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Researchers confirm transcranial stimulation effects and determine a key mechanism

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Praveen Pilly, Senior Research Staff Scientist Credit: © 2017 HRL Laboratories

HRL Laboratories researchers have determined how non-invasive transcranial direct current stimulation (tDCS) could increase performance of associative learning. The researchers found that when applied to the prefrontal cortex, tDCS affects a wide portion of the brain, causing changes in functional connectivity between different brain areas that increased learning speed in macaques.

This new understanding of what tDCS does to the brain and its confirmation of tDCS as a learning aid comes in the context of controversy over previous reports that seemed to show no effect on neuron firing rates in cadaver heads, which was generally believed to be the mechanism of interest. tDCS-based behavioral results have also been questioned on statistical and methodological grounds, but those analyses have been criticized. The new HRL study confirmed behavioral changes that sped up learning with tDCS and found that learning improved regardless of neuron firing rates.

Done in collaboration with McGill University in Montreal and Soterix Medical in New York, the study was sponsored by the Defense Advanced Research Project Agency (DARPA)'s Restoring Active Memory (RAM) program. Published October 12, 2017, in the journal *Current Biology*, tDCS in animals showed learning accelerated by about 40% when given 2 mA noninvasively to the prefrontal cortex without increased neuronal firing. This study showed it was modulated connectivity between brain areas, not neuron firing rates, that accounted for the increased learning speed.

The behavioral task in this experiment was associative learning. The macaques had to learn arbitrary associations between a visual stimulus and a location where they would get a reward—a visual foraging task. The initial foraging trials took about 15 seconds, and once the animal learned the location of the reward, it took approximately 2 seconds to recall and find the target. Subjects in the control condition required an average of 22 trials to learn to obtain the reward right way. With tDCS they required an average of 12 trials.

"In this experiment we targeted the prefrontal cortex with individualized non-invasive stimulation montages," said Dr. Praveen Pilly, HRL's principal investigator on the study. "That is the region that controls many executive functions including decision-making, cognitive control, and contextual memory retrieval. It is connected to almost all the other cortical areas of the brain, and stimulating it has widespread effects. It is also the target of choice in most published behavioral enhancement studies and case studies with transcranial stimulation. We placed the tDCS electrodes on the scalp in both our control and stimulation conditions. The behavioral effect was revealed when they learned to find the reward faster."

"The improved long-range connectivity between brain areas in the high frequency bands and reduced connectivity in the low frequency bands were the determining factors in our study that could explain the learning improvements with tDCS of the prefrontal cortex," Pilly said. "Just because neurons can be more brisk in their firing may not lead to changes in performance. Boosting memory function likely requires better coordination of task-relevant information across the cortex."

More information: Transcranial Direct Current Stimulation Facilitates Associative Learning and Alters Functional Connectivity in the Primate Brain, *Current Biology* (2017). dx.doi.org/10.1016/j.cub.2017.09.020 , www.cell.com/current-biology/f … 0960-9822(17)31185-5

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