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An Open Letter Concerning Do-It-Yourself Users of Transcranial Direct Current Stimulation

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As clinicians and scientists who study noninvasive brain stimulation, we share a common interest with do-it-yourself (DIY) users, namely administering transcranial direct current stimulation (tDCS) to improve brain function. Evidence suggests that DIY users reference the scientific literature to guide their use of tDCS,[1] including published ethical and safety standards.[2–4] However, as discussed at a recent Institute of Medicine Workshop,[5] there is much about noninvasive brain stimulation in general, and tDCS in particular, that remains unknown. Whereas some risks, such as burns to the skin and complications resulting from electrical equipment failures, are well recognized,[6–8] other problematic issues may not be immediately apparent.[9] We perceive an ethical obligation to draw the attention of both professionals and DIY users to some of these issues.[10]

Stimulation affects more of the brain than a user may think

Electrodes are often placed in specific scalp locations to target specific brain regions. However, stimulation extends well beyond the regions beneath the electrodes. Current flows between electrodes in complex ways based on different tissues in the head, and can affect the function of various structures along its path.[11–15] Furthermore, the effects of tDCS can extend beyond brain regions directly affected by the stimulation to connected brain regions and networks.[16–20] These indirect effects of stimulation on connected brain networks may alter brain functions that are unintended. In other words, brain connectivity has an effect on —and can be affected by—brain stimulation.[21–23]

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Potential Conflicts of Interest

M.D.F. and A.P.-L. share intellectual property with Neuroelectrics, a tDCS device manufacturer. A.P.-L. serves on the scientific advisory board of Neuroelectrics.

Stimulation interacts with ongoing brain activity, so what a user does during tDCS changes tDCS effects

Brain stimulation with tDCS has a different effect on neurons that are active during the time of stimulation compared to neurons that are not.[24,25] Because of this feature, the cognitive or behavioral activity occurring while tDCS is applied will modify the effects.[26–29] Stimulation while reading a book, meditating, visually fixating on a point, watching TV, doing arithmetic, sleeping, or playing video games could all cause different changes in the brain. Even activity occurring before tDCS or the time of day tDCS is administered may change the effects of stimulation. Which activity or time of day is best to achieve a certain change in brain function is not yet known.

Enhancement of some cognitive abilities may come at the cost of others

Cognition involves functional networks, with different components (or combinations thereof) responsible for different functions. In addition, brain networks interact with each other, such that modifying activity in one network can change the activity in other networks. Therefore, stimulating one brain area may improve the ability to perform one task but hurt the ability to perform another. For example, tDCS can enhance the rate of learning new material, but at the cost of processing learned material, and vice versa, depending on the stimulation site.[30] Such tradeoffs are likely under-recognized, as most tDCS studies focus on only one or two tasks. Furthermore, such cognitive tradeoffs could develop over time and only become recognizable long after the stimulation.

Changes in brain activity (intended or not) may last longer than a user may think

Brain plasticity is an ongoing process that is in part driven by neural activity itself, so changes initiated during stimulation can be long lasting and even self-perpetuating. Cognitive enhancements (as well as concurrent tradeoffs) have been reported 6 months after stimulation, and may linger beyond then.[30–32] Ongoing regular application of tDCS may be especially effective for sustaining these benefits, but may also increase risks. We have never formally studied tDCS at the frequencies many DIY users experiment with—for example, stimulating daily for months or longer. Because we know that stimulation from just a few sessions can be quite lasting,[31] we infer that changes induced by these protocols may be even more so. We do not know yet whether such changes are reversible, and the possible risks of a cumulative dose over years or a lifetime have not been studied.

Small differences in tDCS parameters can have a big effect

Mild changes in tDCS settings including current amplitude, stimulation duration, and electrode placement can have big and unexpected effects. For example, increasing the stimulation amplitude from 1 to 2mA or increasing the duration from 10 to 20 minutes might be expected to double the effect, but can actually reverse the effect and cause the opposite change in brain function.[33] More stimulation is not necessarily better; more is simply different. Similarly, slight differences in electrode placement can produce dramatic shifts in the shape of the current path, and thus the neurophysiological effects.[34–36]

tDCS effects are highly variable across different people

Results reported in the scientific literature are almost always averaged across groups of subjects because the effect of tDCS on any one individual is variable and unpredictable.[37,38] Even across groups of subjects, tDCS effects can be highly variable. Up to 30% of experimental subjects respond with changes in cortical excitability in the opposite direction from other subjects using identical tDCS settings. Even with consistent changes in cortical excitability, these changes can have different effects on individuals' ability to perform a task,[37] including potentially undesirable effects.[39] Furthermore, this variability occurs despite controlled experimental conditions designed to reduce it. Factors such as age,[40,41] gender,[42] hormones,[43] handedness,[44,45] cognitive ability,[46,47] neurological or psychiatric disorders, medications,[48,49] recreational drugs,[50] neurotransmitter levels,[49] prior exposure to brain stimulation,[51] and differences in head anatomy[12,36,52,53] are likely to impact and could potentially even reverse a given tDCS effect.

The risk/benefit ratio is different for treating diseases versus enhancing function

Despite all the above uncertainty, risks, tradeoffs, and potential detrimental effects of tDCS, there are numerous studies that administer repeated sessions of tDCS with the intent of causing lasting changes in brain function. However, nearly all such studies are performed in patients with brain disease, with the goal of alleviating symptoms. Such studies provide detailed disclosure of risks, according to regulations for informed consent of human research subjects, and risks are evaluated for the patient population to be studied. Consider that the level of acceptable risk is different for healthy subjects, who in general are functioning quite well and thus have less to gain, and more to lose. Application of tDCS in children warrants special consideration given the particularities of the developing nervous system, the scarcity of studies in this population, and that minors are not fully able to assess the risks of tDCS for themselves.

In sum, it is important to know that: (1) the tissue stimulated and effects induced are less deterministic than a user may think, (2) significant tradeoffs may be part of the bargain for functional gains, and (3) whatever brain changes occur may be long-lasting—for better or worse. We encourage consideration of these issues and involvement of health care providers in making decisions regarding DIY brain stimulation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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