Cross-level predictions in language processing

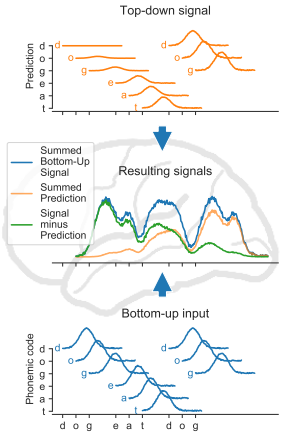
Research Question

Predictive processing of language is well supported

- well known neurocognitive correlates (e.g., N400; [5])
- … typically *within* one level: i.e., from word meaning to word meaning

Predictive Coding theory [1] suggests *hierarchical* predictions

- lower levels influenced by higher levels (e.g., word *forms* predicted by word *meanings*)
- levels play out on different time scales
- initial support for these questions [2] has been questioned [6]
- **Hypothesis**: Predictive coding suggests lower-level (e.g., phonemic) representations should be less strong for more higher-level (e.g., semantically) predictable words



References

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[3] G. M. Di Liberto, J. A. O'Sullivan, and E. C. Lalor. Low-frequency cortical entrainment to speech reflects phoneme-level processing. *Current Biology*, 25(19):2457 – 2465, 2015.

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[5] M. Kutas and K. D. Federmeier. Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual review of psychology*, 62:621–647, 2011.

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Methods

Potsdam Sentence Corpus

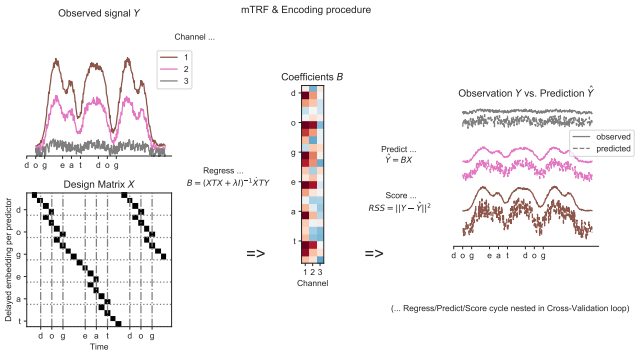
- 144 German sentences, with cloze ratings for each word [4]
- MEG (n=25) and EEG (n=35)

Compute strength of phonemic representations

- fit continuous phoneme encoding model/mTRF [3] to MEG/EEG data
- calculate absolute (cross-validated) residuals per time point and channel (roughly: how similar is the neural activity induced by each phoneme token to the idealized template for that phoneme?)

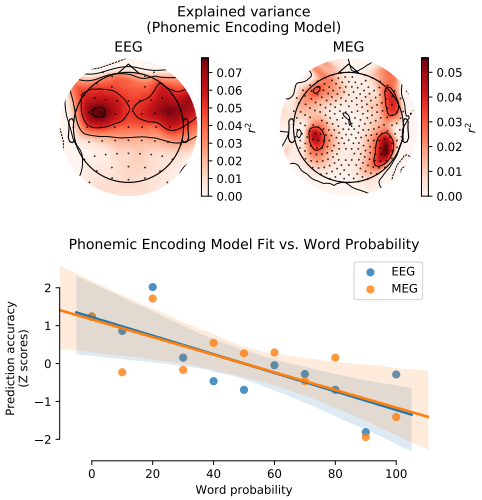
Correlation *word* predictability vs. *phoneme* representation strength

- first approach: for each word, calculate similarity between template (first-level model coefficients) and actual neural activity, and bin by word cloze
- second approach: fit second-level *word cloze* continuous encoding model to *squared residuals* from first level (*RSS* ~ *cloze*)

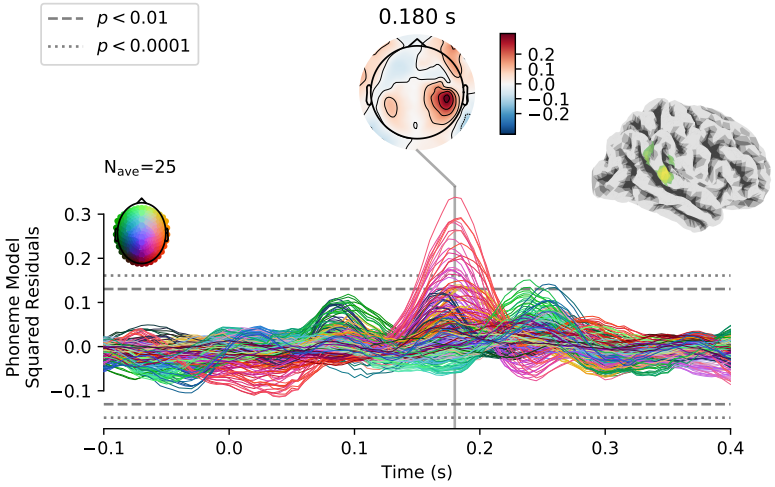


Results

Approach 1: Brain responses to less predictable words are more similar to the template



Approach 2: Regression coefficients from second level (cloze on phonemic encoding residual) encoding indicate at the beginning of words (180ms), the phonemic model fits less well for predictable compared to unpredictable words. (MEG & EEG; only MEG shown, EEG is highly similar)



Discussion Results are in accordance with the hierarchical version of Predictive Coding theory: when processing continuous, congruent speech, phoneme-level representational pattern strength (in pTSG) covaries with word-level predictability - as if predicted phonemes are "predicted away".

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