

## **Julija Erhardt**

University of Zagreb, Faculty of Science, Rooseveltov trg 6, HR-10000 Zagreb

jerhardt@biol.pmf.hr

## **Neuroethics of Sport – Neuroenhancement**

### **Abstract**

*In the pursuit of perfection in a sport arena, with the help of sport science and its accompanying technologies, humans have been pushing up against the limits of their physical body. However, the limits of the human mind have not yet been fully explored. Although a vast majority of sports have a strong component of physical strength and skillfulness, they are tightly interwoven with perceptual and cognitive processes. The perfect performance requires the “perfect brain” and in the quest for excellence athletes are reaching for different means of neuroenhancement. Some of used enhancement methods are subject to doping control, but some of them are (still) out of regulatory boundaries. By integrating neuroscientific knowledge with ethical and social thought, the article will analyze different neuroenhancement approaches of these enhancement methods and related ethical issues.*

### **Keywords**

sport, human enhancement, neuroenhancement, neurodoping, pharmacological enhancement, non-pharmacological enhancement, digital therapeutics, tDCS, TMS

## **Neuroethics – Union of Neuroscience and Philosophy**

At the turn of the century, neuroscience left the framework of medicine and entered everyday life.<sup>1</sup> Neuroscientific discoveries and their accompanying technologies have entered the arena of marketing, law, business, human resources, etc. The possibility to predict, interfere with and control the human mind has attracted great interest, raising a variety of ethical, social, cultural and legal questions, which have all been extended and applied to sports as well. Concurrently, this has been changing the sport as we know it.

Questions that were only raised by moral philosophers in the past now need to be dealt with by scientists and engineers due to advances in science and technology. For example, the famous thought experiment ‘trolley dilemma’ (to avoid the deaths of five people by killing one intentionally), which was strictly a mental exercise in philosopher’s classroom, has a modern version equivalent in the real-life problem of driver-less cars (to kill the owner of the car, or to kill pedestrians which unexpectedly appeared on the road), with consequences that far exceed the classroom problems. These real-life philosophical problems now require scientists and engineers to help solve them and there-

1

This research paper was created as a part of scientific program of Centre of Excellence for Integrative Bioethics, which is being realized

at the Faculty of Humanities and Social Sciences at the University of Zagreb.

fore, the necessity for integrative thinking (philosophical and (bio)ethical) and the joining of contemplative and research fields. This marriage in the field of neuroscience resulted in the creation of neuroethics (Roskies 2016).

With a greater understanding of (athletes) brains and the possibility to influence them in a new way, a different type of responsibility towards the public has been thrust upon scientists and in our case towards the athletes, sports institutions and sports fans. These responsibilities are actualised in this, not any more new branch of ethics – neuroethics. Some philosophers (Alpert 2008; Litton 2007) argue that new knowledge and technological power does not necessarily bring new ethical challenges and does not necessarily call for another discipline. Ethical issues already raised and lessons learned in other disciplines, in the majority of cases could be used in the issues brought up by neuroscience (Alpert 2008; Litton 2007). Furthermore, for many philosophers, the union between natural science and moral philosophy (ethics) is questionable. (Natural) sciences deal with ‘what is’, while ethics with ‘what ought to be’. This ‘is/ought’ distinction, in the case of neuroscientific discoveries, raises the question of whether they should have normative implications and to what extent are they giving us reasons to affect ethical theories (Greene 2003). On the other hand, scientific naturalism holds that scientific discoveries must be incorporated and have normative effects (Felsen *et al.* 2010). Some authors (Kaposy 2010) stand in the middle of these two opinions. Kaposy advocates the inclusion of scientific findings in general, but not when free will, selfhood and personhood are in question, in which cases ethical norms should not be affected by neuroscientific findings. Although further analysis of the union of natural sciences and humanities is beyond the scope of this article, the dilemma will remain. In the meantime, neuroethics has become a prolific research area of neuroscientist and philosophers alike and has developed into a broad field with journals, conferences, and study programs dedicated to it.

The *Stanford Encyclopedia of Philosophy* defined neuroethics as

“... an interdisciplinary research area that focuses on ethical issues raised by our increased and constantly improving understanding of the brain and our ability to monitor and influence it, as well as on ethical issues that emerge from our concomitant deepening understanding of the biological bases of agency and ethical decision-making.” (Roskies 2016)

As it follows from this definition, neuroethics is divided into two major and distinctive parts. First is the *ethics of neuroscience*, which brings up similar types of questions that traditionally bioethics analyses, only related to neuroscience, neurology, psychopharmacology, etc. The other branch is the *neuroscience of ethics*, which deals with issues of the formation of moral opinions, the nature of morality, and how moral questions are created in the brain.

This paper will deal with ethical issues brought to sports by the advancements of neuroscience, neuropharmacology and technology based on neuroscientific advancements, and therefore falls under the *ethics of neuroscience* branch of neuroethics. I will comment on the psychological profile of an elite athlete and evaluate how it can be manipulated by pharmaceutical and non-pharmaceutical means to gain an advantage in sports. Finally, I will discuss bioethical concerns related to those enhancements.

## Sport and (Cognitive) Enhancements

Modern sport is highly competitive, and athletes often do not hesitate to use any means that could help them achieve a competitive edge (Morente-Sánchez & Zabala 2013; Alaranta *et al.* 2013). Sports are not done by some

ideal, perfect creatures, but by people with all their virtues and vices. Some athletes have more integrity than others, leading to games and competitions of a varying degree of fairness. That does not mean that we should not impose a very high bar on rules and expectations. However, it cannot be expected that they will always be followed. Having stricter rules means that those who want to cheat will have to do it more smartly, and be a step ahead of regulatory authorities. Widespread practices of using enhancing substances are periodically revealed by anonymous polls. For example, in the 2011 World Track Field competition, almost a third of all athletes admitted to using performance-enhancing drugs (Chatterjee 2013). Another example is the shocking documentary about Russian doping scandals that indicate the involvement of even high government officials in the doping scandals with the adulteration of test samples and the development of enhancing protocols that will not be visible to doping agencies (Fogel 2017).

Fame and fortune are not linearly distributed between the several excellent athletes competing, but by the ‘winner takes it all’ scenario. Furthermore, winners do not bring fame and fortune only to themselves, but also to a club or country to which they belong, all of which further explains the desire to get to the podium by all means possible. Sport, ideally, should be about how skilful, fast and/or successful a team or individual athlete is at solving obstacles and winning, by using only their own unaltered body and mind. However, doping and/or cheating in sport date as far in the past as competitive sports. Reports about the use of substances that can boost performance and special nutritional ingredients, like sheep testicles (source of testosterone) and hearts have been noted as far as the 8th century BC. In the 3rd century BC, historian reports mention the help of doctors in the preparation of athletes for games and use of herbal potions for strength and endurance, hallucinogens and preparations with analgesic properties. However, doping was punishable even then, with cheaters being banned from competing and shamed for a lifetime (Douglas 2007; Chrysopoulos 2016).

