

# Atypical auditory adaptation to repeated speech in children with dyslexia

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## Summary

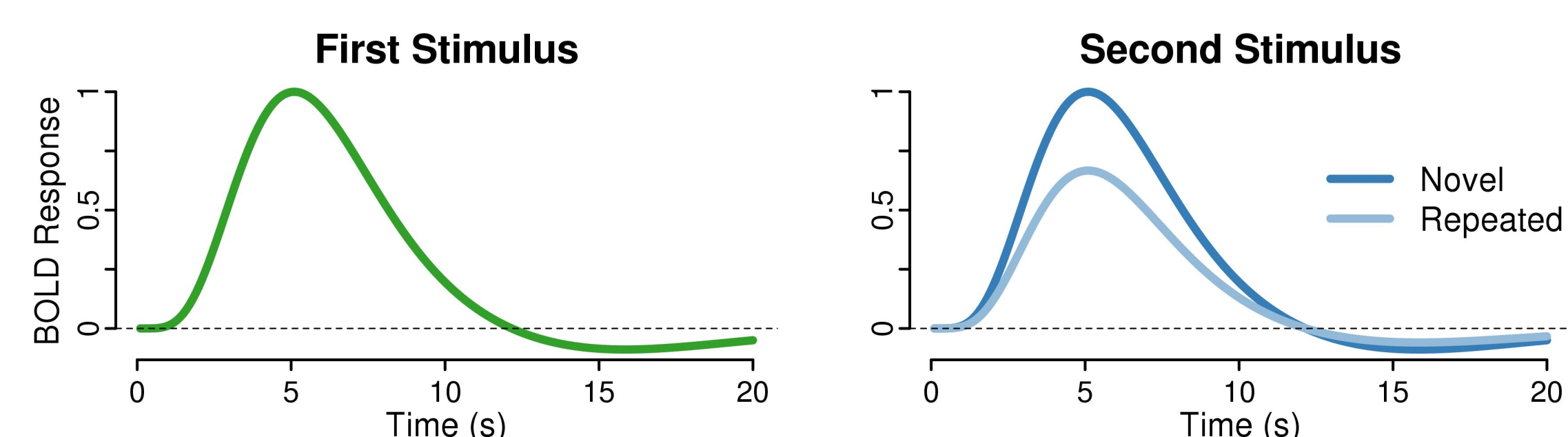
- Dyslexia is a neurological disorder characterized by difficulty learning to read words accurately and fluently.
- Atypical phonological processes are the most common underlying deficit in dyslexia (Gabrieli, 2009).
- How does a phonological impairment adversely affect reading development but leave speech abilities intact?
- Here, adaptation to auditory repetition was used to assess neural sensitivity to stimulus consistency.
- Children with dyslexia exhibit atypical neurophysiological adaptation compared to children with typically developing reading abilities.**

## Adaptation in dyslexia

- Individuals with dyslexia exhibit **perceptual deficits** in tasks that involve neither reading nor language, but for which adaptation-related processes enhance the perceptual performance of typical readers.
  - Impaired thresholds in frequency discrimination with a consistent (anchor) stimulus (Ahissar *et al.*, 2006)
  - Impaired detection of visual and auditory targets in background noise (Sperling *et al.*, 2005; Ziegler *et al.*, 2009)
  - Impaired ability to recognize voices (Perrachione *et al.*, 2011)
  - Atypical auditory brainstem response to repeated vs. unrepeated syllables (Chandrasekaran *et al.*, 2009)

## Adaptation fMRI

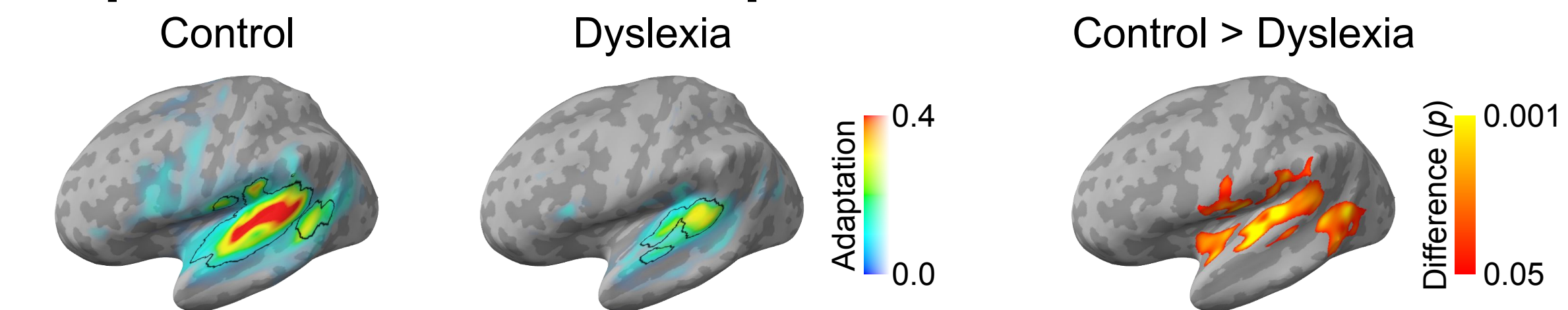
- Stimulus repetition typically results in reduced BOLD response in cortex containing neurons sensitive to that stimulus type (Grill-Spector & Malach, 2001).



