Larger responses to unexpected words between 300–500 ms carry item-specific information in temporal but not inferior frontal cortex: Evidence from MEG representational similarity analysis

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Background

- During language comprehension, less predictable words → larger neural response 300–500 ms (N400) [1]
  - Sources: left temporal cortex; sometimes left inferior frontal cortex [2, 3, 4]
  - Often interpreted as reflecting "prediction error" [5, 6, 7, 8]

Functional significance of PE

- ? Magnitude only: Scalar signal: How much the outcome deviates from prediction
- ? Magnitude + Content: Also preserves item-specific information about the unpredicted input
- ? Hybrid account: Different functions at different levels of the cortical hierarchy

The Challenge

- Traditional event-related analyses: Cannot distinguish response magnitude from representational content
- MEG + Spatial RSA: Used to detect item-specific patterns encoding prior predictions [9], that are reinstated by expected input between 300–500ms [10] within left temporal cortex [11]
- Does the larger 300–500ms response to unexpected input also carry item-specific information?

This Study

- MEG evoked responses + RSA to test whether 300–500ms expectancy-sensitive regions carry item-specific information
- Item-paired design enabled same-word vs. different-word comparisons
- Test the same logic in an implemented predictive coding model [8, 12]

Design & Stimuli

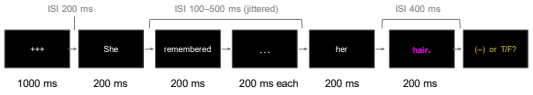
Each unexpected and expected critical word appeared twice per participant, in two different sentence contexts

Unexpected (low constraint context)

She remembered that she wanted to talk about her **hair** — same word (within-pair)
The congresswoman decided it was time to change her **hair**
— different words (between-pair)
She eventually threw it away, because the risotto was too **sour** — same word (within-pair)
Our kids get upset when they receive something that is **sour**

Expected (high constraint context)

When it gets tangled, she has to comb her **hair** — same word (within-pair)
She went to the beauty parlor to perm her **hair**
— different words (between-pair)
She made a funny face because the lemon was too **sour** — same word (within-pair)
The baby's lips pucker when she eats something that is **sour**



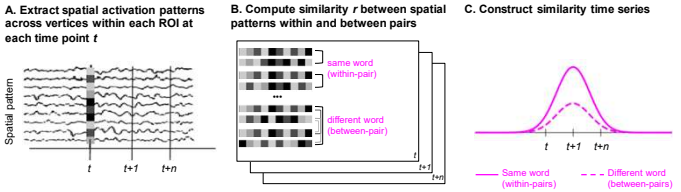
Methods

29 datasets · MEG (306 channels) · MNE-Python · single-trial minimum-norm source estimates on fsaverage

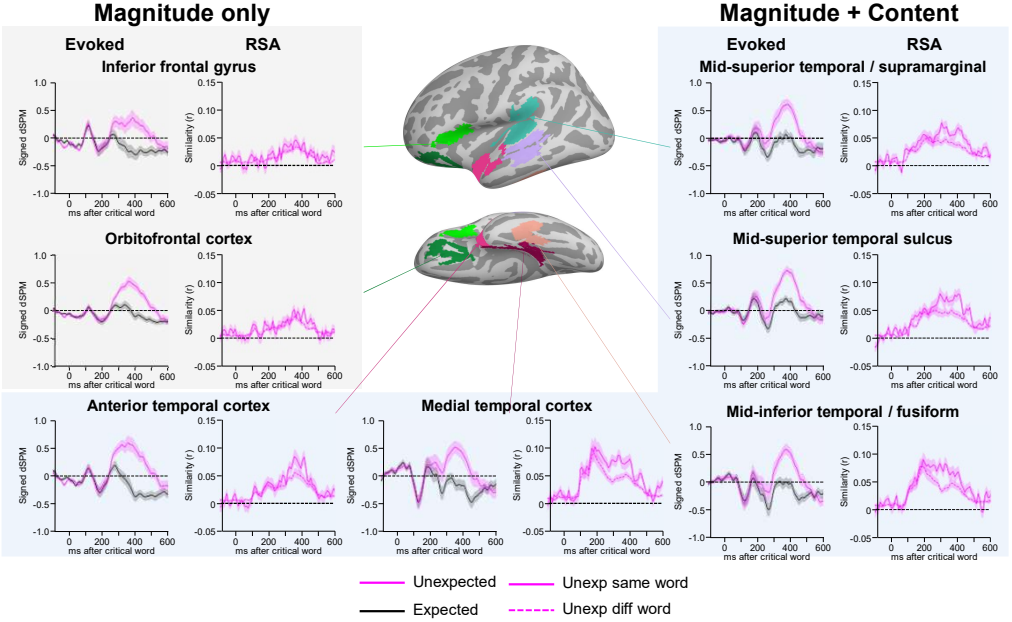
1. Define ROIs from the evoked expectancy effect

