ANALYSIS OF AUTISM SPECTRUM DISORDER USING DEEP LEARNING AND THE ABIDE DATASET

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Abstract - The goal of the present study was to apply deep learning algorithms to identify autism spectrum disorder (ASD) patients from large brain imaging dataset, based solely on the patient's brain activation patterns. We investigated ASD patient's brain imaging data from a world-wide multi-site database known as ABIDE (Autism Brain Imaging Data Exchange). ASD is a brain-based disorder characterized by social deficits and repetitive behaviors. According to recent Centers for Disease Control data, ASD affects one in 68 children in the United States. We investigated patterns of functional connectivity that objectively identify ASD participants from functional brain imaging data, and attempted to unveil the neural patterns that emerged from the classification. The results improved the state-of-the-art by achieving 70% accuracy in identification of ASD versus control patients in the dataset. The patterns that emerged from the classification show an anti-correlation of brain function between anterior and posterior areas of the brain; the anti-correlation corroborates current empirical evidence of anterior posterior disruption in brain connectivity in ASD. We present the results and identify the areas of the brain that contributed most to differentiating ASD from typically developing controls as per our deep learning model.

Key Words: **Autism, fMRI, ABIDE, Resting state, Deep learning**

1. INTRODUCTION

The primary goal of psychiatric neuroimaging research is to identify objective biomarkers that may inform the diagnosis and treatment of brain-based disorders. Data-intensive machine learning methods are a promising tool for investigating the replicability of patterns of brain function across larger, more heterogeneous data sets (Varoquaux and Thirion, 2014). The first goal of the present study was to classify autism spectrum disorder (ASD) and control participants based on their respective neural patterns of functional connectivity using resting state functional magnetic resonance imaging (rs-fMRI) data. We used a deep learning method that combined supervised and unsupervised machine learning (ML) methods. The method was applied to a large population sample of brain imaging data, the Autism Imaging Data Exchange I (ABIDE I). The second goal was to investigate the neural patterns associated with ASD that contributed most to the classification; the results are interpreted in the light of the networks of regions within the brain that differentiate ASD from controls and of previous studies of ASD brain function.

ASD is associated with a range of phenotypes that vary in severity of social, communicative and sensorimotor deficits. ASD diagnostic instruments assess the characteristic social behaviors and language skills (see our result about real-world classification accuracy). Yet neuro scientific research can help bridge the gap between a clear mapping of the complexity of the spectrum of alterations in autism behavior and their neural patterns (Just et al., 2013). Noninvasive brain imaging studies have advanced the understanding of the neural underpinnings of brain-based disorders and their associated behavior, such as ASD and its social and communicative deficits (Aylward et al., 1999; Just et al., 2014; Kana et al., 2009; Schipul et al., 2012). The identification of patterns of activation for ASD and the association of the patterns with neural and psychological components contributes to the understanding of the etiology of mental disorders (Jordan and Mitchell, 2015; Just et al., 2014).

One of the challenges to brain imaging studies of brain disorders is to replicate findings across larger, more demographically heterogeneous datasets that reflect the heterogeneity of clinical populations. Recently, ML algorithms have been applied to brain imaging data to extract replicable brain function patterns. These algorithms can extract replicable, robust neural patterns from brain imaging data of psychiatric disorder patients. This paper focus on studying the brain defects in autistic children. Thus a survey on ABIDE and fMRI is done to understand about the autism spectrum disorder.

2. LITERATURE SURVEY

2.1 Deriving reproducible biomarkers from multi-site resting-state data: An Autism-based example

Resting-state functional Magnetic Resonance Imaging (R-fMRI) holds the promise to reveal functional biomarkers of neuropsychiatric disorders. However, extracting such biomarkers is challenging for complex multi-faceted neuropathology's, such as autism spectrum disorders. In this paper, the feasibility of inter-site classification of neuropsychiatric status, with an application to the Autism Brain Imaging Data Exchange (ABIDE) database a large (N=871) multi-site autism dataset is demonstrated. For this purpose, pipelines that extract the most predictive biomarkers from the data is investigated. These R-fMRI pipelines build participant-specific connectomes from functionally-defined brain areas. Connectomes are then compared across participants to learn patterns of connectivity that differentiate typical controls from individuals with autism. This neuropsychiatric status for participants from the same acquisition sites or different, unseen, ones IS predicted. Among the many imaging techniques available, resting state fMRI (R-fMRI) is a promising candidate to define functional neurophenotypes.

