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# Neuroethical and Social Implications of Using Transcranial Electrical Stimulation to Augment Creative Cognition

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Recent research indicates that transcranial electrical stimulation (tES) of specific brain regions can successfully improve various forms of creative cognition. Although the endeavor to increase human creative capacity is intriguing from a neuroscientific perspective, and of interest to the general public, it raises numerous neuroethico-legal and social issues (NELSI). This review explores these issues by considering (a) whether using brain stimulation to improve creative cognition qualifies as a 'treatment' or an 'enhancement,' (b) how direct-to-consumer (DTC) and do-it-yourself (DIY) use of tES should be regarded and regulated, and (c) what the developing landscape of creativity-related neurostimulation could (and should) become.

Recently, a growing body of research in cognitive neuroscience has employed noninvasive transcranial electrical stimulation (tES) to manipulate—rather than passively observe—specific neural processes. One focus of recent tES investigation concerns the potential to employ such techniques to foster or optimize creative cognition. Current literature indicates that tES can elicit short-term facilitation of specific forms of creative cognition (i.e., creative idea generation, creative idea selection; for full review, see Weinberger, Green, & Chrysikou, 2017). However, several questions persist. For instance, research has not yet adequately addressed the duration of the observed enhancements or the question of whether tES-induced outcomes are affected by repeated or ongoing use. As well, there is little currently known about the neurochemical mechanisms that may subserve the reported changes in creative cognition. And while the use of tES—within parameters described and applied in research and clinical settings—is generally regarded as safe, it remains unknown if and to what extent other patterns of use (and/or misuse) may incur deleterious effects (Bikson et al., 2018).

These questions are of interest to the neuroscientific community as well as public, commercial, and policy sectors as the use of tES expands. Brain stimulation devices are now widely available via a direct-to-consumer (DTC) market, and there is also a growing do-it-yourself (DIY) community in which individuals modify market-available technologies, and/or manufacture their own devices using household items. These developments have fostered a number of neuroethico-legal and social issues (NELSI; Giordano & Olds, 2010), which are important to address when considering the viability, safety, value, and provision of tES in particular clinical, occupational, and lifestyle applications (Giordano, 2012, 2015, 2017). This review examines the use of tES to affect creative cognition, explicates key NELSI that arise from such applications, discusses capacities and limitations of extant ethics and regulations, and proposes a framework to guide current and near-future use.

## TES MODELING AND APPLICATION

tES operates via electrodes placed on the scalp, and is typically used to target a specific region of the brain that is hypothesized to play a critical role in a cognitive ability and/or behavior of interest. To successfully stimulate a

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target region, tES experts will computationally model electrical current flow by segmenting the head into its different structural elements (i.e., skull, scalp and skin, gray matter, white matter, cerebral spinal fluid, etc.) and accounting for the electrical conductivities of each structure. This results in a map of the magnitude of local electrical fields that can be used to determine the appropriate current density, flow, and electrode montage (i.e., arrangement on the scalp) to optimally stimulate the desired region of the brain in safe, effective, and reliable ways (Datta et al., 2009). Differences in tissue and skull conductivities, as well as the spatial precision of the electrical current, impose limitations on the areas that can be targeted. The most widely-used form of tES is transcranial direct current stimulation (tDCS), which passes current between a cathode/return electrode and an anode/active electrode. The resting potential of neurons under the anode is thought to increase (and therefore render these neurons more likely to depolarize), whereas neurons under the cathode decrease in excitability (and are thus less likely to fire). From practical, as well as theoretical, perspectives, the relative value of tES (and other forms of neuromodulation) is based upon the presumption that activity in brain areas and networks can be at least correlated to (if not causally linked to) the occurrence of particular cognitive, emotional, or behavioral events. But causality remains a key issue to the extent that the ever-present "hard problem" of neuroscience (i.e., how *mind* occurs in brain) as posed by Chalmers (1996, pp. xii) still remains incompletely answered. On a practical level, this evokes an *intersection of unknowns*: what is unknown about causality in the brain, and what is unknown about the way new techniques and technologies may affect such processes and their manifestations, especially beyond the short term, which both evokes further NELSI (as related to veridicality of information and informed consent), and fortifies the need to iteratively address such issues, questions, and problems (Giordano, 2012, 2015, 2017). To date, tES has been used to improve cognitive and motor function of patients with Parkinson's Disease (Boggio et al., 2006; Fregni et al., 2006; Pereira et al., 2013); elevate mood of patients with depression (Nitsche, Boggio, Fregni, & Pascual-Leone, 2009); improve performance in tasks of attention, learning, memory (Coffman, Clark, & Parasuraman, 2014), and verbal fluency (Pisoni et al., 2017); and reduce certain forms of performance-related anxiety in healthy subjects (Sarkar, Dowker, & Cohen-Kadosh, 2014).

