Creating a mini-brain to replicate rs-fMRI time series in ASD patients

Jason Bard, Pedro D. Maia

Department of Mathematics, The University of Texas at Arlington, Arlington, TX 76019

Abstract

Autism Spectrum Disorder (ASD) can be defined by a difficulty in social interaction alongside repetitive behaviors or interests. As of 2022, the condition affects approximately 1 in 36 children. The Autism Brain Imaging Data Exchange (ABIDE) consists of brain scan data from over 1,000 subjects, with nearly half diagnosed with ASD. This collection includes detailed patient phenotypic information and functional MRI scans taken at rest (rs-fMRIs), which showcases variations in blood flow and brain activity. A preliminary volumetric analysis of all defined brain regions according to the Harvard-Oxford cortical and subcortical max-probabilistic atlases was conducted to estimate the relative neuron count within each neural network component of a modular neural network (MoNN), which mimics the structure of the human brain by keeping the relative size of each region similar in proportion to the real brain. The objective is to assess whether this MoNN can replicate the input time series data accurately by modifying the scaling factor of all regions. In future research, the network's weight graph will be analyzed to identify distinctive properties that could differentiate between ASD patients and non-ASD individuals. It will also involve integrating a correlation matrix to dynamicize the MoNN and mimic interregional connectivity.

Background

ASD is typically diagnosed in patients between 18-36 months of age, and the severity of symptoms can vary widely, with some individuals having relatively mild symptoms while others have severe impairments. While there is currently no known cure, early intervention and treatments, such as behavioral therapy, speech therapy, and other specifically tailored activities, can help affected individuals develop skills and abilities that allow them to better navigate social situations and ideally to function independently. Research has shown that there are differences in brain structure and function in individuals with ASD, and there is ongoing research aimed at identifying the specific neural mechanisms underlying the disorder.[1] The ABIDE dataset is a collection of publicly available brain imaging data provided by dozens of universities and medical imaging sites. It consists of over a thousand patients near-evenly split into two groups: those in a healthy control group (HC), and those who have been diagnosed with ASD. The dataset as a whole includes both resting-state and task-based fMRI data in addition to clinical and demographic information about the participants, such as age, gender, IQ, handedness, and diagnostic information relating to treat scores and researchers' and interviewers' observations.[2]

Methods

Data was loaded directly from Nilearn, including 80 patients' data from NYU and the Harvard-Oxford atlas as a mask. The patients' functional brain scans were taken to be the full scale of the input from which other smaller inputs could be drawn. These scans were then smoothed by removing background noise and then were run through a mask, which is an object Nilearn uses to identify the overall brain activity in each region of interest using the smoothed image. The relative percentage of each brain region's volume was taken, and after being normalized, a scaling factor was applied to it such that each region would be represented by a bottleneck of neurons in a series of autoencoders representing the activity within. Two series of autoencoders were introduced; one for each set of patients. The losses from each network after training were then collected and then compared.

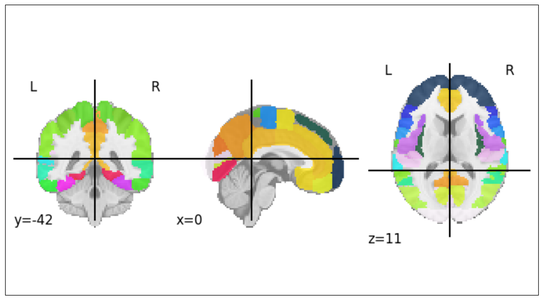

Figure 1. The Harvard Cortical (left) and Subcortical (right) max-probability atlas. Diagrams shows coronal, sagittal, and axial views in that order.

