Structural MRI reveals correlations between individual differences in language-related cognitive abilities and thickness of language-relevant cortical areas

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Introduction

Inconsistent evidence of localized structural differences related to linguistic variables in neurotypical readers:

- Increased grey matter (GM) thickness in left posterior medial regions in resilient vs. poor readers (Welcome et al., 2011).
- Increased GM thickness in left angular gyrus as a function of increased print exposure (Goldman & Manis, 2013).
- Increased GM thickness in LIFG & bilateral STG associated with improved phonological processing (Lu et al., 2007).

BUT

- Reduced GM thickness in right fronto-parietal regions associated with greater processing speed (Lu et al., 2009).
- Reduced GM thickness in left lateral dorsal frontal and left lateral parietal regions associated with improved vocabulary ability (Sowell et al., 2004).

Most investigations have examined a restricted range, either of participants (e.g., university students), or of variables measuring individual differences in language-relevant cognitive abilities.

Current Goal

Examine connections between cognitive abilities and grey matter thickness in a non-clinical population.

- We used a community-based sample, rather than a convenience sample of university students (N = 39, 17 females, age 16 – 24)
- We used an extensive battery of cognitive assessments, including WMC, vocabulary, oral and reading comprehension, phonological processing, reasoning, and print exposure.

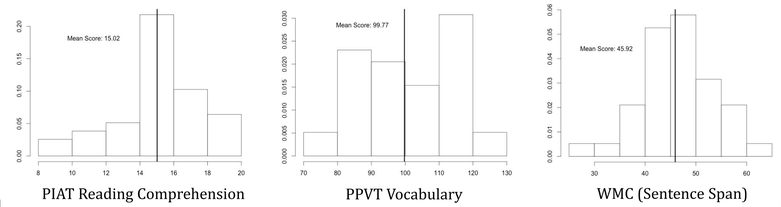
Hypotheses: Increased grey matter thickness may be associated with greater comprehension and/or phonological ability (e.g., Goldman & Manis, 2013); however, reduced grey matter thickness may result from greater phonological, naming, or vocabulary ability (e.g., Lu et al., 2007; Sowell et al., 2004).

Method

- Participants completed a behavioral assessment battery comprised of 16 measures covering a broad range of cognitive abilities.
  - Battery data was submitted to a Principal Components Analysis.
- A 1x1x1 mm high-resolution, three-dimensional T1-weighted sagittal acquisition was acquired (MPRAGE pulse sequence; TE: 3.66 ms; TR: 2530 ms; FA: 7 degrees; FOV: 256x256 pixels; slice thickness 1 mm; 176 slices).
- General linear model analyses were carried out with the Freesurfer image analysis suite (http://surfer.nmr.mgh.harvard.edu).
  - Clusterwise correction for multiple comparisons was applied during the analysis (Hagler et al., 2006).

Results: Individual Differences

Broad range of cognitive abilities in the community sample, e.g.:



PIAT Reading Comprehension | PPVT Vocabulary | WMC (Sentence Span)

- **Following Kaiser's stopping rule (1960) and a scree test (Cattell, 1966), we extracted four varimax-rotated factors explaining 76% of the variance.**
- **These factors align with those identified as important in our previous work (e.g., Braze et al., 2007; Kuperman & Van Dyke, 2011).**
- **ID variables, factors, and highest factor loadings:**

PHONOLOGICAL ABILITY 27%

CTOPP – Phonological awareness	(.72)
Gray Oral Reading Test – fluency	(.52)
Pseudohomophone ID	(.79)
TOWRE (Nonwords)	(.73)
WJ-3 Word Attack	(.86)

COMPREHENSION ABILITY 25%

WJ-3 Word ID	(.68)
Magazine Recognition Test	(.78)
WASI Matrix Reasoning	(.59)
Peabody Picture Vocabulary Test	(.84)
PIAT – Reading Comprehension	(.70)
PIAT – Listening Comprehension	(.62)
Stanford Fast Reading	(.69)
WJ-3 Reading Fluency	(.58)

