Examining the Neurocognitive Basis of Reading Fluency in Children with Dyslexia & Comorbid Dyslexia/ADHD

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Introduction

- Dyslexia and attention-deficit/hyperactivity disorder (ADHD) are among the most common neurodevelopmental disorders, each affecting 5-10% of school-aged children (Boada et al., 2012; Shaywitz et al., 1990; Visser et al., 2014).

- The comorbidity of dyslexia and ADHD is striking, with 25-40% of children with one diagnosis meeting the diagnostic criteria for the other (Carroll et al., 2005; Dykman & Acherman, 1991; Semrud-Clikeman et al., 1992; Willcutt & Pennington, 2000).

- However, limited research has examined the neurocognitive mechanisms underlying the reading challenges present in dyslexia with and without ADHD.

Conclusion

- In-scanner behavioral performance revealed that RD and RD+ADHD groups showed reduced accuracy and slower rate compared to TD. Compared to TD, there was reduced left-hemisphere activation during story reading in both RD and RD+ADHD.

- Within the left-hemisphere reading network, compared to TD there was comparable hypoactive recruitment of the inferior frontal gyrus and fusiform gyrus for RD and RD+ADHD. RD+ADHD differed from TD in the middle temporal gyrus and angular gyrus, whereas RD differed from TD in the superior temporal gyrus and supramarginal gyrus.

- There were no brain activation or in-scanner performance differences between RD and RD+ADHD in contrast to predictions of the 'cognitive subtype' hypothesis positing that RD with ADHD would show more severe deficits than RD alone when reading text.

- These findings further our understanding of the neurocognitive processes supporting reading, and how these processes compare in RD and RD+ADHD.

Implications

➤ Standard behavioral diagnostic reading measures did not differentiate single from comorbid disorders.

➤ Results indicate unique contributions of neuroimaging in differentiating single from comorbid disorders.

➤ Results encourage the use of a multifaceted approach to understanding reading and attention challenges.

Methods

Participants (6-13 years):
- 15 Typically Developing (TD) (M age = 10.5, SD = .83);
- 13 Dyslexia (RD) (M age = 11.7, SD = .82);
- 8 Comorbid Dyslexia/ADHD (RD+ADHD) (M age = 11.4, SD = .83)
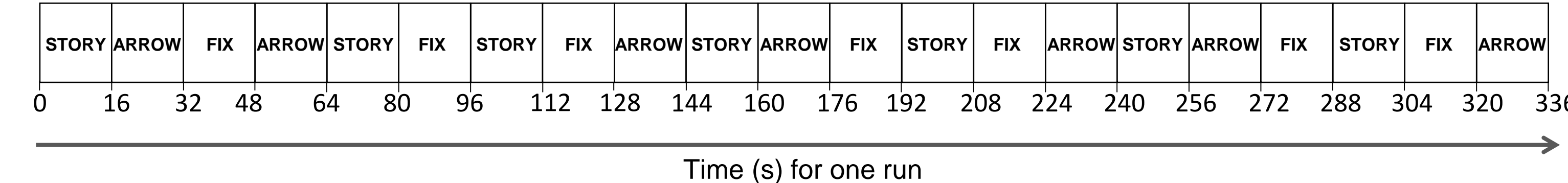
Eligibility Criteria for Groups:

Groups	Reading Measure Standard Score	ADHD
Typically Developing (TD) n = 15	≥ 90 on 4/4 Reading Measures	No
Dyslexia Only (RD) n = 13	< 90 on 2+/4 Reading Measures	No
Comorbid Dyslexia/ADHD (RD+ADHD) n = 8	< 90 on 2+/4 Reading Measures	Yes

- Participants completed behavioral and neuroimaging sessions, as well as a clinical neurological exam for ADHD determination.
- Participants were full term, right-handed, native English speakers, with no history of neurological injury, or psychiatric disorders, & IQ > 80.

