Developmental Change in Brain Oscillations During Early Childhood

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Brain Oscillations

- Brain oscillations underlie cognitive processes
- Involved in short- and long-range communication between neural populations
- Little is known about developmental change in neural oscillations during early childhood
- Unfortunate - early childhood is a period of rapid change in cognitive development that may be linked to change in brain oscillations

Study Goals

- Establish method for assessing brain oscillations in preschool-age children
- Characterize change in EEG power and connectivity from age 3 to 9

Method

Participants: 35 3-year-old, 25 4-year-old, 43 5-year-old, and 13 9-year-old children participated in this study

Resting State : We situated the resting state task in the context of a rocket ship game in which children relaxed to prepare for a rocket ship ride (eyes closed) and looked at planets while in space (eyes open). There were 7 10 s eyes closed trials and 7 10 s eyes open trials.

Measures

EEG Power - Measure of synchronized neuronal firing within frequency band

Frequency bands selected as per Tierney, Gabard-Durnam, Vogel-Farley, Tager-Flusberg & Nelson, 2012

Focused on frontal and posterior regions based on Tomalski et. al, 2013 because known to be involved in executive function development, which emerges rapidly during early childhood (Anguera et al., 2013; Buss & Spencer, under review; Edin et al., 2009; Perone, Almy, & Zelazo, forthcoming).

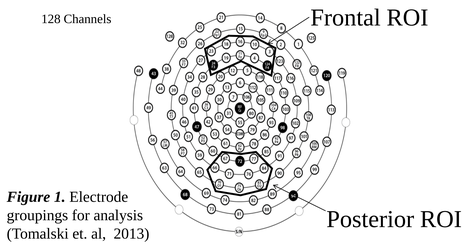


Figure 1. Electrode groupings for analysis (Tomalski et. al, 2013)

Connectivity - Weighted phase lag index (wPLI): synchronized activity between electrodes using phase angle differences, stable within individuals over time, resistant to volume conduction artifacts. Varies between 0 and 1.

Frontal-Posterior Connectivity

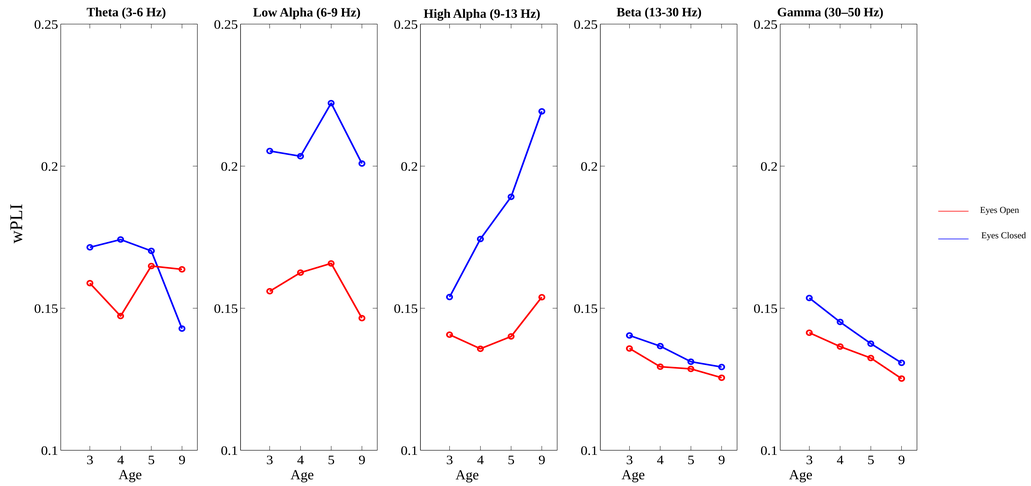
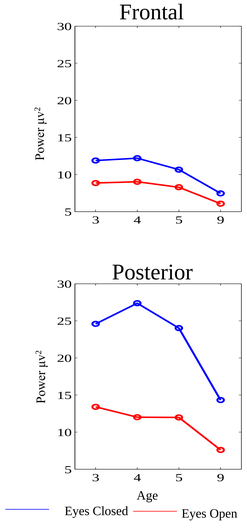


Figure 2. Connectivity between frontal and posterior regions, separated by frequency band with eyes open and eyes closed trials plotted in red and blue, respectively.