## TREATMENT OR ENHANCEMENT?

Does the use of tES to affect creative cognition constitute a treatment or an enhancement? Creative cognition is generally characterized by the mental manifestation of something both novel and useful (Runco & Jaeger, 2012). In light of this definition, it could be questioned whether an individual could lack creative abilities in a way that presents as a medical condition. In other words, could improving one's creative abilities be therapeutically necessary for attaining or regaining some normal characteristic of human cognition? If so, regulations governing the use of tES to facilitate creative cognition could sensibly mirror those of other *treatments* for mental disorders (e.g., use of stimulants to treat attention deficit hyperactive disorder). Alternatively, if lacking creativity is not regarded as a medical condition, and augmenting creative thinking is not viewed as a therapeutically valid intervention, then using tES to improve creativity would be best regarded to be an *enhancement*.

Using brain stimulation techniques to increase specific forms of cognition has been previously classified as an enhancement (Hamilton, Messing, & Chatterjee, 2011), which seems appropriate if creativity is considered as it pertains to artistry or innovation. For example, an accountant who is able to adequately perform the responsibilities of his or her profession, but has significant difficulty engaging in creative domains, such as music and visual arts, should still be able to maintain a reasonably normal and healthy life. The accountant could claim that a lack of creativity renders him or her unable to generate innovative solutions or respond appropriately to intellectual challenges at work, and that some assistance is needed to facilitate such capabilities. Using tES to improve such performance in the workplace would still be regarded as at least an enablement, if not an enhancement, as augmenting a cognitive ability for career advancement and/or lifestyle changes has been proposed as a defining characteristic of neurological interventions that are not a treatment (Savulich et al., 2017; Shook & Giordano, 2016).

But this prompts questions of (a) whether some impairment in creativity might contribute to a disorder in such ways as to qualify as requiring treatment, and (b) if someone could be so deficient in creativity that it hinders their day-to-day life (i.e., beyond limiting career advancement) in ways that are deemed to qualify as a medically-recognized disorder. In the first instance, consider an individual who may be involved in a profession or activity that relies upon aspects of their creativity. Suppose that their capabilities begin to wane, or that they are placed in a situation in which their creative efforts are viewed as inadequate, and that this incurs clinical anxiety or depression. Would the use of tES to restore the individual's creativity be regarded as a treatment?

As a comparison, consider the use of erectogenic drugs in cases of erectile performance anxiety: The disorder is the manifest constellation of psychological signs and symptoms, which could be treated using psycho- and/or sex therapy and/or via psychotropic medications. Yet intervention is directed at improving erectile capability, to thus mitigate performance anxiety. Periodic erectile insufficiency is regarded as the cause of the anxiety, and therefore the use of erectogenic drugs can be (and often is) considered a treatment. To be sure, discourse could be focused upon the underlying reasons for anxious reactions to perceived inadequacy as a psychological condition, and could also center upon the *pharmacologization* of medicine and society, as well as a social trend toward quick fixes. But the central issue is exemplary, and when considering tES, debate could be directed at whether its use to restore or mitigate flagging creativity could or should be held as a treatment, and discussion could banter many of the same issues (i.e., the underlying reason for performance anxieties and feeling of inadequacy; the 'technologization' of medicine and society, etc.; Gini & Giordano, 2010).

In the second instance (viz. -a creativity deficit that hinders day-to-day life), it is difficult to imagine such a case in the absence of extensive comorbid cognitive deficits. Research has generally revealed that creative ability depends on cognitive mechanisms that are involved in a range of other abilities (Smith, Ward, & Finke, 1995), and that are engaged by and contributory to other cognitive functions (Beaty & Silvia, 2012; Guilford, 1967; Kim, 2005); thus, compromised creative ability to the extent that would render deficits in daily functioning is unlikely without more broadly ramifying impairment of these functions. Treating someone with such profound creative deficits would entail interventions beyond tES alone.

However, if tES were found to improve health—even when used in a suite of clinically administered interventions to reduce a particular set of signs and symptoms of an identified medical condition (as in the first instance described herein)—then classifying it as a treatment seems appropriate. The generative and flexible thinking that gives rise to creative cognition have widespread application, and some medical conditions might, in theory, be ameliorated by increasing such cognitive abilities. For instance, tES has been shown to relieve some symptoms of aphasia, at least in the short term (Baker, Rorden, & Fridriksson, 2010; Fiori et al., 2011; Monti et al., 2009). In these studies, reduction of aphasic symptoms (limited verbal output, difficulty naming words) was attributed to both tES-induced increased activity of brain networks associated with cognitive control (Baker et al., 2010) and speech (Fiori et al., 2011), and to induced decreases in excitability of overly active inhibitory networks (viz., disinhibition; Monti et al., 2009). It would be inaccurate to describe aphasia (solely) as a *disorder of creativity*, but alternatively, it could be that some aphasics become anchored on particular words or phrases, and this inflexibility impairs their ability to find new/different ways of articulating a thought. On this hypothetical account, incorporating tES to augment verbal generative flexibility (within a suite of other treatments) may relieve some aphasic signs and symptoms. Similarly, individuals with autism, attention-deficit hyperactivity disorder (ADHD), or frontal lobe damage typically exhibit difficulty with task-switching or cognitive flexibility. Although still entirely speculative, providing stimulation to improve creativity in terms of generative or flexible thinking may be a useful approach to treating certain dimensions of these conditions. In this way, it is possible to imagine that the use of tES to increase creativity might, here too, be appropriately considered—and classified—as a treatment.

