Quantifying waveform shape of EEG alpha and mu oscillations across development

Andrew S. Bender[1], Natalie Schaworonkow[5], & Bradley Voytek[1–4]

[1]Neurosciences Graduate Program, [2]Department of Cognitive Science, [3]Halıcıoğlu Data Science Institute, [4]Kavli Institute for Brain and Mind, UC San Diego. [5]Ernst Strüngmann Institute for Neuroscience, Frankfurt am Main.

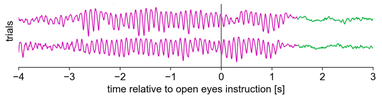
VOYTEKlab

UC San Diego

Introduction

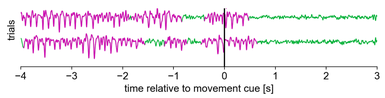
Two prominent alpha-band (8–13 Hz) oscillations

Alpha (8–13 Hz)

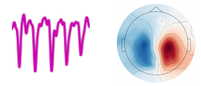


- Strongest with eyes closed
- Triangular shape
- Most prominent in occipital cortex
- Reduced task reactivity in autism spectrum disorder (ASD) (Keehn et al., 2017)
- Implicated in visual attention deficits seen in attention deficit hyperactivity disorder (ADHD) (Vollebregt et al., 2016)

Mu (8–13 Hz)

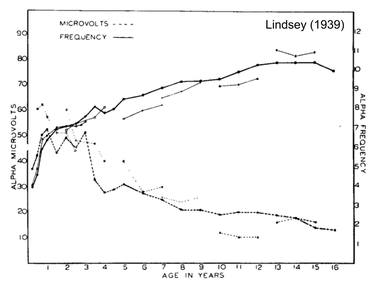


- Strongest when stationary
- μ-shaped
- Most prominent in somatosensory cortex
- Diminished functional suppression in ASD (Hobson & Bishop, 2017)
- Associated with inability to inhibit task-irrelevant sensorimotor areas in ADHD (Ter Huurne, 2017)



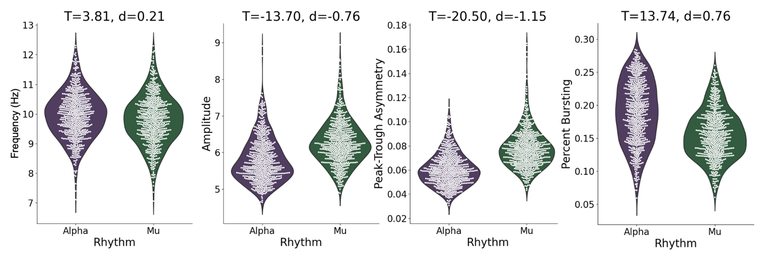
Alpha-band oscillations change across development

- Center frequency of alpha in occipital cortex increases with age (Lindsley, 1939)
- Amplitude of alpha in occipital cortex decreases with age (Lindsley, 1939)
- Center frequency of sensorimotor mu increases with age (Smith, 1941)
- Amplitude of sensorimotor mu increases with age (Johnson et al., 2020)

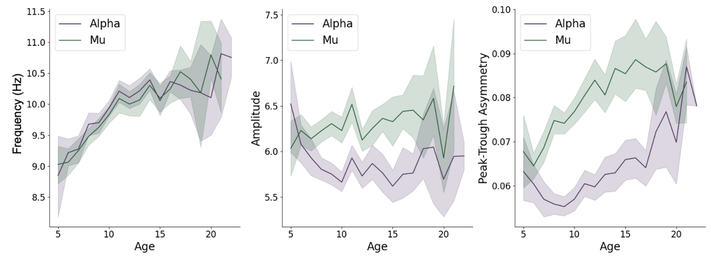


Results

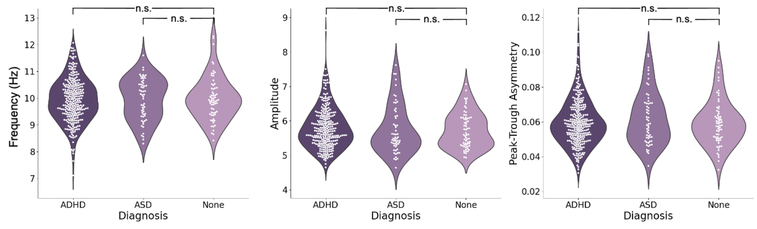
Alpha and mu components have significantly different waveform shape and burst statistics (n = 1007 subjects)



