

Neurocognitive Enhancement: Applications and Ethical Issues

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Abstract

In recent years, the interest in neurocognitive empowerment has increased, thus making it a hot topic, especially because of possible ethical implications. Specifically, the term *neurocognitive empowerment* refers to the use of different neuroscientific techniques and tools that increase the cognitive functioning of the individual beyond the normal threshold—on the one hand, improving functions such as attention, perception, and memory—and, on the other hand, physical and motor functions. Neuroethics is peculiarly interested in monitoring and discussing ethical implications and possible consequences or undesirable effects of neurocognitive strengthening techniques. In particular, the use of different tools for neurocognitive enhancement requires an in-depth analysis of the ethical and legal principles in terms of security and social justice that allow the improvement of mental and physical functions of an individual. The present work aims at introducing the use of specific techniques—such as neurofeedback devices for the enhancement of attention regulation skill—in specific application contexts; that is, sports in which athletes are continuously subjected to external pressures for performance and constant improvement. Furthermore, this document explores possible ethical critical issues raised by such use of neurocognitive enhancement techniques.

Keywords: neuroethics; neurocognitive enhancement; peak performance; wearable devices; sports

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Preliminary Definitions: Why Neurocognitive Enhancement

Neurocognitive enhancement is a theme of the latest definition. Whilst the term *neuroenhancement* was, at first, frequently paired with those of *doping* and *brain drugs* and with the idea of boosting neural activity to improve cognitive and motor skills (Bell, Partridge, Lucke, & Hall, 2013; Dodge, Williams, Marzell, & Turrissi, 2012; Svetlov, Kobeissy, & Gold, 2007), in recent years the interest into its implications and potential for performance improvement and promotion of optimal functioning in many professional contexts has progressively grown (Bell, Bryson, Greig, Corcoran, & Wexler, 2001; Fronda, Balconi, & Crivelli, 2018; Shook & Giordano, 2016).

Neurocognitive enhancement refers, in particular, to qualitative and/or quantitative improvement of specific cognitive–affective skills or sets of cognitive functions (Farah, 2005; Fronda et al., 2018; Lucke & Partridge, 2013; Nagel, 2010, 2014), which can be modulated by means of various neuroscientific techniques. Such techniques (e.g., noninvasive brain stimulation and neurofeedback), by acting on brain structures and on neural networks within the central nervous system, allow modulating brain activity during a given task with the final aim of improving information-processing; optimizing the functionality of perceptual, attention, and cognitive systems; and making them operate in a more adaptive, flexible, and efficient way (Bostrom & Sandberg, 2009; Harvey, 2008). Indeed,

neuroenhancement interventions usually aim to increase mental functioning beyond what is necessary to sustain or restore a condition of individual well-being (Juengst, 1998). The alteration of brain functions occurs because the brain can change in response to stimulating experiences, practice, or specific training (Engvig et al., 2012; Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010; Schooler, 1984; Schooler, Mulatu, & Oates, 1999). Specifically, cognitive enhancement through given training can be aimed at improving a specific function or enhancing the effectiveness of certain activities (Anguera et al., 2013; Chapman et al., 2013; Dahlin, Nyberg, Bäckman, & Neely, 2008; Jaeggi, Buschkuhl, Jonides, & Perrig, 2008; Nyberg et al., 2003; Valenzuela-Fernández, Cabrero, Serrador, & Sánchez-Madrid, 2008; Zelinski & Reyes, 2010). Therefore, through neurocognitive enhancement, it is possible to optimize the functioning of specific cognitive functions to achieve optimal performance (Agar, 2013).

