eSLEEP EUROPE
October 4-6, 2023 | Virtual Congress

Respiration organizes gamma synchrony in the prefronto-thalamic network

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Supported by:
Fonds de recherche Santé Québec | CIHR IRSC Canadian Institutes of Health Research / Instituts de recherche en santé du Canada | NSERC CRSNG

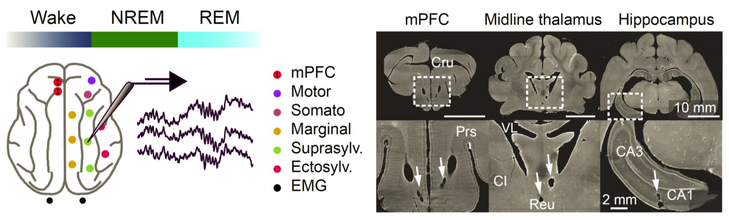
INTRODUCTION

Multiple cognitive operations are associated with the emergence of gamma oscillations inf the medial prefrontal cortex (mPFC).

The mPFC is an anatomical hub that integrates inputs from a diverse set of cortical and subcortical structures[1]. Much of prefrontal output is reciprocated, with the notable exception of the hippocampal afferents, for which no direct prefrontal feedback projections have been found[2].

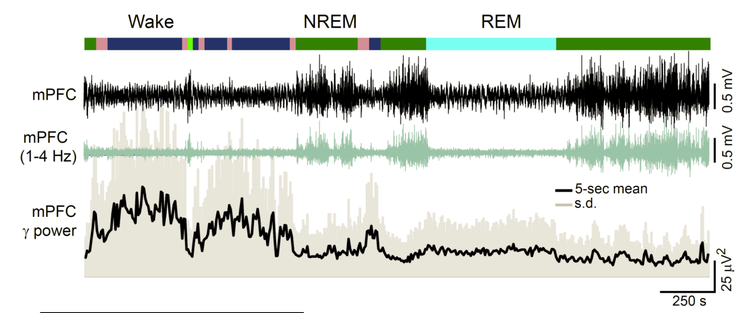
Recent work has shown that respiration is a potent modulator of cortical and hippocampal activity, including gamma oscillations[3-6]. How respiration organizes gamma synchrony in the prefrontal network is unknown.

The nucleus reuniens, a midline thalamic strucutre, links the mPFC and the hippocampus[7-9], forming a functional network that can mediate long-range gamma synchrony between the mPFC and hippocampus.



Local field potential were obtained from the deep layers of the cat mPFC, midline thalamus and ventral hippocampus in head-fixed configuration.

The animals cycled through periods of quieet wakefulness rapid eye movement sleep (NREM) and REM over sessions of 2-4 hours. Recordings were segmented into wake, NREM and REM sessions based on delta (1-4 Hz) power in the mPFC, muscle activity detected by electromyography and eye movements detected by electrooculography.



