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Discussion Article

An ethical discussion of the use of transcranial direct current stimulation for cognitive enhancement in healthy individuals: a fictional case study

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Abstract

Transcranial direct current stimulation (tDCS) is a noninvasive brain stimulation technique. Because of its low cost, ease of use, safety, and portability, tDCS has been increasingly investigated for therapeutic purposes in neuropsychiatric disorders and in experimental neuropsychological studies with healthy volunteers. These experiments on healthy cognition have shown significant effects on working memory, decision-making, and language. Such promising results have fomented reflections on studying tDCS to enhance or modify normal cognitive function, a concept described by some as "cosmetic" neurology. As the field evolves, discussing whether the use of tDCS in these situations is appropriate is important, including how bioethical principles may help resolve these challenges. In this article, we present some examples of the effects of tDCS on cognition in healthy participants as a starting point for this ethical debate. We envision a futuristic "Brain Boosting" tDCS clinic that specializes in cosmetic neurology and cognitive enhancement. Using the typical cases of a fictitious Dr. Icarus as a discussion starting point, we raise some issues that are both humorous and provocative about the use of tDCS in healthy people. The importance of this work is to ask relatively new questions regarding cosmetic neurology in the field of neuromodulation and discuss the related ethical conflicts.
Keywords: brain stimulation, neuromodulation, ethics, cognitive enhancement.

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Introduction

The use of neuromodulatory techniques, specifically transcranial direct current stimulation (tDCS), has increased significantly in the past years. A search of the SCOPUS database using the search term "transcranial direct current stimulation" revealed that only two papers were published in 2000, whereas 1,038 papers were published in 2013. Several studies of tDCS reported promising effects on the enhancement or modification of normal cognitive function (for review, see Utz, Dimova, Oppenländer, & Kerkhoff, 2010). tDCS is delivered with an inexpensive device that can theoretically be assembled by lay people at home. In fact, YouTube videos show people demonstrating how to build a tDCS device (http://www.youtube.com/watch?v=hgFWEBwT6BE; accessed December 13, 2013). However, this raises some important ethical issues regarding the use of such a technique. Some research groups have begun to address this issue (Cohen-Kadosh, Levy, O'Shea, Shea, & Savulescu, 2012; Hamilton, Messing, & Chatterjee, 2011). However, an ethical debate is sometimes too conceptual and particularly hard to follow when considering a broader audience. tDCS, for example, can be used in different situations with interdisciplinary subjects. Another issue is that the simplicity of this technique has made its use and effects appear to be completely innocuous and able to be performed by lay people. Recently, a company (www.foc.us; accessed December 13, 2013) began to offer "tDCS Headsets for extreme gamers" with the motto "Overclock your head!"

Considering these issues, the ethical debate needs to be extended. A novel and particularly interesting approach is the use of narratives and drama in the medical field in a way that promotes higher emotional engagement of the reader (e.g., Rothenberg & Bush, 2012). For example, the use of vignettes is a dramatic

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approach that can enhance emotional engagement, cognitive development, and moral imagination, thus allowing for more ethically sensitive comprehension (Arawi, 2010). In the present article, we use clinical vignettes to foster the ethical debate on the perils of using tDCS as a cognitive enhancer in healthy individuals. We ask some provocative questions regarding the use of tDCS in healthy subjects for "cosmetic" purposes. We imagine a futuristic "Brain Boosting" tDCS clinic that specializes in cosmetic neurology and cognitive enhancement. Using the typical cases of a fictitious Dr. Icarus as a discussion starting point, we mention some provocative issues regarding the use of tDCS in healthy people. Our goal is to discuss relatively new questions regarding cosmetic neurology in the field of neuromodulation and debate the ethical conflicts related to it in a manner that deeply engages the reader.