Neuroscientific Techniques for Sports Performance Enhancement

The interest in neuroscience focuses specifically on the implementation of different interventions aimed at enhancing performance in various contexts, such as sports. In the sports context, there is a continuous demand for improvement in performance across all levels of expertise, from amateurs to semiprofessional and professional athletes. Advances in neuroscience suggest that sports performance can be enhanced by using methods and techniques that modify brain activity, thus leading to the improvement of athletes' mental state and focus, as well as encouraging motor learning (Vargo et al., 2014). Recently, the potential and effectiveness of noninvasive brain stimulation techniques (i.e., neuroscientific intervention techniques, able to safely induce neuromodulation or neurostimulation effects on cortical structures and networks)—and of combined neurofeedback and mental training programs for pursuing such goals and for optimizing athletes' cognitive and behavioral performances—have been more and more explicitly explored (Balconi, Fronda, Venturella, & Crivelli, 2017; Balconi, Pala, Crivelli, & Milone, 2019; Borducchi et al., 2016; Colzato, Nitsche, & Kibebe, 2017; Crivelli, Fronda, Venturella, & Balconi, 2019; Davis, 2013; Lewthwaite & Wulf, 2017). While the attention given to potential applications of noninvasive stimulation and neuromodulation techniques likely followed the need for novel models and methods for intervention and the will to try and

overcome limitations and ethical issues raised by first tentative neuroenhancement approaches based on chemicals and psychoactive drugs, it has to be acknowledged that such potential and its practical–ethical implications in the field of sports practice is still a matter of debate. The growing development of those techniques devised to foster the improvement in sports performance has been, for example, defined as a form of “neurodoping” (Davis, 2013). Several studies (Colzato et al., 2017; Flöel et al., 2011) have demonstrated the effectiveness of brain stimulation and neuromodulation techniques for the enhancement of various cognitive functions even outside the laboratory. In the sports context, in particular, brain stimulation and neural entrainment techniques such as transcranial direct current stimulation (tDCS) and transcranial alternate current stimulation (tACS), which are able to modify cerebral excitability and cortical oscillations by working on specific physiological mechanisms of action (Vernon, 2005), have been used to try and foster optimal neurocognitive efficacy and to improve individual performance (Grosprêtre, Ruffino, & Lebon, 2016). Some studies have shown the effectiveness of these techniques with regard to athletes' physical skills, namely motor learning and muscular strength, and with regard to their cognitive skills, namely learning ability and attention (Vargo et al., 2014). Moreover, recent studies have shown that the use of tDCS to enhance sports performance is useful in modulating and controlling the autonomic nervous system, allowing the increase in the exercise capacity under challenging conditions (Okano et al., 2013; Williams, Hoffman, & Clark, 2013). Another study (Vitor-Costa et al., 2015) demonstrated the tDCS effectiveness in improving muscle fatigue, exercise tolerance, and visuomotor coordination, as well as long-term implicit learning processes (Antal et al., 2004; Reis et al., 2009; Zhu et al., 2015).

In addition to neuromodulation techniques, several studies have demonstrated the effectiveness for enhancing sports individual's cognitive and behavioral performance of practices and training programs aimed at fostering self-awareness and self-regulation skills via mental training and neuroscientific techniques (Crews & Landers, 1993; Haufler, Spalding, Santa Maria, & Hatfield, 2000; Landers et al., 1991; Salazar et al., 1990). Those neurofeedback techniques seem to be able to improve specific aspects of physical or cognitive individuals performance (Alexeeva, Balios, Muravlyova, Sapina, & Bazanova, 2012; Zoefel, Huster, & Herrmann, 2011), such as attention regulation or stress management, by helping practicers to become increasingly aware of their

automatic physiological reactions to different conditions or, for example, of physiological correlates of specific mindsets and by helping them to strengthen individual strategies to adaptively control such reactions and correlates, thus containing or modulating their occurrence.

Similarly, another tool that proved to be useful as a cognitive enhancement technique with relevant effects in terms of performance improvement is biofeedback, which turned out to be valuable for strengthening control over the bodily arousal levels and for empowering emotional regulation and stress management skills, thus helping, for example, practitioners to learn how to contain precompetition anxiety and how to redirect mental resources on their present goals fostering the achievement of optimal performance (Wood, 2006).

Ethical Implications of Performance Enhancement

Despite the positive evidence in favor of the effectiveness of these neurocognitive enhancement techniques in different contexts, cognitive and behavioral performance improvement appears to be a particularly debated topic for possible implications in terms of safety, morals (understood as the result of a system of collective cultural values), and ethics (understood as a set of personally and socially defined behavior rules that guide individuals' actions; Farah et al., 2004; Nagel, 2015; Ray, 2016; Sandel, 2004; Schelle, Faulmüller, Caviola, & Hewstone, 2014; Singh & Kelleher, 2010). Up to now, bioethical debate on neuroenhancement mainly focused on pharmacological, technological, nutritional, and behavioral methods used to enhance individual performance. Specifically, the discipline that investigates the ethical implications of cognitive enhancement techniques and performance is neuroethics. The latter has opened an enduring debate on possible implications and on positive and negative consequences of cognitive enhancement techniques and performance optimization (Farah et al., 2004).