Obviously, from the inception of sports competitions to the present day, athletes have tried anything in the pursuit of perfection. With improvements that sports science and its accompanying technologies have achieved in the field of equipment, nutritional supplements and training regimes, humans have been pushing up against the limits of the human body. However, the limits of the human mind have not yet been fully explored. Although the vast majority of sports have a strong component of physical strength and skillfulness, they are tightly interwoven with broad cognitive processes. Other than unquestionable physical skill and readiness, mental skills and certain (favourable) emotional characteristics are equally important to excel in professional sports. According to Krane and Williams (2010), successful athletes need to be self-confident, able to cope with stress and distractions, able to control emotions and view anxiety as beneficial, remain appropriately activated, have excellent attention and focusing, be highly determined and committed to excellence in their sport. Therefore, ‘athlete identity’ includes spirit, commitment, determination and pride, but also includes mental alertness, headiness, and a belief in the ability to win. Very important are also endurance and perseverance in times of temporary failures (Krane & Williams 2010).

### **Neurobiology of cognition**

Perception, motivation, confidence, perseverance, endurance, emotional stability, anxiety management, etc. are all factors that distinguish exceptional

athletes from the best, and all fall under the broad definition of cognition. All of these need to be combined with fast integration and processing to deliver decisions that are appropriate and possibly the best for the situation. That requires amazing computational abilities that athletes brain needs to deliver from moment to moment. During all of these cognitive processes, the brain undergoes physical and chemical changes in the processes between neurons that are undergoing continuous remodelling. These changes are realised through neuroplasticity, a life-long process that enables the reorganisation of the brain's structure and function, in response to new information, sensory inputs, damage, etc. Scaled down to the level of neurons, it starts with synaptic plasticity actualised through changes in the excitability of neuronal membrane. Through synaptic plasticity, neurons learn and dynamically modulate their strength enabling the brain to be flexible and to adapt to changes. Synaptic plasticity is enabled by changes in gene expression, which further promote dendritic arborization (Lanni *et al.* 2008; Sharma, Classen & Cohen 2013).

The actualisation of cognitive functions always includes more than a single brain circuit and single neurotransmitter. For example, although working memory and attention are strongly linked with the dopamine, working memory can also be influenced by acetylcholine, noradrenaline or serotonergic modulation. On the other hand, subtle but important differences in the fine processing of individual traits can be achieved using a specific single neurotransmitter, e.g. the reinforcement learning of rewards or that of aversive stimuli are mediated by different neurotransmitters. Different cognitive functions are rendered through a complex network of neural circuits, different neural states, and multiple neurotransmitters, which often act through several receptors. Depending on the activated receptor, the produced effects can sometimes be opposite. Neurotransmitters are often modulated by other neurotransmitters in very specific ways and have different modes of action depending on the manner that they are released. Furthermore, their effects can be different in different regions of the brain. The anatomy underlining cognitive traits is also complex, and so is the hierarchical organisation of events in the brain (Hills & Hertwig 2011; Husein & Mehta 2011).

Even when the complexity of the whole system is put this superficially, it is clear that any modulation of brain activity with drugs might influence the brain in a broad and nonspecific way. Electrical treatments allow for treatments to be more focused and directed on specific brain regions. However, their specificity is also insufficient to provide the desired 'fine tuning' of cognitive traits necessary for optimisation in sport, and it is highly unlikely that it could be achieved.

### **Neurodoping and Neuroenhancement in Sport**

According to the WADA World Anti-doping code (2015 with the 2019 amendments), doping is defined as the occurrence of one or more of the anti-doping rule violations outlined in Article 2.1 through Article 2.10 of the Code (WADA 2015). In his book *The Ethics of doping and anti-doping*, Møller declares that

"Doping is simply defined as infringement of WADA's doping regulations. In other words, doping is whatever WADA at any moment assesses it to be. On the basis of a definition that is void of content, the rules of doping risk taking on an entirely random character." Møller (2010)

However, for practical reasons doping can be defined by the *Encyclopedia of Bioethics*:

“There are many definitions of doping, but all of them suggest that doping is the illicit use of drugs with the aim to enhance sports performance and improve an athlete’s ability to win.” (Dikic, Djurdjevic & McNamee 2017)

Similarly, brain doping or neuro-doping is the use of illegal substances or prescription drugs beyond approval with the purpose of cognitive enhancement (Iglseider 2017; Franke & Lieb 2010). Human enhancement (HE) can be defined as “biomedical interventions that are used to improve human form or functioning beyond what is necessary to restore or sustain health” (Moseley & Juengst 2018).

Irrespective of the lack of a universally accepted definition of doping, it always refers to and presents some sort of enhancement. Therefore, all doping is at the same time a form of enhancement, but not all enhancement is necessarily doping. It is obvious that enhancement obtained by recreational sports practices, meditation, yoga, etc., has nothing to do with doping. However, the line between the two is not always clear. Substances or procedures that are not on the WADA list today could find themselves on the list tomorrow. The addition of new substances and procedures to the WADA prohibited list is a continuous process. This process might even reverse at a certain point. For example, Heuberger and Cohen (2019) gave an overview of the available scientific evidence for the performance enhancement of 23 substance classes currently on the WADA list, and have found scientific evidence that only five classes of substances can enhance sports performance. Results like this one might be taken into consideration for WADA decisions in the future. Consequently, neuroenhancement (neurodoping) is the modification of brain processes to improve people who are neither ill nor have some disorder. The substances that are used for neuroenhancement purposes are called “smart drugs” or “nootropics”.

The development of drugs that can affect cognitive and affective functioning came from attempts to improve the functioning of patients with illnesses and disorders. Similar is the case with electrical stimulation of the brain (Roesler & Schröder 2011, Lanni *et al.* 2008, Pelletier & Cicchetti 2015). However, it is very hard to estimate the beneficial *vs* harmful effects of using a particular drug or procedure for healing or enhancement. Historically, substances and procedures are often used for a long time for some benefits, before harmful and/or toxic consequences were detected. A great example comes from the wide use of narcotics and psychoactive drugs, throughout the 19th century and especially the widespread use of methamphetamines during the first half of 20th century, beautifully described in the Norman Ohler book *Blitzed. Drugs in the Third Reich* (2015). Irrespective of the high level of diagnostics and scientific ways of analysing the physiological effects of certain drugs and procedures, we are far from being able to understand the consequences of such use, and especially so when the targeted organ is the brain. Therefore, the estimation of the benefits *vs* harmful effects may never be exact. A large body of knowledge has come from the history of using psychoactive compounds before establishing their addictive or harmful properties.

Irrespective of what is their cognitive target, enhancers, in general, have so far brought up only modest results. Husein & Mehta (2011) presented a theory about the optimal concentration of different neurotransmitters in the brain, below or above which a cognitive trait cannot be optimally expressed. The

concentration of neurotransmitters in the brain, which enables the best functioning of neurons, follows an inverted U-curve. Increasing the concentration of any neurotransmitter above its optimal level can have counter effects and bring a lowering of the desired cognitive function. This is shown in several studies with cognitive enhancers in which they indeed produced a positive effect on cognition in individuals with lower abilities. They were probably on the lower end of the curve, and with additional neurotransmitters, their cognitive functions improved. However, in those with normal or average abilities, enhancers did not produce any effect, sometimes even showing a worsening of performance. In other words, enhancement was possible only for people who were functioning under optimal levels to start with (de Jongh *et al.* 2008; Schleim & Quednow 2017). This does not mean that human cognitive abilities cannot be enhanced, just that every individual set of physiological and ecological constraints needs to be taken into account to achieve an optimal personal state. These personal optimal, or “personal best” states will always have differences across a population. For different cognitive functions to be optimised, a sophisticated individual evaluation about what should be adjusted in each athlete would be needed to achieve the desired change. However, this type of analysis is not possible today.

