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# MEG Encoding using Neural Language & Speech Models and Shared Context Semantics in Listening Stories

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### Summary

- Language models (LMs) predict both text-evoked and speech-evoked brain activity to an impressive degree irrespective of choice of modality.
- Speech-based models (SMs), which would be expected to predict speech-evoked brain activity better, provided they model language processing in the brain well.
- These findings poses several questions:
  - O Are speech models (SMs) outperform language models (LMs) during speech-evoked brain activity?
  - O Do both LMs and SMs combine a new word representation with previous
  - What type of information is shared between LMs and SMs that results in improved brain predictivity?
- We investigate these questions using both LMs (GPT2) and SMs (Wav2vec2.0, HuBERT and Data2vec), and observe how these models predict MEG brain recordings acquired while participants listened to the naturalistic stories.
- Language models outperform speech models irrespective of speech-evoked brain activity.
- Both type of models still behind the estimated noise-ceiling performance.
- Like LMs, previous context is important in predicting MEG recordings for SMs

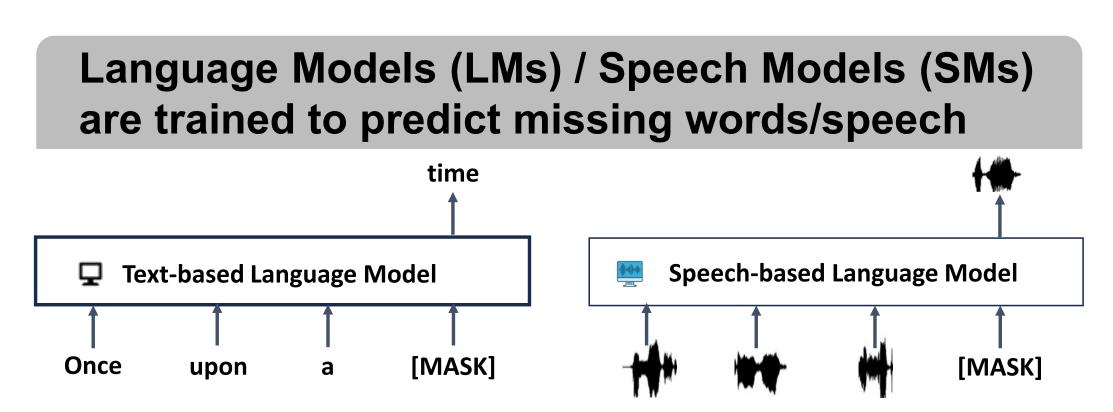


Figure 1:Language Models (LMs) and Speech Models (SMs) have achieved impressive performance across many benchmarks

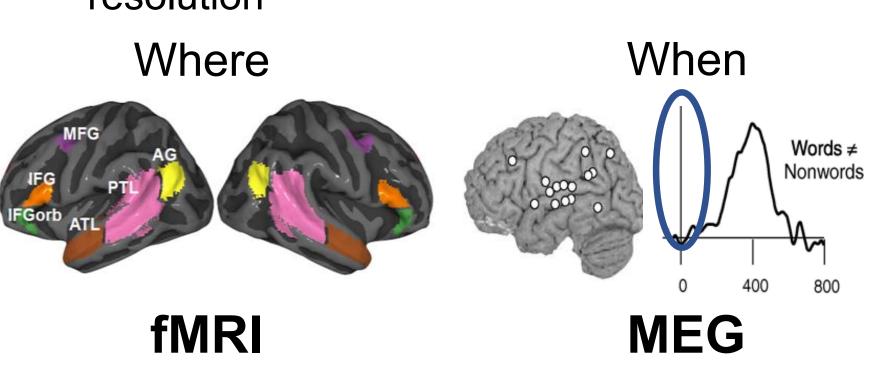
LMs/SMs also predict brain activity evoked by complex

## language (e.g. listening a story) to an impressive degree 1. Learn linear function 2. Test f on held-out data

Figure 2:Brain alignment of a LM/SM

### With MEG we can analyze sub-word time course

- MEG recording data at very fast temporal resolution
- So, we can look at sub-word process
- fMRI recording data at very high-spatial resolution



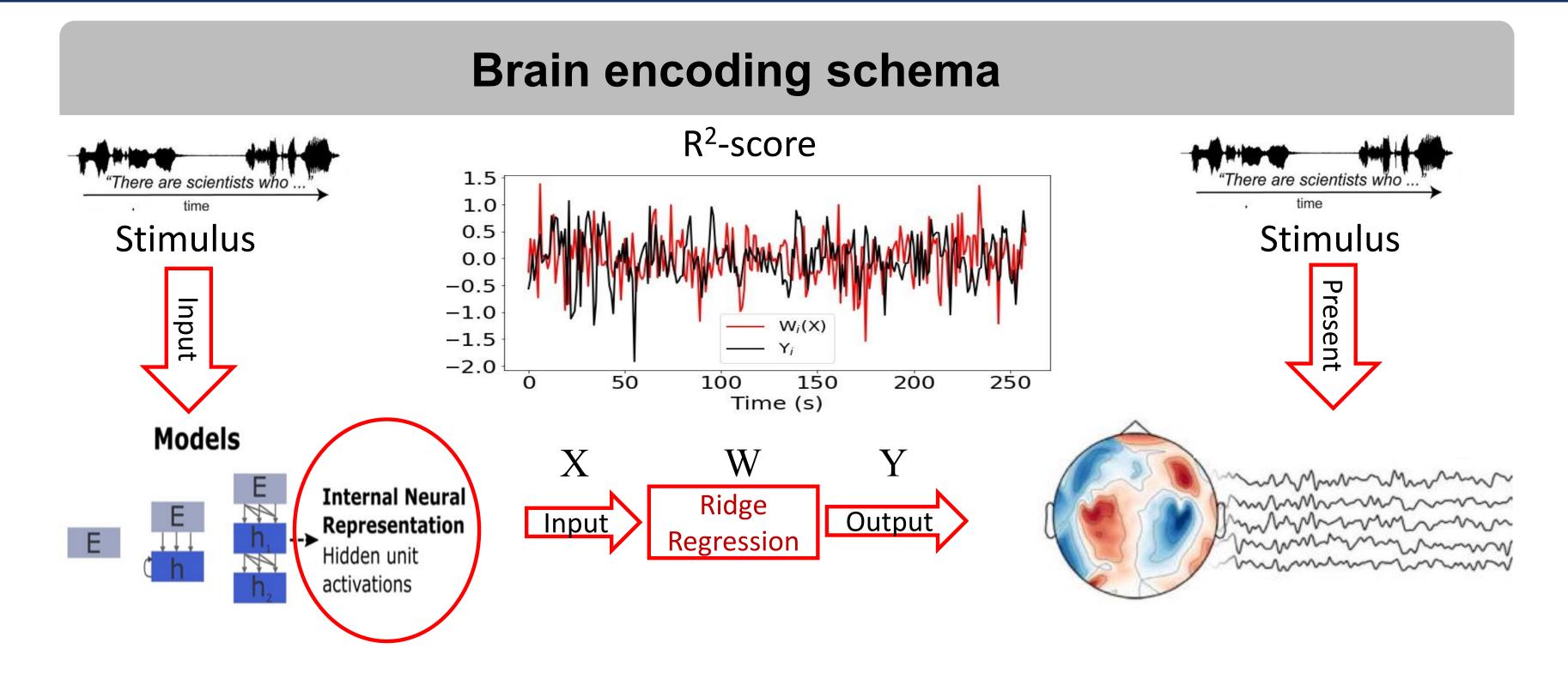