- Unexpected > Expected, 300–500 ms
- signed dSPM; cluster-based permutation
- → seven left-hemisphere clusters, each treated as ROIs for RSA

2. RSA: Does unexpected response encode word identity within each ROI?



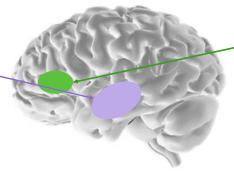
Results



Discussion

Temporal cortex
Magnitude + Content

- Unexpected > Expected
- Same-word > different-word similarity
- Carries item-specific information up the hierarchy
- Updates higher-level representations (cf. [13])



Inferior frontal cortex
Magnitude only

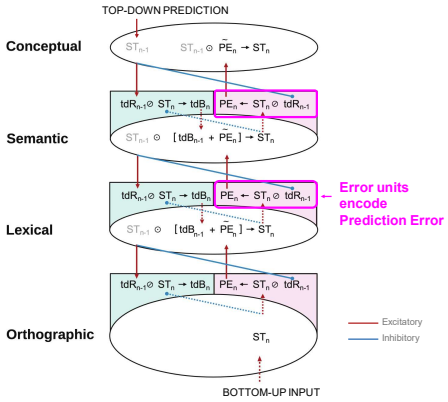
- Unexpected > Expected
- Little item-specific similarity
- May serve as a teaching signal for learning and adaptation (cf. [14, 15])

- N400-window responses to unexpected words have different functional roles across the cortical hierarchy
- Predictive coding model shows how prediction error can carry both overall magnitude and item-specific structure

Predictive coding model

How can the same architecture produce a larger neural response to unexpected than expected words while preserving item-specific information within temporal cortex?

Implemented predictive-coding model of lexico-semantic processing [8, 12]

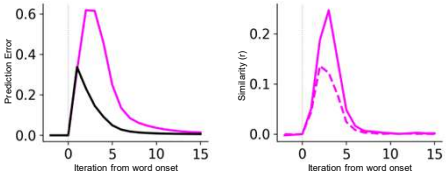


Apply the same evoked & RSA analyses to outputs of simulations at the lexical and semantic levels

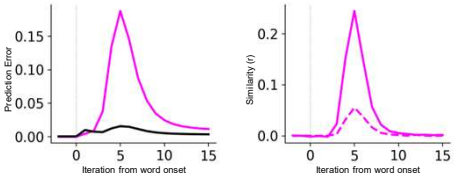
Prediction Error
Unexpected > Expected

Similarity
Unexp. same word > Unexp. diff word

Lexical level



Semantic level



References

[1] Kutas M, Hillyard SA. Nature 1984;307:161–3. [2] Wang L, et al. Cereb Cortex 2023;33:4478–97. [3] Helenius P, et al. Brain 1998;121:1133–42. [4] Lau EF, et al. Nat Rev Neurosci 2008;9:920–33. [5] Brouwer H, et al. Cogn Sci 2017;41:1318–52. [6] Rabovsky M, et al. Nat Hum Behav 2018;2:693–705. [7] Fitz H, Chang F. Cogn Psychol 2019;111:15–52. [8] Nour Eddine S, et al. Cognition 2024;246:105755. [9] Wang L, et al. eLife 2018;7:e39061. [10] Hubbard RJ, Federmeier KD. Cereb Cortex 2021;31:4300–13. [11] Wang L, et al. NeuroImage 2025;308:120977. [12] Nour Eddine S, Yacovone A, Kuperberg GR. Under review. [13] Rao RPN, Ballard DH. Nat Neurosci 1999;2:79–87. [14] Schultz W, et al. Science 1997;275:1593–9. [15] Dell GS, Chang F. Phil Trans R Soc B 2014;369:20120394.

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