Hills & Hertwig (2011) have pointed out the apparent trade-offs that come with the optimisation of cognitive traits and believe that the reason that such trade-offs exist lies in inter-dependencies across cognitive domains, which are evolutionarily optimised and justified. In other words, evolution would have already given us better cognitive abilities if it had been possible with our physiological constraints. Exceptional cognitive function in a certain domain often comes with a higher inclination towards some illness or poor performance in some other function. Savants are a good example of how exceptional functioning across a certain cognitive domain can be united with overall poor mental abilities. Another example is the population of Ashkenazi Jews, which on average have an IQ greater than that of the average European population by 0.7–1.0 standard deviations. However, this higher IQ comes with a higher prevalence in Tay-Sachs, Niemann Pick, Gaucher and some other diseases. Disorders of the sphingolipid metabolism resulted in an increased dendrite development, which is the feature that enables a high IQ, but are the same features that increase the probability of getting the diseases (Hills & Hertwig 2011; Husain & Mehta 2011).

However, exaggerated positive outcomes and ungrounded optimism of neuroenhancement can be found even in the scientific literature. The comprehensive analysis of those trends is presented in excellent reviews of Heinz & Müller (2017) and Schleim & Quednow (2018). Considering the complexity of the brain and its cognitive functions, these enhancement effects cannot be very specific, and it is unlikely that a “set of traits necessary for winning” could be designed. However, the number of “neuroenhancement tools” is continuously growing and progress and achievements applicable to sport will be presented below.

### ***Pharmacological Neuroenhancement***

The first drug described as a cognitive enhancer or a *nootropic* was piracetam, discovered by Corneliu Giurgea in 1964. It is still used for improvements in learning and memory in patients with stroke and has minimal undesirable side effects. The success of piracetam stimulated further research, but all subse-

quent synthesised drugs, regardless of their mode of action (stimulants, anti-depressants) or the neuromodulatory system through which they act (cholinergic, dopaminergic, noradrenergic, serotonergic), have adverse side effects and/or addiction development potential (Smith & Farah 2011).

There are numerous medications with the potential to enhance cognition (Oustram & Stewart 2013). The most sought after drugs in sport are those that can increase alertness, reduce fatigue, affect mood or motor performance. They mostly act through monoaminergic neurotransmitters, activating adrenergic, dopaminergic and serotonergic systems with many substances acting on more than one of these systems. They can act by inhibiting the reuptake of neurotransmitters in the synaptic cleft, by inhibiting enzymes that degrade them, or by mimicking the action of neurotransmitters on their receptors to provide a continuous stimulation (Lee & Silva 2009).

The most common drugs used for enhancement purposes came as a result of clinical research to help the ill (Brukamp & Gross 2012). For illustration, acetylcholinesterase inhibitors (e.g. Donepezil) were developed for improving the memory of elderly patients with early signs of Alzheimer's dementia. Furthermore, attention deficit disorders have been treated with methylphenidate (e.g. Ritalin) and amphetamine derivatives (Adderall), while alertness in narcolepsy patients is achieved with Modafinil (Lee & Silva 2011; Müller *et al.* 2013). Serotonin reuptake inhibitors (SSRIs) are most commonly used in the treatment of affective disorders such as social phobia, obsessive-compulsive disorders, posttraumatic stress disorder, generalised anxiety disorder and depression (Husain & Mehta 2011). Ampakines are so far the only class of drugs that have been developed with the sole purpose of enhancement and not treatment (Lanni 2008).

All of these drugs have also been used in the healthy with the aim of enhancement (Larriviere *et al.* 2009). For example, the use of SSRIs in the healthy seems to reduce negative emotions and positively affects the quality of social interactions. Often used stimulants are amphetamines and their derivatives, or drugs that metabolise to amphetamine or methamphetamine, in small doses when taken by healthy people can promote plasticity and accelerate motor learning (Chatterjee 2004). In addition to individual enhancements, team spirit can contribute strongly towards victory in team sports, and methods to enhance it with the use of oxytocin and/or vasopressin have been evaluated (Fiala 2017).

There are numerous possibilities for treatments that change brain chemistry to increase the probability for an individual athlete or team to win. It is hard to judge how effective these particular treatments are and to what extent they are indeed helping athletes in achieving their goals. Data about cognitive doping in athletes is revealed either from anonymous research studies, from personal testimonies, or through cases when athletes are tested positive. Cognitive doping is not a novelty and data are abundant through the modern history of sport that shows the use of substances that act through the neurotransmitters' systems mentioned above (Avois *et al.* 2006; Docherty 2008; Dietz *et al.* 2013; Pérez Triviño 2014).

The World Anti-Doping Agency (WADA) is a great regulatory factor when the use of harmful and unallowed substances is in question (Docherty 2008). However, athletes and their supporting teams of physicians and scientist are continuously trying to be a step ahead of regulatory authorities, as we have witnessed in the documentary on the infamous doping scandal of Russian athletes (Fogel 2017). This continuous struggle is unlikely to have a foreseeable end.

A special case is present with athletes that have some medical condition and need to use medication for their health problems. In 1992 the International Olympic Committee introduced the therapeutic use exemption (TUE). Athletes with a medical condition need to receive a therapeutic use exemption to be able to continue using medication, otherwise on the WADA Prohibited list (WADA 2019). Although applications for TUE need to be supported by extensive medical documentation, abuses of it are still possible, since it is not always easy to differentiate legitimate therapeutic uses from abuse. For example, improved attention or focus can potentially increase performance in all sports. Therefore, the medication used for ADHD and similar conditions are especially prone to abuse. Literature suggests that the prevalence of ADHD is higher in athletes at both collegiate and professional levels compared to the general population, which might indicate abuse (Nazzari, Mansour & Gross 2014; Reardon 2016). However, reliable scientific literature in this field is scarce. Increased percentages of ADHD in athletes could have a reasonable explanation and information about the abuse of this practice comes primarily from blogs and internet-posts (Saletan 2009; Diller 2013).

The use of substances for the doping of athletes is a well-known ‘old enemy’. However, we are currently witnessing an explosive growth in non-pharmacological methods of influencing and enhancing brain function.

### *Non-Pharmacological Neuroenhancement*

Brain science today is going through a revolution with exponential growth in the number of techniques and methods that measure and evaluate brain functions (Fernandez 2015; Lynch 2018). In parallel, the development of tools and gadgets that can manipulate brain functions, or just teach the person to control their emotions and mental states has also seen exponential growth. The best sign of the growth of a certain field is probably the number of patents filed in that field. From 2000 to 2009, in the field of neurotechnology, 400 patents were filed relating to therapy and neuroenhancement. In 2010 alone, 800 patents were filed, while in 2014, the number of neurotechnology patents filed was 1600 (Fernandez 2017; Rucker 2017). While all of these methods and gadgets are classified as ‘non-invasive’, for some of them, this is not quite justifiable (Davis & Koningsbruggen 2013). Others which are truly non-invasive could be great tools that can be helpful in different spheres of life, and so in sport. Non-pharmacological enhancement methods could cover a very broad spectrum of methods from listening to binaural beats, meditation, hypnosis, psychotherapy, virtual reality to electrical and magnetic brain treatments and brain implants (SharpBrains 2018).

