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Researchers probe links between vision problems and cognition in a pioneering study

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The ability to perceive the world in three dimensions and to see clearly at near and far ranges is coordinated by key eye motor functions, including a mechanism called convergence and accommodation that allows us to see objects at different spatial depths by controlling two sets of muscles to reduce double and blurry vision.

For a small but significant fraction of the population, however, the left and right eyes do not work as a team. The result, known as convergence insufficiency (CI), leads to visual stress and strain and headaches. The impacts on cognition and learning can be severe, particularly for children.

"Near reading is particularly uncomfortable for people with CI, who experience visual stress and fatigue after 15 to 20 minutes of reading," notes Tara Alvarez, a professor of biomedical engineering and the director of NJIT's Vision and Neural Engineering Laboratory. "This is really a problem for students. In terms of cognitive load, if someone is expending significantly more energy acquiring visual information, then less energy is available for cognitive function. This puts students with CI at a competitive disadvantage compared to their peers, especially for timed tests."

Alvarez and other experts in the field estimate that between 12 and 24 million people in the United States, or 4 to 8 percent of the population, have this vision dysfunction. Among people with traumatic brain injuries, the percentage may be as high as 40 percent; children with

Attention Deficit Hyperactivity Disorder (ADHD) are three times as likely to experience it. And while the problem was identified more than a half-century ago, "we still don't know why CI happens. We don't know why one person develops it and another doesn't," Alvarez says.

Armed with a five-year research grant from the National Institutes of Health, Alvarez is poised to begin untangling some of the mysteries behind CI. In a study that is the first of its kind in terms of size and scope, she and her research team will quantify eye movements and functional imaging to understand how an established form of vision therapy leads to a sustained reduction in symptoms related to CI. They are hopeful that the study will lead to new therapeutic interventions and ultimately improve activities of daily living, such as allowing people to read more comfortably for longer periods of time.

In the study, which will enroll more than 100 adults between the ages of 18 and 35, Alvarez and her team will measure changes in eye movement speed with instrumentation she has developed over the past several years with funding from the National Science Foundation. They will also use functional magnetic resonance imaging (fMRI) to map the brain's response to visual stimuli before and after therapy.

"My lab is trying to explain the neuroplasticity, or adaptations, that occur in the brain with therapy to alleviate the symptoms," she says. "Once we understand how neuroplasticity is occurring then our team can systematically develop new therapeutic interventions to further improve vision function, especially in brain-injury populations such as people who have suffered injury from an automobile accident or a blast injury during battle."

She is working in collaboration with Mitchell Scheiman of Salus University (Philadelphia College of Optometry) and Bharat Biswal, chairman of NJIT's Department of Biomedical Engineering.

Scheiman, the primary clinical lead of the study, conducted an earlier randomized clinical trial showing that 73 percent of children with CI experience a significant decrease in visual symptoms and improvement in function when they undergo office-based vision therapy.

However, the underlying neurological mechanism by which the therapy works is still unknown. For his part, Biswal has developed novel brain connectivity algorithms to understand not only which regions of the brain are activated for a given task, but also how the regions communicate with each other.

"The application of his algorithm will lead our team to a much better understanding of how the brain functions before therapy compared to after," Alvarez says.

"You can correct this problem," she adds. "Clinicians would like to see scientific evidence of what is changing in the brain through vision therapy. My research aims to quantify the underlying mechanisms of how vision therapy leads to a sustainable reduction in vision symptoms, including our preliminary published data (from an earlier study) that supports evidence of improved neural synchronization. Such knowledge may lead to new therapies with even better efficacy rates."

Several years ago, she led a much smaller pilot study of the impacts of CI therapy with just a handful of patients. The results were promising. With the current funding from NIH, she and her team have the resources to determine whether the pilot results generalize to a much larger population.

The clear links between vision and cognition lend urgency to the endeavor.

"So much of the brain's cortical real estate is allocated to vision," Alvarez notes, adding, "Humans and other primates are among the few species to possess vergence – the ability to see in depth."

As a researcher, Alvarez says she is "fascinated by how plastic and changeable the oculomotor system is, and I always wanted my work to have a clinical impact."

Going forward, she plans to delve more deeply into traumatic brain injury (TBI) and would like to broaden her scope to include both pediatrics and TBI.

"Ultimately we hope our research will lead to the engineering of new therapies for these populations," she says. "Many studies show that 25 to 40 percent of civilian and up to 50 percent of military traumatic brain injury patients have CI. Hence, research is really needed within these populations."

Provided by New Jersey Institute of Technology

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