Altered brain age maturation in young children with Down Syndrome

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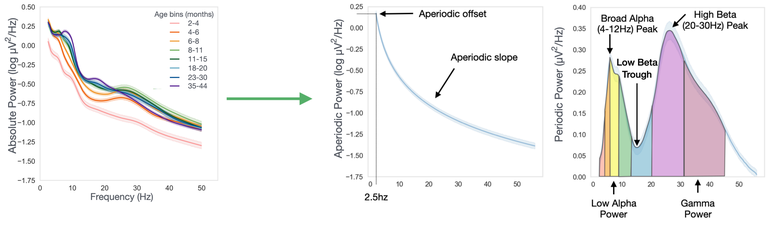
INTRODUCTION

- Limited understanding of brain age maturation patterns in children with Down syndrome (DS) restricts our ability to identify neural biomarkers that could potentially detect significant impairments before they manifest, facilitate earlier targeted interventions, and monitor progress during clinical trials.
- Electroencephalogram (EEG) offers a promising approach for identifying neural biomarkers, providing a safe and accessible measure of electrical activity in the brain's outermost layers. Power spectrum analysis takes EEG waveforms and breaks them down into its component frequencies, allowing us to quantify the electrical activity at frequency bands.
- In children without DS who have no known developmental delays ("Typically Developing (TD) Group"), there are known changes seen in the power spectrum reflective of neural circuit maturation.[1]



- Recent findings suggest children with DS show differential neural patterns compared to both age-matched and cognitively-matched TD groups, including *increased theta power,* prominent *theta peaks*, and *reduced alpha peak amplitude*.[2]
- Further characterization of age-related power spectrum differences could provide the foundation for EEG-based measures that may help clinicians understand individual developmental trajectories and inform targeted therapeutic approaches.

OBJECTIVES

1. Assess differences in EEG power spectra between 1-5 year old children with DS and an age-matched TD group.
2. Explore age-related changes in DS and TD groups, comparing differences in brain maturation trajectories.
3. Compare power spectra features within DS to measures of cognitive development using verbal and non-verbal developmental quotients (VDQ and NVDQ, respectively).

METHODS

- Resting state EEG recordings (2-5 minutes) were collected from 1-5 year old children with DS (n=59) and an age-matched TD (n=59) group across three studies.
- Data was pre-processed using BEAPP/HAPPE quality metrics.[3]