Creativity has also been linked with various mental health disorders, especially schizophrenic spectrum and bipolar disorder. Individuals with schizotypal personality disorder—but not schizophrenia—have been found to display higher levels of *real-life creativity*, as assessed by their careers and hobbies (Kinney et al., 2001). Similarly, people with a genetic risk score for schizophrenia or bipolar disorder were found to have more creativity-centric lives (Power et al., 2015; Richards, 2001). Mild mood elevations, as opposed to bipolar disorder itself, may also be positively associated with creativity (Richards & Kinney, 1990). However, individuals with more severe symptoms appear to show creative deficits. For instance, schizophrenic patients performed poorly on measures of creative ability (Abraham, Windmann, McKenna, & Gunturkun, 2007), especially those tasks that required divergent idea production (Nemoto, Kashima, & Mizuno, 2007). Thus, the relationship between mental health disorders and creativity is not entirely clear. For cases in which mental disorders result in decreased levels of creative ability, the use of tES could be considered a treatment and utilized in the same way as described for aphasia or ADHD. This, however, is further complicated by the extent to which moderate schizotypal and bipolar symptoms may be seen as permissible (i.e., a "trade off") for enabling increased creativity and creative engagement in particular domains.

But consider another possibility; if creativity exists along a spectrum (of varying cognitive processes, skills and patterns in a range of domains), then the point at which the paucity or absence of such qualities is held to be abnormal need not be as high as in the previous illustration. Simply shifting a threshold of what qualities and capabilities are considered to be normal establishes a basis for any intervention to be regarded as a treatment. Simply put, if a set of qualities are defined and quantified (call this $A$), and the presence or absence of $A$ (1) significantly disrupts key aspects of a person's daily function, and/or (2) causes significant distress; then the condition $A$ could be characterized as a disorder (in this case, a hypothetical cognitive creativity disorder). As historical trends in psychiatry have revealed, the impetus to proceed in this direction is often fortified when a viable treatment is available or seen as possible (note, too, that this can create a situation in which an available intervention prompts characterization/classification or even establishment of a disorder that warrants such treatment; what could be conceived as the *reverse justification* scenario). Indeed, many have argued that classifications of psychiatric disorders have been based to varying degrees upon subjective, rather than wholly objective criteria (Alam, Patel, & Giordano, 2012; Benedict, 1989; Eisenman, 1994–1995; Patil & Giordano, 2010; Sadler, 2005; Ghaemi, 2003; Szasz, 1960; Wakefield, 1992). And although the use of brain science to elucidate and define patterns and substrates of normal or abnormal brain structure and function may appeal to claims of objectivity, care must be used if/when employing neurotechnology to both assess and affect the brain, as there is the risk of performativity in both the process itself, and the precepts (of normality/abnormality, etc.) it may yield (Akram & Giordano, 2017; Giordano, 2012; Giordano & Shook, 2015; Stein & Giordano, 2015).

In sum, this section has provided a brief illustration of the primary NELSI arising from the use of tES to augment creative thinking. Evidently, any consideration of using tES to foster or augment creativity can, and should, be framed in light of the ongoing treatment/enhancement discourse (for overview, see Jotterand & Dubljevic, 2016), and if and how extant ethical approaches may be engaged or revised to best guide and govern such use (Shook & Giordano, 2014, 2016).

## CONTEXTS OF USE

If and when utilized as a therapeutic intervention (viz.- as a treatment), devices and methods are (currently and typically) provided under clinical supervision. However, tES devices are relatively inexpensive and easy to obtain as DTC products that are marketed for modifying mood and increasing cognitive focus. As well, tES has attracted the interest of a DIY community that is developing ways of modifying commercially available products (e.g., transcutaneous nerve stimulation units) or making new devices that can be employed to non-invasively deliver electrical current to the brain (for a variety of purposes, ranging from self-treatment of neuropsychiatric conditions, to cognitive and behavioral performance optimization).

