

Language Models as Windows into Human Language Processing: Neural Encoding, Decoding, and Brain Alignment with NLP

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Modern language models are not only tools for processing text; they are also becoming computational instruments for studying how humans understand, predict, and generate language. This tutorial introduces neural encoding and neural decoding to the NLP community through this broader perspective: how can NLP help us understand language processing in the human brain, and how can brain data help us evaluate and improve language models? We will present neural encoding as a way to test whether representations from language models—such as contextual embeddings, surprisal, attention patterns, and layer-wise features—can explain brain responses during reading or listening. We will then introduce neural decoding as the reverse problem: reconstructing linguistic or multimodal content from brain activity using retrieval, representation learning, and foundation-model-guided generation. Rather than framing decoding mainly as brain–computer interface technology, we will connect it to core NLP questions about meaning representation, generation under uncertainty, multimodal grounding, and semantic evaluation. The tutorial assumes no neuroscience background. It combines intuitive foundations, representative papers, practical modeling recipes, notebook-style demos, and discussion of mental privacy, consent, and responsible brain–language technologies.

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Dr. Jingyuan Sun is an Assistant Professor in the Department of Computer Science at the University of Manchester. His research lies at the intersection of artificial intelligence, computational linguistics, and cognitive neuroscience. He develops multimodal models for neural encoding and decoding, including sentence-level brain encoding, fMRI-to-image reconstruction, and semantic video decoding. His work has appeared in venues including NeurIPS, AACL, NAACL, ACL tutorial tracks, and IEEE TNNLS. He has delivered international tutorials at ACL 2024 and IJCAI 2024 and has experience teaching interdisciplinary audiences in NLP, machine learning, and neuroscience.

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Dr. Yunhao Zhang is a Research Assistant Professor at the Institute of Automation, Chinese Academy of Sciences. His research lies at the intersection of artificial intelligence, cognitive neuroscience, and psycholinguistics. He uses large language models to analyze multimodal neuroimaging data, with the goal of investigating the neural mechanisms underlying semantic representation in the human brain. His related work has appeared in venues including NeuroImage, Scientific Data, Language Resources and Evaluation, EMNLP, and CogSci.

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Yifan Wang is a PhD researcher at the University of Manchester with hands-on experience in multimodal learning, biomedical data processing, and neural model implementation. In this tutorial, he will support the practical demonstrations and Q&A, particularly for the neural decoding component.

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Yang Cui is a PhD researcher at the University of Manchester with hands-on experience in multimodal learning, biomedical data processing, and neural model implementation. In this tutorial, he will support the practical demonstrations and Q&A, particularly for the neural encoding and brain-alignment component.