Many of these methods have a historical background of use that has been brought to a new level with the increased sensitivity of detectors as well as new designs, applications or a combination of methods, etc. (Fernandez 2015). For example, the use of binaural beats, which has a very long history and has been used in a clinical setting to induce different brain wave states and treat anxiety, has recently gained in popularity (Doyle 2010). Due to its increased popularity and the spread of its use to the healthy, listening to these binaural beats has gotten a new name. It is called ‘i-dosing’ or ‘digital drugs’ with alleged effects on the mind that range from anti-depressant, faster learning, improved sleep, etc., depending on the range of sounds chosen (Doyle 2010; Chaieb *et al.* 2015). However, despite being increasingly popular, the positive



effects of these ‘digital drugs’ are questionable, as some authors (López-Caballero & Escera 2017) did not notice any positive effects on the mind.

Further is the group of methods that comes under the name of ‘Digital therapeutics’ and/or ‘Digiceuticals’. It is a new field, and its terminology has not settled yet. While some authors are using these terms interchangeably, others consider them to fall into two different categories (Schiess 2016; Carter 2018). Some of them are at the clinical research phase and promise to help complement traditional therapies, or to stand on their own (Farr 2017). Most of these methods use electroencephalography (EEG) to monitor the electrical activity of the brain, interpret the mental states of person and respond in real-time with the appropriate treatments or with the suggestion of procedures that would help a person to achieve the desired state of mind. This technology could mitigate or prevent epileptic seizures, provide help for chronic pain, common movement disorders and some neurological disorders with products that include neurostimulation systems and implantable drug delivery systems. Achieving the desired state of mind is critical in sport and advances that these technologies might bring to the sports field might create an important difference. They could present a shortcut to achieving calmness, focus and concentration, so far obtainable only through conventional methods such as meditation, yoga, etc.

Furthermore, EEGs can be used in tandem with meditation to help build concentration and self-regulation skills. Such devices even exist as ‘wearables’, which are designed to improve mental well-being (e.g. InteraXon’s Muse). Recently, even general-purpose fitness wearables are starting to include mental health and training apps.

All of the mentioned ways of affecting the mind and body have only recently started being developed, and their use is not yet widespread. However, both recreational and professional athletes are inclined to monitor their bodies and monitor their training results, and so their use of fitness wearables are very widespread. The addition of mobile apps that monitor the mind is just an upgrade in the practices to which they are accustomed. However, due to their novelty, there is no big body of data that could prove their efficacy. These methods are all truly non-invasive and present only a minor safety risk if any at all. However, the instruments and gadgets that stimulate the brain with an electrical current or a magnetic field require special attention because their non-invasiveness is arguable, and usage is more widespread (Davis & Koningsbruggen 2013).

### *Electrical and magnetic brain stimulation*

When considering a treatment of the brain with electrical stimulations, it is important to remember that the brain is an electrochemical organ and that all ‘pharmacological’ events at synapsis, i.e. the release of neurotransmitters that are transmitting a message, serve the purpose of inducing (or suppressing) electrical signals to the next neuron or effector organ (muscle, gland). Whether we are acting with drugs or with electrical current, in the end, we are affecting the electrical activity of the brain and changing the formation and strength of nerve circuits. Treating the brain (skull) with an electrical current has a very long history that dates back to the times of the Roman Empire. The sophistication of these electrical treatments mirrors the technological progress of the era. In the Roman times, the treatment included the use of an electrical torpedo fish placed on the head, while in the first half of the 20th century, the

treatment mainly consisted of the infamous electroconvulsive therapies. The modern development of technology has allowed for a much more sophisticated approach to treatment and has, therefore, brought back electrical treatments of the brain into the ‘mainstream’ (cf. Erhardt & Švob Štrac 2016).

### ***Transcranial Direct current stimulation (tDCS)***

Transcranial electric stimulation (TES) comes in several forms (transcranial direct current stimulation, anodal transcranial current stimulation, transcranial alternating current stimulation, random noise stimulation), but the most extensively studied and used is tDCS (Erhardt & Švob Štrac 2016). tDCS works by sending a constant, weak electrical current, usually in the order of 1–2 mA, through electrodes placed on the scalp, which induce an intracerebral current flow. The current, which is continuously applied over 10–20 minutes, passes the scalp and alters spontaneous neuronal activity (Woods *et al.* 2016).

Some clinical studies have reported some promising effects of tDCS when treating patients with depression, chronic pain, schizophrenia, dementia, Parkinson’s disease, cerebral stroke, etc. Additionally, tDCS has been the most widely publically marketed brain stimulation device for cognitive enhancement. Studies in healthy individuals have shown the potential of tDCS to improve working memory, attention, language, mathematics and decision making. The effects of tDCS stimulation are also observed in the functions of the frontal lobe related to impulse control, cognitive control and creativity (Luedtke *et al.* 2012; Feng, Bowden & Kautz 2013; Mondino *et al.* 2014; Kuo, Chen & Nitsche 2017).

Some medical tech companies (Medtronic, Brainlab, Evoke Neuroscience) are developing virtual reality treatments in conjunction with an EEG and/or tDCS, which have found an application and are gaining momentum in, e.g. treating PTSD and phobias through exposure therapy, assisting surgeons in the operating room, or athlete on the sport field. Additionally, several tDCS companies have developed products designed to stimulate the motor cortex of the brain, which specifically targets athletes (Halo; foc.us).

For reliable effects of tDCS treatments, proper positioning of the electrodes during tDCS stimulation is crucial. However, even when tDCS device are designed in such a way that allows for the appropriate montage of electrodes (in a cap with fixed positions for electrodes), proper positioning can still be a challenging task. Sizes and shapes of heads differ, left-handedness could introduce a different brain organization and applying the polarity of the electrodes properly is crucial, but could be puzzling for non-professionals. The neurological effects of tDCS depend on whether the stimulation is anodal or cathodal, as anodal stimulation increases cortical excitability, whilst cathodal stimulation decreases it. The way that the stimulations affect the brain functions is either by causing the neuron’s resting membrane potential to depolarize and therefore promote the transition of signals or by preventing signal transmission or making it difficult due to the hyperpolarization of the post-synaptic neurons. The previous consumption of any stimulants, antidepressants, or any other psychoactive drug could interfere with the electrical treatment making the results unpredictable. The strength and duration of the stimulation are also important and exceeding the optimum duration may be damaging. All of these factors can contribute to the fact that stimulation does not affect the intended areas in the intended way, and can even produce results opposite to those that were expected (Hurley & Machado 2017; Zhao *et al.* 2017).