The use of tES in research settings is largely believed to be safe, and institutional review boards (IRBs) frequently designate tES trials to be minimal risk (Fregni et al., 2015). This designation is contingent upon the careful and measured use of the tES device, a specific research protocol, and requisite qualifications of the research staff. Although DTC tES devices are commercially developed to provide safe delivery of low levels of current via designated electrode montages, home users characteristically do not employ tES under clinical supervision, may not heed instructions provided, and can misuse the products. DIY construction and use can vary considerably and may not be reviewed and guided by an IRB, thus increasing risk(s) to the user (see Fitz & Reiner, 2013).

There can also be substantial differences in the sophistication of the technology and protocols for producing stimulation in DTC or DIY tES devices, as compared to tES utilized in laboratory settings. Research studies have demonstrated short-term facilitation of certain aspects of creative cognition using defined methods and montages of tES (e.g., Chrysikou et al., 2013; Colombo, Bartesaghi, Simonelli, & Antonietti, 2015; Green et al., 2016; Mayseless & Shamay-Tsoory, 2015; Ruggiero, Lavazza, Vergari, Priori, & Ferrucci, 2018). Importantly, these studies were guided by neuroimaging and behavioral investigations that identified brain areas putatively involved and participatory in specific forms of creative cognition (e.g., Green, 2016; Green, Cohen, Raab, Yedibalian, & Grey, 2015). Additionally, optimal tES electrode placement, current intensity, and flow were determined via modeling approaches (as described earlier) to target the intended brain region(s) with a level of stimulation hypothesized to be safe and effective. DTC approaches are generally more constrained and conservative than tES hardware and delivery parameters used in research and/or clinical applications, given that they cannot rely on the expert supervision that helps ensure safety in research and therapeutic contexts. And, although DTC devices and protocols are based upon research studies that have established use parameters required to elicit desired (and marketed) outcomes, as noted previously, actual home use (and user characteristics) can vary. The same can be said for other contexts of use. For example, educators or policy makers may eventually consider applications of tES in the classroom setting to augment student creativity (or other cognitive abilities). There are concerns and equivocal perspectives about how the use of tES (and other forms of neuromodulation) may affect the developing brains of children, and further research will be necessary to define if, and in what ways, such approaches may be most safely and effectively employed for educational purposes (Giordano & DuRousseau, 2011). By and large, however, the issues concerning the safety and effectiveness of use in the home and classroom are the same; and outcomes achieved in research and clinical settings may not be predictive of the results of using devices and methods employed outside of these settings (e.g.- at home, and/or in schools). However, absence of evidence of effect(s) is not evidence of absence of effect(s), and as such, does not, necessarily preclude at-home and/or classroom uses from eliciting some demonstrable outcomes.

Indeed, all application of tES remains a focal issue for ongoing research to further elucidate patterns of utilization, to identify if and under what conditions and protocols various outcomes are achieved, and to document any and all side and adverse effects. This may be particularly critical if/when contemplating the use of tES for children (and even adolescents). To reiterate, little is currently known regarding how electrical stimulation may impact the developing brain, which generates key neuroethical and legal issues pertaining to safety, long-term effects, assent, consent, and continuity of care (Giordano, 2015, 2017). Cohen-Kadosh and colleagues (2012) have recommended concomitant and prospective neuroimaging studies to be employed in research using tES in pediatric populations. This is prudent, and although there are general caveats regarding tES use for children (Bikson et al., 2018), it is important to recognize the relative attractiveness (if not temptation) for parents and/or teachers to employ these methods in an attempt to fortify certain cognitive capacities that may be of value to their children's scholastic and/or artistic performance (Gini, Rossi, & Giordano, 2010; Giordano & DuRousseau, 2011). In reality, it is probable, if not likely, that this will occur and, thus, it will be vital to evaluate if and how tES is being used in such ways. A more thorough depiction and evaluation of tES use (in both adults and children), direct engagement with DIY and DTC users (Fitz & Riner 2013; Wexler, 2016; Wurzman, Hamilton, Pascual-Leone, & Fox, 2016), as well as commercial manufacturers of DTC-marketed devices (Bikson et al., 2018) has been, and will continue to be important and necessary—although this is sometimes easier said than done.

## CONCLUSION: CHARTING A NEUROETHICAL COURSE

Irrespective of whether tES is held to be a treatment or enhancement, questions arise as to the extent of cognitive enhancement researchers can and/or should strive to achieve, how such interventions will be allocated, and the social effect(s) incurred by fortifying individuals' and/or groups' abilities in these ways (for overviews, see Shook & Giordano, 2016; 2017). Prior work has offered a multistep process for evaluating and mitigating risks associated with the use of emerging neurotechnologies, which entails determining when, why, and in whom this technology will be used, explicating the actual capabilities, consequences, and contexts of such use, and detailing steps for ongoing research and care (Giordano, 2015, 2016, 2017). Such a process is recommended for use in this context, as well.

