Bottom-up and Top-Down Propagation of Residual Information Across the Left Fronto-temporal Cortex during Sentence Comprehension: Converging Evidence from M/EEG and Predictive Coding Simulations

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Introduction

Language comprehension: Flow of information across cortical hierarchy

N400 (300–500ms): Evoked by unpredicted words, modulated by predictability. *Feedforward* mapping of lexical representation to semantic features [1,2,3]

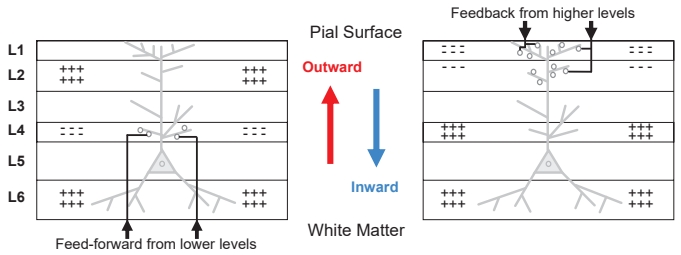
Late Frontal Positivity (LFP, 600–1000ms):

- Sometimes selectively evoked by mispredicted, plausible words [4,5]
- Sometimes evoked by all unpredicted words, modulated by predictability [6,7]

? Higher-level updating & *feedback* [4,5,8]

***Hypothesis*: Reversal of information flow: 300–500ms ⟶ 600–1000ms**

Approach 1: Neurophysiology: MEG Dipole Reversals



Vision object recognition: Dipole reversals in fusiform cortex, consistent with feedforward → feedback ← models [9]

Language comprehension: Mispredicted words: Left temporal cortex 300-500ms → Re-activated with opposite dipole polarity 600–1000ms [10]

Approach 2: Cognitive: Predictive Coding Simulations

PC: *Network architecture* of feedforward and feedback connections + *Optimization algorithm* that approximates Bayesian inference [11-15]

Explains dynamics & functional properties of the N400 as *residual bottom-up lexico-semantic error,* information in input not predicted by higher-level states [16]

Methods

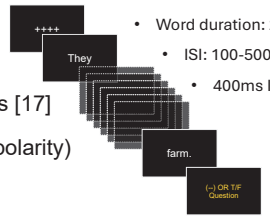
Expected: They raised pigs on their… **farm** (M=89.13%[SD=7.1%];n=210)

Unexpected: They were attacked on their… **farm** (M=0.93%[SD=1.6%]; n=210)

31 native English speakers

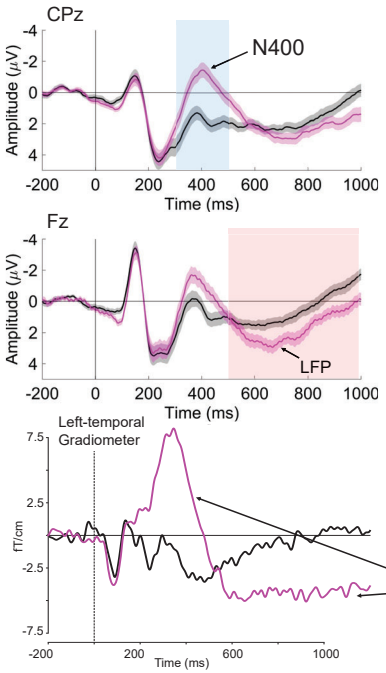
Combined M/EEG + Structural scans [17]

MEG source localization (Retained polarity)