Transcranial direct current stimulation

Dr. Icarus arrived early in his clinic. It was only 7:00 AM, but his assistant was already there, with her soft, polite voice speaking on the phone: "Brain Boosting Clinic. How may I help you?" His clinic was a success, and he was joyful to have another busy day. But first he drank his double espresso and called her: "Pam, I am ready to receive my brain boosting!"

tDCS is a noninvasive brain stimulation technique that delivers weak, direct electric current through two scalp electrodes, leading to cortical hypo- or hyperpolarization according to specified parameters. In the past decades, extensive animal (Brunoni, Fregni, & Pagano, 2011b), neurophysiological (Stagg & Nitsche, 2011), neuropsychological (Utz et al., 2010), and clinical (Brunoni et al., 2011c) studies have shown that tDCS is an effective tool to modulate brain activity. The results demonstrated that anodal (positive) stimulation increases and cathodal (negative) stimulation decreases the activity of neural networks below the electrode. Because of its low-cost, ease of use, safety, and portability, tDCS has been increasingly investigated for therapeutic purposes in neuropsychiatric disorders (Brunoni et al., 2011c). Interesting findings have emerged in both tDCS clinical trials and neuropsychological studies in healthy volunteers. These studies, all in healthy subjects, have shown that motor cortex stimulation enhances motor performance (Boggio et al., 2006a; Boros, Poreisz, Munchau, Paulus, & Nitsche, 2008) and reduces muscular fatigue (Cogiamanian, Marceglia, Ardolino, Barbieri, & Priori, 2007). Somatosensory stimulation increases or decreases pain or tactile thresholds (Antal, Brepohl, Poreisz, Boros, Csifcsak, & Paulus, 2008; Boggio, Zaghi, Lopes, & Fregni, 2008b; Ragert, Vandermeeren, Camus, & Cohen, 2008). Prefrontal stimulation modifies mood (Boggio, Rocha, da Silva, & Fregni, 2008a; Marshall, Molle, Hallschmid, & Born, 2004).

Notably, however, the effects of tDCS are variable and usually short-lived. Important research is being conducted to investigate the optimal parameters to provoke long-term changes (Brunoni et al., 2011c). Nevertheless, such promising results have fomented reflections on studying tDCS to enhance or modify normal cognitive function; a concept described by some as "cosmetic" neurology. Similar to aesthetic surgery, the goal of cosmetic neurology is to (unnecessarily?) modify the function of a non-pathological body for subjective or cosmetic purposes (Cakic, 2009). Notwithstanding, one could raise interesting arguments that favor some "ethical" uses for cognitive enhancement using tDCS, such as for educational purposes or increasing performance in high-risk situations (e.g., air traffic control). As the field evolves, discussing whether the use of tDCS in these situations is appropriate is important, including how bioethical principles may help resolve these challenges.

Impulsivity and social behavior

Dr. Icarus' early morning clients were chief officers of important business enterprises. Although, for many of them, "The Monk and The Executive" provided enough good advice, others required further assistance to modulate their inner urges to achieve pro-social behavior. Interestingly, a few others were simply too compassionate to succeed in the wild corporate world. For these individuals, Dr. Icarus employed a special protocol to diminish their "unbearably" excessive kindness.

tDCS is able to modify complex behaviors, such as impulsivity (a behavioral trait in which one acts without adequate planning or forethought about the unintended implications of the act). Using anodal stimulation over the dorsolateral prefrontal cortex (dlPFC), Fregni, Liguori, Fecteau, Nitsche, Pascual-Leone, & Boggio (2008a) and Boggio, Liguori, Sultani, Rezende, Fecteau, & Fregni (2009b) reported reduced cue-induced smoking craving. Fregni et al. (2008b) showed reduced cue-induced food craving. Boggio, Zaghi, Villani, Fecteau, Pascual-Leone, & Fregni (2010) found that risk-taking could be modulated (i.e., increased or decreased) in marijuana users during a decision-making risk paradigm according to the stimulation parameters. Other studies demonstrated that social behavior could also be modified by tDCS. In one study that assessed moral dilemmas and pragmatic reasoning (Fumagalli et al., 2010), females presented more utilitarian responses (i.e., responses that brought personal gain even at others' expense) after anodal (*vs*. sham) stimulation over the ventral prefrontal cortex. Knoch, Nitsche, Fischbacher, Eisenegger, Pascual-Leone, & Fehr (2008) used tDCS during the Ultimatum Game. In this game, the "proposer" offers a percentage of money to the "responder" who can in turn accept it or not. Low proposals are often rejected because they are perceived as unfair. In this study, responders who received cathodal stimulation over the right dlPFC accepted lower offers than those who received sham stimulation,

