# Spatio-Temporal Analysis of Brain Activity in Epilepsy: A Model-Free Approach


## Abstract

Accurate localization of epileptogenic regions and preservation of eloquent cortex are fundamental objectives in the presurgical evaluation of patients with drug-resistant epilepsy. Functional magnetic resonance imaging (fMRI) and simultaneous electroencephalography-functional MRI (EEG-fMRI) are widely used for this purpose; however, conventional analysis predominantly relies on the General Linear Model (GLM), which assumes a predefined canonical hemodynamic response function (HRF). This assumption may not adequately represent the variability of BOLD responses observed across brain regions, individuals, and pathological conditions such as epilepsy.

This thesis presents Temporal Synchronization Analysis (TSA), a model-free framework for investigating the spatio-temporal dynamics of brain activity without requiring predefined HRF assumptions. The research includes the first application of Inter-Trial Temporal Synchronization Analysis (IT-TSA) to EEG-fMRI data for investigating interictal epileptiform discharge-related brain activity in epilepsy, demonstrating its ability to identify additional activated and deactivated brain regions and characterize their temporal dynamics. Furthermore, the thesis proposes a novel Trial-Averaged Inter-Subject Temporal Synchronization Analysis (TA-IS-TSA) framework for task-based fMRI, enabling the identification and characterization of canonical and non-canonical BOLD responses during language processing.