Neural Activation of Semantic Networks Contribute to Reading Comprehension Skill

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Introduction

About 10% of individuals exhibit reading comprehension (RC) deficits despite intact cognitive and phonological processing.

We propose that these deficits may be due to weak semantic processing systems for printed and spoken language comprehension.

Here we examine neural activity underlying both word- and passage-level processing in the visual and auditory modalities and its relation to RC using Partial Least Squares analysis (PLS).
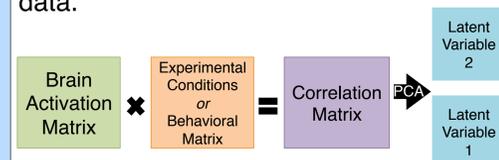
PLS

PLS is a multivariate data-driven method particularly useful for exploring relationships between brain activity and behavioral measures or experimental conditions, allowing for investigation of these relationships without top-down constraints on the outcome.

Task PLS reveals the relationship between brain activation and experimental conditions.
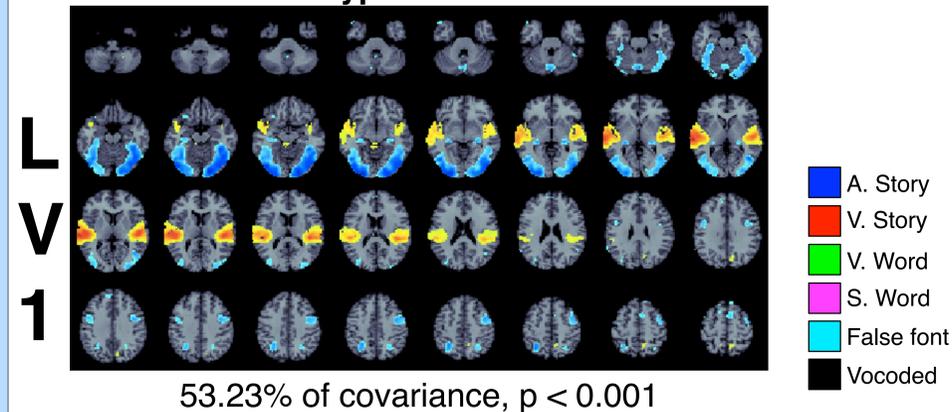
Design scores show how each LV relates to the conditions of the experimental design.

Behavioral PLS reveals the relationship between brain activation and behavioral data.
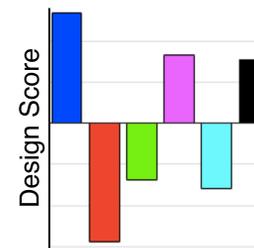
Brain Activation Matrix × Experimental Conditions *or* Behavioral Matrix = Correlation Matrix → PCA → Latent Variable 2 / Latent Variable 1

Results I: Task PLS

Hypothesis 1

L V 1

53.23% of covariance, p < 0.001
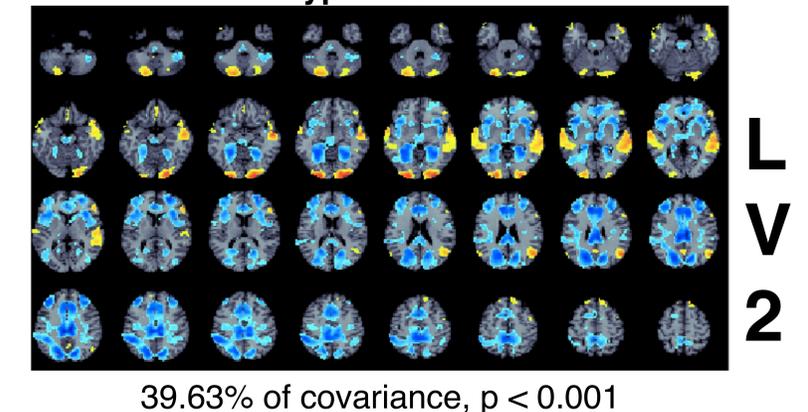
Blue regions show more activation during visual conditions: fusiform gyrus/visual wordform area (VWFA), extrastriate cortex. Red regions show more activation during auditory conditions: superior temporal gyrus (STG), middle temporal gyrus (MTG).

Hypothesis 2

L V 2

Legend:
- A. Story (blue)
- V. Story (red)
- V. Word (green)
- S. Word (magenta)
- False font (cyan)
- Vocoded (black)

39.63% of covariance, p < 0.001

Blue regions show more activation during the word task: medial fusiform, anterior cingulate cortex (ACC). Red regions show more activation during the story task: right angular gyrus (rAG), bilateral anterior temporal lobe (ATL), extrastriate cortex.

