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# "Self-Neuroenhancement": The Last Frontier of Noninvasive Brain Stimulation?

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Dear Editor,

Noninvasive brain stimulation (NIBS) techniques are able to transiently modulate the cortical excitability to induce effects that outlast the stimulation period. Briefly, transcranial magnetic stimulation involves administering magnetic pulses to localized brain areas: a single pulse induces short-lasting effects on ongoing neuronal processes, whereas rhythmic trains of pulses yield long-lasting effects. Transcranial direct-current stimulation (tDCS) is applied over larger cortical areas to send electrical currents through the brain. Finally, transcranial static magnetic stimulation and transcranial focused ultrasonography involve exposing specific brain areas to a magnet positioned on the head or to localized ultrasound energy, respectively.[1]

Different protocols are applied for diagnostic, research, and therapeutic purposes in several neuropsychiatric diseases.[2,3] The aim is to restore an impaired cerebral function or network by modulating synaptic plasticity and functional connectivity. NIBS has been proposed as a therapeutic option in various clinical settings, such as drug-resistant major depression. Clinical and rehabilitative applications of NIBS for other disorders such as stroke, tinnitus, chronic pain, migraine, dementia, Parkinson's disease, dystonia, and sleep disorders are currently in development, with a focus on optimizing the most appropriate target, stimulation protocols, and candidate symptoms to treat.[4,5]

NIBS can be applied also in normal individuals to produce "neuroenhancement," and the possibility to "self-enhance" neurocognitive functions has recently gained attention outside academic fields. In particular, the "neurohackers" are a unofficial movement of people who use home-made devices to provide various types of stimulation (i.e., modified tDCS, transcranial alternating-current stimulation, and transcranial random-noise stimulation) for self-improvement purposes in nonclinical environments.[6] The impacts of NIBS on mood, perception, cognition, and behavior have been demonstrated widely, and this has not only clinical relevance but also ethical, legal, social, and even political implications that remain to be addressed.[1] For example, serious concerns may arise from the application of NIBS to healthy human brains in schools, universities, workplaces, or sports environments.

Some crucial questions need to be addressed regarding NIBS, such as what should be defined as "normal" brain function, what are the long-term effects of NIBS and the associated safety risks, which neurological functions can and cannot be ethically improved, and what are the social implications of "self-induced neuromodulation?" It should be acknowledged that it is difficult to define a cutoff for "normality," since the associated concepts span a spectrum of social and cultural substrates.

We know that NIBS techniques are safe when applied by experienced operators, in a controlled environment, and by following appropriate inclusion/exclusion criteria. However, when they are self-administered using a "do it by yourself" (DIY) device, the risks are unpredictable. Furthermore, brain stimulation performed to enhance normal abilities may have

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negative effects on other functions, possibly influencing a more-widespread brain network with unknown implications.[6]

Further critical questions arise when the target of self-enhancement shifts from cognition to a moral perspective. If NIBS would be able to influence a particular trait, then "neuroenhanced" people might develop different moral, behavioral, and even spiritual features, thus becoming "different" persons.[7] Therefore, performing neuromodulation in order to change temper, personality, and behavior could represent a serious threat to the autonomy and free will of subjects, particularly with reference to military applications or corrective measures for convicts.[8]

Finally, using these devices in such applications could generate social disparity in terms of advantages only being provided to those who have sufficient social and financial resources to afford them. From a long-term perspective, this might lead to a society divided into "enhanced" and "nonenhanced" humans, with obvious social and ethical consequences.

In conclusion, further progress in NIBS will increase the accessibility of this technique and force the scientific community to address questions related to self-identity and morality. Meanwhile, the rise of the DIY movement draws attention to the need to provide appropriate education to the population. The uncontrolled self-administration of NIBS should be discouraged until more data on its long-term safety and efficacy are available. Moreover, the autonomy of subjects should always be ensured—it is mandatory to obtain informed consent based on knowledge of the possible implications for personal identity and conform with all ethics requirements. Neuroenhancement also needs to be politically regulated in order to prevent any social discrimination or unfair use and to support its role as a promising translational resource.

## Author Contributions

Conceptualization: Francesco Fisicaro, Giuseppe Lanza. Writing—original draft: Rita Bella, Manuela Pennisi. Writing—review & editing: Giuseppe Lanza.

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## Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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