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DISCUSSION PAPER: RESPONSE

DIY tDCS: a need for an empirical look

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Recent phenomenal advances in neuroscience have spurred technological progress on direct biological brain interventions. One of these intervention technologies gaining momentum is transcranial direct current stimulation (tDCS). tDCS is especially attractive because it is known to be relatively safe, effective, affordable, and easy to use on individuals (Fitz and Reiner 2013). Most of the reported side effects of tDCS are minor adverse effects (e.g. tingling or itching under the electrodes and headache) (Fregni et al. 2015). Despite some inconsistencies among the results, such as null findings and conflicting outcomes, a number of studies have shown that tDCS can relieve symptoms of various neurological diseases and modulate cognitive functions among healthy subjects (see, for example, Nitsche et al. 2008; Nitsche and Paulus 2011; Lefaucheur et al. 2017). Moreover, with free basic instructions from the web, it costs less than $US50 to get necessary parts to build tDCS, and several commercial devices are also available on the market mostly within a few hundred-dollar range.

These attractive features of tDCS has given rise to a group of people, referred in the discussion piece as 'citizen scientists,' who build or purchase a tDCS device and administer it at home for treatment or enhancement. This group is also called 'Do-It-Yourself (DIY)' users (Fitz and Reiner 2013) or 'home users' (Wexler 2015). The DIY practice has gained attention from media with mixed feelings of excitement and concern (Dubljevic, Saigle, and Racine 2014). Since 2013, responding to the increase of interest in the home use, several companies have launched 'direct-to-consumer' tDCS devices (Wexler 2015), such as Foc.us and Halo.

Researchers from academia have become actively involved in the discussion on the safety, ethical, and legal issues around DIY tDCS. For example, Fitz and Reiner (2013) pointed out potential risks of misusing tDCS-inaccurate placement of electrodes, impairment of cognitive function by reversing polarity, interaction with other extant treatment (e.g. drugs), and unknown long-term effects. Crucial ethical concerns, such as implicit and explicit coercion, justice, and personality/character change, are also examined in the context of tDCS. (Hamilton, Messing, and Chatterjee 2011; Heinrichs 2012; Kadosh et al. 2012; Cabrera, Evans, and Hamilton 2014). Since tDCS is not yet covered under the current United States (US) Food and Drug Administration regulatory regime on medical devices, researchers have proposed various regulatory models regarding tDCS (Dubljević 2015; Maslen et al. 2015; Wexler 2015).

In line with the previous literature, the discussion piece raises valid concerns regarding the DIY use of tDCS from the view of a neuroscientist. First, it argues that the term

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'non-invasive' commonly used to describe tDCS can be misleading and suggests a new term, 'neuron-altering.' It is true that this term may disguise what tDCS actually does in the brain – changing the membrane potential of the neurons – and promote the DIY use of tDCS. Nevertheless, the conventional invasive/non-invasive distinction, which relates to whether a brain intervention involves physical penetration into the skull or not, serves an important role in differentiating not only between brain surgery and brain stimulation but also between different types of brain stimulation. For example, in contrast to tDCS, deep brain stimulation is classified as invasive technology, because an electrode is inserted through the skull to stimulate a target region (Kringelbach et al. 2007).

Second, we already have a term, 'non-invasive neuromodulation,' to indicate that a brain intervention technology is both non-invasive and neuron-altering (Forum on Neuroscience and Nervous System Disorders; Board on Health Sciences Policy; Institute of Medicine; The National Academies of Sciences 2015). Researchers and physicians have been using this term to refer to brain intervention technologies that do not involve physical intrusion to the brain, such as tDCS, transcranial magnetic stimulation, and focused ultrasound. Therefore, instead of discarding the term 'non-invasive,' we can describe tDCS as non-invasive neuromodulation technology to help people understand the mechanism of tDCS in the brain more accurately.

Potential unintended adverse consequences of tDCS examined in the discussion piece – stimulating brain regions remote from target site, misplacement of electrodes, and unintended disruption of excitatory and inhibitory neurons in neural networks – are well-acknowledged concerns already addressed in the previous studies (Hamilton, Messing, and Chatterjee 2011; Cabrera, Evans, and Hamilton 2014; Fitz and Reiner 2013). Application of tDCS in children and adolescents has been a continuous theme in the literature as an intricate issue that involves questions on safety and ethical concerns (e.g. lack of capacity to consent) (Kadosh et al. 2012; Davis 2014; Palm et al. 2016). The possibility of addiction to tDCS is an interesting idea, but given that repeated use of tDCS is needed for longer lasting after-effects (Monte-Silva et al. 2013; Goldsworthy, Pitcher, and Ridding 2015), the risks of prolonged exposure are not limited in the use of tDCS for 'getting high' but relevant to its use for all other purposes.

Since many of the concerns raised in the discussion piece have been explored elsewhere, I would like to direct my response toward what has been missing in the previous literature and the discussion piece – a need for empirical research on the DIY tDCS user community and the mechanism and the optimal protocol of tDCS.