The possible adverse effects of neurocognitive enhancement have been accurately recognized in the loss of interindividual equity and in authenticity of an individual's performance (Butcher, 2003), as well as on possible side effects and unwanted consequences of enhancement techniques and methods (Bostrom & Sandberg, 2009; Farah, 2005; Farah et al., 2004; Wolpe, 2002). Moreover, the possible negative consequences of neurocognitive enhancement techniques have been evaluated in

both individual and social terms (Bostrom & Sandberg, 2009; Butcher, 2003; Farah, 2005; Wolpe, 2002). Farah and colleagues (2004), for example, have highlighted possible problems associated with neurocognitive enhancement techniques in terms of safety, coercion, distributive justice, personality, and tangible values. Regarding safety, the main concerns are related to the uncertainty of possible future side effects derived by the use of various neurocognitive techniques. Concerning coercion and distributive justice, the authors stressed potential ethical issues associated to the presence of and comparison with empowered individuals within different social contexts, such as the workplace, which might lead to situations in which people could be pressured to undergo neurocognitive enhancement protocols and improve their cognitive abilities. Again, another main concern in this regard resides in the fact that the alteration of the overall cognitive functioning, implemented through the use of enhancement drugs or techniques, could modify some personality aspects that would lead to individuals' homologation and to the occurrence of a significant discrepancy between enhanced and unenhanced individuals (Wolpe, 2002). Additionally, altered cognitive functioning in enhanced subjects could also modify individual aspects of the self, thus creating an alteration of the individuals' identity (Butcher, 2003). Furthermore, at the social level, widespread and uncritical use of neurotechnologies and other neurocognitive enhancement techniques could entail high costs for society and lead to the strengthening or creation of social barriers due to the differential use of these techniques and to different opportunities to access them.

These aspects were also emphasized by Fuchs (2006) who noticed some critical aspects of neurocognitive enhancement techniques—such as safety, change of the human condition, and competition—above all within working and sports contexts. Specifically, in the field of sports science and practice, the ethical and moral implications of performance–enhancement interventions are often not properly taken into consideration because athletes are frequently subjected to competitive pressures (Kayser & Broers, 2013; Petróczi, 2013) that lead them to disregard the harmful effects and the possible health consequences of using performance enhancers (Curry & Wagman, 2011; Kayser & Broers, 2013; Morente-Sánchez & Zabala, 2013). On the other hand, other recent studies and research have stressed the possible beneficial effects of neurocognitive enhancement techniques and methods by emphasizing the effectiveness of

neuroscientific techniques in improving and increasing individuals' latent abilities without changing their peculiar and distinctively human characteristics (Cohen Kadosh, Johnson, Dick, Cohen Kadosh, & Blakemore, 2013). Furthermore, other research (Bostrom & Roache, 2011; Bostrom & Sandberg, 2009) has demonstrated the safety and efficacy of external devices for the enhancement of cognitive and behavioral performance compared to the use of psychotropic drugs and brain-computer interface technologies.

The Effects of Using Neuroscientific Techniques to Improve Performance in Sports

As noted above, several studies have highlighted the effectiveness of neurostimulation and neuromodulation techniques in improving and enhancing sports performance. Likewise, different studies have shown the effectiveness of using

techniques based on self-awareness and self-regulation to improve athletes' performance and achieve optimal results (Crews & Landers, 1993; Hammond, 2007; Haufler et al., 2000; Landers et al., 1991; Salazar et al., 1990). As an example, the mechanisms of action of the neurofeedback technique—which is configured as a technique that allows individuals to learn to self-regulate their cortical activity based on the principle of operating conditioning—ground on the delivery of real-time feedbacks (typically acoustic and/or visual feedback) relative to ongoing modulations of brain functioning. Following, processing, and integrating those feedbacks, the practice can learn to modulate the amplitude, frequency, and coherence of distinct electrophysiological components of his or her brain, by voluntarily activating specific states of cortical excitation (Vernon, 2005). See Figures 1 and 2 for visual depictions of the main apparatus of neuroregulation and neuroenhancement.