showing that a complex behavior could be affected by neuromodulation. Lying, too, can be modified by tDCS. Priori et al. (2008) found that anodal tDCS increased the reaction times to deceptive responses but not truthful responses, whereas cathodal and sham tDCS had no effect. Fecteau, Boggio, Fregni, & Pascual-Leone (2013) found that active tDCS over the dlPFC compared with sham stimulation reduced the response latency for untruthful compared with truthful answers.

These initial pilot studies raise an interesting dilemma. What should be the ethical stance with regard to investigating tDCS to explore brain function as the stated purpose of the study, with the goal manipulating behavior (e.g., increasing one's "selfishness")? Two immediate considerations emerge. The first consideration is based on morale. A morally embedded study in the Kantian ("categorical imperative") sense would forbid the researcher from changing a subject's behavior if this would lead to unpleasant collective consequences. The contraposition is based on the principle of autonomy, in which patients should be allowed to decide and choose their own treatment. Both arguments have flaws. For example, it is subjective and utterly impossible to judge what would be the ultimate, collective consequences of changing one's behavior, which could also lead to collective gain. Conversely, how does the biomedical principle of autonomy apply to healthy subjects? Because there is no "treatment" to choose *per se*, the interaction might be less patient-physician and more client-seller. Another issue is that social behavior is understood as a component of one's personality, in contrast to drugs that alter physical and even mental executive function. The dispute here is also between the principle of autonomy and the understanding that there is an ethical boundary in manipulating the "inner self." It should be remembered that changes elicited by tDCS are probably reversible, which is different from psychosurgery, and that the definition of "I" is blurred. Many psychiatric drugs could theoretically be understood as "personality" modifiers. The boundaries of behavioral manipulation, therefore, need to be ethically appraised as the field of neuromodulation progresses toward answering these questions.

Cognitive enhancement

Just after the businessmen left, the students arrived. Dr. Icarus usually sets their appointments before the first morning class. This group had always brought joyfulness to the doctor, making him feel as an educator, contributing to the enlightenment of little minds. He felt especially proud of Carolyn, a 15-year-old girl who had dramatically raised her grades after receiving cognitive tDCS therapy. Dr. Icarus would see her today, and he had prepared a specific protocol for her final math exam.

Several tDCS studies have been performed in patients and healthy volunteers to evaluate the modulation of executive function. The n-back test, a proxy for working memory in which the subject is asked to remember a symbol presented *n* positions previously, has been extensively explored by several authors (Andrews, Hoy, Enticott, Daskalakis, & Fitzgerald, 2011; Boggio et al., 2006b; Fregni et al., 2008b; Ohn et al., 2008). These studies showed that anodal stimulation over the left dlPFC increased performance in this task. Other studies showed that tDCS increased performance in other cognitive tasks such as visual memory (Chi, Fregni, & Snyder, 2010), memory retrieval (Boggio, 2009a), inhibitory control (Hsu et al., 2011), number processing (Cohen Kadosh, Soskic, Iuculano, Kanai, & Walsh, 2010), and others (for review, see Utz et al., 2010).

The discussion of tDCS as a cognitive enhancer resembles that of pharmacological drugs (Greely et al., 2008; Husain & Mehta, 2011) originally designed for attention deficit disorder (e.g., modafinil and methylphenidate) and dementias (e.g., donepezil and memantine) to improve vigilance, memory, attention, and other cognitive skills. In fact, the potential cognitive enhancement effects of tDCS and pharmacological treatments are relatively unknown, partially because previous studies have focused on the clinical improvement of pathological conditions. Therefore, a drug that enhances memory in Alzheimer's disease might lead to only subtle effects in healthy subjects and *vice versa* (Husain & Mehta, 2011). Studies that investigated the effects of these interventions in healthy subjects are necessary. However, more studies on this matter should be conducted only after the ethical aspects of cognitive enhancement have been resolved.

