PROJECT SUMMARY

Project Title: "*Adaptive Brain Training Using fMRI Neurofeedback*"

Abstract

The overall objective of this project is to leverage a novel neuroimaging paradigm – real-time analysis of functional magnetic resonance imaging data (real-time fMRI) – to adaptively update behavioral tasks in a well-controlled and repeatable manner with the goal of regulating activity in specific neural circuitry. The work will bring us closer than ever to defining causal relationships between brain activity and behavior. FMRI remains the gold standard for in vivo whole brain imaging, enabling unprecedented leaps forward in our understanding of brain function as it relates to the instantiation of our rich mental lives and to our behavioral interactions with the world. While clever methods in conventional fMRI have suggested causal networks, rtfMRI takes a radically different approach, i.e. flipping the experimental role of brain and behavior, instituting brain activity as the independent variable and behavior as the dependent variable. This inversion in fMRI methodology has the potential to generate tremendous advances in our understanding of causal brain-behavior relationships. However, neurofeedback is hampered by the individual's ability to discover, remember, and implement appropriate brain regulation strategies, reducing the applicability of the technology. In this project, we propose to bridge the cognitive limitation of extant real-time fMRI approaches through parametric modeling and subsequent adaptive control of circumscribed brain networks. First, we will model the behavior-to-brain relationship in two unique experiment paradigms, one investigating motor learning and the other investigating prospective remembering. Then, we will invert these models to quantitatively regulate the brain-to-behavior relationship using neurofeedback from an adaptive controller that is continuously updated by measurements of brain activity via real-time fMRI. The application of modern control theory to the modulation of functional brain networks will extend and formalize our ability to assess causal brain-behavior interactions.

Relevance

Our project introduces an innovative and interdisciplinary approach to brain science in which exciting methodological advances in brain imaging (real-time fMRI and neurofeedback) and analysis methods (multi-voxel pattern analysis of fMRI data) are being melded with modern adaptive control theory (iterative learning control) and to yield an exciting new experimental paradigm. This paradigm is capable of generating new inferences about the brain-behavior relationship that are otherwise inaccessible using conventional analyses, it crosses disciplinary boundaries, and forms new research partnerships as are central to the mission of UT BRAIN. If successful, this paradigm will enable researchers to tailor any specific task to fit the idiosyncratic cognitive dynamics of each individual in order to reliably induce and sustain a desired brain state. This could pave the way for radical change in testing brain-behavior causality, ultimately leading to more effective delivery of neurotherapy for rehabilitation and neurological disease. Here we highlight two distinct applications of this paradigm, with implications towards treatment of attention and memory disorders and sensorimotor rehabilitation. The research partnership developed as a result of this proposal brings together faculty from the Departments of Psychology, Neuroscience, and Mechanical Engineering at UT Austin. Specifically, Dr. Lewis-Peacock (PI; Psychology), will oversee development of multivariate pattern analysis of real-time fMRI data and its application to understand the strategic deployment of attention and memory during goal-directed behavior (Aim 2). Dr. Sulzer (Co-I; Mechanical Engineering) will design the controllers used for adaptive neurofeedback in both experiments, he will oversee development of univariate real-time fMRI data and its application to motor learning (Aim 1). Dr. Luci (Collaborator; Neuroscience) will advise on sequence development and real-time fMRI data reconstruction and processing techniques.