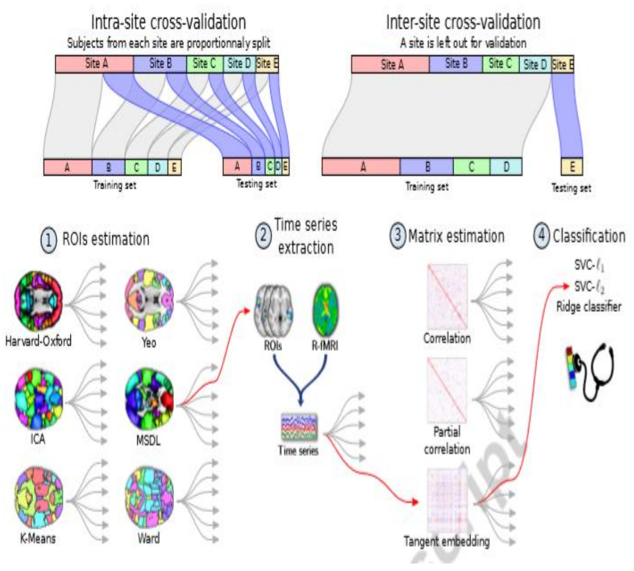

Fig-1- Functional MRI analysis pipeline

2.2 The Role of the Autism Diagnostic Observation Schedule in the Assessment of Autism Spectrum Disorders in School and Community Settings

Autism diagnostic practices among school and clinical psychologists, particularly those using the Autism Diagnostic Observation Schedule (ADOS), were examined using national survey results (N=132). School and clinical psychologists were similar in following the Best Practice Guidelines for screening, diagnosis and assessment. School psychologists were more likely to include a school or home observation and teacher report than clinical psychologists but evaluated significantly fewer children with autism spectrum disorders per year compared to clinical psychologists. School psychologists who were ADOS users were more likely to consider themselves autism experts and include a review of records than ADOS non-users. Perceived advantages of the ADOS included its strength in capturing ASD-specific behaviours and the standardized structure provided for observation, while diagnostic discrimination and required resources were the most commonly identified disadvantages.

2.3 The autism brain imaging data exchange: towards a large-scale evaluation of the intrinsic brain architecture in autism

Autism spectrum disorders (ASDs) represent a formidable challenge for psychiatry and neuroscience because of their high prevalence, lifelong nature, complexity and substantial heterogeneity. Facing these obstacles requires large-scale multidisciplinary efforts. Although the field of genetics has pioneered data sharing for these reasons, neuroimaging had not kept pace. In response, we introduce the Autism Brain Imaging Data Exchange (ABIDE)—a grassroots consortium aggregating and openly sharing 1112 existing resting-state functional magnetic resonance imaging (R-fMRI) data sets with corresponding structural MRI and phenotypic information from 539 individuals with ASDs and 573 age-matched typical controls. Here, we present this resource and demonstrate its suitability for advancing knowledge of ASD neurobiology based on analyses of 360 male subjects with ASDs and 403 male age-matched TCs. We focused on whole-brain intrinsic functional connectivity and also survey a range of voxel-wise measures of intrinsic functional brain architecture. Whole-brain analyses reconciled seemingly disparate themes of both hypo- and hyper connectivity in the ASD literature; both were detected, although hypo connectivity dominated, particularly for corticocortical and inter hemispheric functional connectivity. Exploratory analyses using an array of regional metrics of intrinsic brain function converged on common loci of dysfunction in ASDs (mid- and posterior insula and posterior cingulate cortex), and highlighted less commonly explored regions such as the thalamus. The survey of the ABIDE R-fMRI data sets provides unprecedented demonstrations of both replication and novel discovery. By pooling multiple international data sets, ABIDE is expected to accelerate the pace of discovery setting the stage for the next generation of ASD studies.

Autism Brain Imaging Data Exchange—a grassroots consortium effort dedicated to aggregating and sharing previously collected resting-state functional magnetic resonance imaging (R-fMRI) data sets from individuals with

ASDs and age-matched typical controls (TCs). The focus on R-fMRI was motivated by multiple factors. First, ASD neuroimaging studies have increasingly converged on abnormalities in connectivity among brain regions, rather than local functional or structural abnormalities. Second, R-fMRI approaches are particularly suitable for examining intrinsic functional connectivity (iFC); beyond robust test–retest reliability, R-fMRI sidesteps the challenge of designing tasks capable of probing the wide range of intellectual and behavioral capabilities characteristic of ASDs. Third, as recently demonstrated by the 1000 Functional Connectomes Project and recent efforts from the International Neuroimaging Data-sharing Initiative (INDI; for example, the ADHD-200), R-fMRI data sets from multiple imaging sites can be fruitfully aggregated for discovery and replication.

2.4 Predicting Human Brain Activity Associated with the Meanings of Nouns

The question of how the human brain represents conceptual knowledge has been debated in many scientific fields. Brain imaging studies have shown that different spatial patterns of neural activation are associated with thinking about different semantic categories of pictures and words (for example, tools, buildings, and animals). We present a computational model that predicts the functional magnetic resonance imaging (fMRI) neural activation associated with words for which fMRI data are not yet available. This model is trained with a combination of data from a trillion-word text corpus. Once trained, the model predicts fMRI activation for thousands of other concrete nouns in the text corpus, with highly significant accuracies over the 60 nouns for which we currently have fMRI data. A computational model that makes directly testable predictions of the fMRI activity associated with thinking about arbitrary concrete nouns, including many nouns for which no fMRI data are currently available.