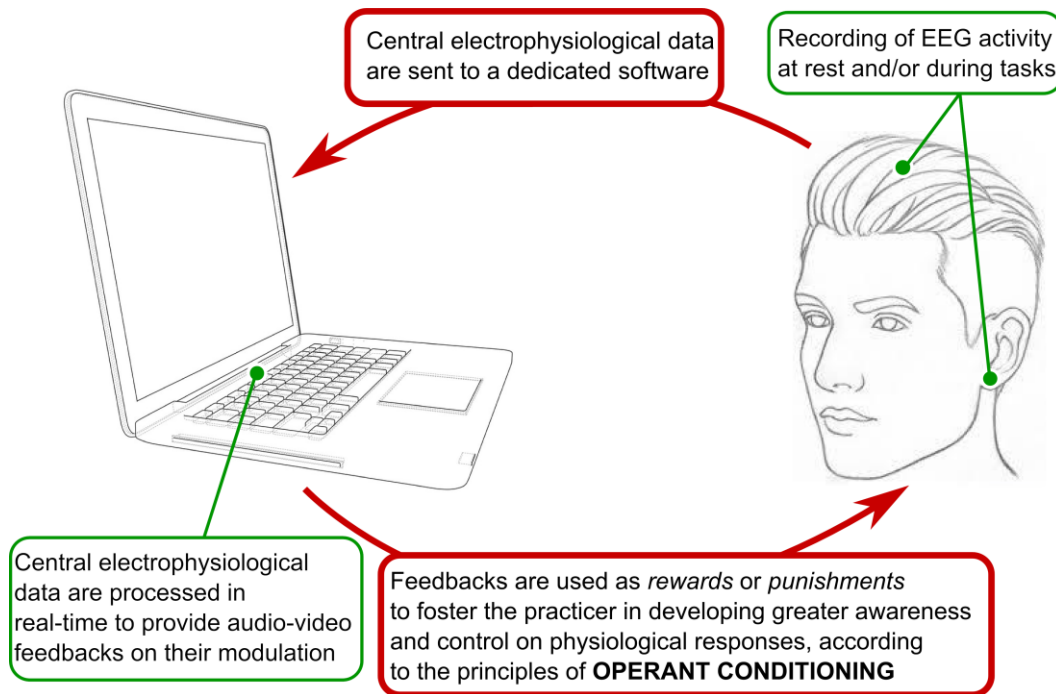


Figure 1. Main steps of the implicit learning cycle promoted by neurofeedback practice.

