Past Word Context Enables Better MEG Encoding Predictions than Current Word in Listening Stories
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Abstract

Brain encoding is the process of mapping stimuli to brain activity. In this study, we encode brain activity recorded through magnetoencephalography (MEG) to explore the nature of language processing in the brain.

MEG enables us to precisely examine the timing of language processing during a naturalistic task: 8 subjects listened to 4 independent stories (Guillaumin et al. 2022).

We parsed or encoded words using several semantic embeddings or features, syntactic parsers, or language models, and predicted MEG activity using these word representations.

We find that only contextual representations of words significantly predict brain activity at word onset. Moreover, the strong dependence of predictivity on past word context suggests that the brain encodes words in transient representations of their past context.

Those findings are aligned with previous studies on MEG encoding showing past information retention at phonemic scale (Guillaumin et al. 2022), and echo research on bird song production showing a preference for past actions encoding at ambiguous transition points in song in HVC (a song-related brain area in songbirds; Cohen et al. 2020).

Brain encoding using word representations

Dataset: MASC-MEG (8 subjects listening to 4 stories)

"She moved her fingers gracefully..."

Word representations (word as vectors)

Language Model (BERT) Word Embeddings (GloVe)

Syntaxic/semantic features

Word representations

MEG recording at word onset (800ms window, 208 sensors)

Model prediction

Predictivity score (R²)

Predictivity is function of context size and direction

Among all word representations, only contextual representations (BERT) are able to significantly predict MEG activity at word onset. (One sample t-test, p<0.05, FDR correction)

Predictivity is mostly significant in temporal and inferior frontal lobes

Method

Preprocessing: MEG activity is filtered (0.5Hz-30Hz) and epoched in 800ms windows around word onset (-0.2s before onset, +0.6s after word onset). First 200ms serve as baseline for detrending.

Encoding models are fitted using linear regression with L2 regularization (regularization parameter found through 10-fold cross validation, for each story and each sensors and timepoints).

R² score significance is assessed using a permutation test (5000 random permutations within each story, FDR corrected using Benjamini-Hochberg method with α=0.05)

Conclusion

Brain activity seems to reflect contextual information. MEG activity is only significantly predicted by BERT contextual embeddings, and predictivity is function of past context size.

High predictivity with lagged encodings suggests that past context plays an important role in encoding current word information in the brain.

In the speaker’s brain, there appears to be an “encoding center of mass” that is responsible for processing long-time dependencies and encoding past actions rather than future actions. This is supported by studies on songbirds, where the brain area involved in managing these dependencies preferentially encodes past actions, particularly during phrases with history-dependent transitions in song. Similarly, research on phoneme representations suggests that past events or actions are held in memory until they are used to disambiguate future events or actions (Guillaumin et al. 2022).

References


