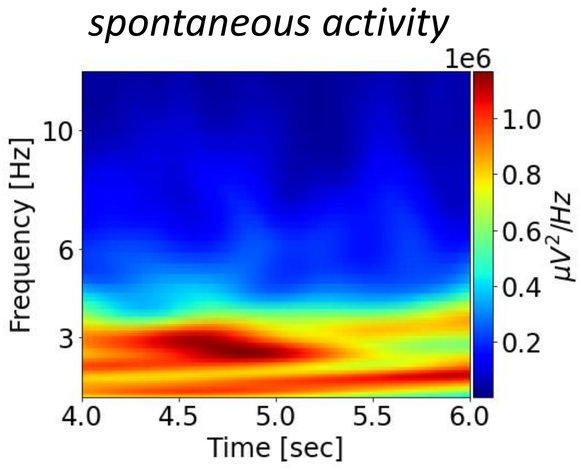




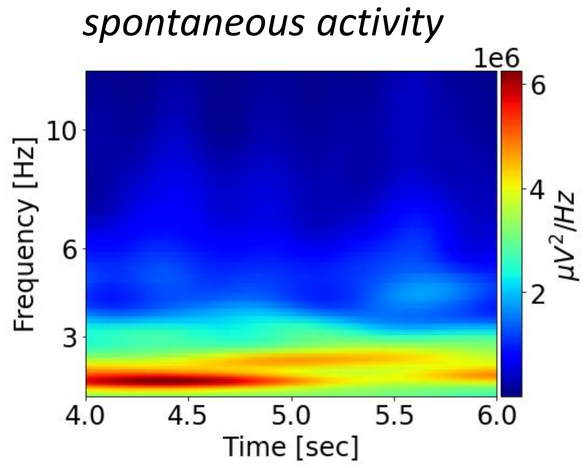
LPFs

Thalamus is dominated by δ band oscillations both at rest and after stimulation. The cortex instead displays also long lasting oscillations in 6-10 Hz band after stimulation, while only δ at resting.

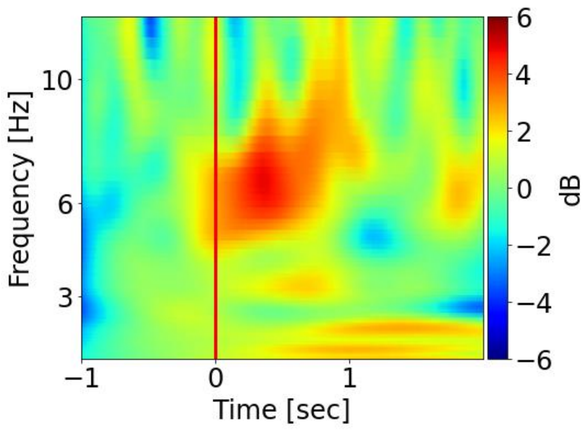
Cortex – spontaneous activity



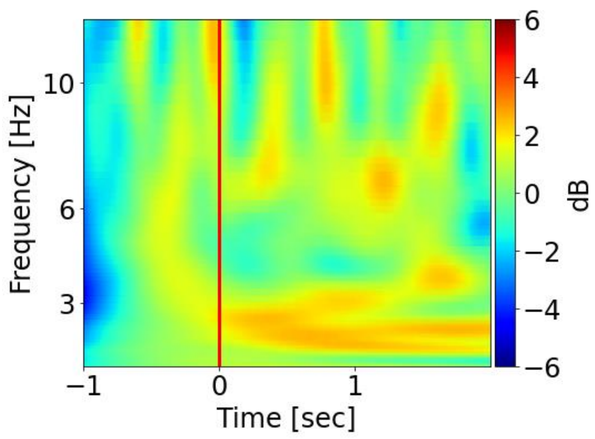
Thalamus – spontaneous activity



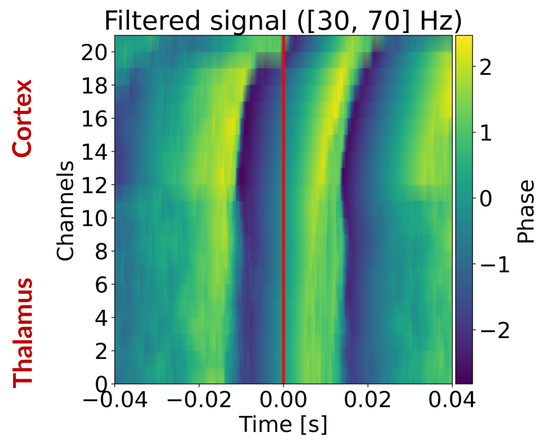
Cortex – after stim (baseline normalized)



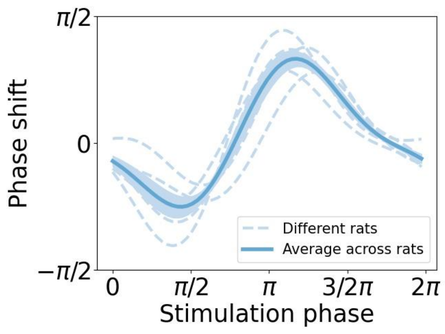
Thalamus – after stim (baseline normalized)