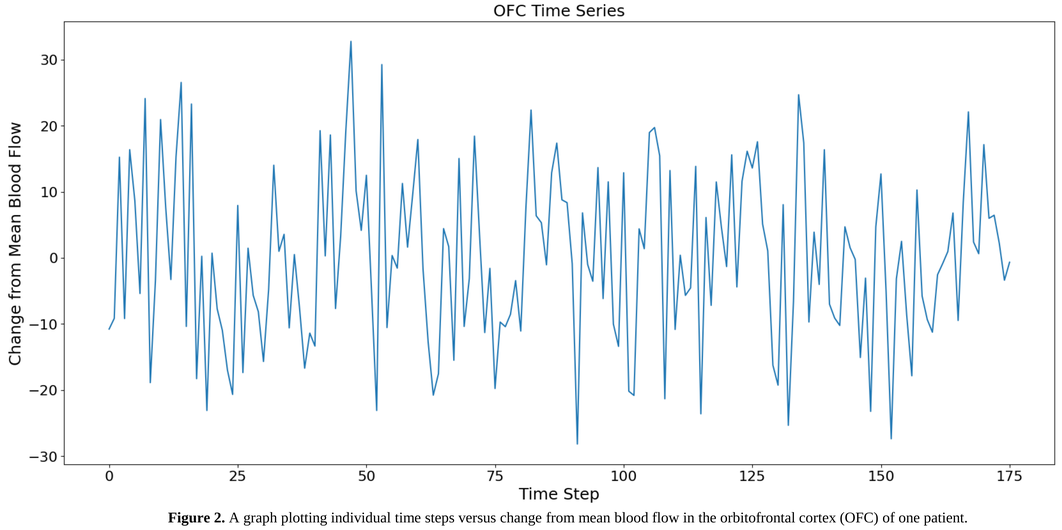

Figure 2. A graph plotting individual time steps versus change from mean blood flow in the orbitofrontal cortex (OFC) of one patient.

Results

MSE losses were lowest in the inferior temporal gyrus for both groups, and similar low losses were observed within the subcallosal, temporal fusiform, orbitofrontal, cuneal, and cerebral cortices. The HC losses were almost always less than the ASD losses, but they were similar for most regions.

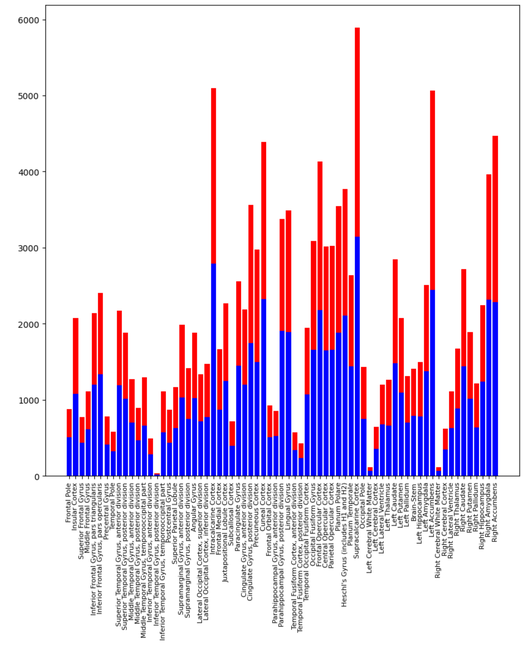

Figure 3. The bar chart of accuracies from repeated application of the autoencoders on all regions of the brain for both groups.

Acknowledgements

Thank you to Dr. Pedro Maia for guidance during this project. Thank you also to Dr. Jonathan Bard (thanks, Dad!) of Baylor Scott & White for his guidance in learning more about general neurology.

References

[1] Ha, Sungji, et al. "Characteristics of Brains in Autism Spectrum Disorder: Structure, Function and Connectivity across the Lifespan." *Experimental Neurobiology*, U.S. National Library of Medicine, Dec. 2015, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4688328.

[2] "ABIDE II." *ABIDE*, NITRC, 27 Mar. 2017, http://fcon_1000.projects.nitrc.org/indi/abide/abide_II.html.