First, as we reviewed earlier, there have been extensive discussions on ethical and legal issues around tDCS, but only a few studies explored what is happening in the DIY tDCS user community, and many ambiguities still exist around this DIY tDCS phenomenon (Jwa 2015; Wexler 2016). At a first glance, it seems like the size of the DIY tDCS population has been rapidly growing for the last few years. For example, by the end of 2013, there were 2700 subscribers across the globe to one of the most well-known and popular tDCS websites – subreddit tDCS (Jwa 2015), but as of May 2017, the number of subscribers reached 9500 (SubreddittDCS). The emergence of new direct-to-consumer brain stimulation devices is another indicator of the increase of home user population (Wexler 2015). However, it may be hard to say that the number of subscribers reflects the actual size of the dedicated DIY user population, who use tDCS regularly and continuously. The insiders from the DIY community acknowledge that there has been hype around the DIY tDCS and many people do not stay as committed users and move on after practicing tDCS for some time (Jwa 2015). The manufacturers of the newly launched devices advertise that they are getting good reviews from hundreds of consumers (Foc.us, Halo), but the actual sales of these devices is unknown and at least one of these manufacturers, Thync, experienced financial difficulties to stay in business (Huet 2016).[1]

More up to date and systematic investigation is necessary to provide a clear empirical illustration of the DIY tDCS user community. It may require an active involvement from government agencies and the users themselves. The tDCS manufacturers could be another important source of information, if they could disclose their sales and the known usage of the devices by their customers. Deeper and correct understanding on the DIY tDCS community will help us to estimate the prevalence of the DIY tDCS and the current practice of tDCS among the users, which is critical information to determine the urgency of an intervention by government agencies or the scientific community.

Second, although tDCS has become widely used in clinical and academic research for the last few decades, the precise neurophysiological mechanism of tDCS and the experiment protocol for desirable effects are still unknown. In fact, most of the concerns around tDCS, for example, its (unintended) effects on neural networks and long-term effects, are empirical questions. These uncertainties around tDCS have been considered as a major cause of the inconsistencies among the results of tDCS studies. For example, Horvath, Forte, and Carter (2015, 545) compared 'every cognitive outcome measure in the literature explored by at least two different research groups' and argued that they found no evidence on the reliable effects of a single session of tDCS in healthy population. Another meta-analysis, focused on the tDCS studies that targeted the dorsolateral prefrontal cortex, reported some apparent conflicting results (Tremblay et al. 2014). These reports have raised the level of skepticism on tDCS as an effective neuromodulation technology.

In the context of DIY tDCS, these uncertainties present practical barriers to coming up with safe and effective protocol guidelines from the neuroscience community, the kind of guidance that the discussion piece is urgently calling for. Several articles discussed safety limits of tDCS based on the accumulated evidence from human and animal trials (Bikson et al. 2016; Woods et al. 2016), but these are not intended to help or guide DIY use. In her 2015 article, Wexler pointed out that physicians and scientists might be reluctant to provide guidelines or recommendations for DIY use since there is no consensus on 'what is safe and what is not safe' yet and providing those guidelines or recommendations could be viewed as promoting DIY use of tDCS (Wexler 2015, 696). Potential liability issues add another layer of difficulties (Wexler 2015).

The good news is that responding to the recent increase of interests in tDCS, researchers have begun to unveil the mechanism of tDCS, especially by combining it with other tools in neuroscience, such as functional magnetic resonance imaging, electroencephalogram, and magnetoencephalograph. Combining tDCS with these tools would allow tracking the flow of current in the brain and measuring the modulatory effects of tDCS at the neuronal level (see, for example, Schestatsky, Morales-Quezada, and Fregni 2013; Hanley, Singh, and McGonigle 2016; Jog et al. 2016). In August 2016, the National Institute of Health Brain Initiative also opened a funding opportunity to study the mechanism of non-invasive neuromodulation technologies, including tDCS (NIH). This funding aims 'to better understand how existing non-invasive neuromodulation devices affect brain circuitry,' which 'should shed light on dose/response relationships that could be used to inform the optimized use of these tools for neuroscience research as well as for clinical application (NIH).' It might be hard to expect that we will get a systematic picture of how tDCS works in the brain in the near future, sufficient to develop safety guidelines for DIY users, but rigorous scientific investigations would resolve at least some of the empirical questions associated with the concerns around tDCS.

As described in the discussion piece, we may live in the 'highly experimental time.' By virtue of its special features, tDCS stands out among the currently available brain intervention technologies as an attractive option for self-experimenters. The DIY tDCS phenomenon has stirred intensive discussions on the safety, ethical, and legal issues around it. With the aid of systematic empirical research on the DIY tDCS community and the mechanism of tDCS, we will be able to craft sound policy and safety guidelines for DIY users and ultimately, realize the promise of tDCS: safe, effective, and affordable therapy and enhancement.

Note

1. Actually Thync is not a tDCS device – it uses pulsed electric currents instead of direct current and stimulates cranial and spinal nerve pathways rather than the brain directly (Thync, Accessed May 10, 2017, http://www.thync.com). However, the fact that a company selling a brain stimulation device intended for home use has experienced financial difficulties gives us a meaningful clue to estimate the current demand for home use brain stimulation devices in general including tDCS.

Notes on contributor

Anita S. Jwa is a doctoral (J.S.D.) candidate at Stanford Law School. Anita received an LL.B. in Law (2006), Cum Laude, and an M.A. in Evolutionary Anthropology (2011) both from Seoul National University. She also earned a J.D. from Vanderbilt Law School (2011). During her studies, Anita worked as a research assistant in Law and the Brain project at Vanderbilt and interned at Ministry of Government Legislation in Korea. Prior to joining Stanford, Anita was a researcher at Seoul National University Law Research Institute, and later on, she worked as a law clerk at Supreme Court of Korea. Anita's J.S.D. research focuses on issues in the intersection of law and neuroscience, especially on neuroethics of cognitive enhancement.

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