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Slow and fast oscillatory dynamics of neural networks during learning of an olfactory discrimination task in rat



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Overview

Question: do dynamics of local field potential (LFP) rhythms correlate to animal performance during learning of an olfactory discrimination task?

Methods:

LFP recordings in a large network (including sensory, motor and limbic areas) during a two-alternative choice task

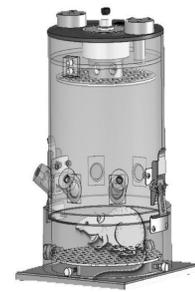
Separate analysis of two frequency ranges (slow frequencies: 1-12Hz: beta: 15-30Hz)

Main conclusions

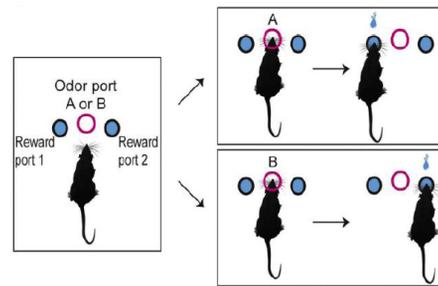
Beta rhythm expression follows context learning - including both odors and reward - and signals behavioral inflexibility

Respiratory and hippocampal theta rhythms appear supported by distinct but overlapping networks which are stable after task acquisition

Whole-body plethysmograph

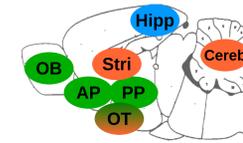


Two-alternative choice task



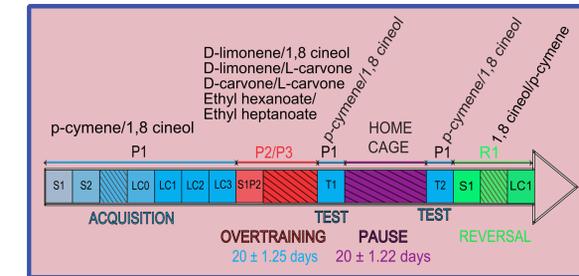
Recorded brain areas:

- Olfactory bulb (OB)
- Anterior piriform cortex (AP)
- Posterior piriform cortex (PP)
- Olfactory tubercle (OT)
- Striatum (Stri)
- Hippocampus (Hipp)
- Cerebellum (Cereb)
- Respiration (Resp)



Conditioning timeline

Learning criterion (LC) was reached when >80% of trials in two successive blocks (30 trials per block) were successful. Each session was composed of about 100 trials.



Main phases:

- Task acquisition (odor pair P1)
- New odor pairs (P2 and P3)
- Short/long term re-test of P1
- Reversal of P1

For all phases:

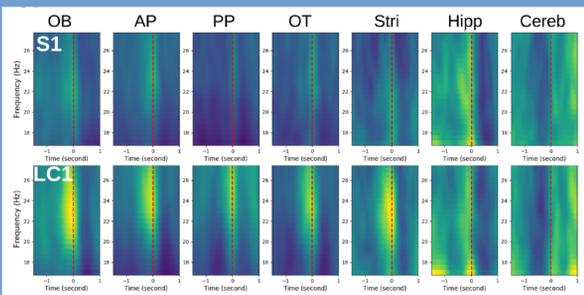
- Pair learning: S1, S2, ...
- Day before, at and after reaching learning criterion: LC0, LC1, LC2...

Beta rhythm

Beta range time-frequency maps

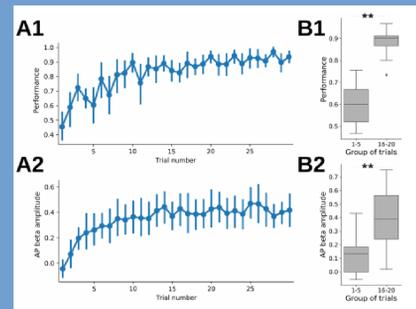
LFP time-frequency maps aligned at exit of odor port (vertical dashed lines) and averaged across rats, hot colors indicate large power.

