

Predictive Coding Across Levels of Language



Research Question

Predictive processing of language is well supported

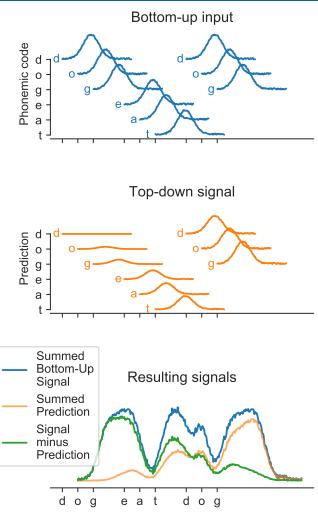
- well known neurocognitive correlates (e.g., N400; [5])
- ... typically *within* one level: i.e., from word meaning to word meaning

Predictive Coding theory [1] suggests *hierarchical* predictions

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

References

- [1] A. Clark. Whatever next? Predictive brains, situated agents, and the future of cognitive science. *The Behavioral and brain sciences*, 36(03):181–204, May 2013.
- [2] K. A. Delong, T. P. Urbach, and M. Kutas. Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*, 8(8):1117–1121, July 2005.
- [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.
- [4] R. Kliegl, E. Grabner, M. Rolfs, and R. Engbert. Length, frequency, and predictability effects of words on eye movements in reading. *European Journal of Cognitive Psychology*, 16:262–284, 2004.
- [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.
- [6] M. E. A. Nieuwland. Limits on prediction in language comprehension: A multi-lab failure to replicate evidence for probabilistic pre-activation of phonology. *BioRxiv*, 2017.



Methods

Potsdam Sentence Corpus

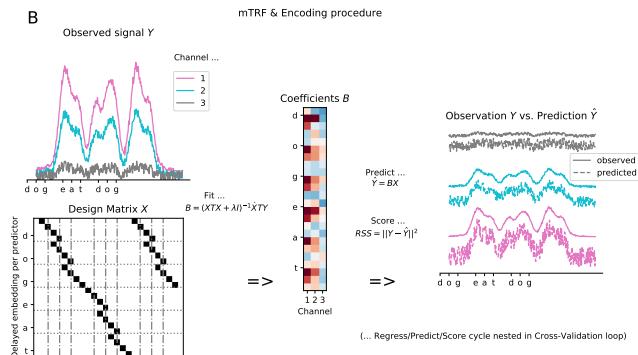
- 144 German sentences, with cloze ratings for each word [4]
- MEG (n=25) and EEG (n=35)

Compute strength of phonemic representations

- fit a phoneme continuous encoding model [3] to MEG and 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?)

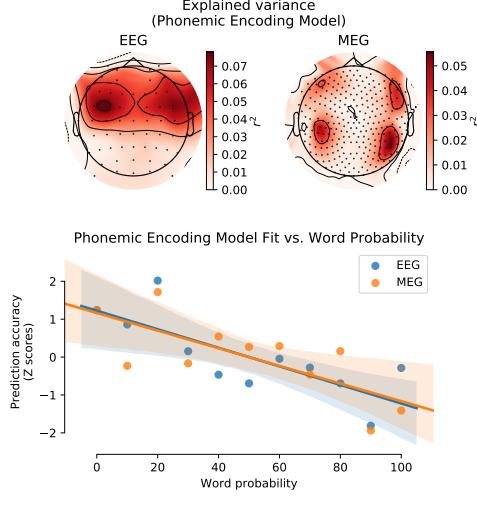
Correlation word predictability vs. phoneme representation strength

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

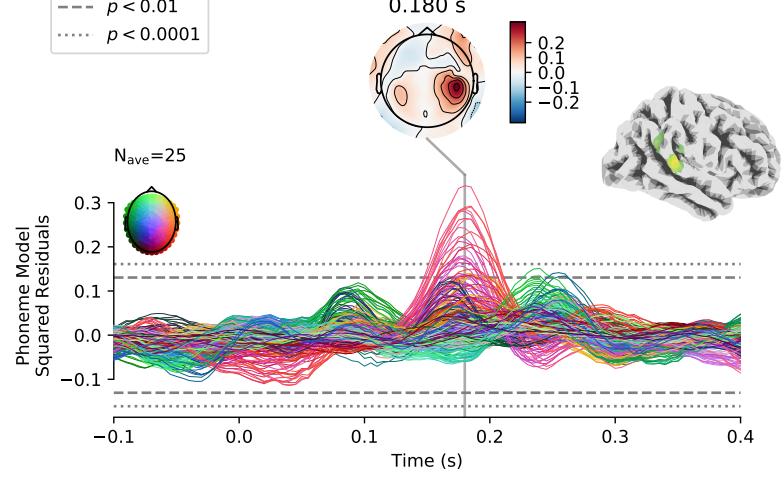


Results

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, the phonemic model fits less well for predictable compared to unpredictable words. (MEG & EEG; only MEG shown)



Discussion Results are in accordance with the hierarchical version of Predictive Coding theory: when processing continuous, congruent speech, phoneme-level representational pattern strength covaries with word-level predictability.