Graph Analysis of EEG Resting State Functional Networks in Dyslexic and Typically Reading Children

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Introduction

Reading involves integrated functioning of **complex brain networks** (Schlaggar & McCandliss, 2007). **Dyslexia** refers to a specific reading disability with a neurobiological component.

Dyslexics present **connectivity disturbances** across the reading network (e.g., Pugh et al., 2003) and other brain networks (e.g. Wolf et al., 2010).

Resting-state activity can characterize functional networks implicated in reading (Koyama et al.,2013; Schurz et al., 2014)

Graph analysis is used to model organization of resting-state whole-brain networks during development (Stam, 2014). **Minimum Spanning Tree** (MST) allows for unbiased group comparisons (Stam et al., 2014)

Previous findings:

- MEG in dyslexics: dysfunctional long and short range functional connectivity (Vourkas et al., 2011), **less organized network** (Dimitriadis et al.,2013)
- Recent MRI study: less integrated configuration in dyslexics, increased local processing and **less long-range communication** (Liu et al.,2015)

Goals

- Examine differences in **topological properties of resting-state functional networks** between children with dyslexia and typical readers

Methods

Participants

29 dyslexics (age 8.46 ± 0.40). Percentile in reading ≤ 10 .
15 typical readers (age 8.75 ± 0.31). Percentile in reading ≥ 25.

EEG recording and signal processing

Biosemi ActiveTwo 64 electrodes; 1024 Hz sampling rate; 2 min. eyes-closed
Interpolation (max. 5 electrodes in one subject)
10 artifact-free 4 s epochs selected (40 s data per subject in analysis)

Spectral power

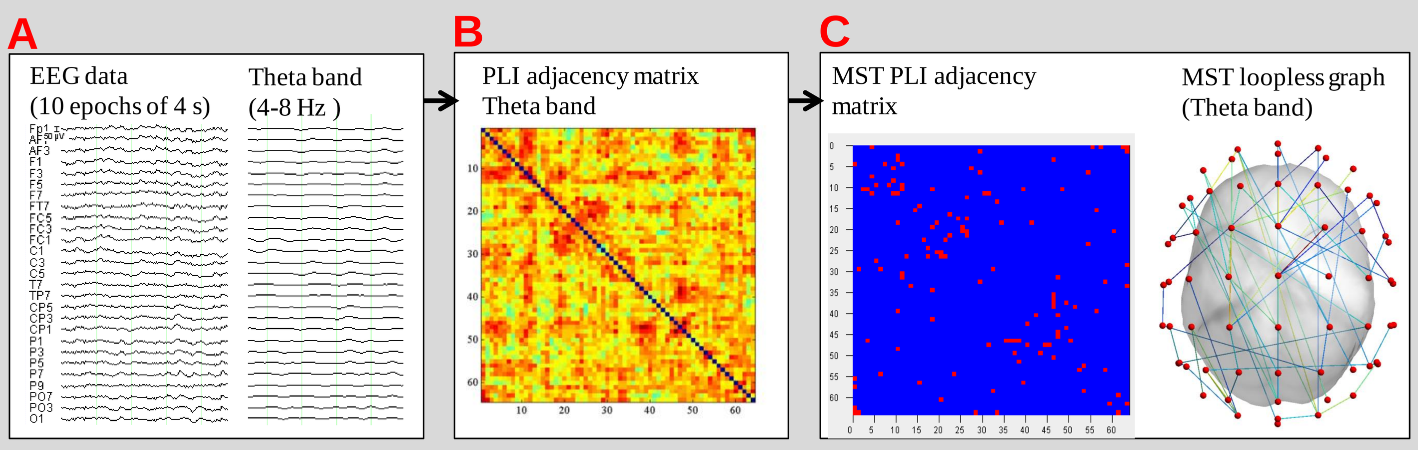
Fast Fourier Transformation (FFT). Resolution:1/4=0.25 Hz.
Bands: **delta** (0.5-4 Hz), **theta** (4-8 Hz), **alpha** (8-13 Hz), **beta** (13-30 Hz) and **gamma** (30-48 Hz).