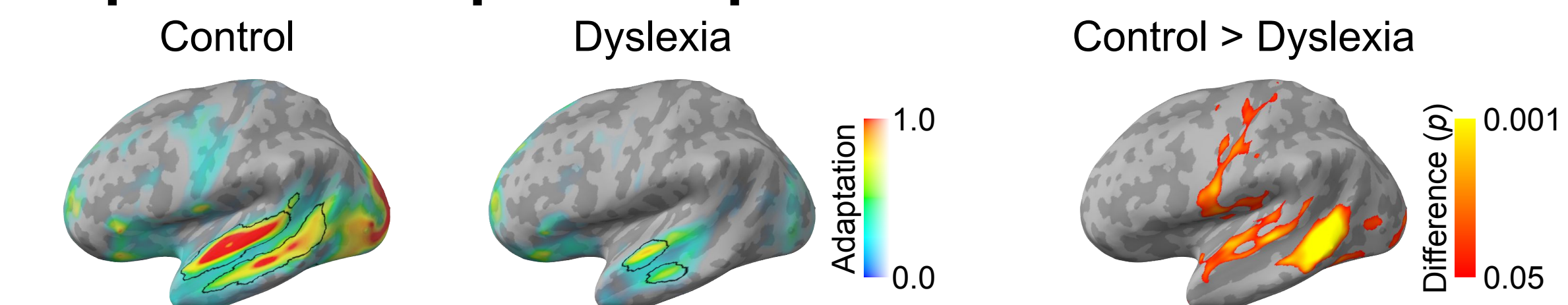
## Neural adaptation in adults

- Compared to adults with typical reading abilities, **adults with dyslexia exhibit reduced neural adaptation to stimulus repetition** (Perrachione, 2012)
- Dysfunctional neural adaptation in adults with dyslexia was observed for every stimulus category measured:
  - Voices (phonetics); Speech; Text; Objects; Faces

