Mapping Memory Retrieval and Structure Building in the Brain

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Introduction

Natural language comprehension relies on at least two cognitive processes:

- Retrieval of memorized elements
- Structural composition

Retrieval is formalized here using "multiword expressions" or MWEs, word clusters that frequently co-occur and are taken to be non-compositional.
Structure-building is formalized using a parsing algorithm to model syntactic composition (see Hale, 2014).

Questions

Where are these two language processing functions localized in the brain?
Are more cohesive MWEs more likely to be retrieved than others?

Data Collection

Participants (n=51) were college-aged, right-handed, native English speakers.
Listened to a spoken recitation of *The Little Prince* for 1 hour and 38 minutes across nine separate sections; 15,388 words in total.
Comprehension was confirmed through multiple-choice questions at the end of each section.

Analysis

Preprocessing was carried out with AFNI version 16 and ME-ICA v3.2 (Kundu et al., 2011).
MWE predictor and parser action count, convolved with HRF, regressed against observed BOLD signal during passive story listening.
GLM analysis includes four regressors of non-interest: word offset, frequency, pitch, intensity.

Predictors

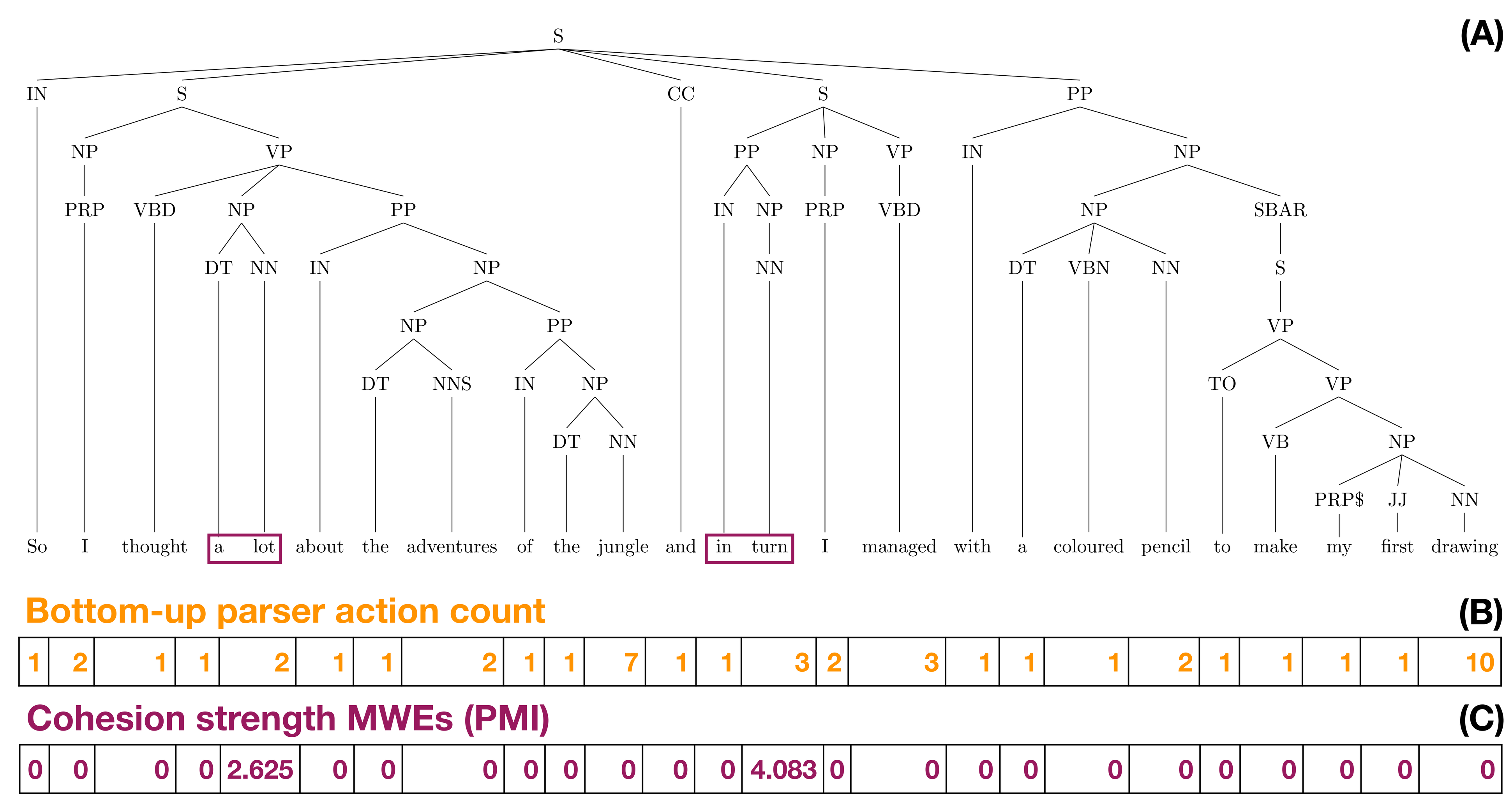

Figure 1: Comparing the word-by-word predictors on a single sentence

Bottom-up Parser Action Count

The number of steps that a bottom-up phrase structure parsing algorithm would take at each word defines a syntactic complexity metric, as shown in Fig. 1.
This predictor is meant to reflect the structure-building effort in the brain.