Moreover, as the capacity to employ neurotechnology to access and affect various dimensions of human cognition increases, extant ethical principles and systems may not always be viable to fully frame the deliberative discourse and decisions required to sustain prudent use of these techniques and technologies in real-world social settings (Shook, Galvagni, & Giordano, 2014). This is especially true in relation to the use of new methods to foster creativity. Hence, new conceptual principles, which more fully capture ethical aspects of self-potentiality, empowerment, nonobsolescence, as well as communal citizenship, may here be of value, not *prima facie*, but taken and used together toward a more integrative ethical framework to guide such uses of technology in practice (Shook & Giordano, 2014).

The endeavor to augment creative cognition through brain stimulation is a compelling line of research, and a provocative topic of discourse and debate. However, even the most promising findings in this area have not irrefutably shown tES to be the most effective way of enhancing creative cognition. Other methods, such as explicit instruction to *be creative* (Green, Cohen, Kim, & Gray, 2012; Weinberger, Iyer, & Green, 2016) and a wide variety of creativity training programs (Scott, Leritz, & Mumford, 2004) have yielded notable improvements in creative ability; and perhaps tES could be employed in synergy with such approaches. Indeed, Green et al. (2016) demonstrated an interaction of tDCS with explicit creativity cueing whereby the greatest gains in creative performance were achieved when tDCS was combined with cueing. At present, there is little evidence to suggest that brain stimulation alone is superior to instructional and/or training approaches. Indubitably, additional studies should be undertaken to investigate these possibilities.

Such studies may reveal that tES, and other neuroscientific and technological approaches, are indeed valid and of value in facilitating aspects of creativity. As well, research to further define neural substrates and mechanisms of creativity will provide a better-informed understanding of those nodes and networks that might be engaged by various tools and techniques of neuroscience and other life and social sciences, and perhaps ultimately the arts and humanities. Yet, elucidating what can be done necessitates discussion and decisions about what should be done; and recognition of what should be done prompts inquiry into if and how it actually can. All things being equal, the ability to fortify or foster creativity appeals as affording meaningful goods to the quality of life. But things are rarely, if ever, equal, and in reality even such a seemingly noble striving incurs a host of ethico-legal and social issues. Perhaps then, what is needed is a bit of creativity (and prudence) to develop and employ technical and ethical methods to advance human creativity.

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## DISCLOSURE STATEMENT

*We declare that the research was conducted in the absence of any financial interests or benefits that could arise from its direct application.*

## REFERENCES

Abraham, A., Windmann, S., McKenna, P., & Güntürkün, O. (2007). Creative thinking in schizophrenia: The role of executive dysfunction and symptom severity. *Cognitive Neuropsychiatry*, *12*(3), 235–258. doi:10.1080/13546800601046714

Akram, F., & Giordano, J. (2017). Research Domain Criteria as Psychiatric Nosology: Conceptual, Practical and Neuroethical Implications. *Cambridge Quarterly of Healthcare Ethics*, *26*(4), 592–601. doi:10.1017/S096318011700010X

Alam, S., Patel, J., & Giordano, J. (2012). Working towards a new psychiatry-neuroscience, technology and the DSM-5. *Philosophy, Ethics, and Humanities in Medicine*, *7*, 1. doi:10.1186/1747-5341-7-1

Baker, J. M., Rorden, C., & Fridriksson, J. (2010). Using transcranial direct-current stimulation to treat stroke patients with aphasia. *Stroke*, *41*(6), 1229–1236. doi:10.1161/STROKEAHA.109.576785

Beaty, R. E., & Silvia, P. J. (2012). Why do ideas get more creative across time? An executive interpretation of the serial order effect in divergent thinking tasks. *Psychology of Aesthetics, Creativity, and the Arts*, *6*(4), 309. doi:10.1037/a0029171

Benedict, R. (1989). *Patterns of culture*. Mariner Books. (Originally published 1934.)

Bikson, M., Paneri, B., Mourdoukoutas, A., Esmaeilpour, Z., Badran, B. W., Azzam, R., … Tyler, W. J. (2018). Limited output transcranial electrical stimulation (LOTES-2017): Engineering principles, regulatory statutes, and industry standards for wellness, over-the-counter, or prescription devices with low risk. *Brain Stimulation*, *11*(1), 134–157. doi:10.1016/j.brs.2017.10.012

Boggio, P. S., Ferrucci, R., Rigonatti, S. P., Covre, P., Nitsche, M., Pascual-Leone, A., & Fregni, F. (2006). Effects of transcranial direct current stimulation on working memory in patients with Parkinson's disease. *Journal of the Neurological Sciences*, *249*(1), 31–38. doi:10.1016/j.jns.2006.05.062

Chalmers, D. J. (1996). *The Conscious Mind: In Search of a Fundamental Theory*. New York, NY: Oxford University Press.

