Changes in Brain Connectivity and Behavioural Reading Ability Following Reading Intervention in Children

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Introduction

Differences in brain connectivity have been associated with reading disability (RD) in children.

Resting-state functional magnetic resonance imaging (fMRI): measures functional brain connectivity using patterns of spontaneous activity over time.
- Reduced functional connectivity in RD during reading and resting state, relative to typical readers[1]
- Changes in resting-state functional connectivity observed in illiterate adults following reading instruction[3]

Diffusion tensor imaging (DTI): measures structural connectivity using static images of white matter connectivity.
- RD is associated with differences in DTI connectivity compared to typical readers[2]
- Increase in DTI connectivity in children with RD following reading intervention[4]

How do measures of functional and structural connectivity change following reading intervention in children with RD?

Methods

Participants
- 9 children with RD (4 female) receiving reading intervention

Descriptive statistics prior to intervention	
Age (years)	10.27 (0.70)
Sight Word Reading (Test of Word Reading Efficiency)	64.56 (9.40)
Nonword Reading (Test of Word Reading Efficiency)	70.44 (9.98)
Reading Comprehension (Woodcock-Johnson)	70.78 (14.50)
Nonverbal Intelligence (WASI Performance IQ)	100.22 (11.98)

Empower™ Reading Intervention[5]
- 110 hours delivered in small-group format throughout one academic year
- Focus on phonological awareness, letter-sound awareness, text comprehension, and metacognitive strategies

Behavioural Reading Measures
Participants completed informal measures of reading pre- and post-intervention.
- *Letter-Sound Identification task*: identifying sounds associated with letters
- *Keyword task:* reading mono- and bisyllabic words taught in Rhyming Strategy in Empower™ program
- *Challenge Word task:* reading multi-syllabic words not taught in Empower™

MRI Data Acquisition
Pre- and post-intervention MRIs using a Siemens 3T Prisma scanner.
- High-resolution anatomical scan
- 8-minute resting state fMRI scan
- 6-minute DTI scan
Resting-state regions of interest (ROIs) and DTI tracts were identified based on those previously implicated in fMRI studies of reading in children[1,2,6].
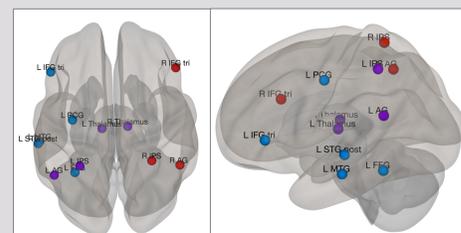
Results

Behavioural Changes in Reading

Measure	Accuracy Pre-Intervention	Accuracy Post-Intervention
Letter-Sound Identification (%)	75 (19)	89 (30)
Keyword Reading (%)	48 (39)	99 (2)*
Challenge Word Reading (%)	24 (28)	85 (13)*
* p < .01		