Reading Fluency In-Scanner Task Stimuli:

Stories (16 seconds)	Arrows (16 seconds)

MRI Methodology:

STORY	ARROW	FIX	ARROW	STORY	FIX	STORY	FIX	ARROW	STORY	ARROW	FIX	STORY	FIX	ARROW	STORY	ARROW	FIX	STORY	FIX	ARROW
0	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320	336

Time (s) for one run

- Participants completed an fMRI reading task during which they read aloud seven paragraph-length stories at their typical reading rate while being recorded.

Data Acquisition:
- Scanner: 3T Siemens Magnetom Trio MRI system
- T2-weighted (32 slices, 3.0 mm iso-voxel, TR/TE/flip angle = 2000 ms, 30 ms, 90 degrees)

Data Analysis:
- fMRI: SPM12
  ➤ Functional images were slice-time corrected, realigned, and coregistered to individual participants T1 MPRAGES.
  ➤ ART toolbox for outlier identification (>1mm motion, global mean intensity >3SD from mean).
  ➤ Slice time corrected, realigned, coregistered whole-brain functional images were entered into a first-level model and contrasts of interest were created.

References

- Boada, R., Willcutt, E. G., & Pennington, B. F. (2012). Understanding the comorbidity between dyslexia and attention-deficit/hyperactivity disorder. Topics in Language Disorders, 32, 264-284.
- Carroll, J. M., Maughan, B., Goodman, R., & Meltzer, H. (2005). Literacy difficulties and psychiatric disorders: Evidence for comorbidity. Journal of Child Psychology and Psychiatry, 46, 524-532.
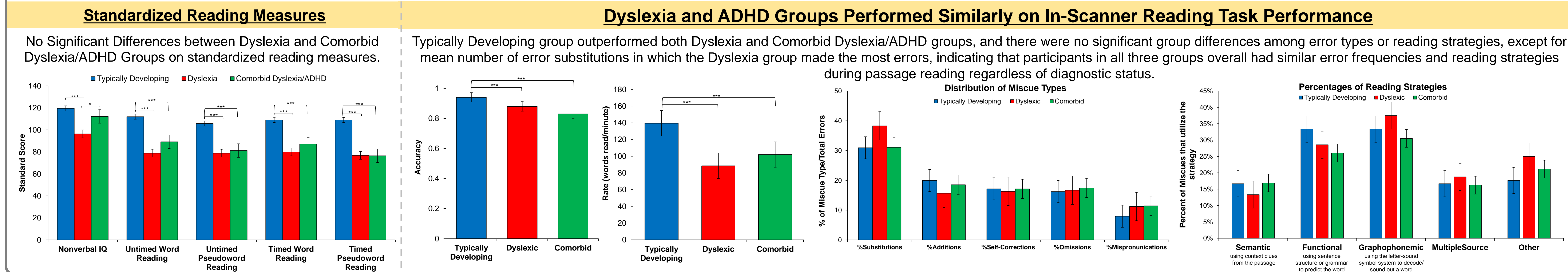- Dykman, R. A., & Ackerman, P. T. (1991). ADD and specific reading disability: Separate but often overlapping disorders. Journal of Learning Disabilities, 24, 96-103.
- Shaywitz, S. E., Shaywitz, B. A., Fletcher, J. M., & Escobar, M. D. (1990). Prevalence of reading disability in boys and girls. Results of the Connecticut Longitudinal Study. Journal of the American Medical Association, 264, 998-1002.
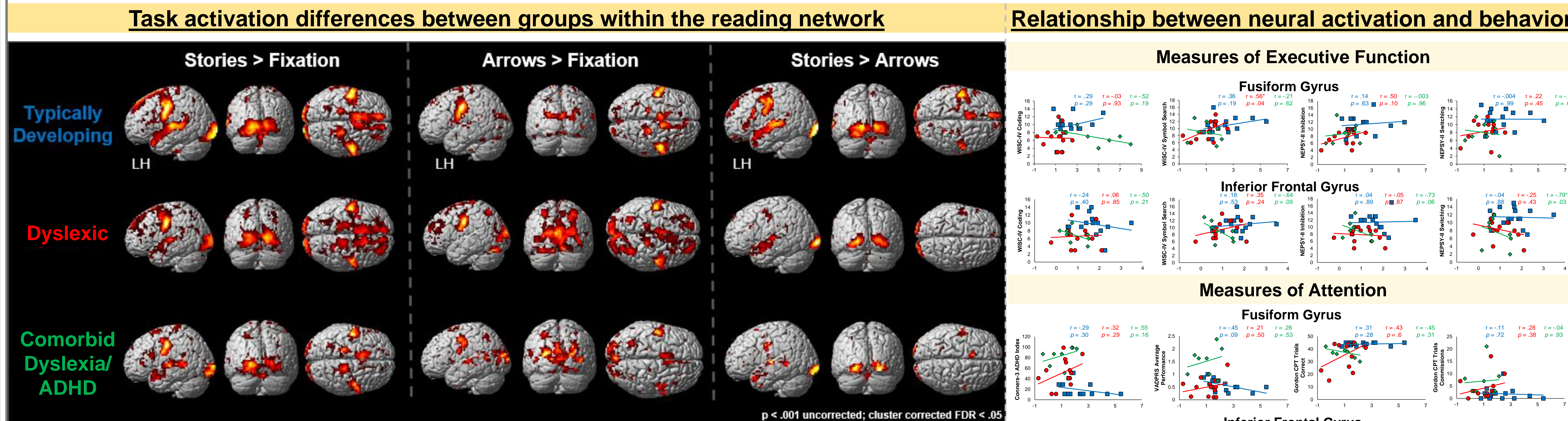- Visser, S. N., Danielson, M. L., Bitsko, R. H., Holbrook, J. R., Kogan, M. D., Ghandour, R. M., Perou, R., & Blumberg, S. J. (2014). Trends in the parent-report of health care provider-diagnosed and medicated Attention-Deficit/Hyperactivity Disorder: United States, 2003-2011. Journal of the American Academy of Child and Adolescent Psychiatry, 53, 34-46.
- Willcutt, E. G., & Pennington, B. F. (2000). Comorbidity of reading disability and attention deficit/hyperactivity disorder: Differences by gender and subtype. Journal of Learning Disabilities, 33, 179-191.

