Using brain activity feedback to automate stimulation technique for treating disorders

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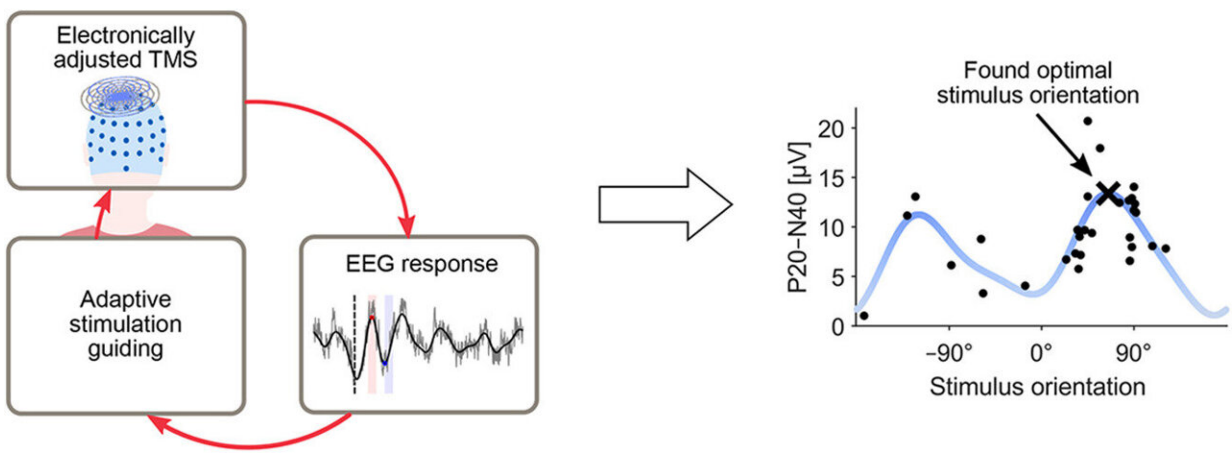

Graphical abstract. Credit: DOI: 10.1016/j.brs.2022.01.016

Medical practitioners have used transcranial magnetic brain stimulation (TMS) for years to treat brain disorders like chronic pain and depression, yet much of the treatment's success has relied on the hands operating the manual device. To bring a better quality of life to more patients, a research team led by Aalto University in Finland has developed a way to quickly find the optimal stimulation for any individual. The results are now available online in *Brain Stimulation*.

TMS works by sending magnetic pulses to the brain with a coil placed on the head. These repeated pulses, which feel like light taps on the head, can alter how neurons communicate—essentially augmenting or decreasing the efficacy of how they talk to one another. Many brain disorders, like stroke and depression, are associated with over- or underactivity of some parts of the brain.

The new method makes use of an algorithm that instantly assesses and adjusts the stimulation placement—with help of electroencephalography (EEG), which detects electrical activity in the brain. The researchers demonstrated how the method automatically finds the optimal stimulation parameters based on measured EEG responses.

"We're basically measuring what happens in the brain immediately after each pulse. Based on the brain's reaction that comes in the first tens of milliseconds—or thousandths of a second—our algorithm will adjust, in real time, how the next stimulation pulse is given. Because we can find the optimal stimulation direction quickly, the method has real potential to improve the efficacy of TMS treatment," says Aino Tervo, a doctoral student at Aalto University and co-lead author on the paper.

Currently, TMS operators need to find the best stimulation location and orientation for each patient's brain manually, a feat informed by training and experience but that brings variable outcomes and is slow. For example, with TMS, users can locate areas of the motor cortex or language network by observing immediate effects on patients' hand movements or speech, a crucial function for surgeons preparing for brain surgery. To target other areas in the brain, like those associated with depression, operators rely on common understanding of where the target area is found in a typical brain—an unreliable, and sometimes tedious, process.

Experiments detailed in the study show that the computer algorithm-powered TMS–EEG feedback loop can find the optimal stimulation direction with a set of 30–60 individual pulses in just 1–2 minutes. In comparison, it may take operators 10–20 minutes to interpret the signals themselves; adding EEG feedback to the mix could stretch out manual assessment even longer.

"The area that we initially assume might be the best to stimulate may not actually be the best. We need information to find the right spot," explains Aalto University Professor Risto Ilmoniemi, who leads the ERC-funded ConnectToBrain project carried out with researchers from the Universities of Tübingen and Chieti-Pescara.

"What the algorithm is able to do is calculate where we can get the best information for finding the optimal stimulation for a particular patient, with the smallest possible number of pulses. Minimizing the number of pulses makes the search faster and more comfortable," explains Ilmoniemi.

Rather than a single copper coil that administers the pulses, the prototype used in this study has two overlapping coils that make the orientation adjustments possible. This is the first step of larger efforts in the ConnectToBrain project to develop a comprehensive system capable of stimulating any part of the brain, or multiple areas simultaneously, in millisecond-scale time intervals.

The newest prototype device has five overlapping coils, which allows both the location and orientation to be adjusted in a specific brain region. Ultimately, these efforts could lead to the ability to instantly follow whether TMS treatment increases or decreases neural activity in key corners of the brain.

More information: Aino E. Tervo et al, Closed-loop optimization of transcranial magnetic stimulation with electroencephalography feedback, *Brain Stimulation* (2022). DOI: 10.1016/j.brs.2022.01.016

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