Decoding Inner Speech Conditions in EEG: Identifying Informative Time Windows in Verbal Working Memory

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1 Introduction

Inner speech refers to the internal, silent use of language and is a key mechanism in verbal working memory. It is assumed to support the temporary maintenance and manipulation of verbal information through internally generated representations that allow information to be actively sustained Kompa and Mueller (2024). It is unclear when these processes are most strongly reflected in brain activity over the course of a verbal memory task. In particular, it is not well understood whether inner speech is primarily tied to the initial encoding of stimuli or whether it continues into later cognitive processing Alderson-Day and Fernyhough (2015).

Understanding the temporal characteristics of inner speech is important for refining how verbal working memory processes are studied and interpreted. Clarifying when inner speech is most strongly expressed in brain signals can therefore improve both theoretical models and experimental designs. The central question of this project is whether a decoding pipeline can classify these conditions above chance level based on brain activity recorded during different parts of a trial.

2 Methods

This project investigates whether patterns in EEG data can be used to distinguish between different task conditions associated with inner speech and verbal working memory. The analysis uses data from an already completed EEG experiment. Participants were presented with three different types of stimuli, followed by fixation periods that are interpreted as maintenance phases. Data is processed using standard EEG procedures, including resampling, detrending, filtering, artifact correction via Independent Component Analysis, and removal of noisy channels, implemented in MNE-Python Gramfort et al. (2013).

The recordings are divided into epochs, i.e., event-locked time windows, within each session. The goal is to determine how well a decoding pipeline can classify which task condition was presented during the epochs. Classification performance is examined over time in order to identify when, relative to the start of the trial, the EEG signal contains the most information about the task condition. This allows for a comparison of predefined epochs as well as a more fine-grained, time-resolved view of how condition-specific information evolves over a relatively long time span.

3 Results

The preprocessed EEG data is currently available, but the results of the decoding pipeline are not yet complete. The overall analysis aims to determine whether task conditions can be reliably distinguished based on EEG data. Permutation testing will be used to evaluate statistical significance by randomly shuffling features and respective condition labels to determine a baseline of random performance. Furthermore, the analysis aims to identify time intervals during which classification performance is highest, in order to estimate when processes related to inner speech are most strongly reflected in brain activity.

4 Discussion

If the classification performance exceeds the chance level, this would indicate that EEG signals contain condition-specific information related to inner speech and verbal working memory. Temporal variations in decoding accuracy would suggest that these representations fluctuate during the encoding and maintenance phases. Identifying time windows with maximum information could help clarify when processes related to inner speech are most active during cognitive processing.

References

Alderson-Day, B. and Fernyhough, C. (2015). Inner speech: Development, cognitive functions, phenomenology, and neurobiology. *Psychological Bulletin*, 141:931–965.

Gramfort, A., Luessi, M., Larson, E., Engemann, D. A., Strohmeier, D., Brodbeck, C., Goj, R., Jas, M., Brooks, T., Parkkonen, L. et al. (2013). Meg and eeg data analysis with mne-python. *Frontiers in Neuroinformatics*, 7:267.

Kompa, N. A. and Mueller, J. L. (2024). Inner speech as a cognitive tool—or what is the point of talking to oneself? *Philosophical Psychology*, 37:1971–1994.