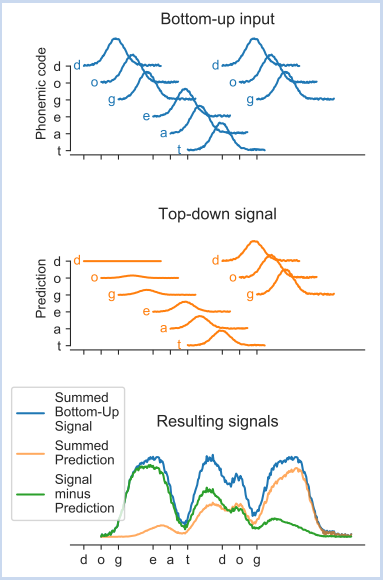
Predictive Coding Across Levels of Language

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.

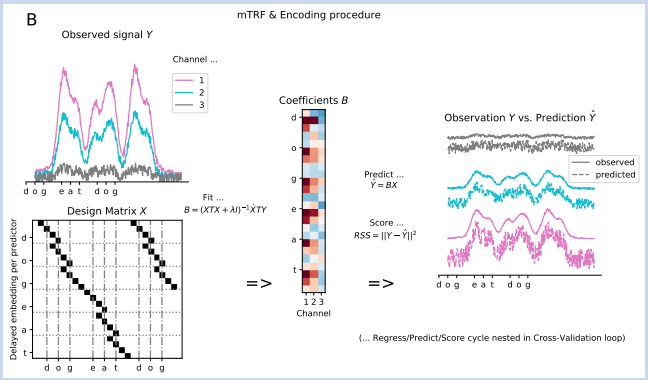
[4] R. Kliegl, E. Grabner, M. Rolfs, and R. Engbert. Length, frequency, and predictability effects of words on eye movements in reading. *European Journal of Cognitive Psychology*, 16:262–284, 2004.

[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.

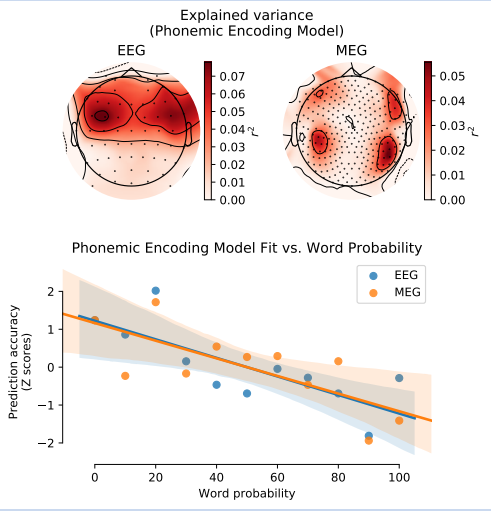
Methods

- Potsdam Sentence Corpus (144 German sentences, with cloze ratings for each word; [4])
- MEG (n=25) and EEG (n=35) data
- 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?)
- compute correlation between *word* predictability and *phoneme* representation strength
  - first approach: fit second-level *cloze* continuous encoding model to *absolute residuals* from first level
  - second approach: for each word, calculate similarity between template (first-level model coefficients) and actual neural activity, and bin by cloze word

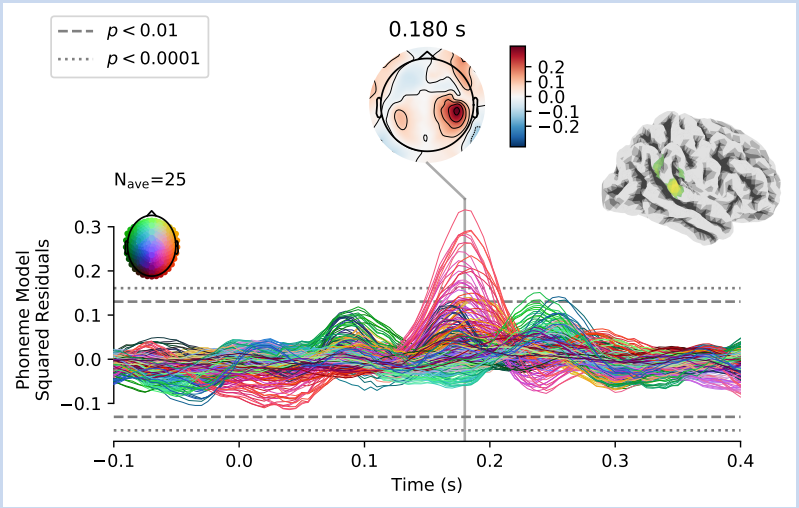


Results

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.

Jona Sassenhagen[1], Benjamin Gagl[1], Christian Fiebach[1]

jona.sassenhagen@gmail [1]Department of Psychology, Goethe University Frankfurt/Main, Germany

Fiebach Lab