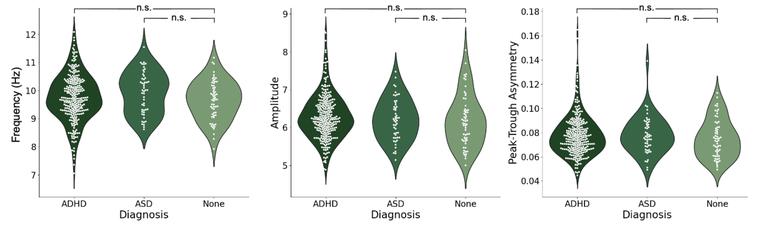
Alpha (n = 653 subjects) and mu (n = 633 subjects) waveforms change across development



Alpha waveform shape features do not differ from participants not given a diagnosis in ADHD nor ASD (n = 480 subjects)

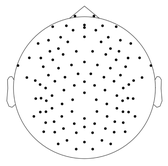


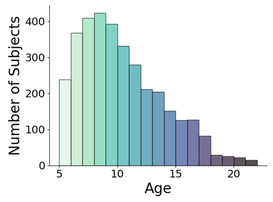
Mu waveform shape features do not differ from participants not given a diagnosis in ADHD nor ASD (n = 480 subjects)



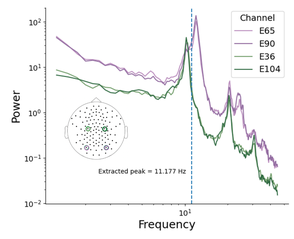
Methods

I) Using resting-state, high-density EEG data for 2525 subjects aged 5-21 from the Healthy Brain Network (Alexander et al., 2017), perform minimal preprocessing (interpolation of high variance channels)

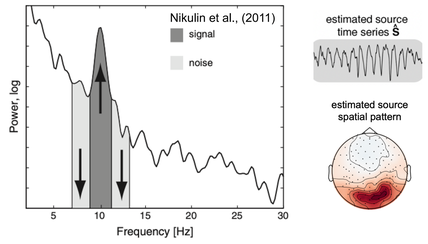




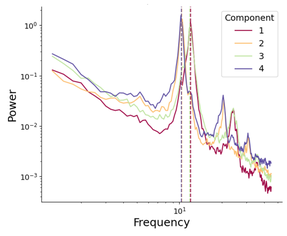
II) Find peak frequency in 6–13 Hz range using FOOOF (Donoghue et al., 2020) in occipital and sensorimotor channels



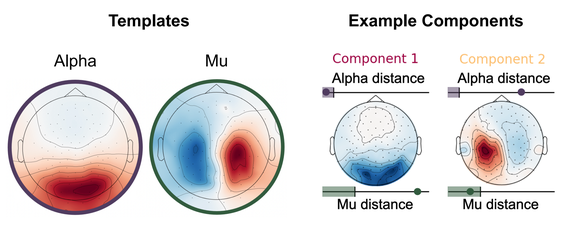
III) Extract oscillatory sources with high alpha SNR using spatio-spectral decomposition (SSD) (Nikulin, et al., 2011)



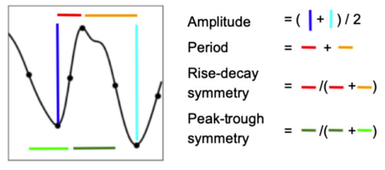
IV) Find peak frequency in 6–13 Hz range using FOOOF (Donoghue et al., 2020) for each SSD component



V) Classify components with SNR > 10 dB as alpha or mu using template matching



VI) Calculate waveform shape features from alpha and mu component time series using bycycle package (Cole & Voytek, 2019)



Cole & Voytek (2019)

Summary

1. Consistent with previous qualitative observations, we quantifiably demonstrated that mu oscillations are far more asymmetrical than alpha oscillations in a large dataset (n = 2525 subjects).
2. Mu oscillations have greater amplitude than alpha oscillations on a cycle-by-cycle basis, but alpha oscillations are more prominent in EEG due to more frequent bursting.
3. We replicated previous findings of (1) alpha and mu center frequencies increases, (2) alpha amplitude decreases, and (3) mu amplitude increases across development.
4. All alpha and mu waveform shape features are similar in both ADHD and ASD to participants without either diagnosis, suggesting that differences in alpha and mu oscillations underlying these disorders are task-specific.

Acknowledgements

Thank you to Michael Preston, Sydney Smith, Eena Kosik, Quirine van Engen, and Ryan Hammonds for helpful discussion about this project. Thank you to the Child Mind Institute for making the Healthy Brain Network data publicly available. These data are licensed and distributed under the Creative Commons, Attribution Non-Commercial Share Alike License (https://creativecommons.org/licenses/by-nc-sa/4.0/)

abender@ucsd.edu

benderas