Learning from High-Dimensional Neuroimaging Data

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Symposium

Current advances in brain imaging technologies have enabled image acquisition at faster rates and with increased resolution. Multiple accessible international brain imaging datasets online also facilitate the generation of neuroimaging big data. Neuroimaging data is itself high dimensional capturing complex spatiotemporal variation across multiple modalities. Learning meaningful summaries from these data using flexible models is a challenging, but critical, endeavor. The extraction of effective biomarkers of both healthy and disordered brains is complex but has the potential to lead to significant impact. This symposium will introduce cutting-edge, machine learning approaches across a transdiagnostic spectrum can be leveraged to (a) reveal connectivity movies—— modeling fluidly varying patterns of functional integration for interpretably presenting and analyzing high dimensional dynamic processes via fMRI signal ;(b) infer schizophrenia subgroups by subspace analysis that adaptively capture both the temporal and spatial variability of functional networks ;(c) explain and estimate individual differences on moment-by-moment ratings of sustained pain based on a connectivity-based neuroimaging biomarker; (d) pinpoint the common and unique neural pathways that underpin similar symptoms across the autism spectrum, and longitudinally predict the risk for mental disorders in healthy adolescents using personality-guided MRI fusion. This symposium will highlight multiple innovative, data-driven frameworks and discuss how they represent a powerful means of extracting useful neural signatures in multiple aspects. Such approaches that try to represent complex change via meaningful data-driven summaries can inform us about the healthy brain as well as provide new insights into the mechanistic understanding of brain disorders.

Objective

- To present multiple cutting-edge machine learning approaches that can capture complementary spatial and temporal features from high-dimensional neuroimaging data.
- To introduce tools incorporating state-of-the-art data fusion and individualized prediction techniques that enable detection of replicable imaging signatures with potential clinical translational impact.
- To introduce a new data-driven framework for identifying “truly dynamic” multi-frame (movie-style) dynamic functional network connectivity states, which can bring complex processes of functional reorganization into better focus, elucidating the dynamic landscape that informs behavior, mood, cognition and other mental functions.

Target Audience

The target audience will be individuals who are interested in learning about advanced engineering solutions and mathematic tools with novel neuroimaging applications. The presented methods include dynamic functional connectivity estimation, subspace analysis, individualized prediction and multimodal fusion.

Presentations

Learning Pain from High-Dimensional Neuroimaging Data

Recent advances in pattern recognition techniques and their application to high-dimensional functional neuroimaging data provide an unprecedented opportunity to develop neuroimaging biomarkers with a high potential for clinical translation. Pain can be a good example case. Pain is a major health issue that causes high socioeconomic costs, but clinical tests to objectively measure and evaluate the level of pain within individual have been lacking. Leveraging machine learning and high-dimensional fMRI data, we aimed to learn signature patterns of pain from high-dimensional neuroimaging data. Here we particularly targeted sustained pain, which is one of the main characteristics of clinically relevant pain and induces dynamic changes in the brain activity and connectivity patterns, providing rich high-dimensional features that we can use for further modeling. In this talk, we will introduce two studies: In the first study, we developed a connectivity-based neuroimaging biomarker of sustained pain. This biomarker showed significant prediction for moment-by-moment ratings of experimental sustained pain. It also explained individual differences in overall pain severity of clinical back pain patients and discriminated patients from healthy controls with high accuracy. In the second study, we focused more on dynamic reconfigurations of functional brain networks during sustained pain. We identified characteristic patterns of network community changes that could classify the pain condition from the control condition and explain the changes in pain ratings over time. We will discuss the details of the model and their implications in the neurobiological understanding of pain. Overall, our studies show how we can learn unique functional brain architectures of sustained pain from high-dimensional neuroimaging data, providing new models that hold a potential for clinical translation as well as new insights into the mechanistic understanding of pain processing in the brain.

Presenter
Jae-Joong Lee, Sungkyunkwan University Seoul, Suwon, Republic of Korea

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Application of Subspace Analysis to Fmri Suggests Schizophrenia Subgroups with Significant Symptomatic Differences

