Investigating the role of context in comprehension using topical surprisal: An fMRI study

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Research Question

1. How does topical context affect our predictions about the next word?
2. Based on those predictions, how does it affect our incremental language processing?

Key Ideas

- Adapt surprisal from information theory to operationalize topical context
- When surprisal is high, the current word is unexpected and cognitive processing effort increases accordingly
- Test this new metric against an analysis of fMRI timecourses collected during naturalistic language comprehension

Prior Work

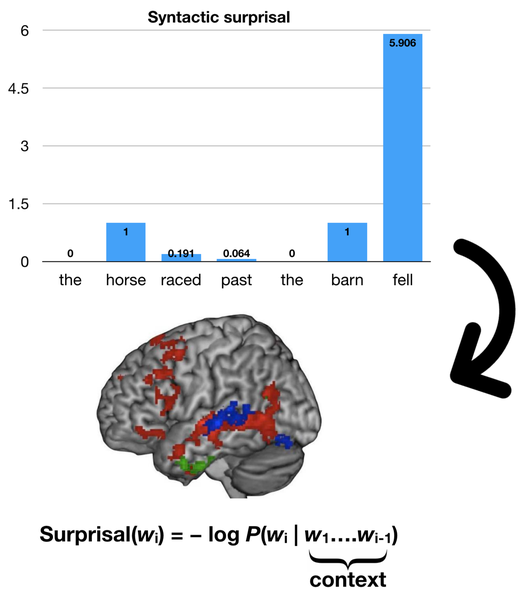
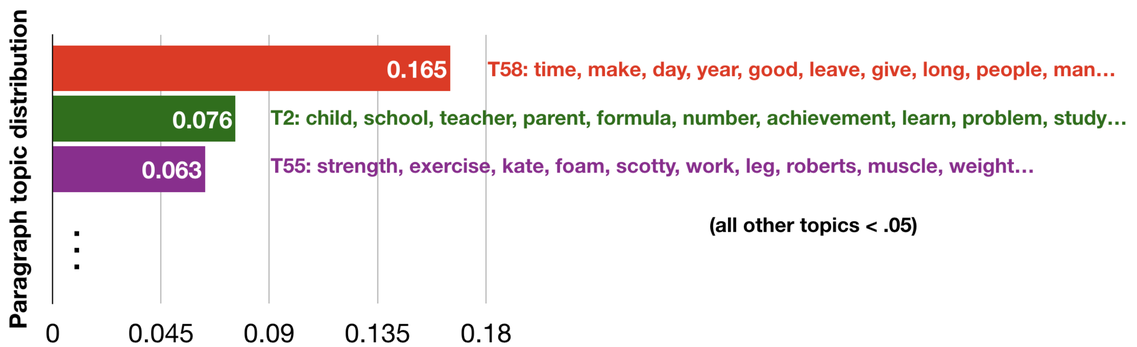


Figure 1:Adapted from Hale (2001) & Brennan et al. (2016)

Topical Surprisal

*During the fifty-four years that I've lived on this planet, I've only been disturbed three times. The first time was twenty-two years ago, by some scatterbrain who fell from god knows where. He made the most dreadful noise, and I made four mistakes in a sum. The second time was eleven **years** ago, by an attack of rheumatism. I don't get enough exercise. I don't have time to stroll about. I am a man of consequence. The third time—well, this is it! I was saying, then, five-hundred-and-one million—*



Pr(*years*|T58) = 0.021, Pr(*years*|T2) = 0.007, Pr(*years*|T55) = 0.005…

$$\text{surprisal}_c(\textit{years}) = -\log \sum_{\text{topic in Topics}} P(\textit{years} \mid \text{topic})\, P(\text{topic} \mid \text{context } c)$$

Topics can be defined and probabilities estimated using a topic model (LDA, Blei et al., 2003)

Estimated a 100-topic model using the Brown corpus (Francis & Kučera, 1964)

Computed topical surprisal for 6,243 non-function words using the paragraph containing the word as its context

Data Collection

51 college-aged, native English speakers listened to *The Little Prince* for 1 hour & 38 minutes across nine separate sections; 15,388 words in total.
Comprehension confirmed through multiple-choice questions (90% accuracy, SD = 3.7%).

fMRI Analysis

Preprocessing was carried out with AFNI version 16 and ME-ICA v3.2 (Kundu et al., 2011).
Topical surprisal predictor, convolved with canonical HRF in SPM12, regressed against observed BOLD signal during passive story listening.
GLM analysis includes four regressors of non-interest: word offset, frequency, pitch, intensity.

Results

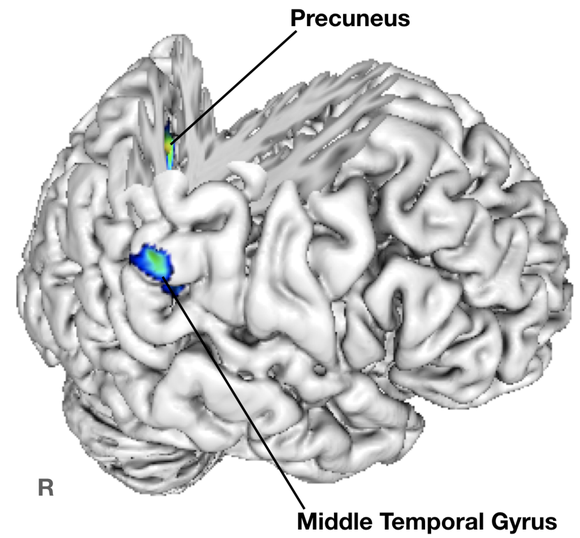


Figure 2:Whole brain contrast image with significant clusters for topical surprisal after FWE voxel correction with $p < 0.05$

Take-aways

- Results corroborate previous work on lexical access and semantic integration (Binder et al. 2009, Graves et al. 2010, Hickok & Poeppel, 2007, Hagoort & Indefrey, 2014)
- Pattern of activation for topical surprisal differs from those reported for lexical surprisal (bilateral ATL & left IFG) and syntactic surprisal (bilateral ATL & left IPL) by Brennan et al., (2016)
- Indicates the centrality of these rMTG & rPrecuneus in processing contextual information during language comprehension and suggests topical surprisal as a cognitively plausible metric.

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