### *Transcranial magnetic stimulation (TMS)*

Transcranial magnetic stimulation (TMS) involves the stimulation of small areas of the brain with a magnetic field that induces an electrical current in the brain tissue. The magnetic field is generated in a coil of wire, and when this coil is held up to the head of a subject, the magnetic field penetrates the scalp and skull inducing a small current in the brain. This current is sufficient to depolarise the neuronal membranes and to generate an action potential (neuronal ‘firing’) (Wagner, Valero-Cabre & Pascual-Leone 2007). Although this technique is usually referred to as non-invasive, this label has the potential to mask the fact that TMS has direct effects on the activity of neurons affecting neuroplasticity. Known risks connected with the use of TMS are the induction of seizures, unwanted effect on cognition and mood, endocrine effects, transient effects on immunity, a transient auditory threshold shift, local pain and headaches and burns caused by scalp electrodes. However, there are also risks of histotoxicity, random and unwanted ‘long-term potentiation’, depression and social and psychological consequences of epi-seizures (Chervyakov *et al.* 2015). TMS can be applied in different modes with completely different outcomes on the treated brain tissue.

However, numerous research and clinical studies have indicated a usefulness of TMS in the treatment of psychiatric diseases (depression, acute mania, bipolar disorders, panic disorders, hallucinations, obsessions/compulsions, schizophrenia, post-traumatic stress disorder), neurologic diseases (Parkinson’s disease, dystonia, tics, stuttering, tinnitus, epilepsy or rehabilitation of aphasia or of hand function after stroke), and pain syndromes (neuropathic pain, visceral pain or migraine) (Sparing & Mottaghy 2008; Bersani *et al.* 2013; Luber & Lisanby 2014; Chervyakov *et al.* 2015).

Companies that produce instruments that can influence the brain via magnetic fields are becoming increasingly common (Neuronetics eNeura, Cervel Neurotech, Brainsway, Magstim etc.). Hospitals and clinics already offer treatments based on brain stimulation, DARPA has awarded contracts to develop systems to augment memory with targeted electrical stimulation techniques, and consumers can buy wearable devices claiming to induce an array of brain states from calming to energising (Dykeman & Basile 2018).

In sports, TMS has found an application in post-exercise facilitation, central fatigue, sensorimotor integration and co-ordination (Goodall *et al.* 2014; Moscatelli *et al.* 2017). A comprehensive overview of TMS is presented in several excellent reviews (López-Alonso *et al.* 2014; Ziemann *et al.* 2015; Chervyakov *et al.* 2015; Ziemann 2017).

### *Neuroethics of sport*

Without having a clear idea of what the core values of sport are, it is difficult to discuss sport ethos and morally permissible practices. However, it is intuitive that doping, and therefore (neuro)doping, is against the spirit of sport as a meaningful and culturally valuable discipline.

At the very beginnings of competitive sports, at the Olympic games in ancient Greece, athletes exercised their bodies in pursuit of the ideal of ‘kalokagathia’, virtue and beauty. They cultivated the spirit of fair competition and sportsmanship. Athletes and spectators were protected during the games from any hostility or war, and the ideals of peace, freedom, equality and mutual respect were promoted (IOA 2018). If we would like to connect the same

ancient Greek ideals to the sport of today, the spirit of ‘winning under any circumstances’ will present an obstacle. However, as Murray noted:

“... athletes are just giving people what they want: (...) Of course the fans in the Roman Coliseum may have loved to see lions tearing the arms off Christians or gladiators hacking each other to death. So ‘what the fans desire’ is not an ethically robust defense.” (Murray 2008: 153)

With the use of non-allowed enhancement methods, inequality and cheating, sport is no longer fulfilling the expectations of a discipline that holds the virtues of ancient Greece. While some see doping as a threat to sports and competitions, others believe that ‘ethics in sport’ is an oxymoron, and that competitive sport is intrinsically unethical. Therefore, the goal of winning justifies (almost) any means to achieve it. Consequently, they also propose the decriminalization of all doping, i.e. free ‘doping for all’ practices in which athletes should have the freedom to decide what they want to do with their bodies (Livingston 2010). It is also not an acceptable approach that could be applied in sports, as whatever one athlete chooses to do affects others in the competition (Murray 2008). Without extensive further categorization of athletes by their extent and type of doping, competitions would become meaningless, or at least, unfair. Moreover, ‘doping for all’ practices cannot be acceptable, as they open the door to coercion and paternalism.

Sport is at the forefront of technological achievements, often adopting them before they get adopted in other areas. Whether it is in the form of new materials for equipment or new exercise and nutrition regimes, applications in sport are sure to be found. Similar is the case with substances and procedures, which can be used for (neuro)enhancement.

The most important concern with pharmaceuticals is their safety, particularly related to long-term use. Many stimulants, which are interesting and are used for neuroenhancement in sport, have a potential for addiction. Defining the boundary between clinical therapy and enhancement is a relevant problem, especially in a scenario when certain drugs and/or procedures are allowed for therapy but are otherwise banned. In addition to safety risks, other traditional ethical issues can also be applied here. The problems of coercion and paternalism inseparably follow any use of doping. The problem of injustice towards the less privileged athletes that cannot afford the sophisticated cocktails of drugs is also pertinent as well as questions about authenticity and identity.

However, pharmacological means of achieving neuroenhancements are well known and regulated. Of the substances used in pharmacological enhancement, some are subject to doping control, but others are (still) unregulated, both of which bring a plethora of ethical issues related to their use, well described in the literature (Mohamed & Sahakian 2012; Goodman 2014; Maslen, Faulmüller & Savulescu 2014).

There is a big disproportion in the regulation of pharmacological and non-pharmacological enhancement methods. While WADA heavily controls pharmacological treatments, there is no mention of the regulation of any non-pharmacological means of enhancement by the Agency. Therefore, the use of non-pharmacological methods of enhancement achieved by brain stimulation is still in a regulatory grey area. These techniques raise important issues to philosophy and ethics of sport. Common to all non-pharmacological enhancement methods is that their use cannot be detected afterwards. There is no known way for regulatory agencies to determine if somebody has used them. Consequently, if a rule cannot be reinforced, it is meaningless to have it.

tDCS and TMS are usually described as a non-invasive technique as no part of the devices breach the skin. However, they have the potential to induce changes in neuron firing and can, therefore, affect the brain neuroplasticity. The brain does not finish developing by the mid to late twenties, and the majority of competing athletes are in that age-range. The use of devices that affect the neuroplasticity of a developing brain could lead to aberrant brain development with abnormal patterns of brain activity and potentially damaging consequences for the future health (Krishnan *et al.* 2015).

Attractively designed tDCS devices are available, with marketing that targets recreational and professional athletes (Halo, foc.us). Research studies, which show better and/or faster results in athletes using those devices, are often presented as a part of the marketing strategy. It is undeniable that there are some favourable results on motor skills in short studies under certain circumstances with the use of these devices. However, we do not know the pros and cons of these technologies sufficiently well to use them widely on the healthy.

Therefore, we have highly sophisticated procedures that could affect performance in sports using unknown mechanisms and at the same time have the potential to change brain plasticity. With their present state of development, their action cannot be very specific (Iuculano & Kadosh 2013; Karabanov *et al.* 2015). The question is how to warn athletes against the use, or for the extremely cautious and controlled use of these gadgets since regulatory authorities can do very little, because they cannot detect it afterwards. It seems that the education of athletes and their teams might be the only option. However, most athletes would still sacrifice their long-term physical and mental health to win. With the pressure to win, bleak and undefined threats of unknown changes to our brain seem too weak and vague to stop the use of a gadget that has the promise of bringing a sporting advantage.

