Electric 'thinking cap' controls learning speed

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Robert Reinhart applies the electrical stimulus to subject Laura McClenahan. After 20 minutes the headband is removed and the EEG cap will capture readings of her brain as she executes the learning task. Credit: John Russell / Vanderbilt University

(Medical Xpress)—Caffeine-fueled cram sessions are routine occurrences on any college campus. But what if there was a better, safer way to learn new or difficult material more quickly? What if "thinking caps" were real?

In a new study published in the *Journal of Neuroscience*, Vanderbilt psychologists Robert Reinhart, a Ph.D. candidate, and Geoffrey Woodman, assistant professor of psychology, show that it is possible to selectively manipulate our ability to learn through the application of a mild electrical current to the brain, and that this effect can be enhanced or depressed depending on the direction of the current.

The medial-frontal cortex is believed to be the part of the brain responsible for the instinctive "Oops!" response we have when we make a mistake. Previous studies have shown that a spike of negative voltage originates from this area of the brain milliseconds after a person makes a mistake, but not why. Reinhart and Woodman wanted to test the idea that this activity influences learning because it allows the brain to learn from our mistakes. "And that's what we set out to test: What is the actual function of these brainwaves?" Reinhart said. "We wanted to reach into your brain and causally control your inner critic."

Reinhart and Woodman set out to test several hypotheses: One, they wanted to establish that it is possible to control the brain's electrophysiological response to mistakes, and two, that its effect could be intentionally regulated up or down depending on the direction of an electrical current applied to it. This bi-directionality had been observed before in animal studies, but not in humans. Additionally, the researchers set out to see how long the effect lasted and whether the results could be generalized to other tasks.

Stimulating the brain

Using an elastic headband that secured two electrodes conducted by saline-soaked sponges to the cheek and the crown of the head, the researchers applied 20 minutes of transcranial direct current stimulation (tDCS) to each subject. In tDCS, a very mild direct current travels from the anodal electrode, through the skin, muscle, bones and brain, and out through the corresponding cathodal electrode to complete the circuit. "It's one of the safest ways to noninvasively stimulate the brain," Reinhart said. The current is so gentle that subjects reported only a few seconds of tingling or itching at the beginning of each stimulation session.

In each of three sessions, subjects were randomly given either an anodal (current traveling from the electrode on the crown of the head to the one on the cheek), cathodal (current traveling from cheek to crown) or a sham condition that replicated the physical tingling sensation under the electrodes without affecting the brain. The subjects were unable to tell the difference between the three conditions.

The learning task
After 20 minutes of stimulation, subjects were given a learning task that involved figuring out by trial and error which buttons on a game controller corresponded to specific colors displayed on a monitor. The task was made more complicated by occasionally displaying a signal for the subject not to respond—sort of like a reverse "Simon Says." For even more difficulty, they had less than a second to respond correctly, providing many opportunities to make errors—and, therefore, many opportunities for the medial-frontal cortex to fire.

The researchers measured the electrical brain activity of each participant. This allowed them to watch as the brain changed at the very moment participants were making mistakes, and most importantly, allowed them to determine how these brain activities changed under the influence of electrical stimulation.

Controlling the inner critic

When anodal current was applied, the spike was almost twice as large on average and was significantly higher in a majority of the individuals tested (about 75 percent of all subjects across four experiments). This was reflected in their behavior; they made fewer errors and learned from their mistakes more quickly than they did after the sham stimulus. When cathodal current was applied, the researchers observed the opposite result: The spike was significantly smaller, and the subjects made more errors and took longer to learn the task. "So when we up-regulate that process, we can make you more cautious, less error-prone, more adaptable to new or changing situations—which is pretty extraordinary," Reinhart said.

The effect was not noticeable to the subjects—their error rates only varied about 4 percent either way, and the behavioral adjustments adjusted by a matter of only 20 milliseconds—but they were plain to see on the EEG. "This success rate is far better than that observed in studies of pharmaceuticals or other types of psychological therapy," said Woodman.

The researchers found that the effects of a 20-minute stimulation did transfer to other tasks and lasted about five hours.

The implications of the findings extend beyond the potential to improve learning. It may also have clinical benefits in the treatment of conditions like schizophrenia and ADHD, which are associated with performance-monitoring deficits.

More information: Paper: www.jneurosci.org/content/34/12/4214.full