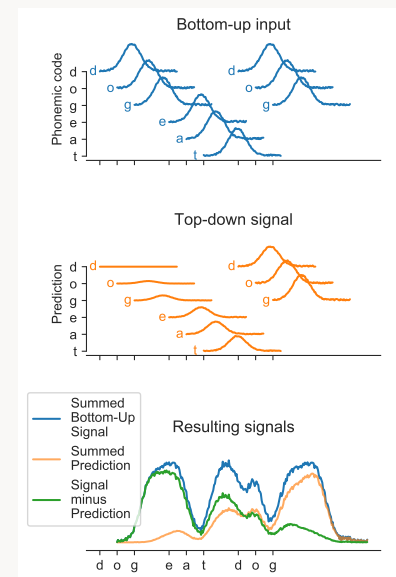# Predictive Coding Across Levels of Language

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
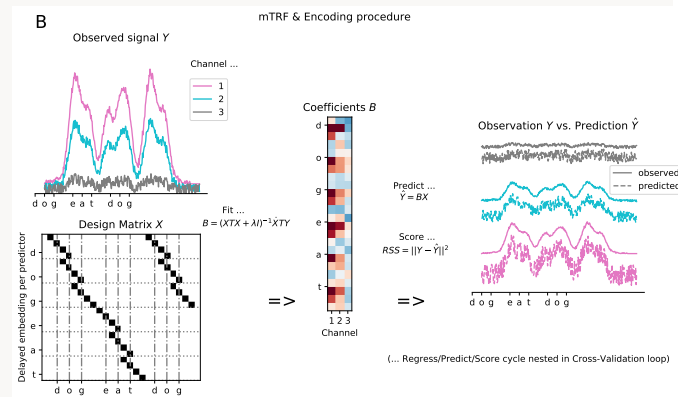
References

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Bottom-up input

Top-down signal

Resulting signals

Summed Bottom-Up Signal / Summed Prediction Signal / Signal minus Prediction

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


B — mTRF & Encoding procedure

Observed signal Y; Design Matrix X; Coefficients B; Observation Y vs. Prediction $\hat{Y}$

Fit … $B = (X^TX + \lambda I)^{-1}X^TY$

Predict … $\hat{Y} = BX$

Score … $RSS = ||Y - \hat{Y}||^2$

(… Regress/Predict/Score cycle nested in Cross-Validation loop)

Results

Approach 1: Brain responses to less predictable words are more similar to the template
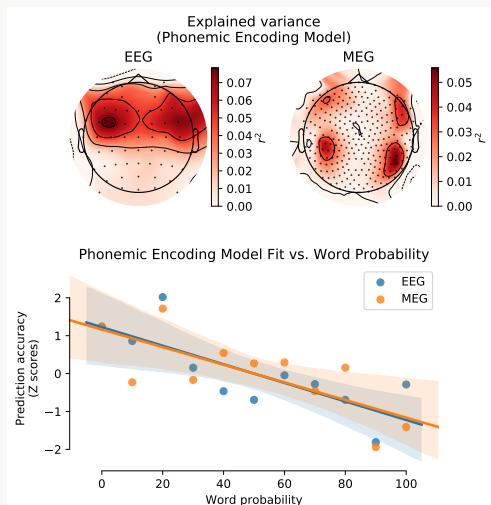
Approach 2: Regression coefficients from second level (cloze on phonemic encoding residual) encoding indicate at the beginning of words, the phonemic model fits less well for predictable compared to unpredictable words. (MEG & EEG; only MEG shown)

Explained variance (Phonemic Encoding Model)
EEG / MEG

Phonemic Encoding Model Fit vs. Word Probability

0.180 s

$N_{ave}=25$
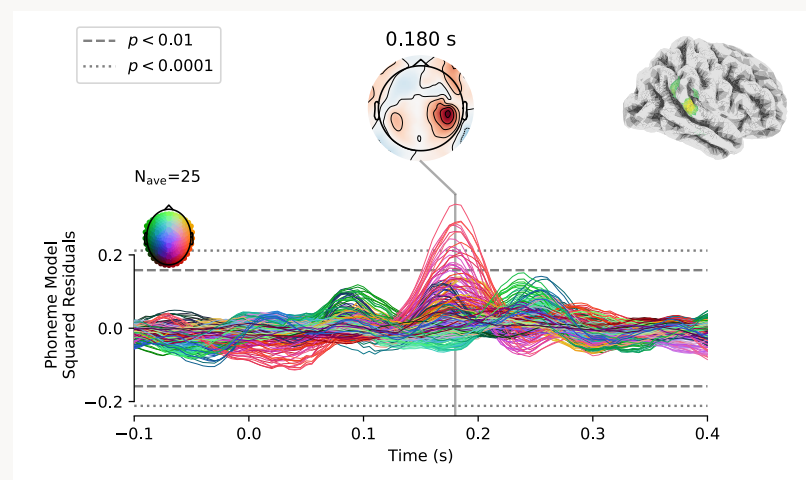
Discussion Results are in accordance with the hierarchical version of Predictive Coding theory: when processing continuous, congruent speech, phoneme-level representational pattern strength covaries with word-level predictability.

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