One obvious controversy, exemplified by Dr. Icarus' client Carolyn, is whether enhancing cognition by means of drugs or tDCS is cheating by giving one person an unfair advantage over others. However, as discussed in a recent *Nature* article, there currently exist many other forms of cognitive enhancement, such as caffeine and private tutors, and many other cognitive tools, such as computers and the Internet (Greely et al., 2008). Cognitive enhancement might be considered cheating only if it temporarily boosts performance (for exam purposes, for instance), whereas its use could be considered fair when used for long-term learning, perhaps associated with standard educational methods (Greely et al., 2008). tDCS could theoretically be used for both short- and long-term purposes, and developing regulatory protocols may be necessary to guarantee its "fair" use in academic and intellectual settings.

This risks of "forced" enhancement

After a short lunch, Dr. Icarus resumed his service in the clinic. Among the variety of clients he had seen in the afternoon, he felt especially sensitive to one young man. He worked as an air traffic controller at the International Airport, and the Air Safety Department declared that all air traffic controllers were obliged to receive cognitive enhancement. This man was

exasperated because he could not lose his job, although he was not entirely comfortable with receiving "brain boosting" treatment.

An important bioethical question regarding cognitive enhancement is whether its widespread, popularized use and proven efficacy could be used to coerce people to receive it (Greely et al., 2008). The above case of Dr. Icarus illustrates a difficult trade-off in neuroethics. On one hand, vigilant air traffic controllers reduce the risk of accidents, thus indirectly contributing to the safety of thousands of lives. On the other hand, this would be a clear contradiction of the principle of autonomy and one's undeniable right to decide whether or not he wants to receive an intervention.

Along these lines, Hamilton et al. (2011) discerned explicit from implicit coercion. The latter is illustrated in Dr. Icarus' case and reflects the covert pressure of an ever-demanding society on the work performance of individuals. This issue is very real in some fields. For example, 25% of university students have ever used stimulants to increase their academic performance (Greely et al., 2008). Explicit coercion is the use of an intervention, chiefly for legal/penalty purposes, against the will of the individual. Hamilton et al. (2011) mentioned that tDCS could be used by police to detect deception because it interferes with the ability to lie. In such a case, another issue is whether the people who administer tDCS could themselves refuse to deliver "forced" tDCS. Anesthesiologists have recently refused to participate in lethal injection procedures (Denno, 2007). If tDCS has the potential to be used in forced procedures, then researchers and physicians must discuss their participation in these non-clinical contexts.

Administering tDCS *Pro Bono*

The last appointments for the day in Dr. Icarus' clinic were booked by people who were unable to pay his expensive fees. When he started his clinic, he felt happy doing this charity work, although this project was currently running very chaotically. The waiting list was 6 months long, and Dr. Icarus had elaborated a triage system to select the poorer clients. There were no perfect criteria, and people were consequently always complaining and asking for urgent appointments. "I must terminate this pro bono *project at once," he used to think when he heard the crowd yelling at his door.*

An important issue in the discussion of cognitive enhancement is how to respect the principle of justice (i.e., to equally offer therapy to all members of society). Interestingly, cognitive improvement can bring gains in productivity and work performance. Therefore, if it were offered unequally, then this would increase the gap between those who can afford it and are therefore able to receive its gains and those who cannot afford it (Hamilton et al., 2011). This differential advantage would, in fact, render cognitive enhancement therapy an unfair method in competitive places. However, unclear is who should and should not pay for one's own improvement in cognitive abilities. Insurance companies and governments with universal healthcare access could not consider it a medical intervention because it is offered to healthy people. In some specific, limited situations (e.g., educational purposes), universal access may be granted to students. In other contexts, however, the criteria may be blurred. Moreover, if cognitive enhancement is considered to provide unfair advantages to a few, then society would have to forbid its use as a private, paid service.