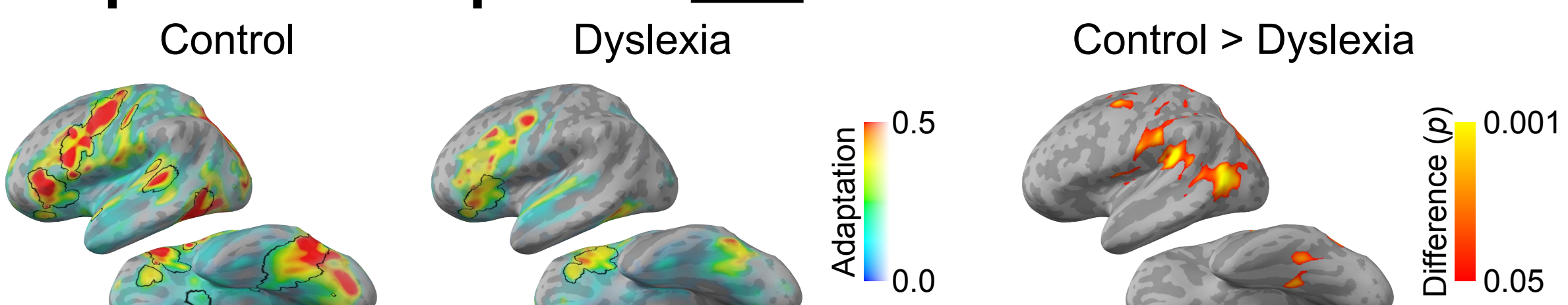
### Adaptation to consistent phonetics



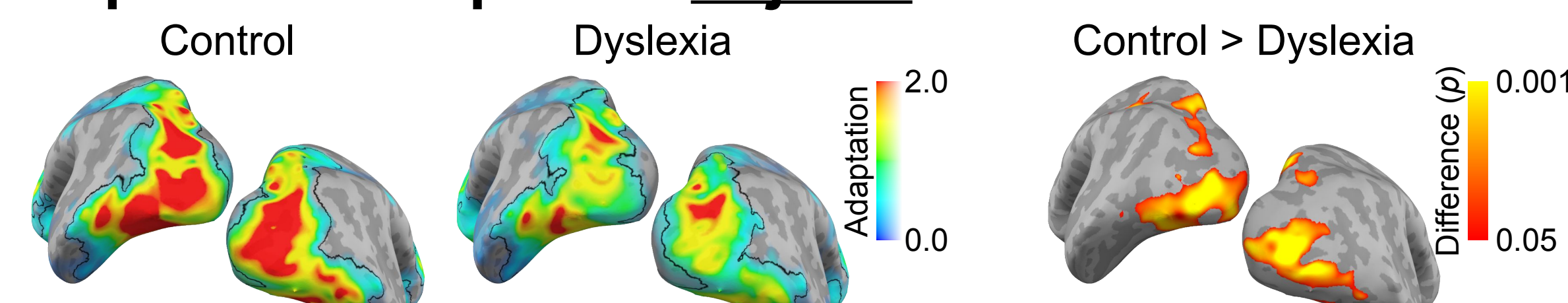
### Adaptation to repeated speech



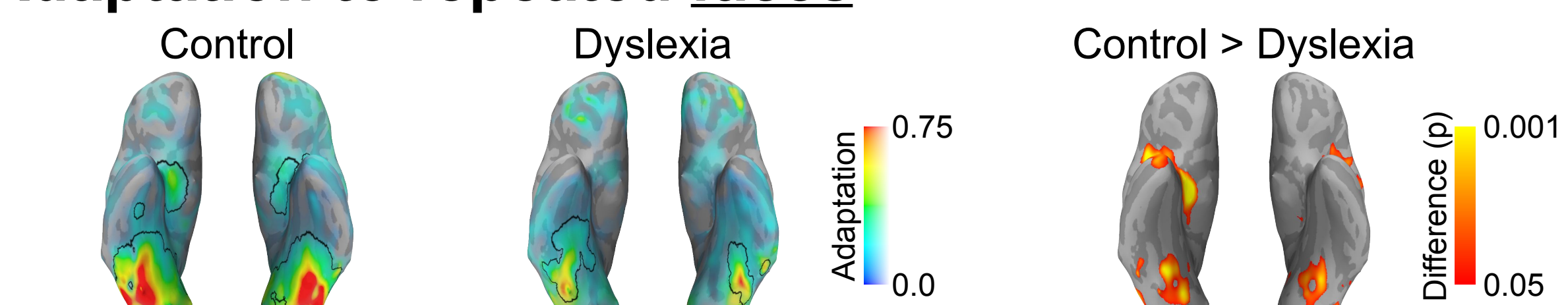
### Adaptation to repeated text



### Adaptation to repeated objects



### Adaptation to repeated faces



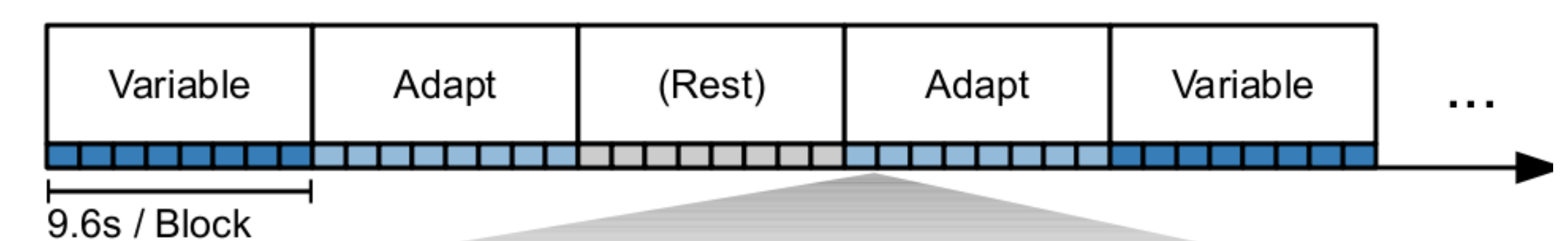
## Methods

- Participants:** Children with dyslexia ( $N=27$ ); and age- and IQ-matched typically developing controls ( $N=25$ ).
  - Dyslexia:** <16%ile on 2+ reading subtests; **Control:** >25%ile on all reading tests
- fMRI acquisition:** 3T, whole-brain, continuous-sampling EPI, TR=2.0s, 3mm<sup>3</sup> voxels, 146 volumes, plus high-resolution (1mm<sup>3</sup>) MPRAGE structural scan.
- fMRI analysis:** motion correction, spatial smoothing, high-pass filter, artifact detection, coregistration; 1st-level fixed-effects and group-level mixed-effects analyses.