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2. Ferino, F., Thierry, A. M. & Glowinski, J. Anatomical and electrophysiological evidence for a direct projection from Ammon's horn to the medial prefrontal cortex in the rat. Experimental brain research 65, 421-426 (1987).
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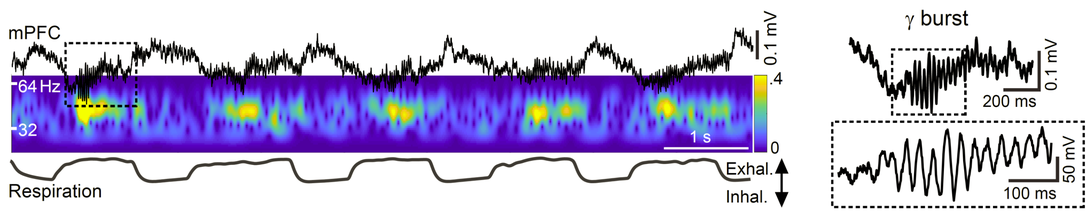
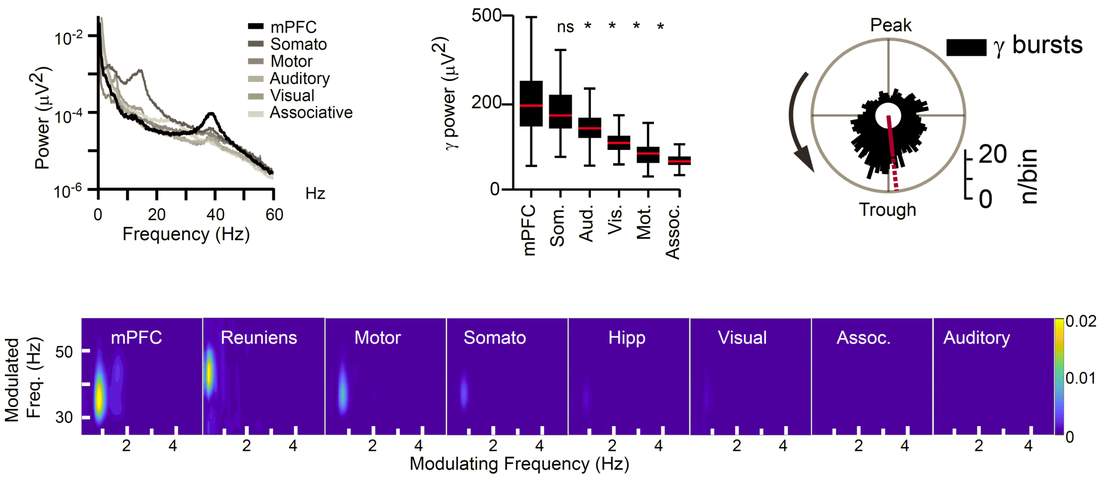
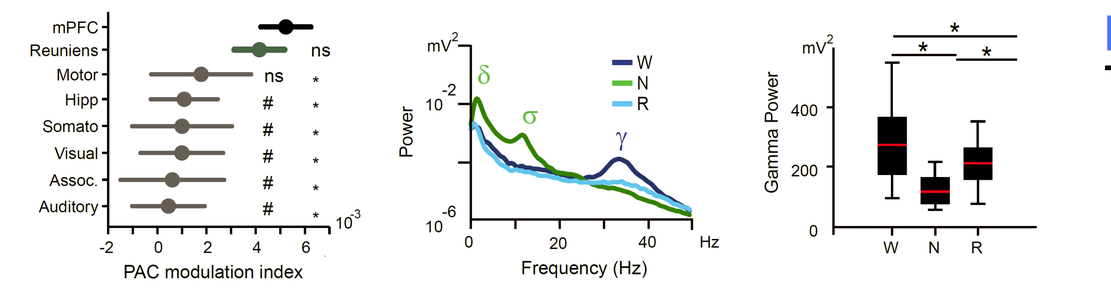
RESULTS

