"Data analytics for the nervous system activity: new feature extraction tools"

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"The nervous system holds a highly significant role within the human body, regulating bodily activities, maintaining homeostasis, and gathering and synthesizing information from various body systems. This complexity attracts the attention of multiple scientific disciplines, exploring different aspects of its functioning. The integration of knowledge stemming from different areas of study is an open and significant question in these fields. Indeed, recent findings highlighted how traditionally independent aspects of the nervous system's functioning may actually be intertwined: the apparently counter intu- itive link between autonomic activity and some psychiatric disorders (e.g. schizophre- nia) is only one instance of this phenomenon.

This thesis operates within the realms of neurophysiology and computational psychia- try. While the first studies the nervous system's physiological functioning, the second examines the alterations due to psychiatric conditions, drawing from statistics, machine learning, and related computational approaches. In these fields, managing data di- mensionality poses a significant hurdle, compounded by the intricate neural anatomy. Furthermore, the dynamic interactions within this system exhibit extreme complexity, marked by non-linear patterns. These technical challenges give rise to theoretical and computational issues, often addressed through oversimplification. This work employs two main methodological approaches, Functional Data Analysis and spectral analy- sis, individually and in combination, to extract relevant features from biomedical signal data. These approaches are validated across three categories of biomedical signals: fMRI, EEG, and ECG.

Specifically, each section of this thesis concentrates on a unique data source and in- troduces a methodology tailored to the most relevant aspects of the respective case study. In the first part, we tackle data dimensionality and anatomical complexity in fMRI data. We validate the use of Functional Data Analysis based data reduction tech- niques on grey matter volume data, optimizing parameter selection, and incorporating Functional Data Analysis based metrics into the computation of functional connectivity maps. The second part leverages the non-linear dynamics present in EEG signals to assess cognitive activity, utilizing Functional Data Analysis, spectral-based methods, as well as their combination. The final segment of the work focuses on evaluating Autonomic Nervous System activity through spectral-based metrics. After addressing questions about sex-based differences in neurophysiology, we propose novel spectral- based metrics to further investigate sympathetic nervous system tone."

Keywords: nervous system, neuroimaging, functional data analysis, spectral analysis, data dimensionality, computational psychiatry, neurophysiology.