Although neuroenhancements in their current state do not offer a miraculous effect to the athlete, when hundredths of the second divide the winner from the rest, even a small change could be valuable. Another valuable remark by Davis (2013) is that these techniques have not been tested under real competitive sport conditions, and most research studies are done on ordinary people and not elite athletes. Possibly, as in the case with cognitive abilities, people with lower capabilities could see an increase in performance, while similar treatments in ordinary and above-average people could have no effect, or even an opposite one (de Jongh *et al.* 2008). Elite athletes, who are already ‘enhanced’ by their natural talent and hard work, might not be good subjects for this type of neuroenhancement.

Some people’s objection to (neuro)enhancement is related to the fact that victory without effort and sacrifice is not valuable. Techniques that could turn an ordinary person into an elite athlete and/or winner with moderate amounts of training do not exist and will likely not be available any time soon. To gain physical power and relevant skills, athletes will still have to train very hard, smart and for very long periods. When it comes to distinguishing between several equally excellent top athletes, techniques like these might make a difference. However, other than the already discussed problem of unintended changes to brain plasticity, danger also lies in the possibility of producing an effect opposite to the desired one. Having the treatments closely followed by experienced physicians and scientists could reduce the probability of having contra effects. Widely marketed tDCS devices that follow a ‘one size fits all’ principle (Halo; foc.us), could hardly be sufficiently precise for use in elite sports. The imposition of paternalistic measures could be justified to prevent

the sport from becoming an experimental field and athletes from becoming guinea pigs. The regulation of non-pharmacological enhancement tools is undoubtedly going to present a challenge for policymakers.

Another issue created by the use of non-pharmacological enhancers based on the reading of EEG profiles is that of privacy. Some wearables and digital therapeutics include the measuring of hours of athletes' EEG data. This data can reveal a lot about the functioning of the brain and the state of mind of an athlete. A question arises of who could have access to this data and to whom does it belong. In sport, this information is available to medical teams and coaches encroaching on athletes' privacy.

Although the main ethical dilemma regarding the use of non-pharmacological enhancement is safety, these gadgets can be questioned based on fairness (justice), as they are not accessible for less developed countries and more impoverished athletes and clubs. Additional ethical concerns, like coercion, the meaning and value of identity and authenticity are not going to be discussed here, since they are in essence not different from other types of enhancement that are very well elaborated in several excellent papers (Murray 2008; Brunkamp & Gross 2012; Maslen, Faulmüller & Savulescu 2014).

## Conclusion

Due to the advancements that science and technology of sport have brought to the field of equipment, nutritional supplements and training regimes, athletes have been pushing up against the limits of the human body. The limits of mind, however, have not yet been fully explored. After having resolved our genetic code, the next frontier in our body is our brain, which we happen to know the least about. Even though it might be our most interesting organ giving us our personality, individuality and emotions, it has been the least explored. One of the reasons might be the fact that it is well protected and hidden under the thick, protective skull. In the physiology of our body, we understand parameters that indicate an organs health and a possible shift from it, (e.g. blood pressure 120/80, that indicates the health of the cardiovascular system). Contrary to that, the brains 'vital signs' have been assessed only by indirect behaviour-based tests, which are susceptible to biases. Only recently have methods been developed that would indicate the health of the brain and help us define how a healthy brain 'baseline' should look. Irrespective of our lack of understanding of the brain, there is an entire history of pharmacological and electrical treatments of the brain behind us.

The real revolution in the understanding of the brain is happening now, when technology has given us some very sophisticated tools, helping us to see through the skull and to detect even the slightest changes in impulses and signals happening underneath. We have witnessed an exponential growth in technologies that measure and evaluate the functions of the brain. This is changing the way that we do many things today (in the classroom, law court, etc.) and is undoubtedly changing how we do sports. Some see it merely as a continuation of technological progress that has now reached the brain. As Jacques Ellul stated:

"The term *technique*, as I use it, does not mean machines, technology, or this or that procedure for attaining an end. In our technological society, *technique is the totality of methods rationally arrived at and having absolute efficiency* (for a given stage of development) in every field of human activity. Its characteristics are new; the technique of the present has no common measure with that of the past." (Ellul 1964: xxv)

The subject of that unstoppable technological progress, on the quest to reach ‘absolute efficiency’, is now the organ that makes us who we are. However, due to the complexity of the brain, attempts at enhancing the brain are destined to have uncertain outcomes.

Modern sport is highly competitive, and athletes rarely hesitate to achieve a competitive edge by any means possible. However, the promise of fame and fortune often outweighs reasonable cautions and lowers the perceived risks, turning athletes into human guinea pigs. Side effects are a problem with any medical treatment, but unintended consequences on the organ that controls the totality of our physiological and psychological functioning are probably more than most would accept if they had the knowledge and freedom to decide.

Finally, we should pose the initial question of what the aim of the sport is, and how would we like to achieve it? Probably, the most appropriate response would be the quote from T. Murray (2008):

“Let the dialogue flourish, and let the games begin.” (Murray 2008: 158)

## Literature

Alaranta, A. *et al.* (2006): “Self-Reported Attitudes of Elite Athletes Towards Doping: Differences Between Type of Sport”, *Int J Sports Med* 27 (2016) 10, pp. 842–846. doi: <https://doi.org/10.1055/s-2005-872969>.

Alpert, S. (2008): “Neuroethics and Nanoethics: Do We Risk Ethical Myopia?”, *Neuroethics* 1 (2008) 1, pp. 55–68. doi: <https://doi.org/10.1007/s12152-007-9001-5>.

Avois, L. (2006): “Central nervous system stimulants and sport practice”, *Br J Sports Med* 40 (2006) suppl. 1, pp. i16–i20. doi: <https://doi.org/10.1136/bjism.2006.027557>.

Bersani, F. S. *et al.* (2013): “Deep transcranial magnetic stimulation as a treatment for psychiatric disorders: A comprehensive review”, *Eur Psychiat* 28 (2013) 1, pp. 30–39. doi: <https://doi.org/10.1016/j.eurpsy.2012.02.006>.

Brukamp, K.; Gross, D. (2012): “Neuroenhancement – A Controversial Topic in Contemporary Medical Ethics”, in: Clark, P. A. (ed.), *Contemporary Issues in Bioethics*, InTech, pp. 39–50. doi: <https://doi.org/10.5772/35001>.

Carter, G. (2018): “What Are Digiceuticals?”, *Healthcare Professionals Group – LinkedIn* (8 February 2018). Available at: <https://www.linkedin.com/pulse/what-digiceuticals-glenn-carter> (accessed on 18 December 2018).

Chaieb, L. *et al.* (2015): “Auditory beat stimulation and its effects on cognition and mood states”, *Front Psychiatry* 6 (2015), pp. 1–9. doi: <https://doi.org/10.3389/fpsy.2015.00070>.

Chatterjee, A. (2013): “Gearing up for New Currents in Sports Enhancement”, *The Neuroethics Blog* (15 October 2013). Available at: <http://www.theneuroethicsblog.com/2013/10/gearing-up-for-new-currents-in-sports.html>. (accessed on 18 December 2018).