Prefrontal gamma oscillations are dependent on waking state

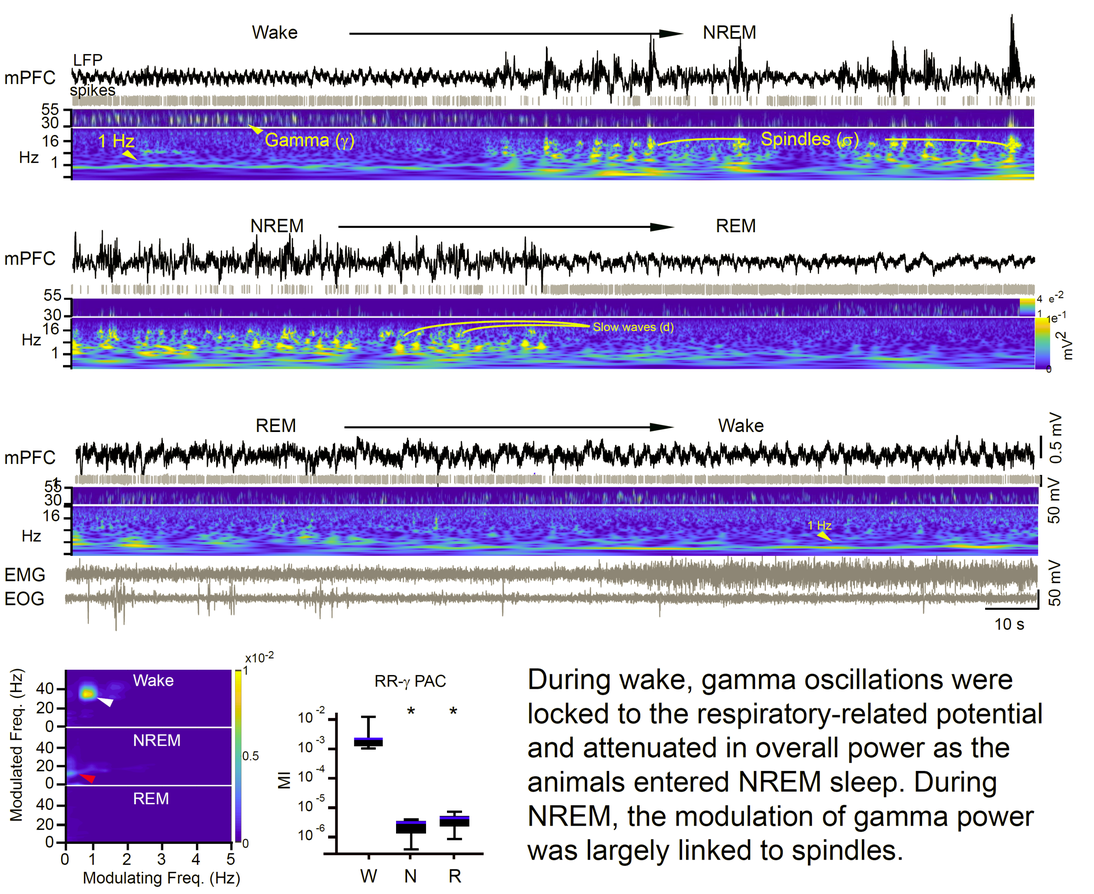


mPFC recordings were characterized by rhythmic variations in gamma power resulting from brief gamma bursts which recured every 1-2 seconds and were phase-locked to the envelope of a 1-Hz prefrontal rhythm.



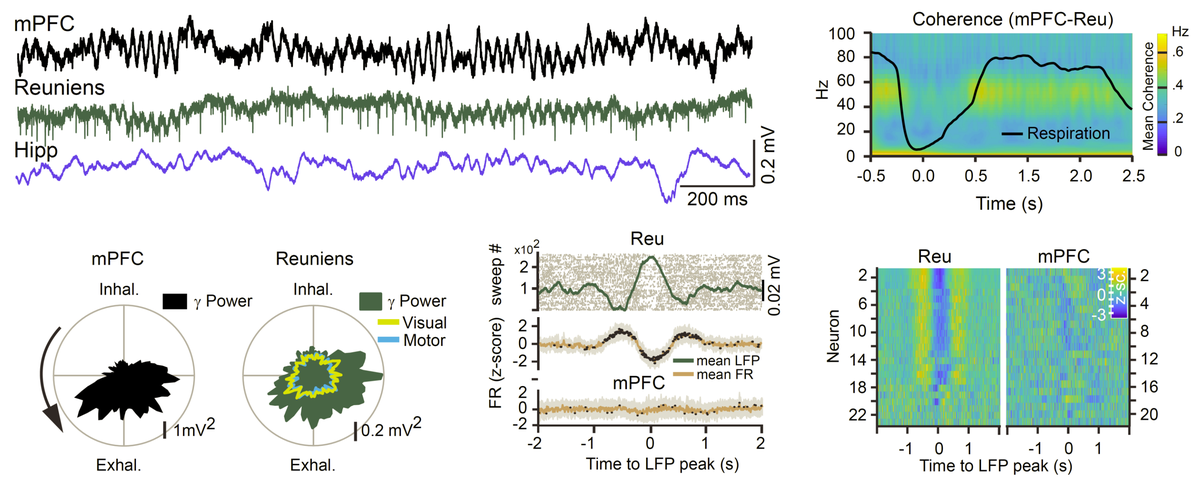


The power of gamma oscillations and the phase-locking of gamma oscillations to the respiratory-related potential were highest in the mPFC. mPFC gamma power was highest during wake states, compared to NREM and REM states.