Design Score
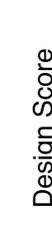
Methods & Hypotheses

Two fMRI tasks (N = 28, M Age = 16.90, 18 F):
- **Word Task** (4 event types) *event-related*
  - Visual word: Printed real words, e.g. roof
  - Spoken word: Spoken real words, e.g. "post"
  - False font: Printed symbols, e.g. ♦□✠●
  - Vocoded speech
- **Story Task** (2 block types) *blocked*
  - Excerpts of a narrative presented aurally (Audio condition) or visually (Visual condition)
- **Behavioral Measures**
  - Kaufman Test of Education Acheivement (KTEA) reading comprehension

Task PLS Hypotheses:
1) Print and speech conditions should dissociate across tasks.
2) Story and Word tasks should dissociate.

Behavioral PLS Hypotheses:
3) RC is related to activation in semantic areas during passage comprehension, regardless of modality.
4) RC is related to the difference in activation in semantic areas during written word and passage comprehension.

Results II: Behavioral PLS

Hypothesis 3

84.68% of covariance, p < 0.001

RC Correlation
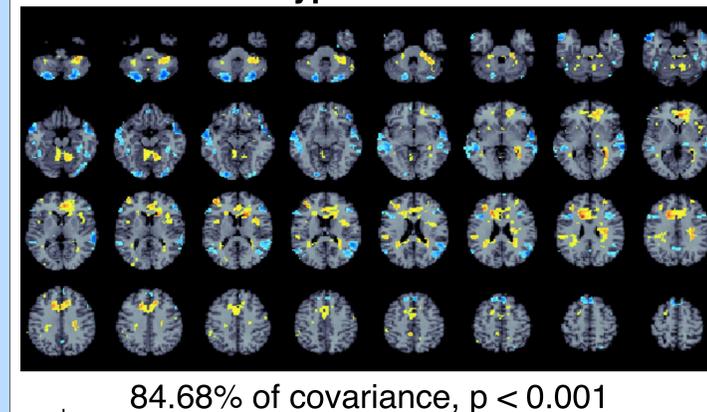
Blue regions show areas positively correlated with RC: anterior temporal pole (ATP), middle temporal gyrus (MTG), angular gyrus (AG). Red regions show areas negatively correlated with RC: anterior cingulate cortex (ACC).

- A. Story (blue)
- V. Story (red)

Hypothesis 4

57.71% of covariance, p < 0.001

RC Correlation
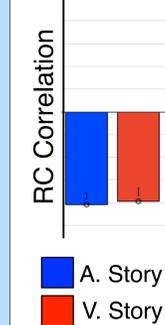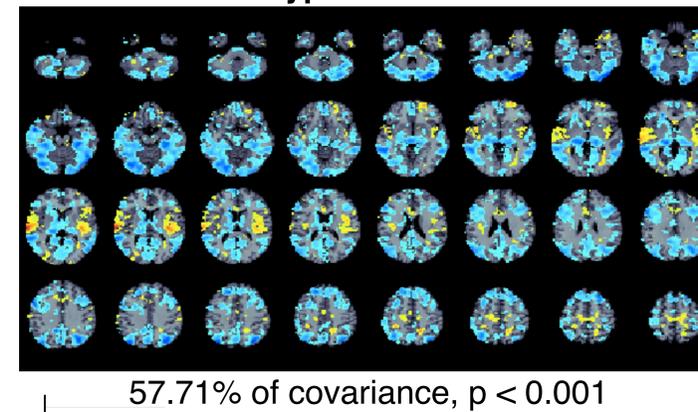
Blue regions show areas positively correlated with RC: visual wordform area (VWFA), extrastriate cortex, thalamus, hippocampus. Red regions show areas negatively correlated with RC: superior temporal gyrus (STG), insula.

- V.Story (red)
- V. Word (green)
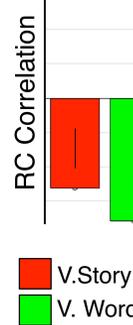
Discussion

Task PLS
1) Visual areas (VWFA, extrastriate) do activate differently than auditory processing regions (STG) in visual vs. auditory conditions of both tasks.
2) Areas involved in comprehending sentences (ATL, rAG) activate more in the story task, and regions involved in single-word comprehension (medial fusiform) and switching among stimuli (ACC) activate more in the word task.

Behavioral PLS
3) Better comprehenders show more semantic activation (MTG) in the passage task *regardless of modality*.
4) Better comprehenders show more visual activation (VWFA, occipital) in *both* written passage and word tasks. Poorer comprehenders show phonological processing (STG) in response to *both* written tasks.

References
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Lee, Y., Anaki, D., Grady, C. L., & Moscovitch, M. (2012). Neural correlates of temporal integration in face recognition: An fMRI study. *NeuroImage*, *61*(4), 1287–1299. doi: 10.1016/j.neuroimage.2012.02.073