Chatterje, A. (2004): “Cosmetic neurology. The controversy over enhancing movement, mentation and mood”, *Neurology* 63 (2004) 6, pp. 968–974. doi: <https://doi.org/10.1212/01.WNL.0000138438.88589.7C>.

Chervyakov, A. V. (2015): “Possible mechanisms underlying the therapeutic effects of transcranial magnetic stimulation”, *Front Hum Neurosci.* 9 (2015), pp. 1–14. doi: <https://doi.org/10.3389/fnhum.2015.00303>.

Chrysopoulos, P. (2017): “Doping in Ancient Greece Olympic Games”, *Greek Reporter* (12 August 2016). Available at: <https://greece.greekreporter.com/2016/08/12/doping-in-ancient-greece-olympic-games/> (accessed on 18 December 2018).

Davis, N. J. (2013): “Neurodoping: Brain Stimulation as a Performance-Enhancing Measure”, *Sports Medicine* 43 (2013) 8, pp. 649–653. doi: <https://doi.org/10.1007/s40279-013-0027-z>.

Davis N. J.; van Koningsbruggen, M. G. (2013): “‘Non-invasive’ brain stimulation is not non-invasive”, *Front Syst. Neurosci.* 7 (2013), pp. 1–4. doi: <https://doi.org/10.3389/fn-sys.2013.00076>.

Dietz, P. *et al.* (2013): “Associations between Physical and Cognitive Doping – A Cross-Sectional Study in 2.997 Triathletes”, *PLoS ONE* 8 (2013) 11, e78702. doi: <https://doi.org/10.1371/journal.pone.0078702>.

Diller, L. (2013): “The NFLs ADHD, Adderall Mess”, *HuffPost* (5 February 2013). Available at: [https://www.huffpost.com/entry/nfl-adderall\\_b\\_2245271](https://www.huffpost.com/entry/nfl-adderall_b_2245271) (accessed on 18 December 2019).

Dikic, N.; Djurdjevic, N.; McNamee, M. J. (2017): “Doping”, in: ten Have, H. (ed. 2016): *Encyclopedia of Global Bioethics*, Springer, pp. 979–990.

Docherty, J. R. (2008): “Pharmacology of stimulants prohibited by the World Anti-Doping Agency (WADA)”, *British J Pharmacol.* 154 (2008) 3, pp. 606–622. doi: <https://doi.org/10.1038/bjp.2008.124>.

Douglas, T. (2007): “Enhancement in Sport, and Enhancement outside Sport”, *Studies in Ethics, Law and Technology* 1 (2007) 1, pp. 1–11. doi: <https://doi.org/10.2202/1941-6008.1000>.

Doyle, R. S. (2010): “I-dosing: Digital Drugs and Binaural Beats”, *Psychology Today* (15 July 2010). Available at: <https://www.psychologytoday.com/intl/blog/you-20/201007/i-dosing-digital-drugs-and-binaural-beats> (accessed on 18 December 2018).

Dykeman, D. J.; Basile, T. C. (2018): “Patent Strategy is Crucial for Wearable Innovations”, *Fierce Electronics* (5 April 2018). Available at: <https://www.sensorsmag.com/components/patent-strategy-crucial-for-wearable-innovations> (accessed on 18 December 2018).

Ellul, J. (1964): *The Technological Society*, translated by John Wilkinson, Vintage Books, New York.

Erhardt, J.; Švob Štrac, D. (2016): “Non-Pharmacological Tools for Neuroenhancement. Neuroethical Issues”, *Synthesis Philosophica* 31 (2016) 1, pp. 181–194. doi: <https://doi.org/10.21464/sp31113>.

Farr, C. (2017): “Can ‘Digital Therapeutics’ Be as Good as Drugs?”, *MIT Technology Review* (7 April 2017). Available at: <https://www.technologyreview.com/s/604053/can-digital-therapeutics-be-as-good-as-drugs/> (accessed on 18 December 2018).

Felsen, G. *et al.* (2010): “Neuroscience Evidence *Should* be Incorporated into Our Ethical Practices”, *AJOB Neuroscience* 1 (2010) 4, pp. 36–38. doi: <https://doi.org/10.1080/21507740.2010.514883>.

Feng, W.; Bowden, M. G.; Kautz, S. (2013): “Review of transcranial direct current stimulation in poststroke recovery”, *Topics in Stroke Rehabilitation* 20 (2013) 1, pp. 68–77. doi: <https://doi.org/10.1310/tsr2001-68>.

Fernandez, A. (2015): “10 Neurotechnologies About to Transform Brain Enhancement and Brain Health”, *SharpBrains* (10 November 2015). Available at: <https://sharpbrains.com/blog/2015/11/10/10-neurotechnologies-about-to-transform-brain-enhancement-and-brain-health/> (accessed on 18 December 2018).

Fernandez, A. (2017): “The Digital Revolution Meets the Human Brain”, *HuffPost* (6 December 2017). Available at: [https://www.huffpost.com/entry/the-digital-revolution-me\\_b\\_7556038?guccounter=2](https://www.huffpost.com/entry/the-digital-revolution-me_b_7556038?guccounter=2) (accessed on 18 December 2018).

Fiala, A. (2017): “Team Spirit, Team Chemistry, and Neuroethics”, *Sport, Ethics and Philosophy* 11 (2017) 3, pp. 357–369. doi: <https://doi.org/10.1080/17511321.2017.1291711>.



*Foc.us* (2018): Available at: <https://www.foc.us> (accessed on 18 December 2018).

Fogel, B. (2017): *Icarus*, Netflix.

Goodall, S. *et al.* (2014): “Transcranial magnetic stimulation in sport science: A commentary”, *Eur J Sport Sci* 14 (2014) suppl. 1, pp. 332–340. <http://doi.org/10.1080/17461391.2012.704079>.

Goodman, R. (2014): “Humility pills: Building an Ethics of Cognitive Enhancement”, *J Med Phil.* 39 (2014) 4, pp. 258–278. doi: <https://doi.org/10.1093/jmp/jhu017>.

Greene, J. (2003): “From neural ‘is’ to moral ‘ought’: what are the moral implications of neuroscientific moral psychology?”, *Nature Reviews. Neuroscience*, 4:Oct (2003), pp. 847–850. doi: <https://doi.org/10.1038/nrn1224>.

*Halo* (2018). Available at: <https://www.haloneuro.com/science> (accessed on 18 December 2018).

ten Have, H. (ed. 2016): *Encyclopedia of Global Bioethics*, Springer.

Heinz, A.; Müller, S. (2017): “Exaggerating the benefits and downplaying the risks in the bioethical debate on cognitive neuroenhancement”, in: ter Meulen, R.; Mohammed, A.; Hall, W. (eds.), *Rethinking Cognitive Enhancement: A Critical Appraisal of the Neuroscience and Ethics of Cognitive Enhancement*, pp. 69–86, Oxford University Press, Oxford. doi: <https://10.1093/acprof:oso/9780198727392.001.0001>.

Hills, T.; Hertwig, R. (2011): “Why Aren’t We Smarter Already: Evolutionary Trade-Offs and Cognitive Enhancements”, *Curr Dir Psychol Sci* 20 (2011) 6, pp. 373–377. doi: <https://doi.org/10.1177/0963721411418300>.