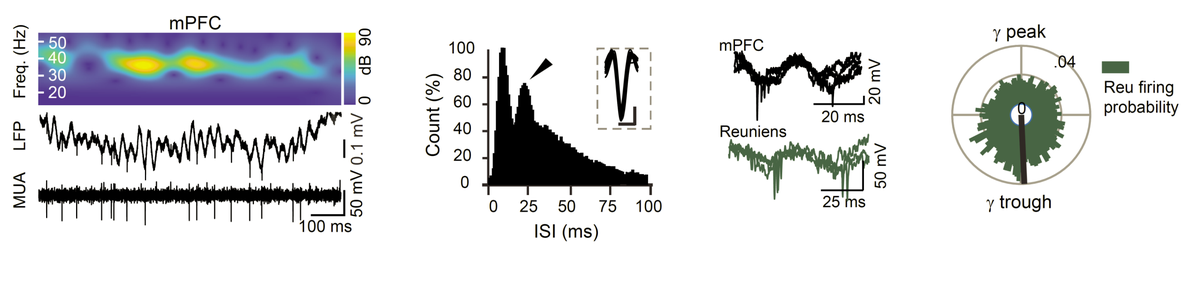


During wake, gamma oscillations were locked to the respiratory-related potential and attenuated in overall power as the animals entered NREM sleep. During NREM, the modulation of gamma power was largely linked to spindles.

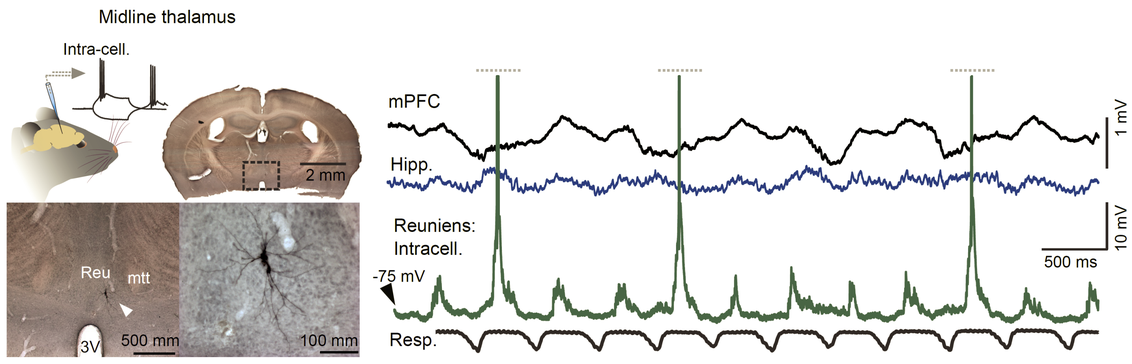
Respiration modulates prefronto-thalamic gamma oscillations



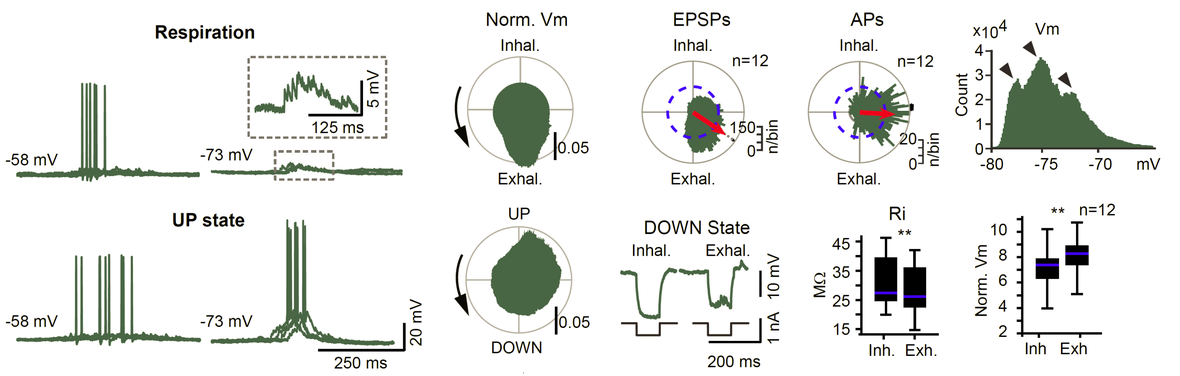
The coherence between prefrontal gamma and reuniens gamma oscillations was dependent on respiratory phase. Respiration also modulated reuniens firing rates.



Respiration drives synaptic activity in the reuniens



In vivo intracellular recordings of the ventral midline thalamus in anesthetized mice showed that respiration and the slow oscillation modulate synaptic activity in neurons of the nucleus reuniens.



CONCLUSIONS

Respiration modulates gamma oscillations in the mPFC and motor cortex but not in other cortical areas

Prefronto-thalamic gamma synchrony is phase-locked to exhalation in waking states

Synaptic activity in the nucleus reuniens of the thalamus is modulated by respiration

Respiration-gamma coupling is selectively dependent on wake states

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