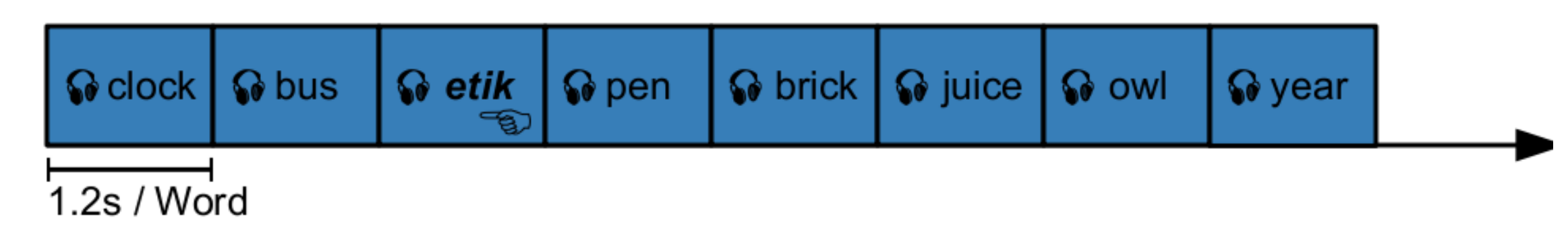
Reading Profile			
	Control	Dyslexia	Difference
Age (years)	7.8 ± 0.7	7.9 ± 0.6	$p = 0.62$
WRMT Word Identification	119.0 ± 9.4	81.7 ± 8.8	$p < 0.0001$
WRMT Word Attack	114.3 ± 10.2	84.5 ± 8.9	$p < 0.0001$
TOWRE Sight Word Efficiency	114.3 ± 9.0	81.2 ± 10.7	$p < 0.0001$
TOWRE Phonemic Decoding	112.7 ± 9.5	77.2 ± 8.0	$p < 0.0001$
WJ-III Reading Fluency	121.0 ± 15.1	88.0 ± 9.6	$p < 0.0001$
CTOPP Phonological Awareness	116.3 ± 13.7	93.7 ± 9.5	$p < 0.0001$
