Both behavioral and neural indices of phonological ability predict reading fluency in adults

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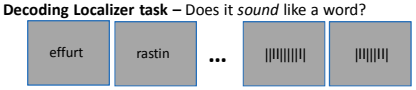
Introduction

- **Reading ability varies widely, even in adults.**
  - Like many cognitive abilities, reading ability lies on a continuum, with reading disabled individuals representing the bottom tail of a normal distribution (Scarborough, 1984; Shaywitz et al, 1992).
- **In the large bodies of literature on development and dyslexia, it is clear that phonological processing skill is an influential factor in reading ability.**
  - Children's performance on simple games that measure phonological awareness (e.g., rhyming), is predictive of later reading achievement (Stanovich, 1986; Wagner & Torgesen, 1987).
  - Converging evidence points to the hypothesis that phonological processing is the core deficit in developmental dyslexia (e.g., Ramus, 2001).
- **Hypothesis: Phonological processing skill should predict reading ability in adults at both the behavioral and the neural levels.**
  - Decoding ability, specifically, as measured by performance on pseudoword reading tasks, should positively correlate with reading fluency.
  - In addition, activity in the decoding network – inferior frontal gyrus (IFG) and superior temporal gyrus (STG), e.g. – should also correlate with reading ability.
- **The direction of the brain-behavior relationship is difficult to predict.**
  - The neural efficiency hypothesis – improved performance is achieved using fewer resources – would predict lower activity in highly skilled readers (Newman & Just, 2005).
  - Previous dyslexia literature –underactivation in posterior regions – would predict higher activity in highly skilled readers (e.g., Paulesu et al., 2001).

Methods

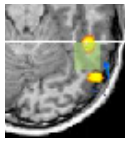
- Participants: 35 right-handed adults with average to above-average nonverbal IQ scores (as assessed by Woodcock-Johnson Tests of Cognitive Ability; Woodcock, McGrew & Mather, 2001).
- Standardized tests were administered in Session 1:
  - Reading: Gray Oral Reading Test (GORT), Nelson Denny (ND), Word ID
  - Decoding: Word Attack, Test of One Word Reading Efficiency (TOWRE)
  - Other: Verbal and Spatial IQ estimates, Processing Speed, Rapid Picture Naming
- "High skill" and "low skill" reading groups were created by median split of Reading Composite score (based on averaged GORT and ND)
- Structural and functional MRI data were acquired in Session 2:
  - **Decoding Localizer task –** Does it *sound* like a word?



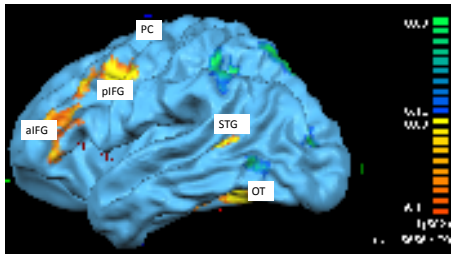
  - **Passage reading task –** (Read the stories at a natural pace; test after scan)

- Decoding regions were individually localized in each subject
- Region of Interest activity during single-word and passage reading tasks were compared across reading skill groups and correlated with Reading Composite scores.

Individual Localization of Decoding Network: Decoding – Barcode Judgment



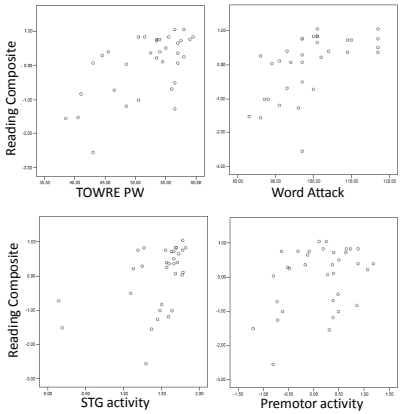
Individual Regions of Interest were localized using bounding boxes, defined by literature coordinates.



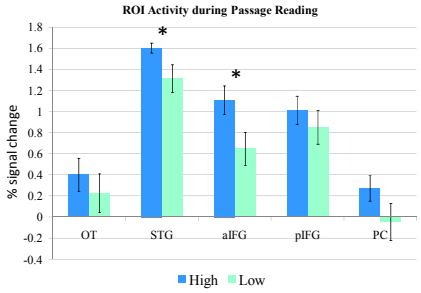
Example subject's 3D contrast map. Regions of Interest: anterior IFG, posterior IFG, Premotor Cortex, Superior Temporal Gyrus, and Occipitotemporal region

Correlations

		Reading Composite
Behavioral Performance	Word Attack	0.57**
	TOWRE Pseudoword	0.60**
	Word Identification	0.61**
	Rapid Picture Naming	0.33
	Processing Speed	-0.15
	Verbal IQ	0.45*
	Spatial IQ	0.12
Decoding ROI activity during Passage Reading	Occipitotemporal Region	0.30
	Superior Temporal Gyrus	0.44*
	Anterior Inferior Frontal Gyrus	0.25
	Posterior Inferior Frontal Gyrus	0.25
	Premotor Cortex	0.36*



ANOVA

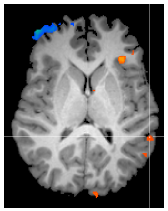


Effect of Reading Rate/ Exposure

- Correlations between number of passages read per block and ROI activity were non-significant
- Regression Analysis, with Composite Reading as Dependent Variable, revealed a unique contribution of STG activity to variance in reading ability

	R-square change (P)
I. Passages read per block	0.16 (<.05)
II. STG activity during Passage Reading	0.17 (<.05)

- Positive relationships were replicated in single-word localizer task. Highly skilled readers activated STG and portions of IFG to a higher degree:



Results

- This study's aim was to explain some of the variability in adults reading skill in terms of phonological decoding ability at the behavioral and neural levels.
- Performance on standardized decoding tests correlated positively with performance on reading tests.
- fMRI activity in the decoding network correlated positively with performance on reading tests, independently of reading rate.

Discussion

- These findings extend the relationship between phonological processing and reading ability, as seen in developmental and dyslexia literatures, to the skilled adult population.
- The imaging data provide support for the underactivation of posterior regions in poor readers, which is well documented in dyslexia literature, and indicate that some of this underactivation may be associated with poor phonological decoding.
- A novel contribution of this study is the use of a natural reading task in the scanner. The findings suggest that natural, fluent reading is achieved by online coordination of decoding and other processes.
- STG was one region within the decoding network that significantly contributed to reading ability. This relationship may be attributed to its involvement in grapheme-phoneme integration (vanAtteveldt et al, 2004), phonological learning (Majerus et al, 2005), or accessing lexical phonology (Graves et al, 2008).
- Increased premotor activity in good readers may reflect the positive influence of subarticulation on fluent reading.

Future Directions

- This study examined only one aspect of phonological processing, decoding. Future studies might focus on other types—e.g., phonemic awareness, verbal short term memory—in order to lend further support to the relationship between phonological processing and reading.
- The present findings did not lend support to the neural efficiency hypothesis. The hypothesis may only be applicable to skills more basic than reading, which requires a widely distributed network of activation. Components of network-wide efficiency may be a) increased use of core component processes, and b) decreased use of late-stage or compensatory processes, reflected in higher and lower activation in the respective substrates. Future studies might test this new hypothesis.