In this context, tDCS is a relatively affordable therapy. Devices can be built with less than US$500.00 (Brunoni et al., 2011c). This is much cheaper than other brain stimulation techniques such as repetitive transcranial magnetic stimulation, and even drugs used for cognitive enhancement when considering long-term use. In fact, tDCS devices could be theoretically built with a "user-friendly" cap that allows domestic or residential use of the device. This would further decrease its final price, thus avoiding operational or staff costs, although this could also be a safety concern as discussed below.

Safety

It was the end of another busy day for Dr. Icarus. He stayed in the clinic until the evening, and his secretary had already left. While gazing at his shining tDCS devices, he reappraised his secret idea of "tDCS-ing" himself to further increase his own cognition. Although no one had ever done this, Dr. Icarus was sure that nothing bad would happen.

The next morning, Pam found her boss sleeping with the tDCS device on his head. She realized with dismay that Dr. Icarus had applied tDCS to his brain all night. She observed two bruises over his scalp, and the tDCS device flashed "low battery." After waking him up, he reported an intense headache. A further examination of the device revealed that it had been hacked to deliver an electric charge 1,000-times higher than usual.

Analogous to the tragic fate of Icarus who got his wings and flew too close to the Sun and had his wax wings melt, our mythical Dr. Icarus also did not follow the normal safety rules and allowed his *hubris* to overcome *phronesis*. In fact, safety is a key issue for cognitive enhancement because it proposes an intervention for the healthy. In this context, tDCS can be considered a safe intervention for several reasons: (1) the electric current applied is very low (1-2 mA over an area of 25-35 cm^2) and generated by three 9 V batteries; (2) there is no direct contact between the electrodes and the brain, with several layers between them, including the scalp, skull, cerebrospinal fluid, and meninges; and (3) the electrodes are embedded in saline, minimizing tissue resistance and avoiding overheating (Brunoni et al., 2011c; Nitsche et al., 2008). In recent reviews (Brunoni, Amadera, Berbel, Volz, Rizzerio, & Fregni, 2011a; Poreisz, Boros, Antal, & Paulus, 2007), the most common adverse events reported were headache,

itching, tingling, a burning sensation, and discomfort, which were short-lived and presented the same frequency in both the experimental and placebo groups. Importantly, however, most studies applied tDCS for only a few sessions. Still unknown is whether more severe adverse effects could emerge following repeated, daily tDCS. Liebetanz, Koch, Mayenfels, Konig, Paulus, & Nitsche (2009) showed that tDCS was able to induce brain damage in experimental animals, but only when it was used at two orders of magnitude higher than usual. Further studies in experimental animals and clinical trials are still necessary to establish the optimal safety parameters.

Dr. Icarus completely recovered from his tDCS accident, but after that day he accessed a scientific literature database to download several papers concerning the safety and ethics of tDCS. He concluded that further studies should be conducted to establish all of the necessary parameters for clinical application. He decided to step back from his Brain Boosting Clinic ... for now.

Conclusion

tDCS is being remarkably referred to as "the thinking cap" (Hamilton et al., 2011), not only because of its unique aspect on one's head but also because it has the true potential to improve cognition in healthy people. However, to verify the extent of such potential, further methodological advances and bioethical discussions are warranted. Both aspects are linked because adequate trial methodology can be set only when research results are properly discussed. In this work, we raised important issues such as (1) whether the modulation of "inner-self" characteristics, such as personality, impulsivity, and social behavior, is acceptable; (2) whether tDCS-induced cognitive enhancement is valid as an adjuvant, fair technique for educational purposes or should be considered "cheating"; (3) the consequences of the widespread use of neuromodulation for those who either cannot afford it or are not willing to receive it; and (4) the safety aspects of tDCS. Some of these issues are currently being addressed in experimental research, the results of which are likely to be very relevant as tDCS moves into clinical practice. Although the use of tDCS for "cosmetic" purposes might be appealing, important bioethical questions should be discussed by researchers, physicians, and society.

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