CTOPP Phonological Memory	109.9 ± 11.7	90.9 ± 9.4	$p < 0.0001$

- Task:** Auditory deviant detection (time-reversed word) with orthogonal adaptation manipulation:
- Variable condition:** Every word in the block was different.
- Repeated condition:** A single word was presented repeatedly.

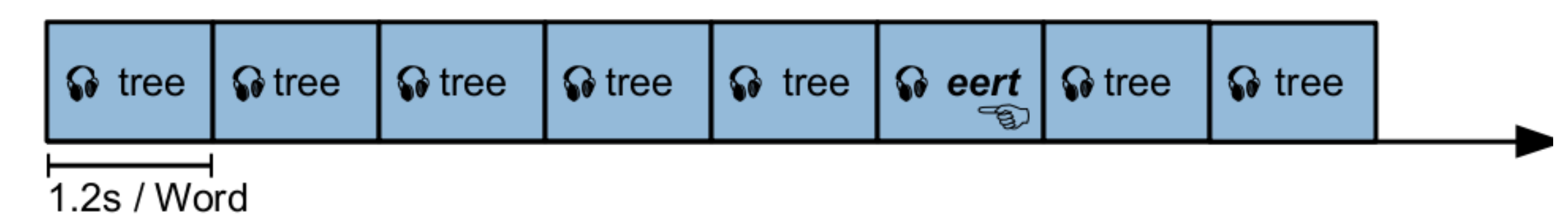
### A. fMRI Run (4:48)



### B. Variable Blocks (10 / run)



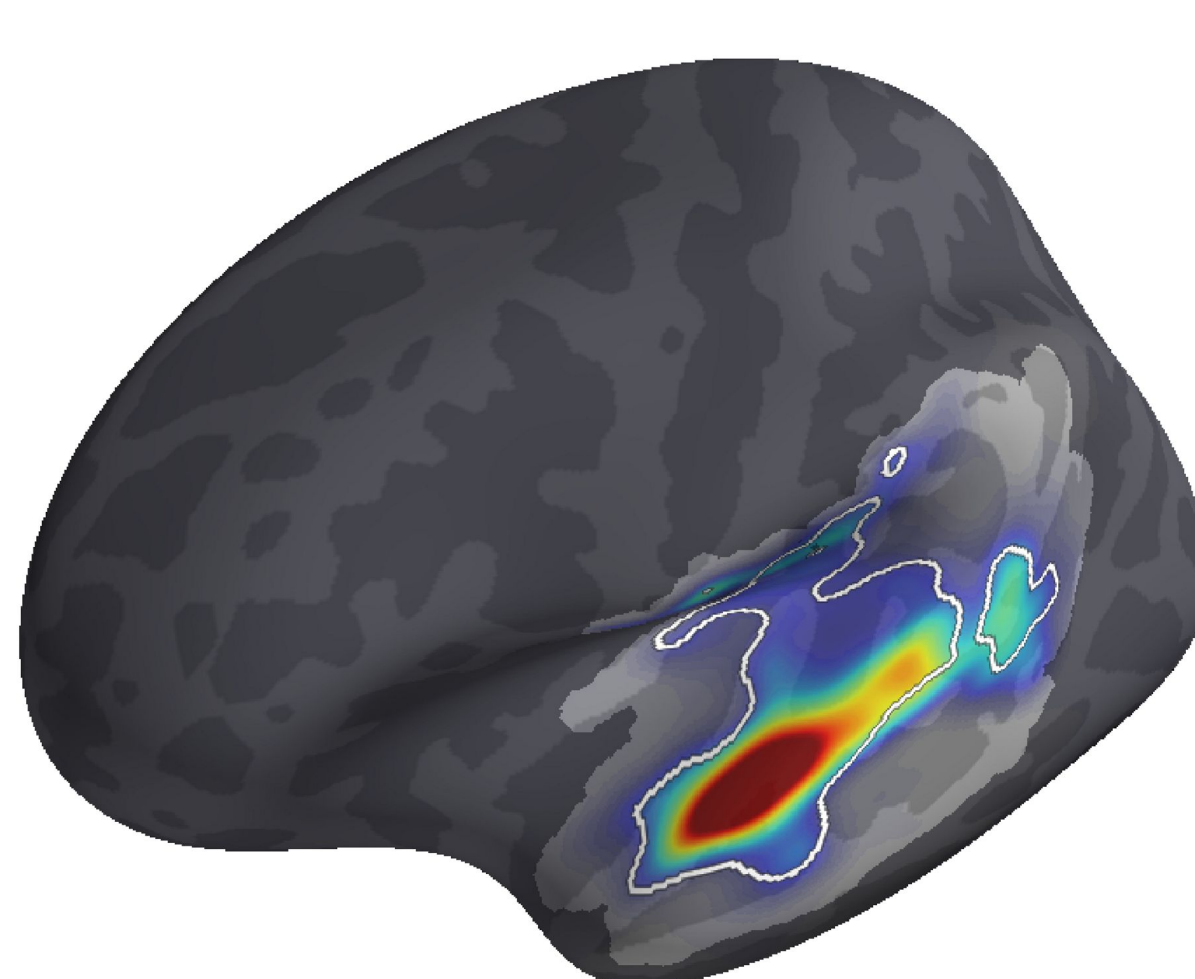
### C. Adapt Blocks (10 / run)