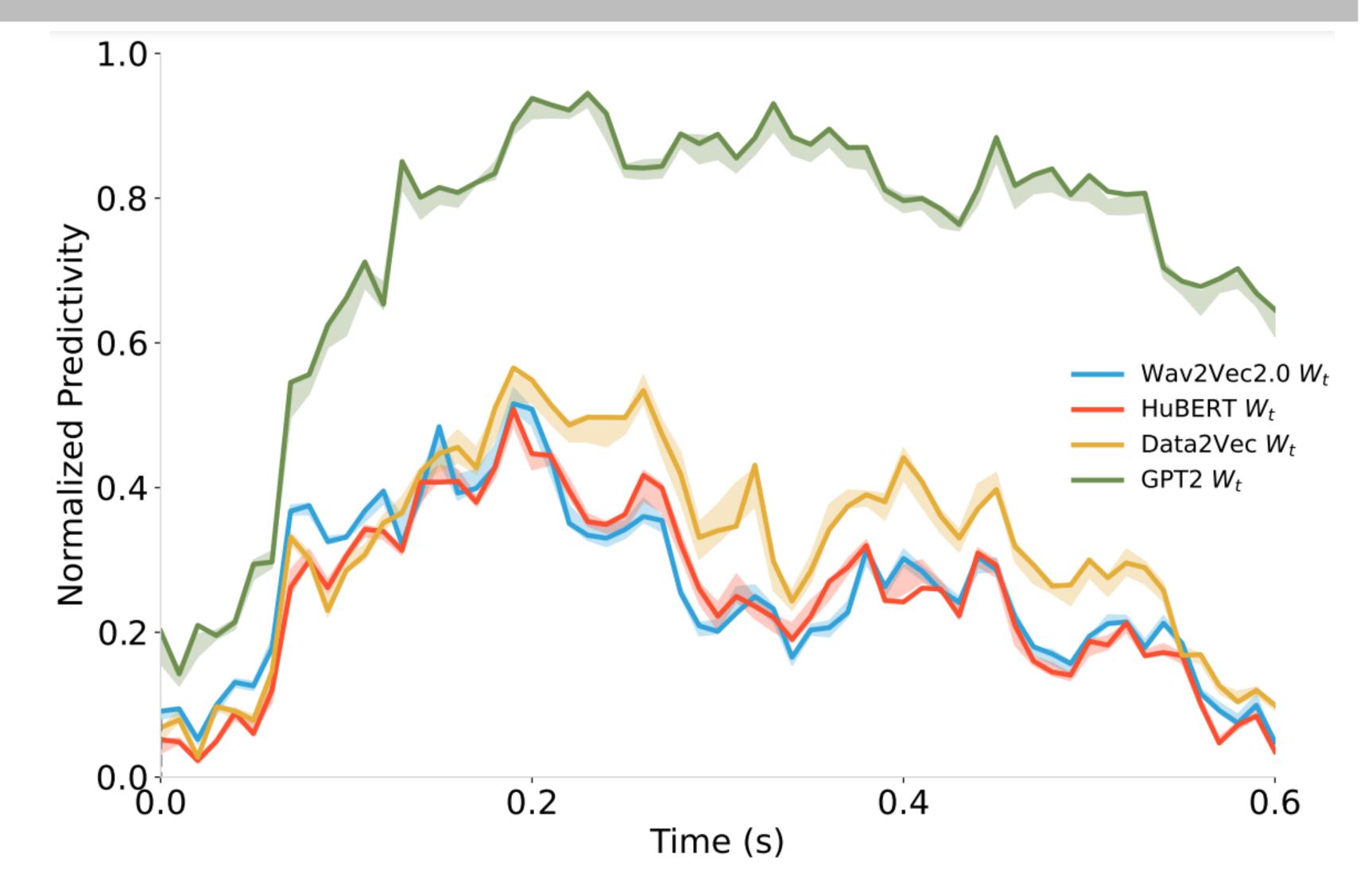