1. Eyes closed greater in all frequency bands, all ages but 9-year old theta connectivity.
2. High alpha has drastic increase over development, especially in eyes closed condition.
3. Higher frequencies (beta, gamma) show decrease over development.

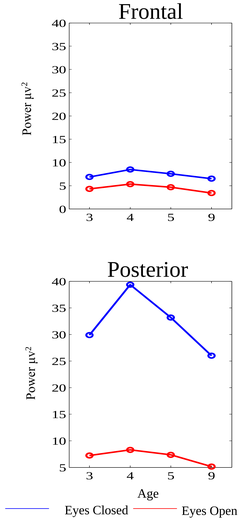
Frontal-Posterior EEG Power

Theta (3-6 Hz)



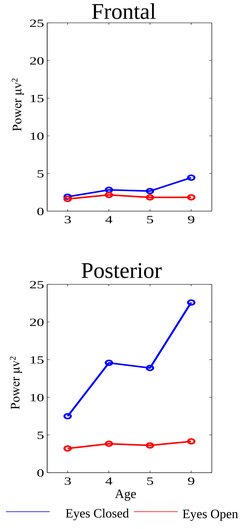
1. Power decreases between early and middle childhood (main effect of age).
2. Especially strong over the posterior region while eyes are closed (condition x region interaction).

Low Alpha (6-9 Hz)



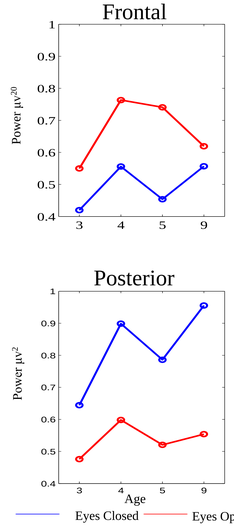
1. Stronger when eyes closed than eyes open (main effect of condition).
2. Especially strong over the posterior region when eyes are closed (condition x region interaction)

High Alpha (9-13 Hz)



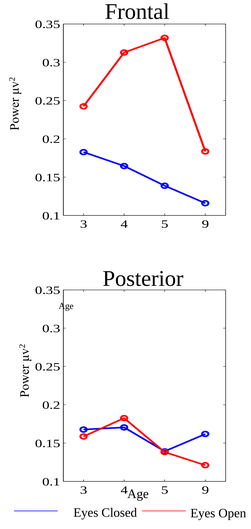
1. Increases over development when eyes are closed in both regions (region x condition x age interaction)
2. No evidence of high alpha increases while eyes are open over the posterior region

Beta (13-30 Hz)



1. When eyes are closed, posterior region power increases from 3 to 4 and 3 to 9 (region x condition x age interaction)
2. First frequency band to have higher power in eyes open than eyes closed (frontal only)

Gamma (30-50 Hz)



1. Stronger over frontal than posterior only when eyes are open; no differences when eyes closed (region x condition interaction)
2. Stronger when eyes open than eyes closed at ages 3, 4, and 5 but not age 9 (condition x age interaction)

Conclusions and Future Directions

- Examined how different frequencies operate in the different contexts
- Power was stronger over the frontal region with eyes open than eyes closed in the high frequency bands (beta and gamma).

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  Are high frequency oscillations associated with the frontal region involved in sustained attention (rocket ship task)?

- Connectivity in high frequency bands (beta and gamma) between the frontal and posterior regions decreased over development.

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  Is interregional communication becoming more efficient over development?

- Future research will examine connection between EEG power and cognitive development