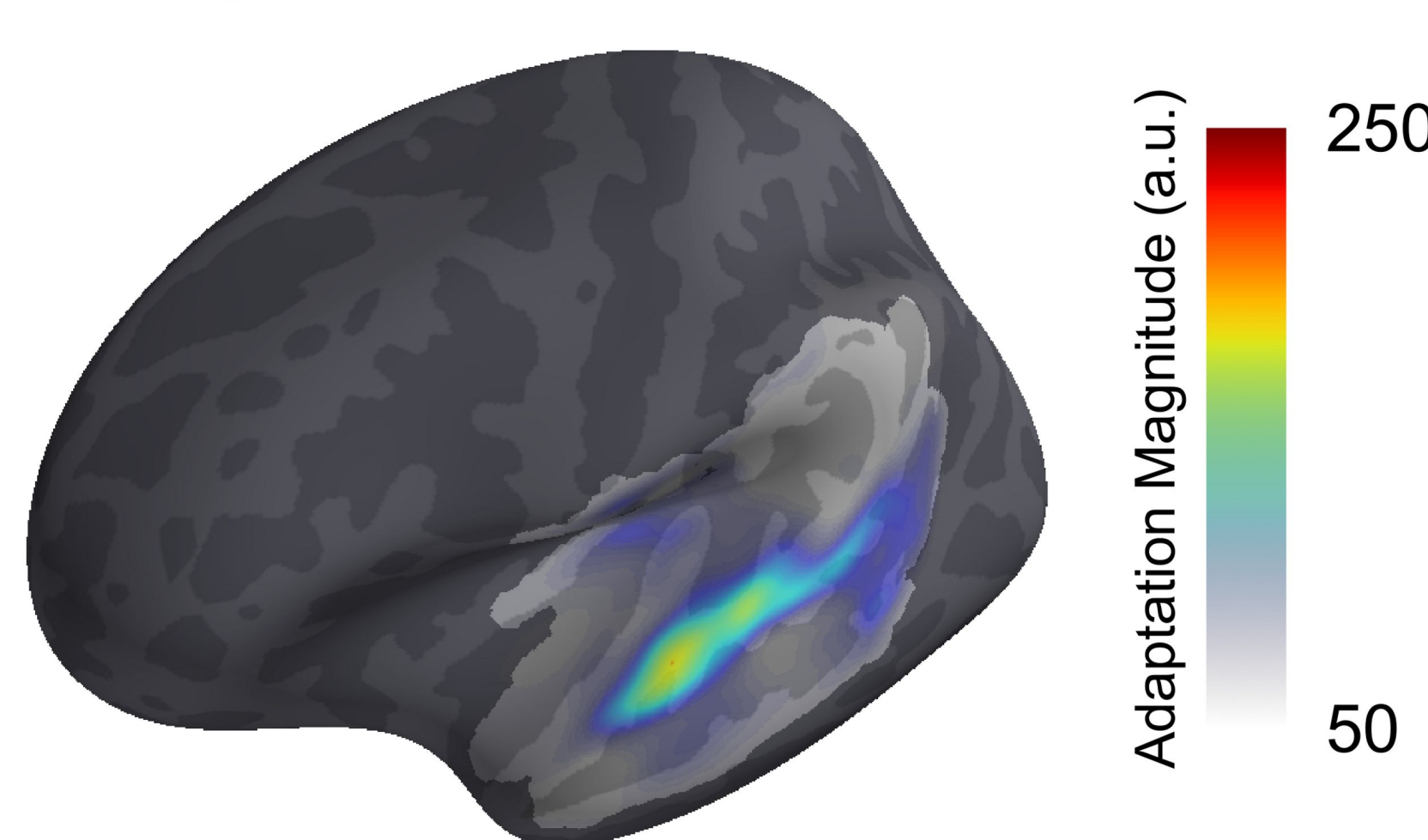
## Results

### Neural Adaptation to Repeated Speech (Variable > Repeated)

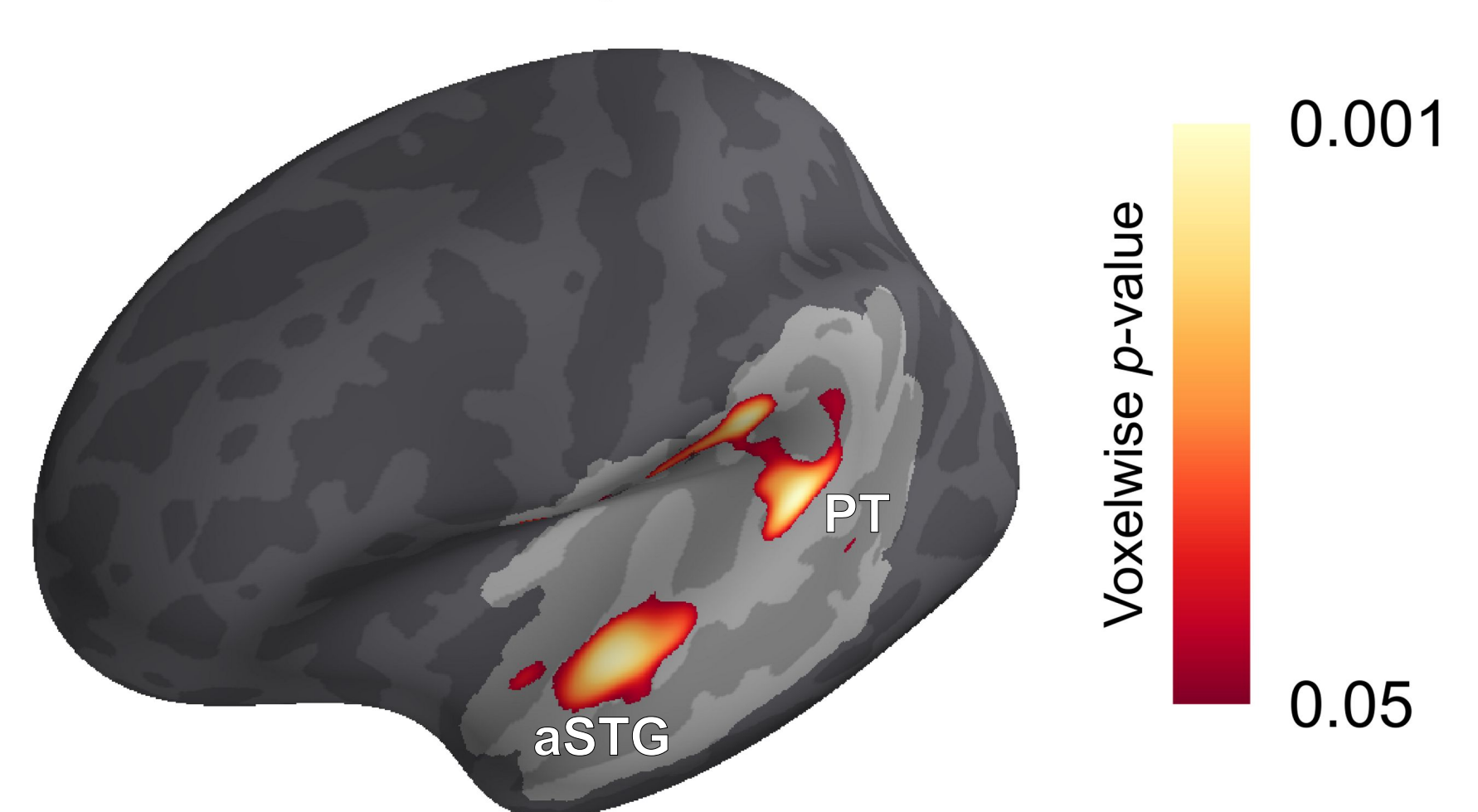
#### A. Control



#### B. Dyslexia



#### C. Control > Dyslexia

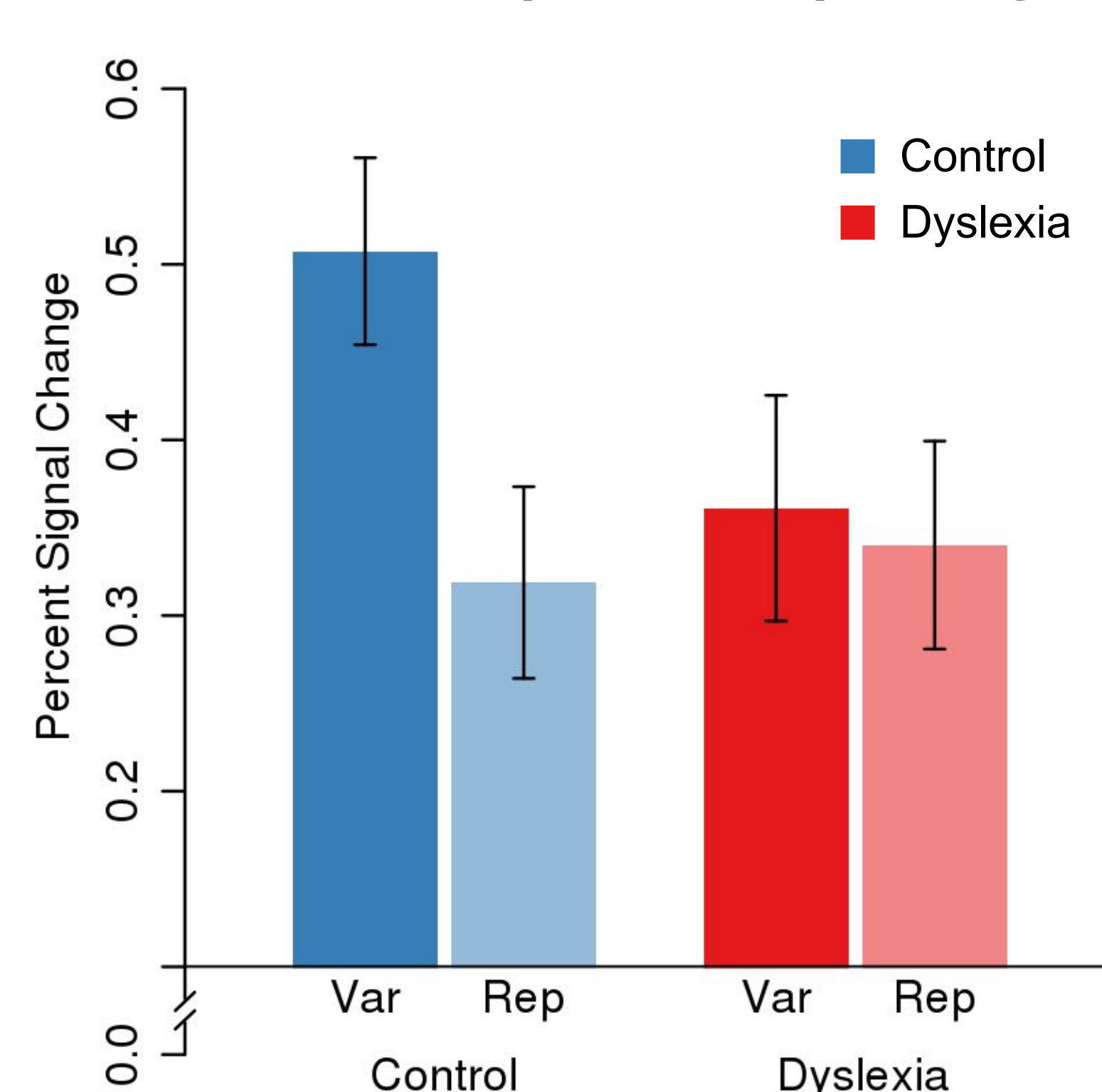


- Children with typical reading development showed extensive adaptation to repeated speech in the superior temporal lobe, especially aSTG.
- Outlines depict areas of significant adaptation (voxel  $p < 0.05$ , cluster FWE  $p < 0.05$ )