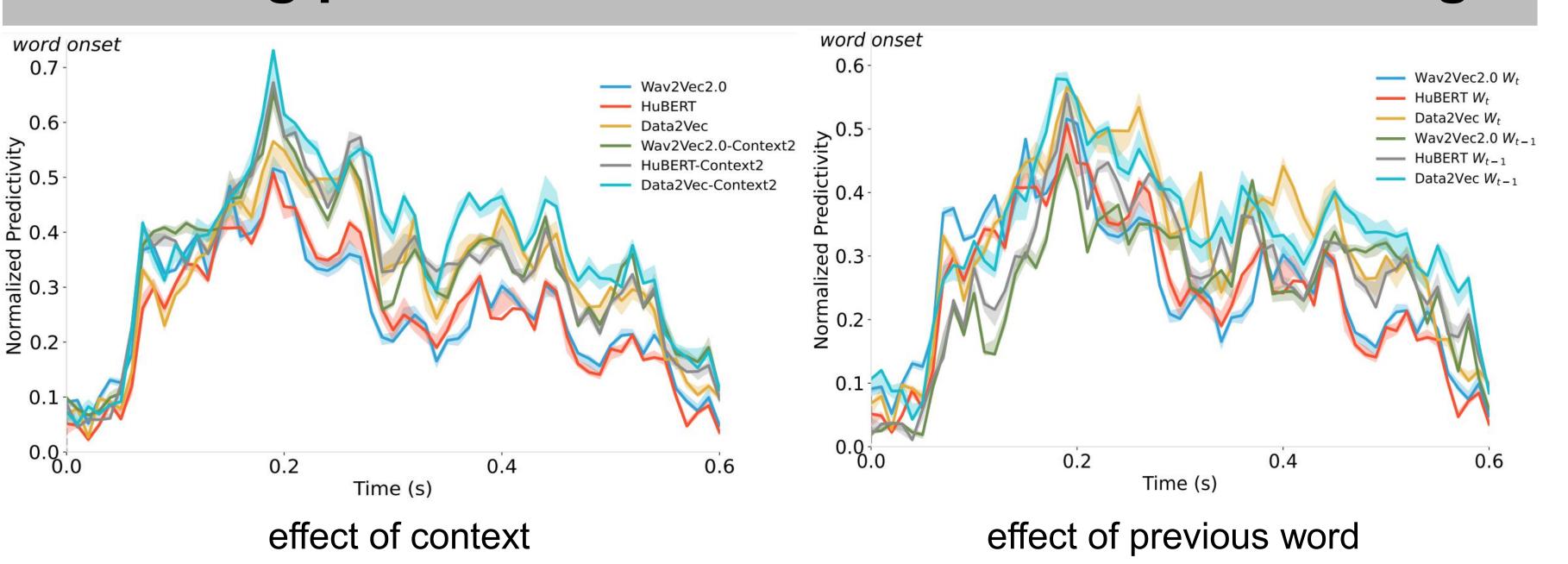