Chrysikou, E. G., Hamilton, R. H., Coslett, H. B., Datta, A., Bikson, M., & Thompson-Schill, S. L. (2013). Noninvasive transcranial direct current stimulation over the left prefrontal cortex facilitates cognitive flexibility in tool use. *Cognitive Neuroscience*, *4*, 81–89. doi:10.1080/17588928.2013.768221

Coffman, B. A., Clark, V. P., & Parasuraman, R. (2014). Battery powered thought: Enhancement of attention, learning, and memory in healthy adults using transcranial direct current stimulation. *NeuroImage*, *85*(3), 895–908. doi:10.1016/S0028-3932(03)00124-6

Cohen-Kadosh, R., Levy, N., O'Shea, J., Shea, N., & Savulescu, J. (2012). The neuroethics of non-invasive brain stimulation. *Current Biology*, *22* (4), R108–R111. doi:10.1016/j.cub.2012.01.013

Colombo, B., Bartesaghi, N., Simonelli, L., & Antonietti, A. (2015). The combined effects of neurostimulation and priming on creative thinking: A preliminary tDCS study on dorsolateral prefrontal cortex. *Frontiers in Human Neuroscience*, *9*, 403. doi:10.3389/fnhum.2015.00403

Datta, A., Bansal, V., Diaz, J., Patel, J., Reato, D., & Bikson, M. (2009). Gyri-precise head model of transcranial direct current stimulation: Improved spatial focality using a ring electrode versus conventional rectangular pad. *Brain Stimulation*, *2*, 201–207. doi:10.1016/j.brs.2009.03.005

Eisenman, R. (1994–1995). *Contemporary social issues: Drugs, crime, creativity, and education*. Ashland, OH: Bookmasters.

Fiori, V., Coccia, M., Marinelli, C. V., Vecchi, V., Bonifazi, S., Ceravolo, M. G., … Marangolo, P. (2011). Transcranial direct current stimulation improves word retrieval in healthy and nonfluent aphasic subjects. *Journal of Cognitive Neuroscience*, *23*(9), 2309–2323. doi:10.1162/jocn.2010.21579

Fitz, N. S., & Reiner, P. B. (2013). Journal of Medical Ethics. *The Challenge of Crafting Policy for Do-It-Yourself Brain Stimulation*, medethics-2013. doi:10.1136/medethics-2013-101458.

Fregni, F., Boggio, P. S., Santos, M. C., Lima, M., Vieira, A. L., Rigonatti, S. P., … Pascual-Leone, A. (2006). Noninvasive cortical stimulation with transcranial direct current stimulation in Parkinson's disease. *Movement Disorders*, *21*(10), 1693–1702. doi:10.1002/mds.21012

Fregni, F., Nitsche, M. A., Loo, C. K., Brunoni, A. R., Marangolo, P., Leite, J., … Simis, M. (2015). Regulatory considerations for the clinical and research use of transcranial direct current stimulation (tDCS): Review and recommendations from an expert panel. *Clinical Research and Regulatory Affairs*, *32*(1), 22–35. doi:10.3109/10601333.2015.980944

Ghaemi, S. N. (2003). *The Concepts of Psychiatry: A Pluralistic Approach to the Mind and Mental Illness*. Maryland, USA: Johns Hopkins University Press.

Gini, A., & Giordano, J. J. (2010). The human condition and strivings to flourish. In J. Giordano & B. Gordijn (Eds.), *Scientific and Philosophical Perspectives in Neuroethics* (pp. 343–354). New York, NY: Cambridge University Press. doi:10.1017/cbo9780511676505.019

Gini, A., Rossi, J. P., & Giordano, J. (2010). Considering enhancement and treatment: On the need to regard contingency and develop dialectic evaluation – A commentary on Singh and Kelleher. *AJOB-Neuroscience*, *1*(1), 25–27. doi:10.1080/21507740903504392

Giordano, J. (2012). Neurotechnology as demiurgical force: Avoiding Icarus' folly. In J. Giordano (Ed.), *Neurotechnology: Premises, Potential, and Problems* (pp. 1–14). Boca Raton, FL: CRC Press.

Giordano, J. (2015). A preparatory neuroethical approach to assessing developments in neurotechnology. *AMA J Ethics*, *17*(1), 56–61.

Giordano, J. (2016). Neurotechnological progress: The need for neuroethics. In F. Gonzalez (Ed.), *The Next Step: Exponential Life* (pp. 316–330). Madrid, Spain: BBVA Press.

Giordano, J. (2017). Toward an operational neuroethical risk analysis and mitigation paradigm for emerging neuroscience and technology (neuroS/T). *Experimental Neurology*, *287*(4), 492–495. doi:10.1016/j.expneurol.2016.07.016

Giordano, J., & DuRousseau, D. (2011). Toward right and good use of brain-machine interfacing neurotechnologies: Ethical issues and implications for guidelines and policy. *Cognitive Technology*, *15*, 5–10.

