

Investigating Explore–Exploit Tradeoffs in Memory Search Using EEG and Computational Methods

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When retrieving information from memory, people can either remain within a familiar cluster of related ideas (exploitation) or shift toward a new, less familiar cluster (exploration). These explore–exploit decisions determine how we navigate our mental networks, yet it is unclear whether people actively choose to explore or if such shifts happen passively based on how memory is organized. This research examines the neural and behavioral patterns involved in memory search, with a primary focus on midfrontal theta oscillations as a marker of cognitive control during exploratory shifts. We also record well-studied ERP components, P300 and N400, to compare theta activity with established neural signals related to uncertainty and semantic prediction.

Participants complete three EEG-recorded tasks designed to capture memory search behavior. The Verbal Fluency Task (VFT) directly measures semantic memory search. Participants are given a category—animals, occupations, or foods—and asked to generate as many items as possible in five minutes. Responses typically form clusters of related items (e.g., “dog, cat, horse”) followed by switches to a different cluster (e.g., “shark, dolphin, whale”). These switches represent exploratory transitions. By giving participants ample time in each category, we can capture multiple explore–exploit transitions and measure whether midfrontal theta oscillations—brain rhythms linked to cognitive control and decision-making—consistently increase in the seconds before participants shift to a new cluster. Such increases would suggest that exploration is guided by active brain processes rather than happening by chance.

The other two tasks are included to provide well-understood benchmarks for interpreting exploration in memory search. The Balloon Analogue Risk Task (BART) measures how participants make decisions under uncertainty and elicits the P300 ERP component, a well-researched signal associated with evaluating risk and updating decisions. The Cloze task asks participants to predict the missing final word in a sentence, such as “She spread the toast with...,” eliciting the N400 ERP component, a well-studied marker of how the brain processes expected versus unexpected words. Because P300 and N400 are among the most extensively characterized ERP components related to uncertainty-driven exploration, they provide a useful comparison for examining whether similar neural mechanisms, such as midfrontal theta oscillations, support exploratory behavior in memory search.

Because people differ in how they perceive clusters, we will use computational models to classify each VFT response as exploration or exploitation, accounting for semantic and phonological similarities. EEG analyses will then test whether theta power before exploratory switches correlates with individual differences in P300 and N400 amplitudes. We are still in the early stages of data collection, but if these relationships are found, they would indicate that exploration in memory is supported by active prediction. The results could offer new insight into how humans navigate memory and inform assessments of cognitive flexibility in clinical populations, including individuals with schizophrenia and dementia.

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