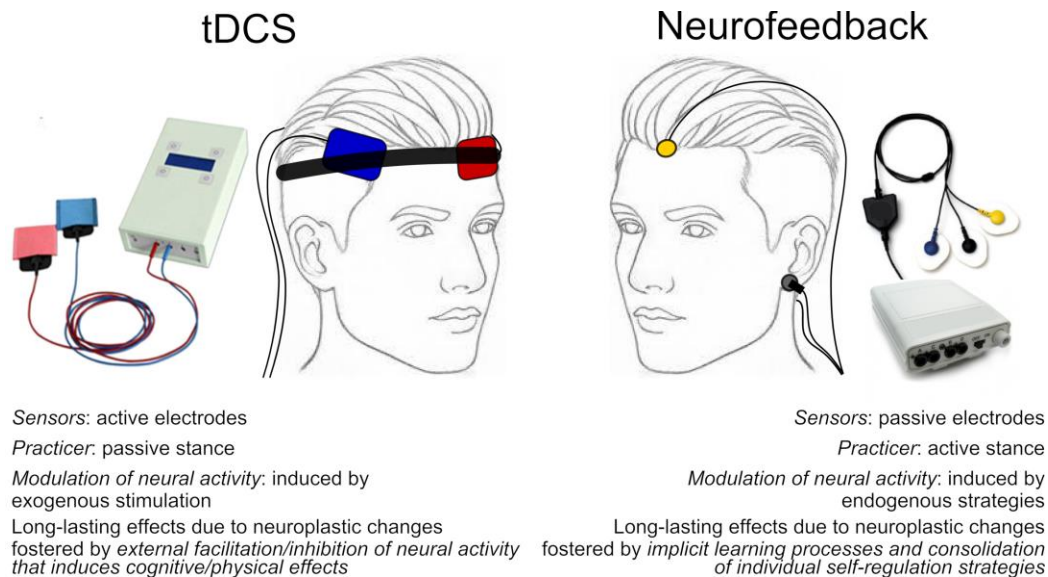


Figure 2. Transcranial electrical stimulation and neurofeedback practice: schematic representations of illustrative montages and devices with reference to selected key aspects of the two intervention methods.

It has been shown that the use of neurofeedback in sports allows enhancing athletes' performance through the association between particular patterns of brain activity and behavioral states classified as optimal, improving some principal functions such as the level of concentration, attentive abilities, motivational status, and will (Balconi, Fronda, & Crivelli, 2018; Hung & Cheng, 2018).

For example, Balconi et al. (2017) observed the effectiveness of undergoing a mindfulness-based training supported by a wearable neurofeedback device in terms of enhanced cognitive performance, increased concentration, optimized attention regulation, and decreased stress levels in a sample of semiprofessional athletes. Specifically, the efficacy of an intensive 14-day treatment supported by the use of a highly usable and portable neurofeedback device was measured during two assessment phases (T0, T1), during which cognitive, electrophysiological (EEG), autonomic (biofeedback), and neuropsychological outcome measures were collected. Empirical observations added to the limited pieces of evidence suggesting that neurofeedback, through the modulation of electrophysiological central activity (Balconi et al., 2017; Mirifar, Beckmann, & Ehrlenspiel, 2017), could be an effective method for strengthening attention and emotional regulation, coping with stress, adaptive orientation of mental resources, focusing, and sensorimotor efficiency (Balconi et al., 2018; Crivelli et al., 2019). Again, those observations are

also in line with other studies that, in different applied contexts, have observed the effectiveness of different neurofeedback-based training programs as valid enhancement tools able to provide a real-time performance feedback that leads to improved behavioral and physiological markers of neurocognitive efficiency (Balconi et al., 2018; Crivelli et al., 2019; Enriquez-Geppert, Huster, & Herrmann, 2013; Koberda, Moses, Koberda, & Koberda, 2012).

Conclusion

This article provides an overview of the debated topic of neurocognitive enhancement, emphasizing the possible effectiveness and benefits of using neuromodulation and awareness techniques in enhancing sports performance. In this article, a specific focus is also placed on the importance of neuroethics as a discipline that deals with considering the ethical and moral implications of the methods used to achieve optimal performance. The neuroethical debate has mainly focused on the importance of assessing the consequences and possible damage of the use of drugs (Repantis, Schlattmann, Laisney, & Heuser, 2010; Verhaeghen, Marcoen, & Goossens, 1992), neurostimulation, and neural entrainment techniques for the enhancement of sports performance (Davis, 2013). Despite the ethical controversies, these latter neuroscientific techniques have shown themselves to be promising in the enhancement of particular essential functions

for the achievement of optimal results such as the facilitation of different cognitive abilities (Chatterjee, 2004; Sahakian & Morein-Zamir, 2011), motor learning, muscle strength, and learning skills (Antal et al., 2004; Reis et al., 2009; Vernon, 2005; Zhu et al., 2015).

Further, those benefits are demonstrated by several studies, which have reported no relevant side effects and evidence for better regulation of attention and cognitive control mechanisms following the completion of a combined mindfulness–neurofeedback program within different laboratory and applied contexts (Balconi et al., 2017, 2018, 2019; Crivelli et al., 2019). These results confirm that training self-awareness and self-regulation skills through the use of a wearable neurofeedback device might help athletes, through implicit learning, to improve their ability to focus, to intentionally redirect their attention resources, and to optimize body performance. The effectiveness of these techniques prefigures them as a possible future way to safely improve the mental and physical performance of athletes in different sports contexts.

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