PROCESSING SPEED 15%

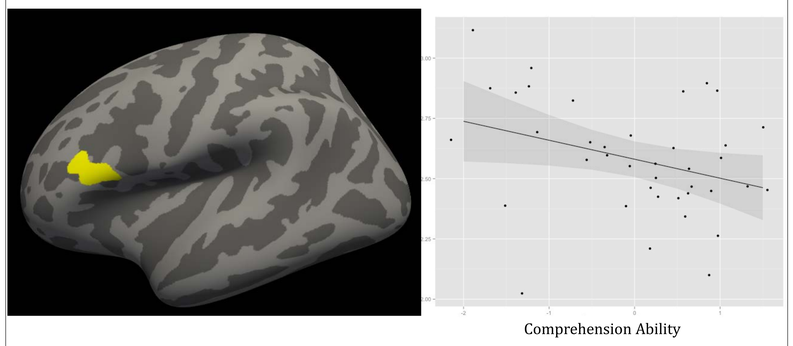
CTOPP – Rapid Letter Naming	(.88)
TOWRE (Words)	(.76)

WORKING MEMORY 9%

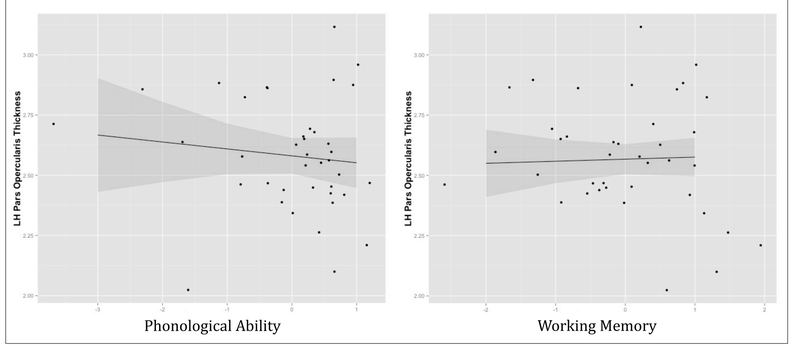
Listening Span (WMC)	(.89)

Results: MRI

Initial results indicate that Comprehension Ability is associated with cortical thickness of *pars opercularis* (BA 44). Higher comprehension ability is correlated with reduced grey matter thickness (p = .041).



In addition, we also observed a GM thickness x Phonological Ability x Working Memory interaction (p = .0482) in pars opercularis, also indicating that higher ability was associated with reduced GM thickness.



Conclusions

- Higher comprehension ability, phonological ability, and WMC were associated with GM *thinning*, rather than GM thickening. This is consistent with developmental accounts of cortical thinning in areas associated with skilled and/or mature performance, e.g., motor skills (Sowell et al., 2004).
  - BUT: Thinning was not observed in Broca's Area in Sowell et al. (2004).
- BA 44 is associated with critical higher-level language functions (e.g., sound-to-articulation mapping, Saur et al., 2008, 2010; processing non-adjacent elements in syntactically complex (Friederici, 2011) and non-canonical input (Braver et al., 2011). It has also been associated with conflict resolution ability (January et al., 2008; Novick et al., 2005).
- Suggests that language-relevant cortical structures continue to mature well into adolescence/young adulthood.

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SELECTED REFERENCES: Braze, D., Tabor, W., Shankweiler, D., & Mencl, W. (2007). Speaking up for vocabulary: Reading skill differences in young adults. *Journal of Learning Disabilities,* 40(3), 226-243 • Goldman, J. & Manis, F. (2013). Relationships among cortical thickness, reading skill, and print exposure in adults. *Scientific Studies of Reading, 17*, 163-176. • Sowell, E., Thompson, P., Leonard, C., Welcome, S., Kan, E., & Toga, A. (2004). Longitudinal mapping of cortical thickness and brain growth in normal children. *Journal of Neuroscience, 24*(38), 8223-8231.