Brain Stimulation 6 (2013) 713–714

Contents lists available at SciVerse ScienceDirect

Brain Stimulation

journal homepage: www.brainstimjrnl.com

Editorials

Overclock Your Brain for Gaming? Ethical, Social and Health Care Risks

"Overclock your brain using transcranial Direct Current Stimulation (tDCS) to increase the plasticity of your brain. Make your synapses fire faster. Let the force of electricity excite your neurons into firing faster"

This is how Foc.us Labs (http://www.foc.us) introduced a new device to improve performance at video-games. The device is meant for self-administration of imperceptible, transcranial currents to the prefrontal cortex, and can be tuned by a smartphone app. Everybody can buy it by a mouse click. This is an example of how market goals may overcome ethics by threatening users' and gamers' health and imposing high social risks.

Indeed, the boundaries between video-gaming for fun, for money, and the development of gaming addiction are subtle, and hence easily crossable. In the last decade, the online gaming scenario has completely changed. There has been an exponential growth of platforms and dedicated portals, along with a decrease of gamers' age. According to a 2012 survey (Forbes, Dec 20th, 2012, "The Year of eSports"), 4 millions of gamers currently play within the Electronic Sport League, and 8 millions in the North American Major League of Gaming (MLG). During the last year, MLG has observed a +334% increase of live viewings of online tournaments (from 3.5 to 11.7mln; +636% in the last two years), with followers from 175 different countries.

eSport has hence evolved in a very profitable activity. Tech companies support cyber-leagues and major events, providing substantial money prizes (up to 1mln$ for a single contest) and media coverage. As a consequence, the number of occasional players turning into professional gamers has increased (The Economist, Jan 14th, 2013, "Mouse sports"). Professional gamers earn an average annual income ranging from $12,000 to $30,000, with an average playing time ranging from 6 to 8 h per day. This new scenario resulted in an increase of competitiveness and determination to excel, making tools like *foc.us* a possible short-cut to money and glory. The emergence of uncontrolled use of brain-boosting tools may have an even more worrying substrate, that is, gambling. According to The Economist (July 8th, 2010, "YouBet"), gambling has become a major international commercial activity, with the legal gambling market totaling an estimated $335 billion in 2009, of which $25 billion from online gaming.

Individuals with reduced inhibitory control of prefrontal activity may develop pathological gambling, that is the difficulty to control the impulse to gamble. This may lead to devastating consequences on familiar and social life [1]. Interestingly, Foc.us Labs suggests the prefrontal cortex as target brain site for the self-administration of foc.us tDCS. Given the evidence of a relationship between tDCS on the prefrontal cortex and risk-taking behaviors [2,3], prolonged self-administered tDCS over this brain region may induce frequent – if not already addicted – gamers to cross the boundary toward pathological gambling. Social and health care systems do not need additional burden for an already expanding pathology.

tDCS is a non-invasive brain stimulation (NIBS) neuromodulatory technique used in brain research, whose potential clinical applications to treat pathological neuropsychiatric conditions are rapidly growing [4,5]. The rationale to use tDCS as a neuromodulatory treatment is that it modifies cortical excitability in a polarity-specific manner, with effects lasting even after the stimulation has ceased. tDCS applied over the prefrontal cortex can induce long-lasting improvements in cognitive abilities [4], as accelerating learning times to identify concealed objects in naturalistic environments, with a dose–response effect of applied current strength [6]. Evidence-based clinical efficacy in large clinical trials on the use of prefrontal tDCS for treatment of depression and other psychiatric disorders is still weak, but randomized, controlled multicentric trials are currently ongoing worldwide (see http://clinicaltrials.gov). These studies will provide an answer about the real efficacy on clinical grounds.

Other types of NIBS techniques (i.e., alternating current and random noise stimulation), which could be also applied through the *foc.us* device, may speed up logical reasoning abilities by 15% in healthy subjects resolving complex cognitive tasks [7], and improve arithmetic calculation [8], with persisting neuroplastic [4,5] and metabolic [9] after-effects. Unlike other NIBS techniques such as repetitive transcranial magnetic stimulation [10], official safety guidelines based on a large consensus within neuroscience community are not yet available for transcranial electrical current stimulation.

Behavioral changes induced so far by transcranial electric stimulation of the brain are generally modest, and do not impact everyday life activities. However, this is not sufficient to reassure about prolonged, uncontrolled, use of self-stimulation outside the lab boundaries. It cannot be excluded that long periods of stimulation, even with intensities of few milliamps, may raise safety issues [4,5] especially if the tDCS device is used by a lay person with no medical or credited supervision. In addition, it is worth noticing that animal models of brain damage following transcranial electrical stimulation have been documented [11]. Although a direct transfer of these effects on humans is premature, the sentence "*The foc.us gamer headset offers no medical benefits, is not a medical device, and is not regulated by the FDA*" appearing on http://www.foc.us is worryingly misleading in light of the above considerations.