Giordano, J., & Olds, J. (2010). The interfluence of neuroscience, neuroethics, and legal and social issues: The need for (N) ELSI. *AJOB Neuroscience*, *1*(4), 12–14. doi:10.1080/21507740.2010.515964

Giordano, J., & Shook, J. R. (2015). Minding brain science in medicine: On the need for neuroethical engagement for guidance of neuroscience in clinical contexts. *Ethics in Biology, Engineering and Medicine*, *6*(1–2), 37–42. doi:10.1615/EthicsBiologyEngMed.2015015333

Green, A. E. (2016). Creativity, within reason: Semantic distance and dynamic state creativity in relational thinking and reasoning. *Current Directions in Psychological Science*, *25*(1), 28–35. doi:10.1177/0963721415618485

Green, A. E., Cohen, M. S., Kim, J. U., & Gray, J. R. (2012). An explicit cue improves creative analogical reasoning. *Intelligence*, *40*(6), 598–603. doi:10.1016/j.intell.2012.08.005

Green, A. E., Cohen, M. S., Raab, H. A., Yedibalian, C. G., & Gray, J. R. (2015). Frontopolar activity and connectivity support dynamic conscious augmentation of creative state. *Human Brain Mapping*, *36*(3), 923–934. doi:10.1002/hbm.22676

Green, A. E., Spiegel, K. A., Giangrande, E. J., Weinberger, A. B., Gallagher, N. M., & Turkeltaub, P. E. (2016). Thinking cap plus thinking zap: TDCS of frontopolar cortex improves creative analogical reasoning and facilitates conscious augmentation of state creativity in verb generation. *Cerebral Cortex*, *27*(4), 2628–2639. doi:10.1093/cercor/bhw080

Guilford, J. P. (1967). *The Nature of Human Intelligence*. New York, NY: McGraw-Hill.

Hamilton, R., Messing, S., & Chatterjee, A. (2011). Rethinking the thinking cap Ethics of neural enhancement using noninvasive brain stimulation. *Neurology*, *76*(2), 187–193. doi:10.1212/WNL.0b013e318205d50d

Jotterand, F., & Dubljevic, V. (Eds.). (2016). *Cognitive Enhancement: Ethical and policy implications in international perspectives*. New York, NY: Oxford University Press.

Kim, K. H. (2005). Can only intelligent people be creative? A meta-analysis. *Journal of Secondary Gifted Education*, *16*(2–3), 57–66. doi:10.4219/jsge-2005-473

Kinney, D. K., Richards, R., Lowing, P. A., LeBlanc, D., Zimbalist, M. E., & Harlan, P. (2001). Creativity in offspring of schizophrenic and control parents: An adoption study. *Creativity Research Journal*, *13*(1), 17–25. doi:10.1207/S15326934CRJ1301_3

Mayseless, N., & Shamay-Tsoory, S. G. (2015). Enhancing verbal creativity: Modulating creativity by altering the balance between right and left inferior frontal gyrus with tDCS. *Neuroscience*, *291*, 167–176. doi:10.1016/j.neuroscience.2015.01.061

Monti, A., Cogiamanian, F., Marceglia, S., Ferrucci, R., Mameli, F., Mrakic-Sposta, S., … Priori, A. (2009). Improved naming after transcranial direct current stimulation in aphasia. *Journal of Neurology, Neurosurgery & Psychiatry*, *79*(4), 451–453. doi:10.1136/jnnp.2007.135277

Nemoto, T., Kashima, H., & Mizuno, M. (2007). Contribution of divergent thinking to community functioning in schizophrenia. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *31*(2), 517–524. doi:10.1016/j.pnpbp.2006.12.001

Nitsche, M. A., Boggio, P. S., Fregni, F., & Pascual-Leone, A. (2009). Treatment of depression with transcranial direction current stimulation (tDCS): A review. *Experimental Neurology*, *219*(1), 14–19. doi:10.1016/j.expneurol.2009.03.038

Patil, T., & Giordano, J. (2010). Ontological assumptions of the medical model of psychiatry. *Philosophy, Ethics, and Humanities in Medicine*, *5*, 3. doi:10.1186/1747-5341-5-3

Pereira, J. B., Junque, C., Bartres-Faz, D., Marti, M. J., Sala-Llonch, R., Compta, Y., … Tolosa, E. (2013). Modulation of verbal fluency networks by transcranial direct current stimulation (tDCS) in Parkinson's disease. *Brain Stimulation*, *6*(1), 16–24. doi:10.1016/j.brs.2012.01.006

Pisoni, A., Mattavelli, G., Papagno, C., Rosanova, M., Casali, A. G., & Romero Lauro, L. J. (2017). Cognitive enhancement induced by anodal tDCS drives circuit-specific cortical plasticity. *Cerebral Cortex*, *10*, 1–9. doi:10.1093/cercor/bhx021

Power, R. A., Steinberg, S., Bjornsdottir, G., Rietveld, C. A., Abdellaoui, A., Nivard, M. M., Cesarini, D. (2015). Polygenic risk scores for schizophrenia and bipolar disorder predict creativity. *Nature Neuroscience*, *18* (7), 953–955. doi:10.1038/nn.4040

Richards, R., & Kinney, D. K. (1990). Mood swings and creativity. *Creativity Research Journal*, *3*(3), 202–217.