Functional connectivity (A - B)

Phase Lag Index (PLI) calculated for each band separately. Filtering as in Brainwave (C.J. Stam, http://home.kpn.nl/stam7883/brainwave.html)

Minimum Spanning Tree (C)

Unique **loop-less** sub-graph based on the weighted connectivity matrix (per band). Fixed number of nodes (*N = 64 electrodes*) and links (*m = N-1*). Calculated with Kruskal's algorithm. Represents the **sub-network with maximum connectivity**

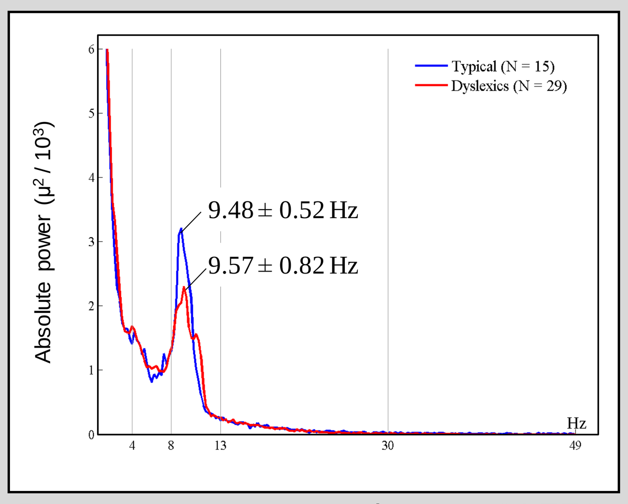


Schematic of the graph analysis.

Results

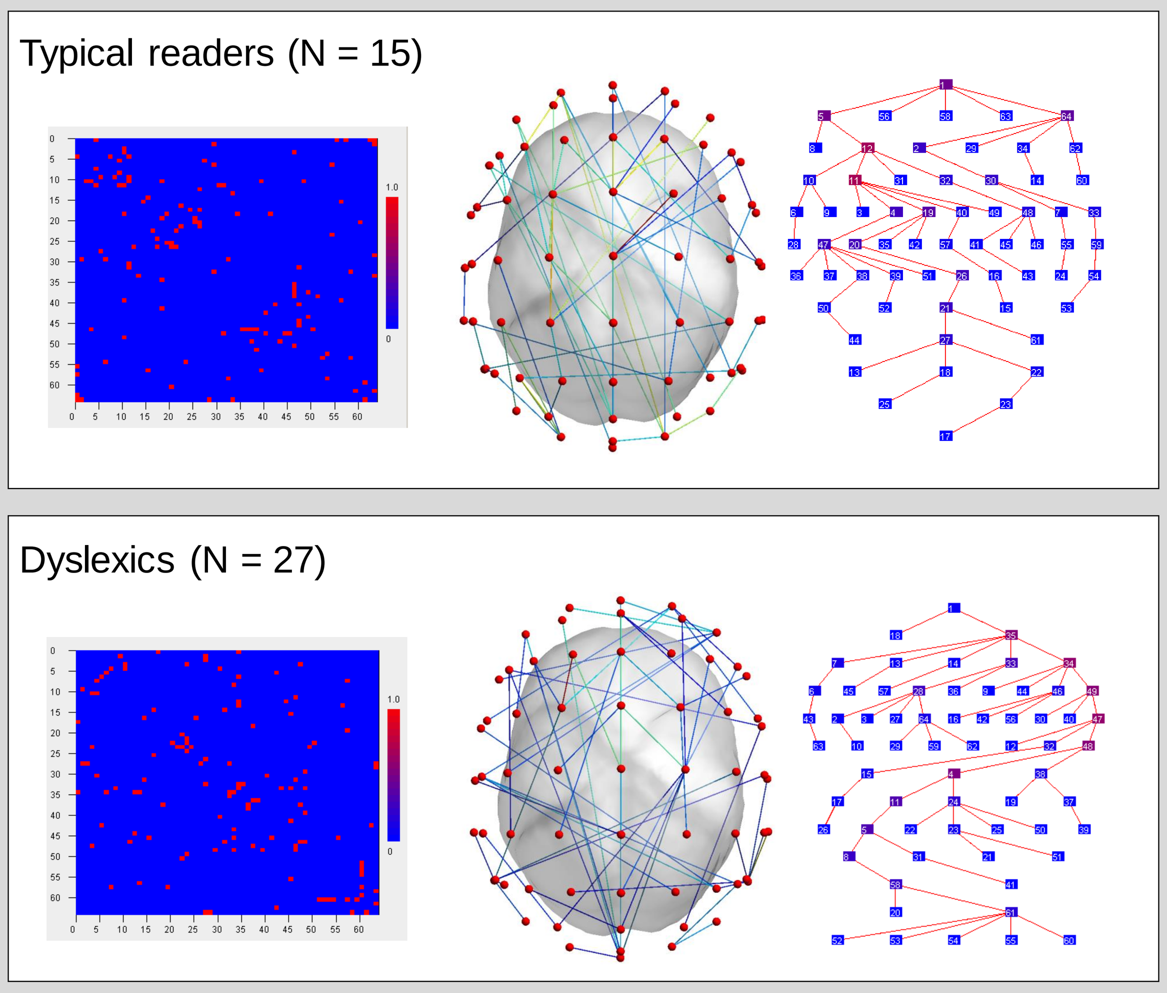
Group differences in **MST** measures in the **theta band** :