Resting-State Regions of Interest

DTI Connectivity

DTI data were preprocessed and analyzed using Automated Fiber Quantification for SPM in MATLAB. Fractional anisotropy values at nodes along each tract were compared between pre- and post-intervention using paired-samples t-tests. Red represents increased FA from pre- to post-intervention while blue represents decreased FA ($p < .05$, permutation-based corr.).
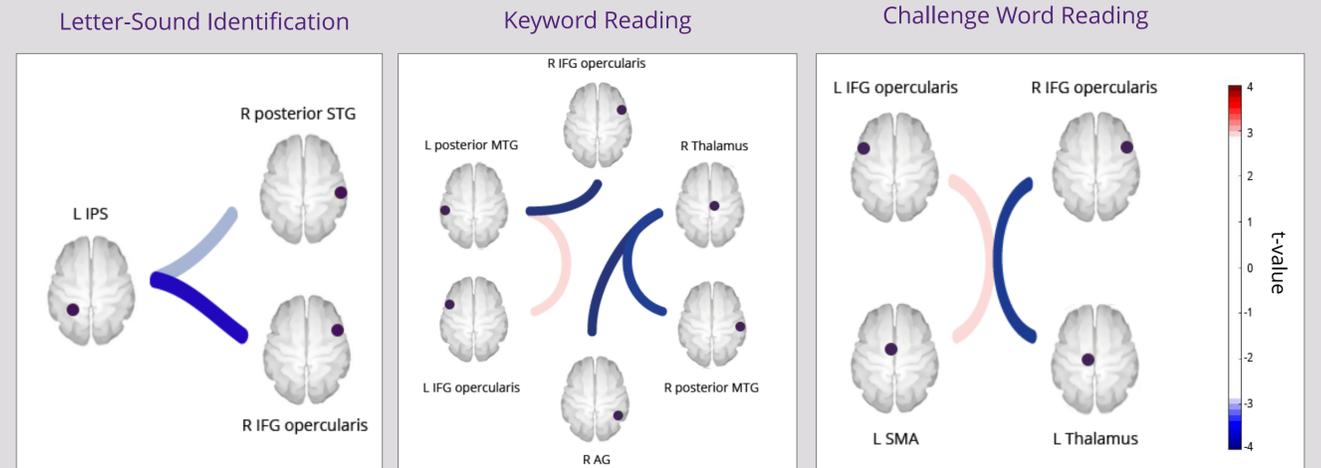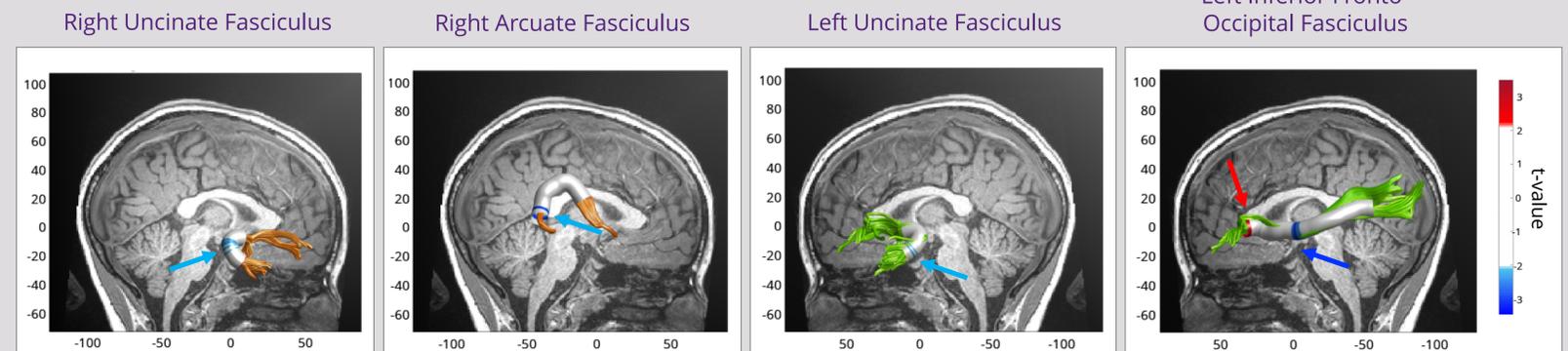
Resting-State Connectivity

Resting-state fMRI data were preprocessed and analyzed using CONN-fMRI toolbox for SPM in MATLAB. Differences in resting-state connectivity pre- and post-intervention were examined using regression models, with change in behavioural scores added to the models as predictor variables. Red represents positive associations between change in connectivity and behavioural scores, while blue represents a negative relationship between change in connectivity and behavioural score ($p < .05$, FRD corr.).

Letter-Sound Identification

- R posterior STG
- L IPS
- R IFG opercularis

Keyword Reading

- R IFG opercularis
- L posterior MTG
- R Thalamus
- L IFG opercularis
- R posterior MTG
- R AG

Challenge Word Reading

- L IFG opercularis
- R IFG opercularis
- L SMA
- L Thalamus

Right Uncinate Fasciculus

Right Arcuate Fasciculus

Left Uncinate Fasciculus

Left Inferior Fronto-Occipital Fasciculus

Implications

Changes in resting-state functional connectivity were observed pre- to post-intervention, and were associated with change in behavioural reading abilities including letter-sound knowledge, sight word reading, and decoding.
- Greater improvement on the reading tasks was associated with reduced resting-state functional connectivity for connections between right hemisphere regions as well as connections across hemispheres
- Improvement on the reading tasks was also positively associated with connectivity between left hemisphere regions
Changes in DTI connectivity showed a similar pattern of neural changes from pre- to post-intervention.
- Tract integrity was reduced from pre- to post-intervention in right hemisphere tracts and some left hemisphere tracts. Increased tract integrity was observed in the left inferior fronto-occipital fasciculus.

Overall, these findings suggest an **atypical reliance on right hemisphere and interhemispheric connections in RD** prior to reading intervention. With reading intervention, children may begin to rely more on neural pathways within the left hemisphere, strengthening or increasing the efficiency of the left hemisphere tracts and functional connections.

Future Directions
- Examine whether connectivity prior to intervention may predict behavioural growth in reading skills during intervention
- Recruit additional subjects to increase sample size

References
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