Project Summary

Overview

GeoGaze is a novel Human-Technology Frontier solution that leverages eye tracking to augment learner cognition in real time based on effective media integration strategies for students with differences in working memory capacity, a key predictor of learning. Games, simulations, intelligent tutors, augmented and virtual reality and other contemporary learning technologies all use multiple media to present information, and effective integration of information from multiple media is required for learning to occur. Given the ubiquitous nature of multimedia in 21st century learning, it is puzzling why we know so little about how individual differences such as working memory capacity influence multimedia learning. This project addresses this important gap and explores the efficacy of a gaze-driven display solution to augment neurodiverse learners' cognition in real time, an individual-differences approach to adaptive multimedia learning that has not been attempted before. This R&D program is executed in the important context of learning geoscience, a multidisciplinary science that crosses many STEM disciplines, including physics, chemistry, and biology, as well as engineering and mathematics. Our interdisciplinary and multi-institutional team will propel the science of multimedia learning leveraging our experience of successful collaboration and convergence research (NSF Science of Learning Collaborative Network LENS, #1540888) and expertise in education, psychology, gaze-driven display technology, machine learning.

Intellectual Merit

Studies of multimedia learning traditionally focus on final learning outcomes but what happens during the learning process (e.g., multimedia integration strategies) is often unexplored. Knowing only the outcome of the interaction (i.e., whether the learner has mastered the material as intended) does not generate insights for the design of effective interventions tailored specifically to learning needs. Additionally, despite the widespread use of multimedia in K-12 and higher education, adaptive multimedia learning solutions that individualize learning based on strategy use relative to the learner's working memory capacity do not currently exist. The proposed research and development addresses these shortcomings to gain a robust perspective of how students with working memory capacity differences learn geosciences in multimedia environments and how their cognition can be improved using gaze-driven adaptive learning technology, GeoGaze. This project will advance our understanding of STEM learning and learning environments along several important dimensions:

- *Conceptual:* Our work will increase holistic understanding of how students with working memory differences integrate information from multiple media as they learn authentic STEM content.
- *Methodological:* We will integrate behavioral and psychophysiological data and employ high-dimensional data visualization, cluster analysis, and machine learning (multi-layer backpropagation neural network analysis) to understand how to support learners with working memory capacity differences in STEM multimedia environments.
- *Technological:* We will design and test a novel gaze-driven Human Technology Frontier solution for adapting multimedia learning in real time based on effective media integration strategies relative to learner differences in working memory capacity.
- *Empirical:* Our research will generate new and important empirical evidence for using real-time gaze-driven adaptation of learning materials to augment neurodiverse learners' cognition.

Broader Impacts

Understanding how individual differences in working memory capacity influence STEM learning and how to support neurodiverse learning using adaptive learning technologies is critical to ensuring a diverse STEM workforce and an informed citizenry. Our proposed R&D will result in important broader impacts:

- Most STEM learning occurs in multimedia environments. We will address important gaps on how individual differences influence multimedia learning and how to leverage this knowledge to augment learner cognition in multimedia environments in real time.
- STEM education would benefit from more R&D on adaptive multimedia solutions, particularly those that use non-invasive approaches such as eye tracking, to provide just-in-time support.
- Our work promotes ecological and population validity in the science of learning, focusing on neurodiverse community college students and authentic geoscience learning materials.
- Our R&D focuses on geoscience, one of the least diverse STEM fields (Cramer et al., 2015).
- The gaze data used for GeoGaze can be down sampled for use in webcam-based eye tracking with potential for adoption on any device with a webcam and a browser with Javascript support.