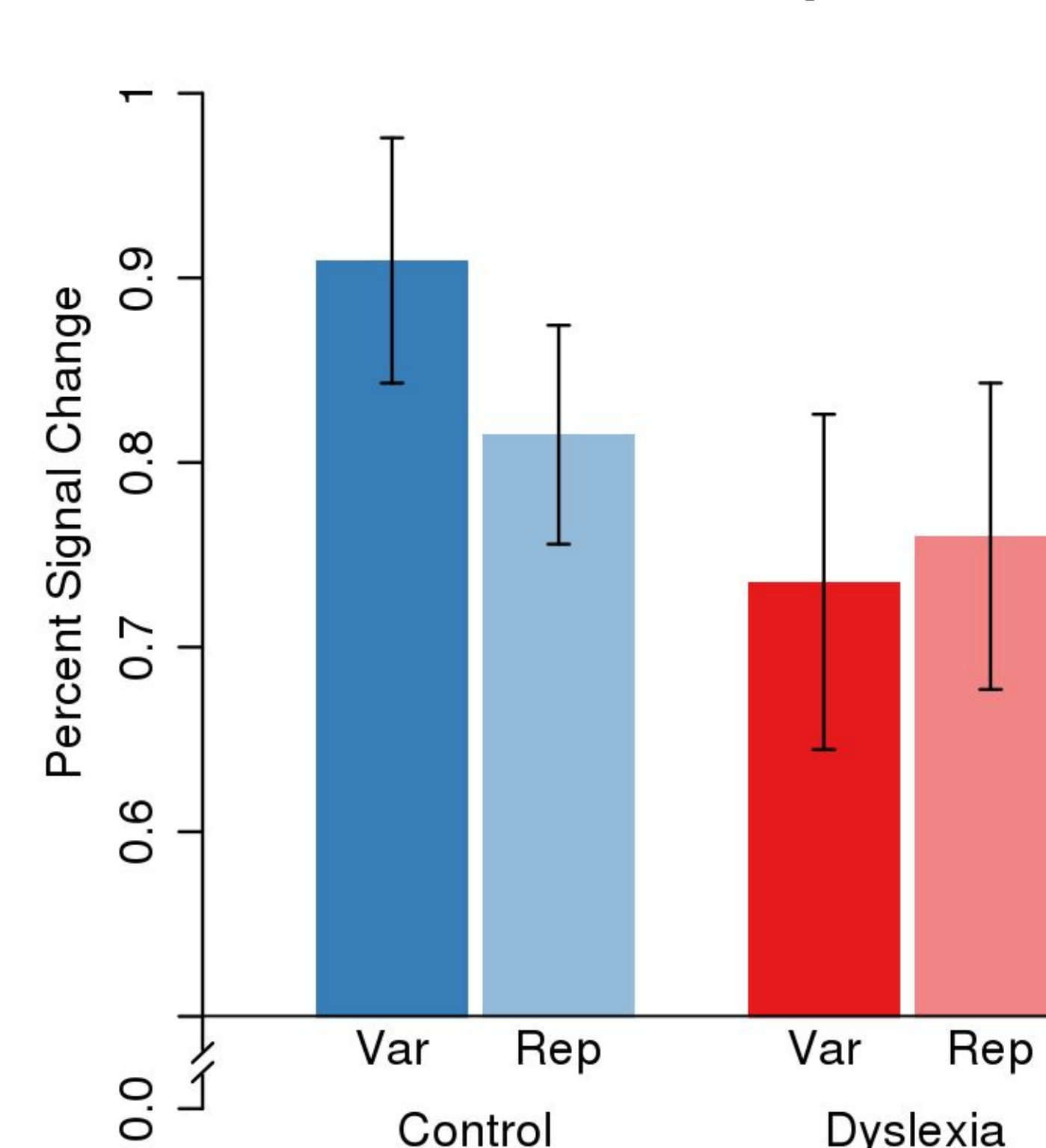
- Children with dyslexia exhibited minimal to modest adaptation over a more circumscribed area.
- The amount of adaptation to repeated speech was not significant in children with dyslexia.

- Directly contrasting the magnitude of adaptation between the two groups revealed areas of significantly diminished adaptation in children with dyslexia: (voxel  $p < 0.05$ , cluster FWE  $p < 0.05$ )
  - aSTG:** known to be important for processing speech content (Scott *et al.*, 2000)
  - PT:** known to be important for processing phonetic and phonological structure of speech. (Hickok, 2009)

### Anterior Superior Temporal Gyrus



### Planum Temporale



### In-scanner Behavior

	Control	Dyslexia	Difference
Motion (vol.)	14.6 ± 5.8	14.3 ± 6.7	$p = 0.88$
Task ( $d'$ )	6.0 ± 1.7	4.8 ± 2.1	$p = 0.05$

- BOLD responses ( $\beta$ -values) were extracted from anatomical ROIs based on a parcellation optimized for speech studies (Tourville & Guenther, 2012).
- Children with dyslexia show little response difference between variable and repeated stimulus presentation.
  - Relatively low BOLD response to both.
- Variable condition for typical readers produces greatest BOLD response.

## Discussion

- Children with dyslexia exhibit atypical neural adaptation to repeated spoken words in aSTG and PT: core auditory association areas for speech and phonological processing (Scott *et al.*, 2000; Hickok, 2009).
- Atypical adaptation to repeated speech stimuli in children with dyslexia closely reflects the same neurophysiological deficits seen on this task in adults with dyslexia (Perrachione, 2012).
- A neural insensitivity to repetition may impair detection of phonetic consistency, precluding development of the robust phonological representations that are critical for learning to read (Gabrieli, 2009).
- Different models of speech perception differentially emphasize the importance of phonetic-phonemic mapping for recognizing words (Goldinger, 1998).
- Children and adults with dyslexia may preferentially recognize spoken language via *episodic* routes, which emphasize mnemonic processes over top-down adaptation from phonetics to phonemes.
- May contribute to intact speech, but impaired reading, in dyslexia.

## References

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