1935-861X/$ – see front matter
http://dx.doi.org/10.1016/j.brs.2013.07.005

Moreover, NIBS is not, and should not be intended as, a magic tool which selectively increases brain performance following a simple additive process. The human brain is a magnificent example of evolution-driven engineering, whose neural networks are dynamically integrated and organized both at local and global scale. The effects of a prolonged exposure to an external intervention might not be intended, as Foc.us labs claims, as merely localized under the electrode, and consequently it would not only affect the single function supported by that region, but also other processes. The prefrontal cortex, which is highly interconnected with much of the brain, including other cortical, subcortical and brain stem sites, is indeed a key hub for several executive, cognitive, affective and emotional functions [12]. It is therefore unlikely that prolonged daily self-stimulation of this region will result only in a selective improvement of gaming abilities. Additionally, potential undesired functional compensation is possible, involving other functional networks and, in turn cognitive domains.

Besides eSport and pathological gambling, there should be a serious concern on what types of consequences an uncontrolled clearance of NIBS through the foc.us or similar "brain-doping" tools may result in. Considering its emerging cognition-boosting capability [7–9], or even just its documented efficacy as a painkiller [5], NIBS based on self-administered currents may turn into a worrisome scenario in the next decade. Given its easy accessibility to the public and the misleading communication about potential side-effects that we are documenting here, a firm information campaign supported by the scientific community is needed.

Finally, as Foc.us Labs states itself, the possibility to self-modulate one's own brain activity without any medical or external control makes this practice somehow conceptually similar to the "overclocking" process that gamers easily apply on their computer hardware, by boosting central or graphical processors performance beyond the limit fixed by manufacturers. The direct comparison of informatics and biological models incorporated in the Human-Information-Processing theory is a groundbreaking theoretical advance for the understanding of principles governing human brain functioning. Clearly, there are major concerns about going too far with the brain-computer analogy. It is worth to keep in mind that hardware overclocking usually corresponds to an initial increase in hardware performance, but it inevitably leads to its premature wearing out. What about the brain?

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References

[1] Ashley LL, Boehlke KK. Pathological gambling. J Psychoactive Drugs 2012;44:27–37.
[2] Fecteau S, Knoch D, Fregni F, Sultani N, Boggio P, Pascual-Leone A. Diminishing risk-taking behavior by modulating activity in the prefrontal cortex: a direct current stimulation study. J Neurosci 2007;27:12500–5.
[3] Boggio PS, Campanhã C, Valasek CA, Fecteau S, Pascual-Leone A, Fregni F. Modulation of decision-making in a gambling task in older adults with transcranial direct current stimulation. Eur J Neurosci 2010;31:593–7.
[4] Kadosh RC, Levy N, O'Shea J, Shea N, Savulescu J. The neuroethics of non-invasive brain stimulation. Curr Biol 2012;22:R108–11.
[5] Nitsche MA, Cohen LG, Wassermann EM, Priori A, Lang N, Antal A, et al. Transcranial direct current stimulation: state of the art 2008. Brain Stimul 2008;3:206–23.
[6] Clark VP, Coffman BA, Mayer AR, Weisend MP, Lane TD, Calhoun VD, et al. TDCS guided using fMRI significantly accelerates learning to identify concealed objects. Neuroimage 2012;59:117–28.
[7] Santarnecchi E, Polizzotto NR, Godone M, Giovannelli F, Feurra M, Matzen L, et al. Frequency-dependent enhancement of fluid intelligence induced by transcranial oscillatory potentials. Curr Biol 2013;23:1449–53.
[8] Kadosh RC, Soskic S, Iuculano T, Kanai R, Walsh V. Modulating neuronal activity produces specific and long-lasting changes in numerical competence. Curr Biol 2012;20:2016–20.
[9] Snowball A, Tachtsidis I, Popescu T, Thompson J, Delazer M, Zamarian L, et al. Long-term enhancement of brain function and cognition using cognitive training and brain stimulation. Curr Biol 2013;23:1–6.
[10] Rossi S, Hallett M, Rossini PM, Pascual-Leone A. Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. Clin Neurophysiol 2009;120:2008–39.
[11] Liebetanz D, Koch R, Mayenfels S, König F, Paulus W, Nitsche MA. Safety limits of cathodal transcranial direct current stimulation in rats. Clin Neurophysiol 2009;120(6):1161–7.
[12] Kolb B, Mychasiuk R, Muhammad A, Li Y, Frost DO, Gibb R. Experience and the developing prefrontal cortex. Proc Natl Acad Sci U S A 2012;109(Suppl. 2):17186–93.