- Word duration: 200ms
- ISI: 100-500ms
- 400ms ISI on SFW

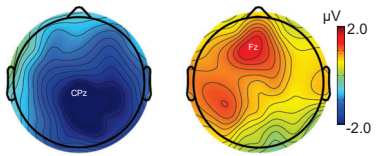
M/EEG Results



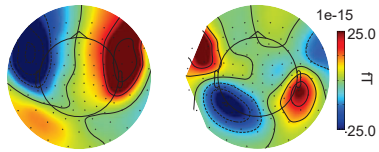
Unexpected – Expected

300-500ms **600-1000ms**

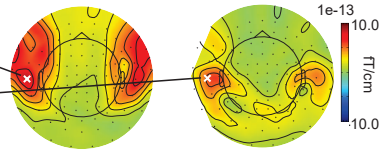
ERPs



MEG: Magnetometers



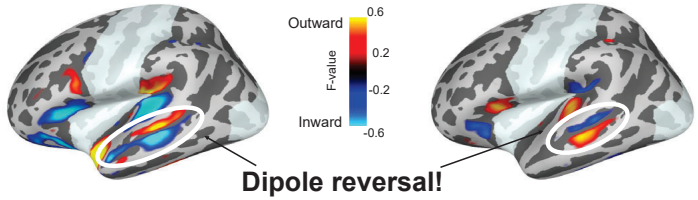
MEG: Gradiometers



Polarity change: compatible with a dipole reversal in cortex BUT NOT diagnostic

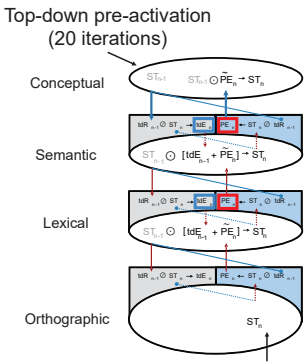
MEG Source Activity: Unexpected – Expected

300-500ms **600-1000ms**



Dipole reversal!

Simulation Results



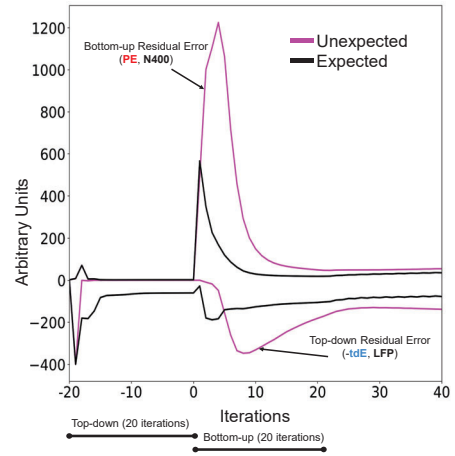
Expected: Target pre-activation: 90% (remaining activation across remaining units)

Unexpected: Target pre-activation: 0% (all words uniformly pre-activated)

Residual lexico-semantic error

Simulated N400: Bottom-up error

Simulated LFP: Top-down error



Unexpected:

"N400" window: Semantic features of target + orthographic neighbors activated→ ↑bottom-up error (propagated up hierarchy)

"LFP" window: Semantic features of orthographic neighbors→ ↑top-down error (propagated back down hierarchy)

Expected:

"N400" window: Pre-activation of target→↓bottom-up error

"LFP" window: Pre-activation of target→ reduced activation of semantic features of orthographic neighbors→↓top-down error (see Poster E35 for more!)

Discussion

- **Neurophysiological:** Feedforward dipole (300–500ms) to feedback dipole reversal (600–1000ms)
- **Cognitive:** Feedforward, residual bottom-UP error and feedback, residual top-DOWN error
- **Converging evidence:** Reversal of cortical information flow to incoming words during sentence comprehension

Acknowledgements & References

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References: [1] Kutas & Hillyard (1984). *Nature;* [2] Kutas & Federmeier (2011). *Annual Review of Psychology;* [3] DeLong, Urbach, & Kutas (2005). *Nature;* [4] Federmeier et al., (2007). *Brain Research;* [5] Kuperberg, Brothers, & Wlotko (2020). *JCN;* [6] Payne & Federmeier (2017). *JCN;* [7] Rommers & Federmeier (2018). *Cortex;* [8] Brothers et al., (2020). *Neurobiology of Language;* [9] Ahlfors et al., (2015). *Neuroscience letters;* [10] Wang et al., (2023). *Cerebral Cortex;* [11] Mumford (1992). *Biological cybernetics;* [12] Rao & Ballard (1999). *Nature;* [13] Lee & Mumford (2003). *JOSA;* [14] Spratling (2008). *Vision research;* [15] Spratling (2016). *Cognitive processing;* [16] Eddine et al., (2024). *Cognition;* [17] Gramfort et al., (2013). *Frontiers in Neuroinformatics*