Figure 3:Approach to directly test for the alignment between a LM/SM and MEG brain recordings.

## Encoding performance of LM and SMs



## **Encoding performance SMs: Contextual Embeddings**



Brain alignment – 4-fold Cross-Validation + Ridge regression • 4 natural stories (11, 002 words) x 768 ⇒ **MEG-MASC Dataset** 3 stories in training & 1 story in testing 800ms signal window around word onset: 200ms before (baseline correction). • 208 MEG sensors x 81 time points ⇒ MEG predictions (same dimensions as actual brain activity) structural MRIs • 18 participants 3 Speech language models

#### Wav2vec2.0 HuBERT which is the first operation of the control of the Data2Vec 1 Text language Model (GPT2) (3) 4-fold Cross-Validation (1) Naturalistic story listening dataset (2) Brain Alignment: Dataset Curation

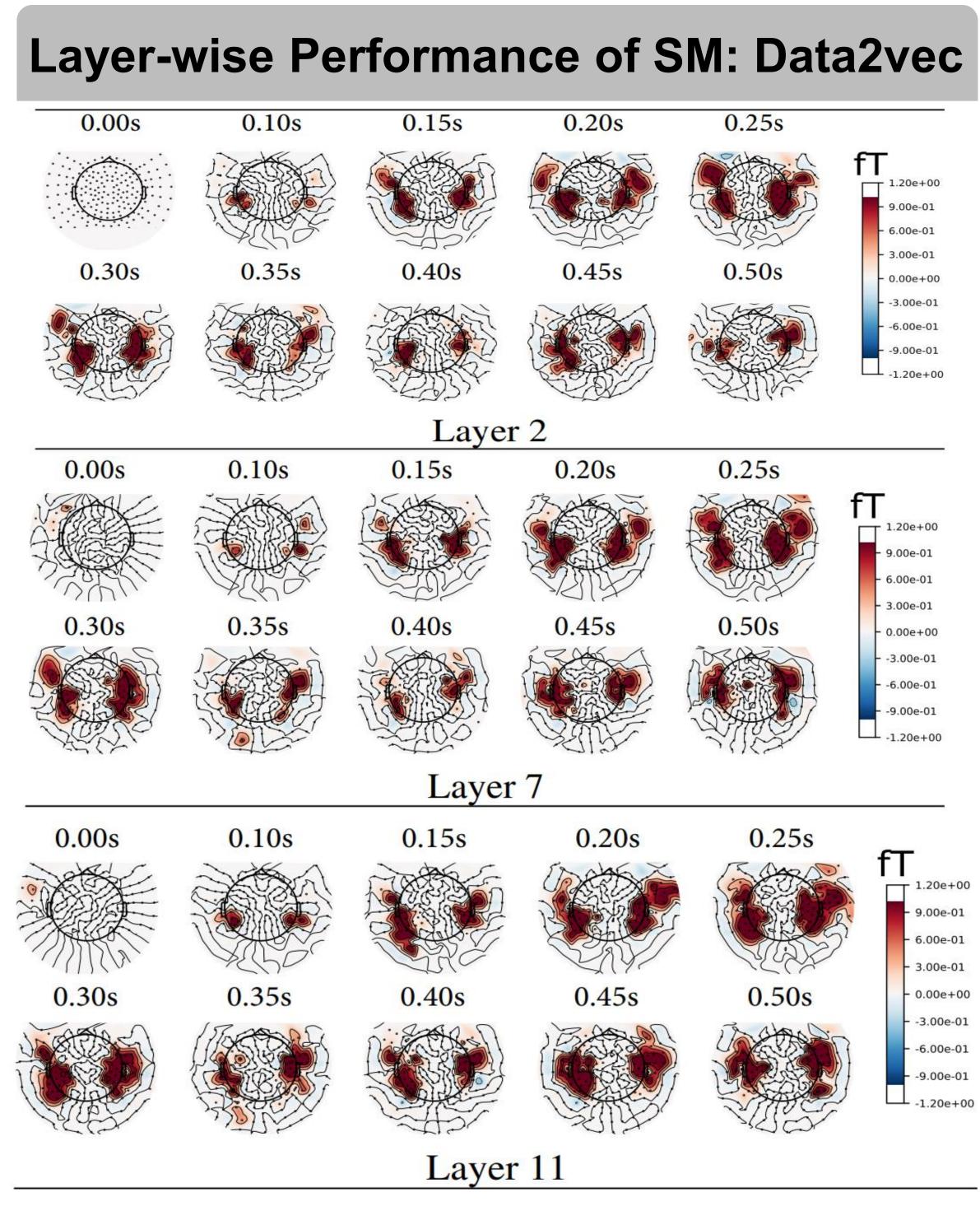


Figure 5:Topo map for Average Normalized predictivity by Data2Vec (across subjects) for MEG activity. Word onset is at 0ms. Layer 2 (top), Layer 7 (middle), and Layer 11 (bottom).

### References

[1] Toneva et al. 2019.

Interpreting and improving natural-language processing (in machines) with natural language-processing (in the brain).

[2] Gwilliams et al. 2022.

Meg-masc: a high-quality magneto-encephalography dataset for evaluating natural speech processing.

[3] Oota et al. 2023.

Meg encoding using word context semantics in listening stories.

### Acknowledgements

• We thank Inria for the PhD funding and ANR DeepPool project.