Energizing the brain: Combating worker fatigue using wearable neurotechnology

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Fatigue due to extended periods of work and insufficient rest can impair job performance, situation awareness, and decision-making capabilities, even when it's needed most. Specifically, in safety-critical environments, such as responding to wildfires, fatigue has been associated with a two-fold increase in the risk of injuries and errors, and a four-fold increase in safety-compromising behaviors during emergencies.

To mitigate these outcomes, researchers at Texas A&M University are evaluating how the impact of fatigue-causing performance declines in safety-critical workers, such as firefighters, nurses, and emergency room (ER) doctors, can be delayed through the use of transcranial direct current stimulation (tDCS), a wearable and noninvasive brain stimulation technology that uses weak electrical currents to stimulate certain parts of the brain.

"Administrative and personal countermeasures, such as sleep/shift schedules, education and stimulants like caffeine, take a reactive approach and are largely impractical during emergencies. In some cases, they are accompanied by substantial health side effects," said Dr. Ranjana Mehta, associate professor in the Wm. Michael Barnes Department of Industrial and Systems Engineering. "Transformative human augmentation paradigms to proactively tackle fatigue deficits through noninvasive neurostimulation have proven more effective than stimulants and may address prevailing adoption barriers."

The research team also includes Reed Smoot, an undergraduate student in the Department of Electrical and Computer Engineering, and Rohith Karthikeyan, a doctoral student in the J. Mike Walker Department of Mechanical Engineering, and first author and lead doctoral student on the study.

The team conducted a three-session experimental study with 32 participants. At each session, participants completed an hour-long fatiguing cognitive task that has been shown to disrupt and impair an individual's cognitive processes and executive functions, i.e., working memory. Participants either received anodal stimulation, associated with the enhancement of the stimulated brain area, received a sham (placebo) stimulation or did not receive the stimulation on each of the three sessions.

The stimulation was provided at the 20-minute mark during the fatiguing task for 10 minutes at 1 mA (milliampere). Task performance, fatigue responses, effort, discomfort and heart-rate variability were also evaluated.

Out of the counterbalance of anodal stimulation, sham stimulation and no stimulation, the team found that by exciting neuronal activity through anodal stimulation, task performance under fatigue improved by approximately 15% (ranging from 10-50% across the study pool), while it decreased under the other two sessions.

The researchers were also able to capture the selective benefits of anodal stimulation on response selection, e.g., choosing an appropriate action to take, which was enhanced when the stimulation was provided. While inhibitory control, or the ability to inhibit impulsive, natural, and habitual responses did not increase, individuals were able to preserve this cognitive function under anodal stimulation, which otherwise declined significantly under sham or no stimulation. Additionally, these improvements were comparable for both men and women.

Fatigue is a personal experience and is impacted by both declines in cognitive and neural resources, but also motivation. A unique aspect of this work was to understand and capture the various gains that neurotechnologies can provide.

"The stimulation-related improvements were not available at a perceptual level, i.e., individuals did not report lower fatigue ratings under the anodal stimulation. We are currently investigating how such solutions will be trusted and operationalized in the field, especially within human-centered systems," Karthikeyan said.

The study findings emphasize the potency of neurostimulation as an equitable fatigue countermeasure to support workers during high-risk fatiguing operations, such as responding to emergencies that can last several days or weeks, especially given the shortage in the ER workforce.

"We still have some way to go before this technology can be rolled out in the field. Our study employed stimulation parameters at levels not previously tested, largely to shed light on dose-response relationships, but also keeping in mind what is practically feasible and ethical if such technology were to be utilized in ER operations," Mehta said.

The team has since begun the next phase of empirical testing along with customer discovery efforts with emergency responders using the Innovation Corps Sites program offered by the Texas A&M Engineering Experiment Station.

"We are committed to developing trustworthy engineering solutions that work for emergency responders when they need it; thus, adopting a human-centered approach is critical," Mehta said.

More information: Rohith Karthikeyan et al, Anodal tDCS augments and preserves working memory beyond time-on-task deficits, *Scientific Reports* (2021). DOI: 10.1038/s41598-021-98636-y

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