Title:
Building a Foundation fMRI Model for Identifying Neurodevelopmental, Degenerative, and Genetic Disorders

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Abstract:
Functional Magnetic Resonance Imaging (fMRI) has emerged as a critical tool for understanding the functional architecture of the human brain. However, its clinical application remains limited due to the lack of generalized models capable of capturing the diverse patterns associated with neurological and psychiatric disorders. This proposal aims to build a foundation fMRI model—analogous to foundational models in vision and language—that can generalize across tasks and disorders to identify a wide range of neurodevelopmental (e.g., autism spectrum disorder, ADHD), degenerative (e.g., Alzheimer's, Parkinson's), and genetic (e.g., Fragile X, Down syndrome) brain conditions. By integrating large-scale multi-site fMRI datasets and employing advanced deep learning paradigms including contrastive learning, transformer-based architectures, and domain adaptation techniques, this work will lead to the development of a unified, interpretable, and clinically meaningful brain representation space. The final goal is to create a robust model that can transfer across disorders, generalize across populations, and offer insights into shared and distinct neural mechanisms of brain disorders.

Objectives:

1. Develop a large-scale fMRI dataset harmonized across multiple studies and cohorts.
2. Build a foundational model that captures hierarchical, multi-timescale, and multi-modal brain representations.
3. Investigate transfer learning across diagnostic categories, using both supervised and self-supervised objectives.
4. Evaluate and validate the model's performance on benchmark classification and anomaly detection tasks.
5. Improve interpretability through attention mechanisms and post hoc explainability tools.

Methodology:

- **Data Collection & Harmonization:** Aggregate fMRI scans from public datasets such as ABCD, ADNI, HCP, UK Biobank, and disorder-specific repositories. Preprocess using standardized pipelines (e.g., fMRIPrep).

- **Model Design:** Explore transformer architectures with spatio-temporal attention and graph neural networks (GNNs) to model brain connectivity.
- **Learning Objectives:** Use self-supervised learning (e.g., contrastive loss, masked modeling) to learn general-purpose embeddings, combined with supervised fine-tuning for specific diagnostic tasks.
- **Transfer Learning & Generalization:** Test transferability of learned representations across sites, age groups, and disorders.
- **Interpretability:** Apply saliency maps, attention analysis, and brain atlases to interpret learned features.

Significance:

This research will lay the groundwork for building general-purpose fMRI models akin to foundation models in other domains, facilitating scalable and robust diagnostic tools for brain health.