- clear increase of beta rhythm for expert rats at port exit in all structures except Hipp and Cereb

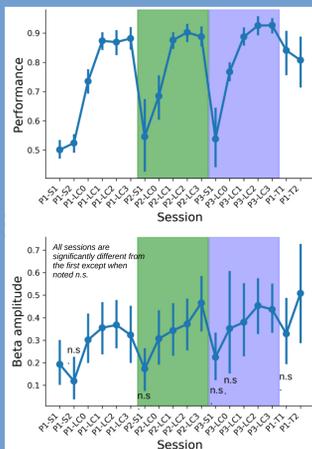


Parallel dynamics of performance and AP beta amplitude within sessions

Beta amplitude is measured, in expert sessions, from 400 ms before port exit to 100 ms after port exit, dynamics is similar for other structures

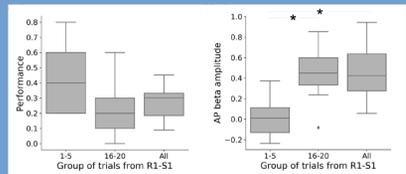


Parallel dynamics of performance and AP beta amplitude across sessions



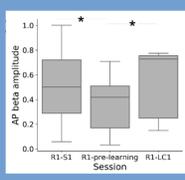
Beta amplitude is measured from 400 ms before port exit to 100 ms after port exit and averaged across session trials, dynamics is similar in other structures

First reversal session displays low performance but high beta amplitude

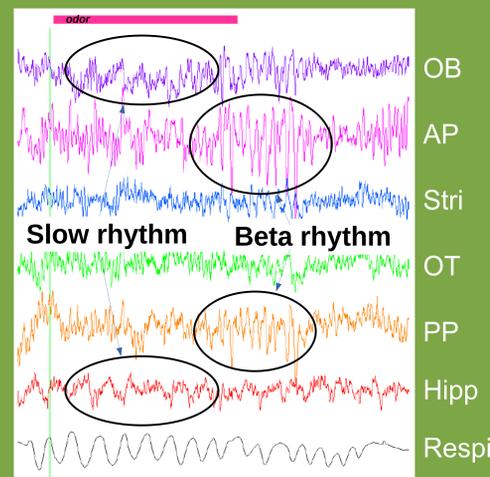


During reversal sessions, beta amplitude decreases before performance increases again

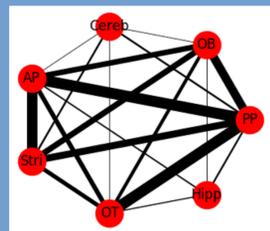
R1-pre-learning is the session where rats come back to their « naive » behavior



Typical recording



Beta network revealed by intertrial coherence analysis (WPLI)



Line thickness represents significance of coherence across rats.

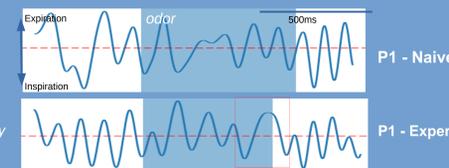
- beta network is remarkably stable across learning, but overall coherence strength is proportional to beta amplitude

Slow rhythms

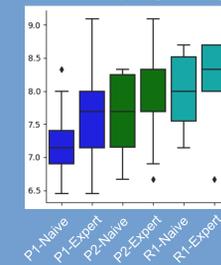
Respiration (2-12Hz, entrains olfactory areas) and theta (6-9Hz)

Sniffing strategy adapts with expertise

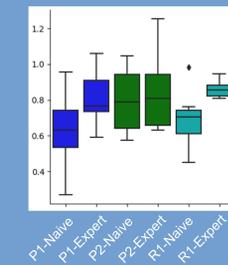
Examples of respiratory traces around odor sampling



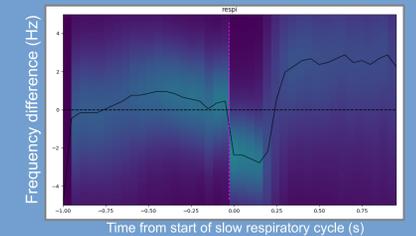
Respiration frequency at odor sampling start (Hz)



Sampling duration (s)



Respiration is about 1Hz faster than theta rhythm but they get closer before the slow respiratory cycle (at port exit, see red box on the left)



Distribution of frequency difference at each time point, trials are aligned on the beginning of the slow respiratory cycle.

Theta frequency is remarkably stable before and during odor sampling, changes in frequency difference are only due to respiration dynamics.

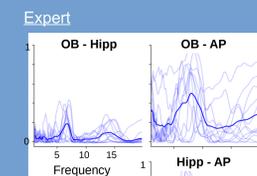
Phase-locking value-based definition of respiratory and theta networks

Phase is estimated 50ms before slow respiratory cycle

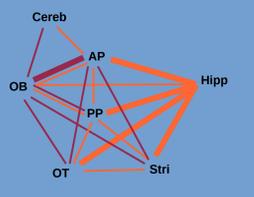
- AP and PP appear at the interface of both networks in expert rats



Intertrial coherence (WPLI) analysis shows distinct but overlapping networks



Attempt of respiratory and theta network scheme based on WPLI analysis in expert rats



Examples of WPLI analysis in expert rats (done at 200ms after start of odor sampling)