

Testing the Effects of Transcranial Direct Stimulation on Human Learning

Laura Matzen (PI) and Michael Trumbo

An LDRD-developed capability based on transcranial direct current stimulation leads to improved cognitive performance for workers in demanding positions, particularly in national security domains.

Training a person in a new knowledge base or skillset is extremely time consuming and costly, particularly in highly specialized domains such as the military and the intelligence community. Recent research in cognitive neuroscience has suggested that a technique called transcranial direct current stimulation (tDCS) has the potential to revolutionize training by enabling learners to acquire new skills faster, more efficiently, and more robustly (Bullard et al., 2011). In tDCS, a small region of the brain is stimulated with a weak electrical current (1-2 milliamps) via an electrode placed on the scalp. This current makes the neurons in the vicinity of the stimulation either more or less likely to fire, depending on the polarity of the electrical field. Although tDCS has been used for over 50 years, recent advances in technology have created a surge of new applications (Utz et al., 2010) and devices that are readily available to the public. Most of the research in this rapidly developing field has been focused on medical applications, such as treating migraines or assisting with rehabilitation of brain injuries. However, tDCS has many potential applications with implications for national security and those applications have received little attention to date. In this LDRD, Sandia researchers established a new tDCS capability to study how this technique could impact human performance in national security domains.

The project tested the effects of tDCS on two types of memory performance that are critical for learning new skills: associative memory and working memory. Associative memory is memory for the relationship between two items or events. Enhancing this kind of memory could provide substantial benefits to the speed and robustness of learning new information. The experiment used a naturalistic associative memory task in which participants were asked to remember the links between faces and names, a task that is difficult for most people because face-name pairs are relatively arbitrary. In the double-blind experiment, the participants received either active (2.0 mA of current) or sham (0.1 mA of current) via an electrode placed on the scalp over the left inferior frontal gyrus. The results showed that participants who received active stimulation correctly recalled 50% more names, on average, than participants who received sham stimulation. The results of the associative memory study are in press in the journal *Brain Research*.



Working memory refers to the amount of information that can be held in mind and processed at one time, and it forms the basis for all higher-level cognitive processing. Researchers investigated the effects of tDCS stimulation on verbal and spatial working memory capacity, as well as the degree of transfer between tasks that were practiced during stimulation and tasks that were not. The goal of this study was to determine if it is possible to improve working memory capacity and higher-level cognitive performance with tDCS, and if so, to determine whether tDCS-induced facilitation of performance is task-specific or general. The results showed that certain stimulation parameters led to both improvements in the practiced working memory task and transfer to other tasks, such as a fluid intelligence test.

Taken together, the two experiments in this project provide strong support for the idea that tDCS can improve cognitive performance. By improving associative memory performance, tDCS can have a substantial impact on the speed at which people are able to learn new information and skills. By increasing working memory capacity, it can improve overall cognitive performance in demanding situations that place a high burden on working memory or adaptive reasoning. This work has potential applications in numerous national security domains, since most of these domains ultimately rely on human performance and decision making, leaving open the possibility for human error. There are also many domains in which people must learn complex skills or how to use extremely complex tools, whether those tools are hardware, software, or systems. This LDRD, combined with other ongoing research in this area, indicates that tDCS has the potential to improve human cognitive performance and to help people learn information faster and remember it better. That can impact any number of real-world applications through improving human performance.

Sandia National Laboratories
Laboratory Directed Research and Development

We welcome your questions, comments, and ideas for future LDRD projects to feature!
Email your feedback to Marie Arrowsmith, mdarrow@sandia.gov



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The Role of Real-Time Decision Making in Grid Resilience

Laurie Burnham (PI), Michael Haass, Christina Warrender, Susan Stevens-Adams, Kerstan Cole, James Forsythe

Sandia researchers have developed a patent-pending method for measuring automation in major data acquisition systems, which will ultimately improve the safety and security of our energy grid.

The rapid transformation of the electric grid to a modern computer-based automation system has resulted in unprecedented amounts of data that must be translated into actionable events by system operators in real time. While these changes have brought intelligence to the grid, lowering costs, speeding restoration times and enabling an increase in solar- and wind-generated electricity, they have also fundamentally changed the way the distribution grid operates.

Working with collaborators at Burlington Electric Department, Green Mountain Power and Vermont Electric Cooperative, the IGRID team is studying how these grid changes—specifically the increase in automated technologies and associated data—affect operators' workloads and decision-making abilities, with the intent of linking the findings back to grid performance.

To meet its objectives, the IGRID team has created a novel method for measuring automation using information contained in the supervisory control and data acquisition (SCADA) systems that feed data from distributed sensors back to the control room. The effort, led by team member Michael Haass, has resulted in a patent-pending analytical method that could transform the way automation is integrated into industrial control processes. The method's impact lies in its ability to provide a richly detailed view of the balance between operator- and machine-made decision-making and identify the key factors that may affect grid performance, including operator workload and weaknesses or gaps in automation systems. These moment-by-moment details can be analyzed over simple periodic time periods (for example, weekly, or monthly), during critical events (such as storms or system upgrades), or for specific subsystems and provide utilities with an unprecedented ability to predict and mitigate problems.



The grid's technological transformation will introduce multiple and novel challenges that will increase an operator's cognitive load and impact his/her critical thinking and decision-making abilities...the consequences of which are unknown.

A technical advance describing this new method has been filed and preliminary applications will be presented in an invited session paper at the 2015 *International Conference on Applied Human Factors and Ergonomics*.

READ MORE:

S. Stevens-Adams, K. Cole, M. Haass, C. Warrender, R. Jeffers, L. Burnham, and C. Forsythe (2015), Situation awareness and automation in the electric grid control room, 6th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences, AHFE 2015.

UPCOMING LDRD EVENTS

AUGUST 20 DS&A Ending Project Reviews	AUGUST 30 SFO Portfolio Review & Concurrence
AUGUST 26 CIS Ending Project Reviews	SEPT 4 Nano/Micro Ending Project Reviews

LDRD PROJECTED BUDGET AND STATUS

FY15 Q4 \$146 MILLION 380 PROJECTS FUNDED AT \$144.7 MILLION

AWARDS & RECOGNITION for LDRD Participants

Susan Rempe was recognized as having made Time Magazine's online list for one of "The Five Best Ideas of Today," for her work on a drug that could destroy the deadly childhood disease known as acute lymphoblastic leukemia—and potentially other cancers as well.

Bill Stygar received the 2015 Erwin Marx Award at the combined IEEE Pulsed Power Conference and Symposium on Fusion Engineering on May 31-June 4, 2015 in Austin, TX.

The paper describing LDRD work, entitled *Density Estimation Using Muon Imaging* was selected as the Best Paper for the Environmental Engineering Geophysics Society Symposium on Application of Geophysics to Engineering and Environmental Problems.