Research Award Brief

Modeling and EEG Studies of Motivation and Attention Dynamics: An Individualized Approach to Enhance Learning (2017-2019)

PI: Sridevi Sarma, Ph.D.
Associate Professor
Department of Biomedical Engineering
Whiting School of Engineering

Co-Investigators: Susan Courtney, Ph.D.
Professor
Department of Psychological and Brain Sciences
Krieger School of Arts & Sciences

Research Question: How can we characterize individual differences in learning behaviors as a function of motivation and attention; and how can we identify the underlying neural mechanisms?

Interdisciplinary Approach: PI Sarma, is a control theorist and computational neuroscientist. Co-Investigator, Dr. Susan Courtney, is a cognitive neuroscientist and expert on the neural systems underlying working memory for different types of information. The goals of the project require true interdisciplinary collaboration in order to define the relevant cognitive neuroscience hypothesis to be tested, to determine the appropriate experimental variables to be manipulated in the data collection, and to develop and evaluate the computational model necessary to test that hypothesis. In particular, Dr. Courtney appreciates that latent cognitive, emotional, and attentive processes play a significant role in associative learning. Her data and studies have clearly shown that individuals vary greatly in their behaviors, presumably because they vary greatly in these latent processes. Dr. Sarma has techniques of estimating these latent processes from measurable data through state-space modeling techniques that have significantly greater predictive power precisely because they take these latent processes ("states") into account.

Potential Implications of Research: This project addresses fundamental questions of cognitive neuroscience regarding the interactions among motivation, attention, learning, working memory, and cognitive control. The knowledge gained from this project and subsequent follow-on studies will have broad impacts on all of these areas of cognitive neuroscience, which are often studied in isolation. Further, understanding the mechanisms underlying relationships among motivation, attention, learning, and memory could have profound effects on the effectiveness of educational practices and other public policies. The procedures and knowledge developed here could readily be used to develop automated tools for individualized classroom or computer-based learning. A reliable method for quantitatively assessing each individual's sensitivities to positive, negative, and loss-avoidance feedback, and then employing individually-tailored feedback in subsequent learning experiences should facilitate attention control and optimize learning across individuals. This project will enable testing an example of how such a tool might work.

Current motivational salience through expectation of reward, punishment, or loss-avoidance is known to increase attention and learning. Learned associations between valuable outcomes and particular stimuli affect behavior and attention, even after participants are told that the stimuli are irrelevant and may be detrimental to current performance. Although this attention capture can negatively impact learning in unstable contexts, when reward contingencies *are* stable, attention is directed quickly to the most important information, potentially enhancing learning. The effects of past associations on current attention and learning could thus be exploited to enhance subsequent learning, as has been done with retrieval practice and repetition spacing effects. Motivational incentives are used ubiquitously in educational settings, but their effectiveness is limited by individual differences and the ways in which the induced attentional biases can either enhance or impair learning in new contexts. To address these challenges, the proposed project will rigorously examine the effects of reward and loss-avoidance associative learning on subsequent attentional biases and learning. We will collect behavioral and electroencephalography (EEG) data to develop a computational model of task inputs and internal state variables (latent variables related to learning) that determine neural activity and behavioral output (accuracy and reaction times of motor responses) during and after associative learning. The EEG data provides neural outputs at various stages throughout a trial, including perceptual processing and working memory maintenance, which also change over time with learning, overriding, and unlearning reward and loss-avoidance associations. Importantly, the model continually estimates dynamic changes in the internal states of the system (related to learning) that link task inputs to the neural and behavioral outputs. This approach enables a more rigorous characterization of individual differences in these behaviors and their underlying neural mechanisms, and enables prediction of what task manipulations enhance an individual's current performance and subsequent learning.

For more information, please contact Sridevi Sarma (sree@jhu.edu).