Activity propagates from thalamus to cortex

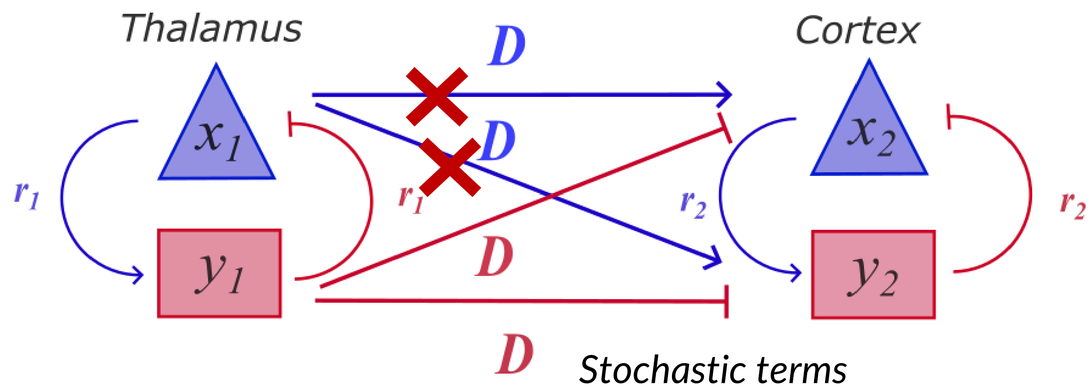


cortex Phase Response Curve of 3 Hz oscillation is robust across rats



The model

Two nodes (thalamus and cortex) directed chain. Each node is a **damped oscillator** (stochastic Wilson Cowan type). Whisker stimulation simulation: facilitation of thalamus-cortex synapses, i. e. increase in coupling D.



Stochastic terms

$$\frac{dx_i}{dt} = \frac{1}{\gamma_i}\left(F[s_{x_i}] - x_i\right) + \frac{1}{\sqrt{V_1\gamma_i}}\sqrt{F[s_{x_i}] + x_i}\,\xi_i^1$$

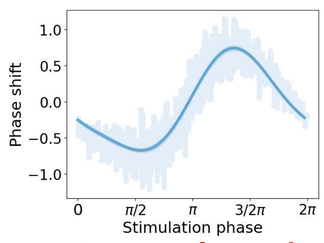
$$\frac{dy_i}{dt} = \frac{1}{\gamma_i}\left(F[s_{y_i}] - y_i\right) + \frac{1}{\sqrt{V_1\gamma_i}}\sqrt{F[s_{y_i}] + y_i}\,\xi_i^2$$

$$s_{x_i} = -r(y_i - p) - Dy_{i-1} + Dx_{i-1} \qquad F(s) \propto \frac{1}{1 + e^{-s}}$$

$$s_{y_i} = r(x_i - (1-p)) - Dy_{i-1} + Dx_{i-1}$$

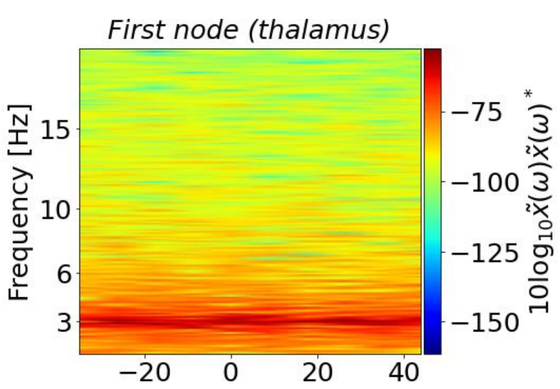
$$r = r_1 = r_2$$

Single node PRC consistent with data

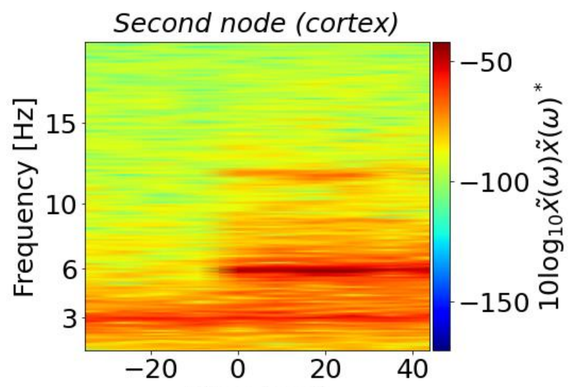


First, the nodes are set to oscillate at 3 Hz spontaneously, and weakly coupled. If the stimulation is introduced as an increase of the coupling with the first inhibitory sub-population only, a frequency at 6 Hz is analytically predicted to appear in the second node!

First node (thalamus)



Second node (cortex)



Conclusions

Our data analysis shows that **evoked collective oscillations** are present in the barrel after whisker stimulation, whose response propagates from thalamus to cortex. Our modelling framework highlights an alleged important effect played by **effective inhibitory coupling** for the birth of 6-10 Hz frequency band, that coexists with the δ one.

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