Richards, R. (2001). Creativity and the schizophrenia spectrum: More and more interesting. *Creativity Research Journal*, *13*(1), 111–132. doi:10.1207/S15326934CRJ1301_13

Ruggiero, F., Lavazza, A., Vergari, M., Priori, A., & Ferrucci, R. (2018). Transcranial direct current stimulation of the left temporal lobe modulates insight. *Creativity Research Journal*, *30*(2), 143–151. doi:10.1080/10400419.2018.1446817

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal*, *24*, 92–96. doi:10.1080/10400419.2012.650092

Sadler, J. Z. (2005). *Values and Psychiatric Diagnosis*. Oxford: Oxford University Press.

Sarkar, A., Dowker, A., & Kadosh, R. C. (2014). Cognitive enhancement or cognitive cost: trait-specific outcomes of brain stimulation in the case of mathematics anxiety. *Journal of Neuroscience*, *34*(50), 16605–16610.

Sarkar, A., Dowker, A., & Cohen Kadosh, R. (2014). Cognitive enhancement or cognitive cost: Trait-specific outcomes of brain stimulation in the case of mathematics anxiety. *Journal of Neuroscience*, *34*(50), 16605–16610. doi:10.1523/JNEUROSCI.3129-14.2014

Savulich, G., Piercy, T., Brühl, A. B., Fox, C., Suckling, J., Rowe, J. B., … Sahakian, B. J. (2017). Focusing the neuroscience and societal implications of cognitive enhancers. *Clinical Pharmacology & Therapeutics*, *101*(2), 170–172. doi:10.1002/cpt.457

Scott, G., Leritz, L. E., & Mumford, M. D. (2004). The effectiveness of creativity training: A quantitative review. *Creativity Research Journal*, *16*(4), 361–388. doi:10.1080/10400410409534549

Shook, J. R., Galvagni, L., & Giordano, J. (2014). Cognitive enhancement kept within contexts: Neuroethics and informed public policy. *Frontiers in Systems Neuroscience*, *8*, 1–8. doi:10.3389/fnsys.2014.00228

Shook, J. R., & Giordano, J. (2014). A principled, cosmopolitan neuroethics: Considerations for international relevance. *Philosophy, Ethics, and Humanities in Medicine*, *9*, 1. doi:10.1186/1747-5341-9-1

Shook, J. R., & Giordano, J. (2016). Neuroethics beyond normal: Performance enablement and self-transformative technologies. *Cambridge Quarterly of Healthcare Ethics*, *25*(1), 121–140. doi:10.1017/S0963180115000377

Shook, J. R., & Giordano, J. (2017). Neuroethical engagement on interdisciplinary and international scales. In *Debates about neuroethics*. (pp. 225–245). Springer, Cham.

Smith, S. M., Ward, T. B., & Finke, R. A. (Eds.). (1995). *The Creative Cognition Approach*. Massachusetts, USA: MIT Press.

Stein, D. J., & Giordano, J. (2015). Global mental health and neuroethics. *BMC Medicine*, *13*(1). doi:10.1186/s12916-015-0274-y

Szasz, T. S. (1960). The myth of mental illness. *American Psychologist*, *15* (2), 113. doi:10.1037/h0046535

Wakefield, J. C. (1992). The concept of mental disorder: On the boundary between biological facts and social values. *American Psychologist*, *47*(3), 373. doi:10.1037/0003-066X.47.3.373

Weinberger, A. B., Green, A. E., & Chrysikou, E. G. (2017). Using transcranial direct current stimulation to enhance creative cognition: Interactions between task, polarity, and stimulation site. *Frontiers in Human Neuroscience*, *11*, 246. doi:10.3389/fnhum.2017.00246

Weinberger, A. B., Iyer, H., & Green, A. E. (2016). Conscious augmentation of creative state enhances "real" creativity in open-ended analogical reasoning. *PloS One*, *11*(3), e0150773. doi:10.1371/journal.pone.0150773

Wexler, A. (2016). A pragmatic analysis of the regulation of consumer transcranial direct current stimulation (tDCS) devices in the United States. *Journal of Law and the Biosciences*, *2*(3), 669–696.

Wurzman, R., Hamilton, R. H., Pascual-Leone, A., & Fox, M. D. (2016). An open letter concerning do it yourself users of transcranial direct current stimulation. *Annals of Neurology*, *80*(1), 1–3. doi:10.1002/ana.24689