- **Leaf fraction** (number of nodes with degree one) was *lower* in dyslexics vs. typical readers.
  F (1, 40) = 10.24, p = .003, η^2 = 0.20
- **Diameter** (largest distance between any 2 nodes) was *higher* in dyslexics vs. typical readers.
  F (1, 40) = 4.27, p = .045, η^2 = 0.10
- Trend for higher **eccentricity** (related to node centrality) in dyslexics vs. typical readers (p = .070)

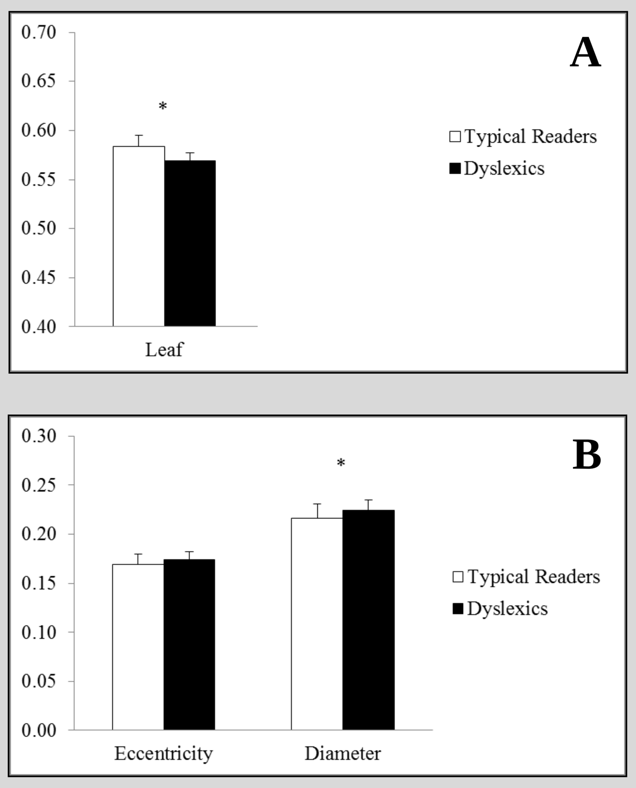


Power spectrum averaged across 64 EEG scalp channels for typical readers *(blue)* and dyslexics *(red)*

No group differences in connectivity (PLI) or FFT power



MST matrices (left panels) and MST graphs (center and right panels) for the theta band for typical readers (above) and dyslexics (below)



(A) Group averages for leaf fraction, (B) eccentricity and diameter measures of the MST. Open bars refer to typical readers and filled bars to dyslexics. * p < 0.05

Discussion

- Dissociation between PLI connectivity vs. network analysis of EEG data
- **Less integrated** network configuration in dyslexics. More *line-like tree* (higher diameter , lower leaf).
- Relation of MST and conventional graph measures (simulation study; Tewarie et al., 2015)
  - higher diameter and lower leaf relate to longer *path length* ; reported in dylsexics (Liu et al., 2015)
  - Leaf positively relates to network *scale-freeness* (presence of interconnected hubs).
- Role of **theta** in working memory, language processing and large network activity (Stein & Sarnthein., 2000). Previous evidence for abnormalities in theta activity in dyslexia (e.g., Goswami, 2011)

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