CLIMB: A Novel Framework for Unveiling Hidden Patterns in Brain Aging Dynamics Through Resting-State fMRI and Curriculum Learning

Kharade, Ameya (School: Nashua High School South)

The brain doesn’t always age at the same pace as the rest of the body. Some people's brains stay sharp well into old age, while others show signs of decline decades earlier. Detecting these hidden shifts early could revolutionize how we fight Alzheimer’s and other neurodegenerative diseases—but current methods struggle to predict who is at risk. This study developed a model, CLIMB (Connectivity-based Learning with Iterative Multistage Brain analysis), to change that. Instead of trying to learn all at once, CLIMB progressively learns from simpler to increasingly precise tasks, pinpointing unique patient-level patterns linked to accelerated aging. This was validated across 1400+ scans ($p<0.001$) through my novel fMRI augmentation method (ASWAC), outperforming traditional static chunking. By studying resting-state brain scans, it estimates a person’s “brain age” with 58% greater accuracy than current models, reducing error by more than six years. What’s groundbreaking is what it uncovered: on average, executive & memory, visual, and motor networks show the fastest aging, often before symptoms appear. This means that subtle shifts in brain connectivity—years before traditional cognitive tests detect problems—could signal early risk for disorders like Alzheimer’s. Even beyond aging, CLIMB proved its ability to uncover hidden brain patterns by predicting biological sex with 93% accuracy, showing its power to detect meaningful differences in brain function. With further development, this approach could lead to early screening tools, personalized intervention, and a deeper understanding of how lifestyle, genetics, and mental health shape brain aging. By decoding the hidden timeline of brain health, CLIMB takes us one step closer to preventing cognitive decline before it begins.

Awards Won: