Neurological disorders are the second leading cause of deaths globally. However, due to several challenges like high-dimensional multi-modal neuroimaging data, and different effects on individual patients, there are several gaps in understanding the nature and issues related to these disorders.

We propose to address some of these challenges by developing novel algorithms that combine signal processing and machine learning techniques. First, we establish Electro-corticography (ECoG) as a viable approach for language cortex localization. Towards this, we propose to use the full frequency spectrum and employ random forest classifier to perform an inter-channel comparison of the 1D ECoG signals. This enables us to extract more discriminative features and to open more research avenues into ECoG signal analysis.

We next explore the potential of deep learning to improve the ECoG channel classification accuracy. We develop a multi-domain framework by combining time domain and frequency domain features. A sliding window data augmentation strategy enables the application of deep learning in this otherwise limited dataset.

We extend our analysis to multi-dimensional data (3D/4D MRI) and device a new approach to better understand the human brain. We identify a multi-modal approach combining 3D MRI data and 4D functional MRI data, to distinguish between healthy groups based on skill specialization, and identify several functional and anatomical differences between chess masters and novice players.

Finally, we propose a capsule-based encoder network to learn a stronger representation of high-dimensional, noisy data. We develop a variational capsule encoder that learns from the data distribution and produces strong latent representations.

The proposed approaches may help narrow the regions to be tested in pre-surgical localization tasks and in better surgery planning as well as pave the way for a holistic view of the human brain by novel multi-modal approaches.