Multiword Expressions

742 MWEs were identified in the dataset through a transition-based MWE analyzer (Al Saied et al., 2017).
These word clusters were quantified using a measure, Pointwise Mutual Information, calculated using the formula below with frequency counts from COCA

$$\mathrm{PMI} = log_2 \frac{c(w_n^1)}{E(w_n^1)} \quad (1)$$

Conclusion

1. Phrase structure composition involves Inferior Frontal Gyrus and Anterior Temporal region, consistent with earlier studies (Brennan et al., 2012; Pallier et al., 2011; Snijders et al., 2009).
2. Positive correlation of PMI in Precuneus and Supplementary Motor Area suggest that more cohesive expressions rely on these areas.
3. Less cohesive MWEs activate core areas of the language network implicated in composition.

Result

Structure-building correlates with widespread bilateral activity, particularly in Anterior Temporal Lobe and Inferior Frontal Gyrus.
Increasing cohesiveness of MWEs, positively correlates with Precuneus and Supplementary Motor Area activation.
Activity in Left Pars Triangularis, bilateral Pars Opercularis and posterior Middle Temporal Gyrus was observed in proportion to decreasing lexical cohesion.

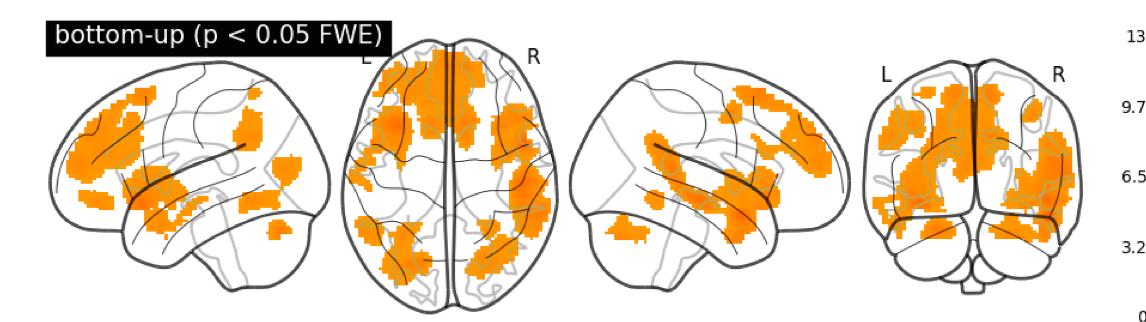

Figure 2: Significant clusters for bottom-up parser action count after FWE voxel correction ($p < 0.05$ & $k > 50$).

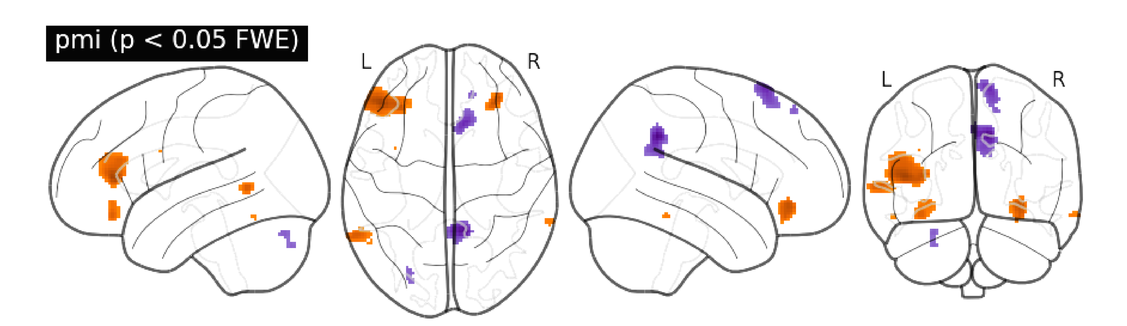

Figure 3: Significant clusters for multiword expressions after FWE voxel correction ($p < 0.05$ & $k > 50$). Increasing cohesion measures are represented in violet and decreasing cohesion measures are represented in orange.

Acknowledgements

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Selected References

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