Behavioral Performance

Standardized Reading Measures

No Significant Differences between Dyslexia and Comorbid Dyslexia/ADHD Groups on standardized reading measures.

Dyslexia and ADHD Groups Performed Similarly on In-Scanner Reading Task Performance

Typically Developing group outperformed both Dyslexia and Comorbid Dyslexia/ADHD groups, and there were no significant group differences among error types or reading strategies, except for mean number of error substitutions in which the Dyslexia group made the most errors, indicating that participants in all three groups overall had similar error frequencies and reading strategies during passage reading regardless of diagnostic status.

Neural Activation during Task Performance

Task activation differences between groups within the reading network

Stories > Fixation | Arrows > Fixation | Stories > Arrows

Typically Developing / Dyslexic / Comorbid Dyslexia/ADHD

p < .001 uncorrected; cluster corrected FDR < .05

Relationship between neural activation and behavior

Measures of Executive Function

Fusiform Gyrus / Inferior Frontal Gyrus

Measures of Attention

Fusiform Gyrus / Inferior Frontal Gyrus

Measures of Reading Ability

Fusiform Gyrus / Inferior Frontal Gyrus

Reading Network Regions of Interest Analysis for Stories > Fixation

Inferior Frontal Gyrus — Supramarginal Gyrus — Angular Gyrus — Middle Temporal Gyrus — Superior Temporal Gyrus — Fusiform Gyrus

Left Hemisphere

Typically Developing | Dyslexic | Comorbid Dyslexia/ADHD