# Exploring brain states with simultaneous EEG-fMRI

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## 1 Introduction

The brain is often studied through relatively stable patterns of activity and connectivity, yet cognition also depends on how these patterns change over time. Brain states, understood here as recurring, temporally bounded configurations of neural activity and functional coupling that vary across cognitive and behavioral conditions, shift attention from isolated responses to the broader organization of ongoing brain activity and may provide a common framework for relating neural dynamics across methods and scales (Greene et al., 2023). They allow us to ask how neural configurations emerge, persist, and transition across contexts such as rest, perception, and task performance. Because these configurations are spatially distributed and temporally dynamic, we explore them with simultaneous EEG-fMRI, combining spatial resolution of fMRI with temporal resolution of EEG.

## 2 Methods

A sample of 50–60 healthy adults and 30 adults diagnosed with depression will undergo simultaneous EEG-fMRI during three conditions: rest, video watching, and a cognitive task. The video condition will present naturalistic clips with varying content, allowing state dynamics to be examined during continuous stimulation that changes perceptual, emotional, and cognitive demands. The cognitive task will manipulate perceptual and attentional switching across visual (focus on either color or motion in a dot-cloud display) and auditory trials (left-right localization of designated sound). EEG will be recorded with a 128-channel MR-compatible system. EEG and fMRI data will be preprocessed separately; EEG preprocessing will target gradient, ballistocardiogram, ocular, muscular, and movement-related artifacts (Kraljič et al., 2022).

EEG analysis will include microstate analysis to examine recurrent scalp topographies and their temporal parameters (occurrence, duration, coverage, and transition probabilities), and time-frequency analysis to examine oscillatory power and frequency-specific dynamics. fMRI analysis will focus on dynamic functional connectivity to estimate recurrent network-coupling patterns and activation analysis for the task condition. Individual structural MRI will support EEG source reconstruction, linking scalp-level EEG measures to cortical sources and fMRI networks. EEG and fMRI time series will be aligned using scanner triggers, allowing measures to be temporally related to each other, including comparisons between dynamic functional connectivity patterns and EEG microstate dynamics (Abreu et al., 2021).

## 3 Results

Rest, video watching, and task performance are expected to differ in the temporal organization of recurrent neural patterns rather than in one unique state per condition. Rest may show more spontaneous dynamics, video watching stimulus-linked audiovisual patterns, and the cognitive task more frequent switching between sensory, attentional, and control-related configurations. The expected outcome is therefore not a fixed catalog of universal brain states, but a comparison of how different measures describe state-like dynamics. The depression group will allow testing whether altered network organization is reflected in state dynamics.

## 4 Discussion

The approach has several limitations. Recording sessions will last 3–4 hours because high-density EEG preparation and signal checks are time-consuming, which may increase fatigue and reduce data quality. Simultaneous EEG-fMRI also requires extensive artifact correction, and interpretation will depend on preprocessing and analysis choices.

By treating brain states as an empirical and methodological problem rather than a predefined category, this study may clarify how different measures capture dynamic brain organization.

## References

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