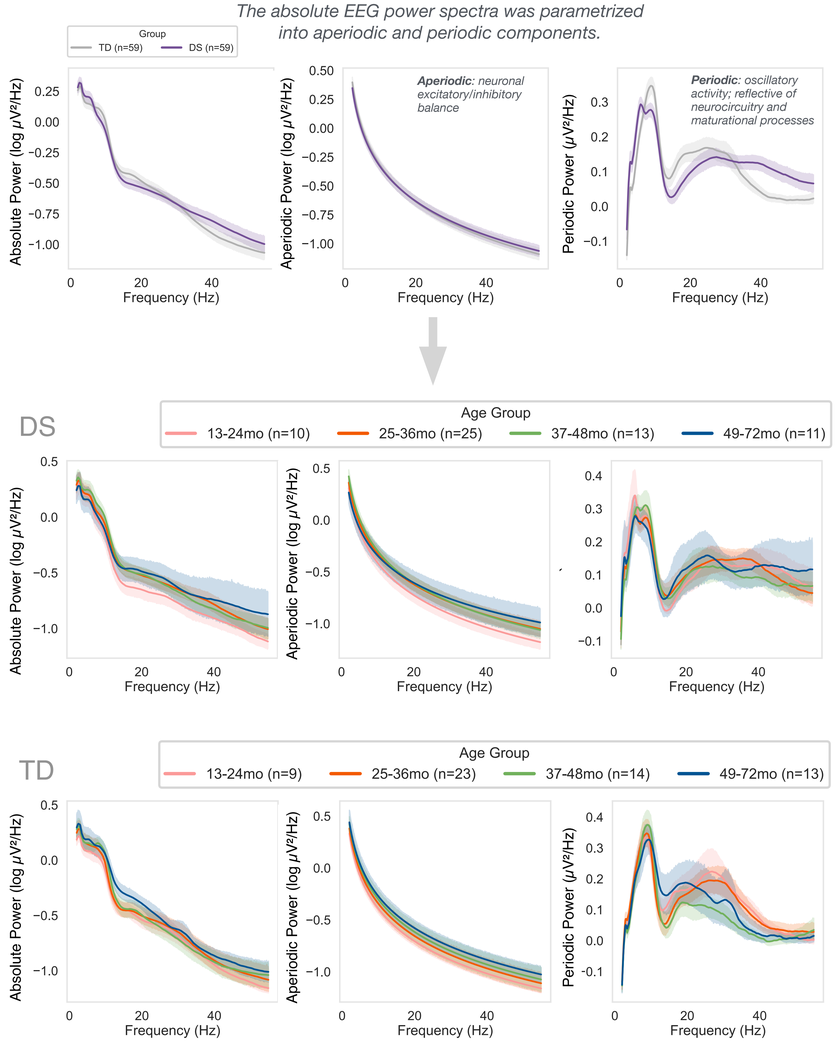
Participant Characteristics

	DS	TD
N (% Male)	59 (54.2)	59 (62.7)
Age (SD)	35.6 (13.7)	36.6 (13.7)
VDQ	55.2 (12.9)	107.7 (20.0)
NVDQ	55.8 (13.9)	100.74 (16.0)

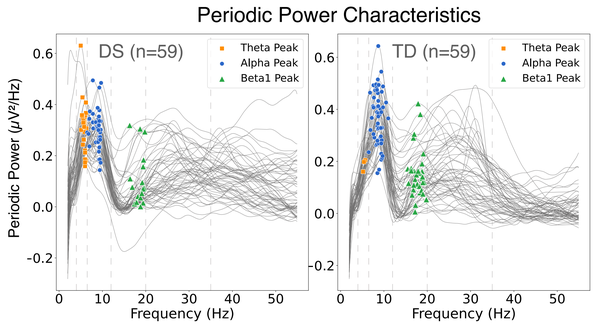
RESULTS

Whole Brain EEG Power Spectra

The absolute EEG power spectra was parametrized into aperiodic and periodic components.



1. Children with DS have a higher occurrence of a theta peak, and a lower occurrence of alpha and beta peaks



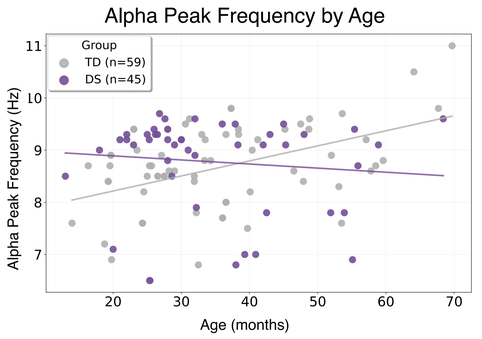
Theta peak (4–6.5Hz)
DS = 45.8%, TD = 5.1%
$\chi^2(1) = 23.64$, $p < .001$

Alpha peak (6.5–12Hz)
DS = 76.3%, TD = 100%
$\chi^2(1) = 13.70$, $p < .001$

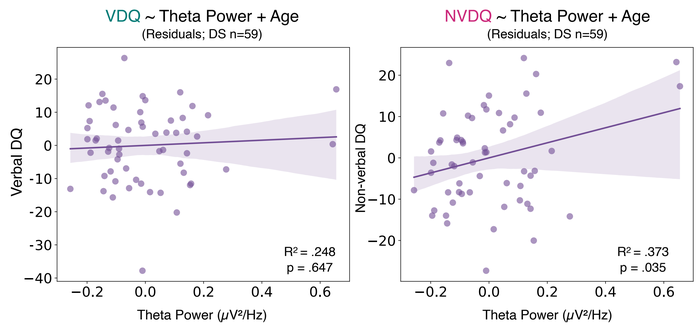
Low beta peak (12–20Hz)
DS = 28.8%, TD = 55.9%
$\chi^2(1) = 7.81$, $p = .005$

2. Alpha peak frequency showed expected significant age-related increases in the TD group, but not in children with DS.

TD: $\beta = .029$, $p < .001$
DS: $\beta = -.008$, $p = .471$
Group Inx.: $\beta = -.037$, $p = .004$



3. In DS, theta periodic power was positively associated with NVDQ, but not VDQ.



SUMMARY & FUTURE DIRECTIONS

- Children with DS show **significantly altered age-related neural patterns** in their resting state EEG.
  - Power spectrum analysis revealed that children with DS had more theta peaks, and fewer alpha and beta peaks. In TD children, a positive relationship was seen between age and alpha peak frequency, however, this was not observed in children with DS.
  - Increased periodic theta power was associated with increased non-verbal, but not verbal, developmental quotients, suggesting an early relationship between theta power and cognitive development, but not with language.
- These findings support the use of EEG in **identifying neural patterns as potential predictive biomarkers** of development in DS. Longitudinal studies are needed to understand **how these patterns change** over time and are related to cognitive trajectories.

REFERENCES

1. Wilkinson et al., Nat Commun., 2024, PMID: 38987558
2. Geiger et al., Neurobiol Dis., 2024, PMID: 39173846
3. Levin et al., Front Neurosci., 2018, PMID: 30131667

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