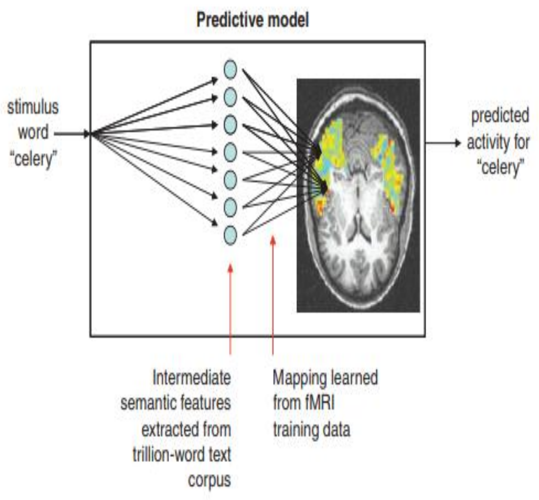

Fig-2-Form of the model for predicting fMRI activation

2.5 Atypical frontal-posterior synchronization of Theory of Mind regions in autism during mental state attribution

This study used fMRI to investigate the functioning of the Theory of Mind (ToM) cortical network in autism during the viewing of animations that in some conditions entailed the attribution of a mental state to animated geometric figures. At the cortical level, mentalizing (attribution of metal states) is underpinned by the coordination and integration of the components of the ToM network, which include the medial frontal gyrus, the anterior paracingulate, and the right temporoparietal junction. The pivotal new finding was a functional under connectivity (a lower degree of synchronization) in autism, especially in the connections between frontal and posterior areas during the attribution of mental states. In addition, the frontal ToM regions activated less in participants with autism relative to control participants. In the autism group, an independent psychometric assessment of ToM ability and the activation in the right temporoparietal junction were reliably correlated. The results together provide new evidence for the biological basis of atypical processing of ToM in autism, implicating the under connectivity between frontal regions and more posterior areas.

2.6 Disease state prediction from resting state functional connectivity

The application of multivoxel pattern analysis methods has attracted increasing attention, particularly for brain state prediction and real-time functional MRI applications. Support vector classification is the most popular of these techniques, owing to reports that it has better prediction accuracy and is less sensitive to noise. Support vector classification was applied to learn functional connectivity patterns that distinguish patients with depression from healthy volunteers. In addition, two feature selection algorithms were implemented (one filter method, one wrapper method) that incorporate reliability information into the feature selection process. These reliability feature selections methods were compared to two previously proposed feature selection methods. A support vector classifier was trained that reliably distinguishes healthy volunteers from clinically depressed patients. The reliability feature selection methods outperformed previously utilized methods. The proposed framework for applying support vector classification to functional connectivity data is applicable to other disease states beyond major depression.

Synchronous low-frequency (<0.1 Hz) fluctuations have been identified from time series of resting-state (subjects resting quietly, no prescribed task) functional MRI (fMRI) images. These fluctuations are thought to represent changes in blood flow and oxygenation due to spontaneous neuronal activity. Correlations between these fluctuations in spatially remote brain regions meet the definition of functional connectivity. Resting-state functional connectivity (FC) exists in a variety of known brain network and is consistent across subjects. Beyond investigating the underlying functional network structure of the brain, resting-state FC differences may also serve as markers for disease. Indeed, studies have shown altered resting-state FC in diseases such as attention deficit hyperactivity disorder and major depressive disorder (MDD).

These shortcomings can be overcome by applying multivoxel pattern analysis (MVPA) methods, which have relevance for brain state prediction and real-time fMRI applications. MVPA methods are sensitive to spatially distributed information that univariate methods ignore. MVPA algorithms learn patterns from multivariate datasets that optimally differentiate observations into predetermined categories. Support vector classification (SVC) is one of the most popular MVPA methods owing to reports that it offers better prediction accuracy and is less sensitive to noise than alternative MVPA approaches

3. CONCLUSIONS

Autism is a group of complex disorders of brain development. The autism students need special training to make them familiar to regional language. the results suggest that deep learning methods may reliably classify big multi-site datasets. Classification across multiple sites has to accommodate additional sources of variance in subjects, scanning procedures and equipment in comparison to single-site datasets. Such variation adds noise to the brain imaging data that challenges the ability to draw signatures from the brain activation that can classify disease states; yet the achievement of a reliable classification accuracy despite such noise generated from different equipment and demographics shows promise for machine learning applications to clinical datasets, and for future application of machine learning in the assistance of identification of mental disorders.

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