Neuroimaging features such as those extracted from functional magnetic resonance imaging (fMRI) data have demonstrated their ability in distinguishing subject groups. It is of great interest and importance to investigate their ability in subgrouping within a population group. An important application is in the discover of heterogeneity of schizophrenia, which plays a key role in providing personalized treatment. We propose two effective methods for the identification of potential schizophrenia subgroups using fMRI data. Both methods are based on independent vector analysis (IVA). IVA extends independent component analysis to multiple datasets by making effective use of statistical dependence across datasets without imposing additional constraints in neither the temporal nor the spatial domain. The first method is IVA for common subspace extraction (IVA-CS) that enables effective subspace analysis of multi-subject data. Besides the extraction of meaningful common and distinct subspaces, IVA-CS also extracts group-specific features that allow for the identification of significant schizophrenia subgroups. Another method is adaptively constrained IVA (acIVA) that can capture both the temporal and spatial variability of functional networks, and can thus help characterize not only temporal brain dynamics but dynamics in the spatial domain which is usually ignored. Since both neural activity and functional connectivity are shown to be related to mental and cognitive processes, we study the activity-connectivity co-evolution patterns by correlating the activity variation with the dynamic functional network connectivity matrices. We demonstrate that the dynamic activity-connectivity patterns are also effective in inferring schizophrenia subgroups. More importantly, the subgroups we identify using both methods show significant differences in terms of their brain networks as well as the clinical symptoms.

Presenter
Qunfang Long, University of Maryland, Baltimore County Baltimore, MD, United States

Connectivity Movies: Modeling fluidly varying patterns of functional integration with multiframe evolving dynamic functional network connectivity states (EVOdFNCs)

The study of brain network connectivity as a time-varying property began relatively recently and to date has remained primarily focused on capturing a handful of discrete states that represent fixed, transiently-realized, patterns of functional organization measured on timescales shorter than that of the full scan. Capturing canonical representations of temporally evolving patterns of connectivity is a challenging and important next step in fully leveraging the information available in large resting state functional magnetic resonance imaging (rs-fMRI) studies. We will discuss a new data-driven framework for identifying “truly dynamic” multiframe (movie-style) dynamic functional network connectivity (dFNC) states. Our approach employs a continuity-preserving planar embedding of high-dimensional whole-brain time-varying functional network connectivity measurements. This step converts multisubject high-dimensional dFNC observations into 2d trajectory segments with local neighborhoods that incorporate both the high dimensional geometry and subject identity. Line segments summarizing the tangent field to this locally-defined flow are then lifted back into the higher dimensional native dFNC state space, inducing a set of multiframe evolving dFNC representations (multiframe dynamic components (mdcs)) that function as basis objects with respect to which observed high-dimensional trajectories are parameterized. Characterizing intervals of dFNC observations as time-indexed weight-vectors on the mdcs allows a more “multivariate” level of richness in the observed dynamics to be expressed in terms of interpretable underlying dynamic components. Finally, by clustering timepoints of these multivariate mdc timeseries, we obtain weight-vector centroids that induce multiframe evolving dFNC states (evodFNCs) from the mdcs, a step that facilitates assessment of group differences in a fluidly varying connectivity via the occupancy, dwell times and transitions between clusters that themselves represent evolving connectivity patterns. This framework is highly flexible, accommodating different levels of temporal resolution and different levels of resolution on the tangent field to the planar trajectory segments. The ability to capture longer patterns of fluidly evolving connectivity brings complex processes of functional reorganization into better focus, elucidating the dynamic landscape that informs behavior, mood, cognition and other mental functions. Applied to data from a large rs-fMRI study of schizophrenia, we find that patients and controls exhibit different dynamics around common transiently realized whole-brain connectivity states, and that those patients with higher levels of key symptom are more distinguishable from other patients under this dynamic lens than they are with the typical dFNC analysis using a set of fixed summary states. The functioning human brain is constantly in flux: reorganizing, reacting, learning, adapting – and fMRI technology brings us, at coarse resolution, inside the “living” brain. Innovation in data-driven frameworks for interpretably presenting and analyzing high dimensional dynamic processes revealed by the fMRI signal will support continued progress toward understanding the brain with non-invasive functional imaging.

Presenter

Robyn Miller, Tri-institutional Center for Translational Research in Neuroimaging and Data Science (TReNDS) Atlanta, GA, United States

Multimodal Fusion with ReferenceA key to better understand the linkage underlying human behavior, multi-view brain alterations, and disease risks/subtypes

Data-driven, multi-modal brain imaging data fusion has been proven to be able to capture more views of brain aspects and co-variations among modalities, compared to separated analysis within each modality alone. However, the number of studies that do true multimodal fusion (i.e. capitalizing on joint information among modalities) is still remarkably small given the known benefits. Guided by clinical interest such behavior, symptomatic metrics, one can identify the associated multimodal brain signatures more accurately by supervised learning, which may further instruct the longitudinal disease risk prediction or subtype classification for individual patient. This talk will focus on developmental disorders and give two examples on using multimodal information to 1) explore common and unique alterations in autism subtypes by symptom-guided fMRI-sMRI fusion, and their replication in ABIDE datasets. 2) to longitudinally predict potential risks in adolescents to suffer from several mental disorders by personality-guided MRI fusion based on IMAGEN data. Both of studies show that multimodal fusion with reference may provide more clues to deepen our understanding of the development disorders, and thus may facilitate early diagnosis or intervention.

Presenter

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