Representations of spatial location by aperiodic and alpha oscillatory activity in working memory

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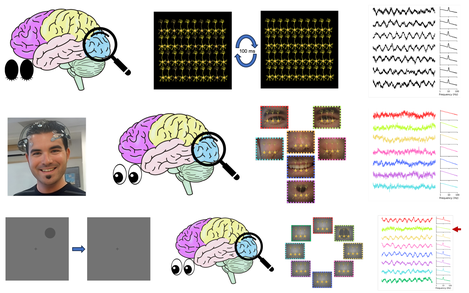
Introduction

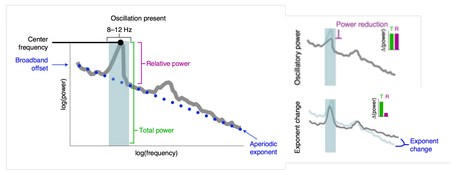


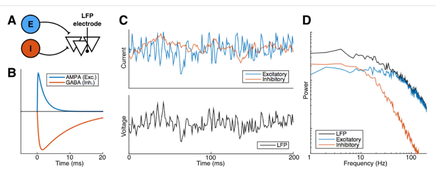
Alpha oscillations in spatial attention working memory (WM)

- Alpha oscillations are most prominent during eyes closed.
- Opening the eyes requires encoding of complex visual environment, reducing alpha activity and making aperiodic activity the dominant feature of the signal.
- In working memory, alpha inhibits the retinotopic regions that are not actively retaining stimulus features across the memory delay.

The importance of spectral parameterization

- The Hilbert transform conflates changes in aperiodic exponent with changes in alpha total power.
- Without spectral parameterization[1], we are unable to adjudicate whether aperiodic exponent or alpha power underlies spatial WM representations.



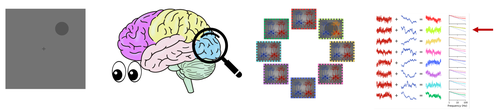


Aperiodic exponent as a proxy for E/I balance

- Computational modeling shows that changes in E/I balance can be estimated from the slope of the electrophysiological power spectrum[2].
- Predictions from modeling are supported by empirical data from rats, macaques, and humans[2].

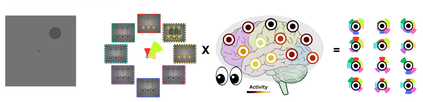
Hypotheses

1. Encoding of spatial location by total alpha power during **WM maintenance** is reflective of true differences in **alpha oscillatory power**.
2. Initial encoding of spatial location during **stimulus presentation** is supported by changes in **E/I balance** that are reflected in **aperiodic exponent** changes.

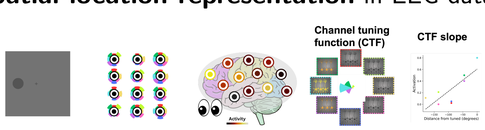


Inverted Encoding Models

I. Fit spatial location **encoding model** to EEG data:



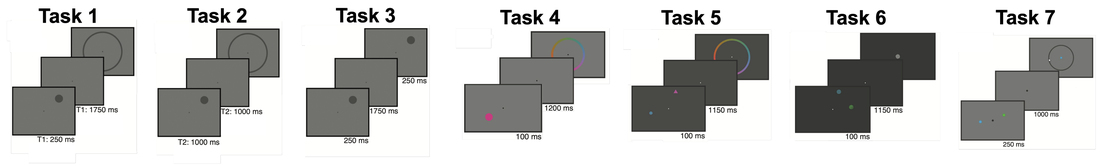
II. Invert encoding model[3] to estimate **strength of spatial location representation** in EEG data:



Dataset and Methodology

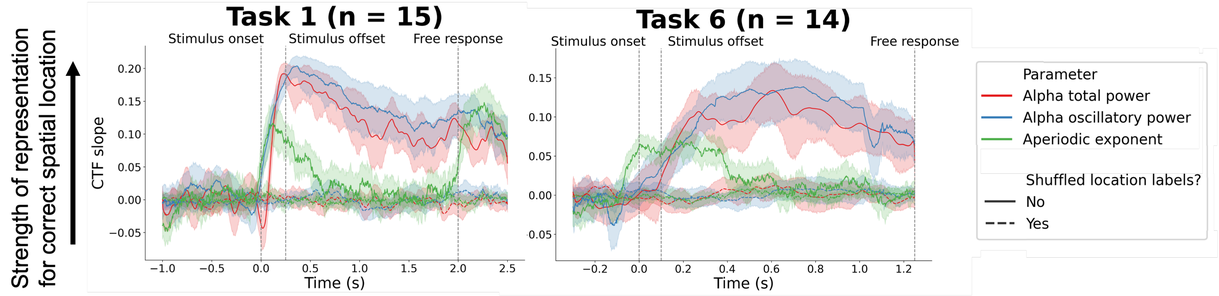
Sliding-window spectral parameterization[1] to estimate **aperiodic** and **alpha oscillatory** activity in a composite spatial WM dataset[3–5] across **7 tasks** and **112 subjects**:

112 subjects
~872 trials
~27 channels
~775 timepoints
2,071,005,276 spectra
0.002 s
1 day/86,400 s
~48 days
1/68 cores
24 hours/day
~17 hours



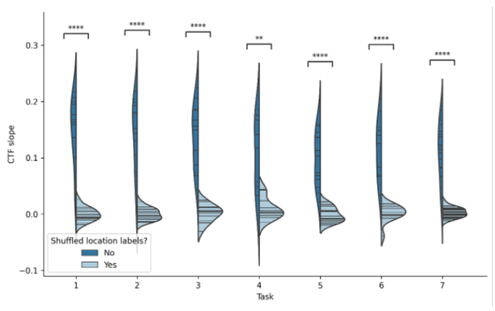
Results

Aperiodic exponent and alpha oscillatory power dynamically represent spatial location in spatial WM task:

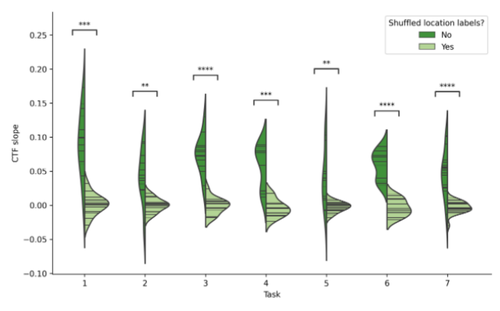


Across **all seven tasks**, there is significant representation of spatial location by:

1. **aperiodic exponent** during the **first 400 ms**:



2. **alpha oscillatory power** during **WM**:



References:

1. Donoghue, T. *et al. Nature neuroscience* **23,** 1655–1665 (2020).
2. Gao, R. *et al. Neuroimage* **158,** 70–78 (2017).
3. Foster, J. J. *et al. Journal of neurophysiology* **115,** 168–177 (2016).
4. Foster, J. J. *et al. Current Biology* **27,** 3216–3223 (2017).
5. Sutterer, D. W. *et al. PLoS biology* **17,** e3000239 (2019).

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