Hurley, R.; Machado, L. (2017): “Using tDCS priming to improve brain function: Can metaplasticity provide the key to boosting outcomes?”, *Neurosci Biobehav Rev* 83 (2017), pp. 155–159. doi: <https://doi.org/10.1016/j.neubiorev.2017.09.029>.

Husain, M.; Mehta, M. A. (2011): “Cognitive enhancement by drugs in health and disease”, *Trends Cogn Sci* 15 (2011) 1, pp. 28–34. doi: <https://doi.org/10.1016/j.tics.2010.11.002>.

*International Olympic Academy* (2018): “The legacy of Olympic games”, *IOA*. Available at: <http://ioa.org.gr/the-legacy-of-ancient-olympic-games/> (accessed on 18 December 2018).

Iuculano, T.; Kadosh, R. C. (2013): “The Mental Cost of Cognitive Enhancement”, *J Neurosci* 33 (2013) 10, pp. 4482–4486. doi: <https://doi.org/10.1523/jneurosci.4927-12.2013>.

de Jongh, R. *et al.* (2008): “Botox for the brain: enhancement of cognition, mood and pro-social behavior and blunting of unwanted memories”, *Neurosci Biobehav Reviews* 32 (2008) 4, pp. 760–776. doi: <https://doi.org/10.1016/j.neubiorev.2007.12.001>.

Kaposy, C. (2010): “The Supposed Obligation to Change One’s Beliefs About Ethics Because of Discoveries in Neuroscience”, *AJOB Neuroscience* 1 (2010) 4, pp. 23–30. doi: <https://doi.org/10.1080/21507740.2010.510820>.

Karabanov, A. *et al.* (2015): “Consensus Paper: Probing Homeostatic Plasticity of Human Cortex with Noninvasive Transcranial Brain Stimulation”, *Brain Stim* 8 (2015) 5, pp. 993–1006. doi: <https://doi.org/10.1016/j.brs.2015.06.017>.

Krane, V.; Williams, J. (2010): “Psychological characteristics of peak performance”, in: Williams, J.; Krane, V. (eds.), *Applied Sport Psychology* (6th ed.), pp. 169–188, McGraw-Hill, Boston.

Kuo, M.-F.; Chen, P.-S.; Nitsche, M. A. (2017): “The application of tDCS for the treatment of psychiatric diseases”, *Int Rev Psychiatry* 29 (2017) 2, pp. 146–167. doi: <https://doi.org/10.1080/09540261.2017.1286299>.

Lanni, C. *et al.* (2008): “Cognition enhancers between treating and doping the mind”, *Pharmacological Research* 57 (2008) 3, pp. 196–213. doi: <https://doi.org/10.1016/j.phrs.2008.02.004>.

Larrieviere, D. *et al.* (2009): “Responding to requests from adult patients for neuroenhancements”, *Neurology* 73 (2009) 17, pp. 1406–1412. doi: <https://doi.org/10.1212/WNL.0b013e3181beecfe>.

Lee, Y.-S.; Silva, A. J. (2009): “The molecular and cellular biology of enhanced cognition”, *Nature reviews Neuroscience* 10 (2009) 2, pp. 126–140. doi: <https://doi.org/10.1038/nrn2572>.

Litton, P. (2007): “Nanoethics? What’s New?”, *The Hastings Center Report* 37 (2007) 1, pp. 22–25.

Livingston, E. (2010): “Sport ethics—An oxymoron?”, *J Sci Med Sport* 13 (2010) suppl. 1, e1–e107. doi: <https://doi.org/10.1016/j.jsams.2010.10.645>.

López-Caballero, F.; Escera, C. (2017): “Binaural Beat: A Failure to Enhance EEG Power and Emotional Arousal”, *Front Human Neurosci.* 11 (2017). doi: <https://doi.org/10.3389/fnhum.2017.00557>.

López-Alonso, V. *et al.* (2014): “Inter-individual variability in response to noninvasive brain stimulation paradigms”, *Brain Stimul* 7 (2014), pp. 372–380. doi: <https://doi.org/10.1016/j.brs.2014.02.004>.

Luber, B.; Lisanby, S. H. (2014). “Enhancement of human cognitive performance using transcranial magnetic stimulation (TMS)”, *Neuroimage* 85 (2014) 3, pp. 961–970. doi: <https://doi.org/10.1016/j.neuroimage.2013.06.007>.

Luedtke, K. *et al.* (2012): “Transcranial Direct Current Stimulation for the Reduction of Clinical and Experimentally Induced Pain. A Systematic Review and Meta-analysis”, *Clin J Pain* 28 (2012) 5, pp. 452–461. doi: <https://doi.org/10.1097/ajp.0b013e31823853e3>.

Lynch, Z. (2018): “Neurotechnology and Society”, *Lifeboat Foundation*. Available at: <https://lifeboat.com/ex/neurotechnology.and.society> (accessed on 18 December 2018).

Maslen, H.; Faulmüller, N.; Savulescu, J. (2014). “Pharmacological cognitive enhancement – how neuroscientific research could advance ethical debate”, *Front. Sys. Neurosci.* 8 (2014), pp. 1–12. doi: <https://doi.org/10.3389/fnsys.2014.00107>.

Mohamed, A. D.; Sahakian, B. J. (2012): “The Ethics of elective psychopharmacology”, *Int J Neuropsychopharm* 15 (2012) 4, pp. 559–571. doi: <https://doi.org/10.1017/S146114571100037X>.

Mondino, M. *et al.* (2014): “Can transcranial direct current stimulation (tDCS) alleviate symptoms and improve cognition in psychiatric disorders?”, *World J Biol Psychia* 15 (2014) 4, pp. 261–275. doi: <https://doi.org/10.3109/15622975.2013.876514>.

Morente-Sánchez, J.; Zabala, M. (2013): “Doping in Sport: a review of elite athletes’ attitudes, beliefs, and knowledge”, *Sports Med* 43 (2013) 6, pp. 395–411. doi: <https://doi.org/10.1007/s40279-013-0037-x>.

Moscatelli, F. *et al.* (2017): “Transcranial magnetic stimulation (TMS) application in sport medicine: A brief review”, *Acta Medica Mediterranea* 33 (2017) 3, pp. 423–430. doi: [https://doi.org/10.19193/0393-6384\\_2017\\_3\\_062](https://doi.org/10.19193/0393-6384_2017_3_062).

Moseley, D.; Juengst, E. (2018): “Human enhancement”, *Stanford Encyclopedia of Philosophy*. Available at: <https://plato.stanford.edu/entries/enhancement/> (accessed on 18 December 2018).

Møller, V. (2010): *The Ethics of Doping and Anti-Doping: Redeeming the Soul of Sport?*, Routledge, New York.

Murray, T. H. (2008): “Sports Enhancement”, In: Crowley, M. (ed.), *From Birth to Death and Bench to Clinic: The Hastings Center Bioethics Briefing Book for Journalists, Policy-makers, and Campaigns*, The Hastings Center, Garrison (NY), pp. 153–158.

Nazzer, A.; Mansour, M.; Gross, K. A. (2014): “ADHD and adolescent athletes”, *Fronti Pub Health* 2 (2014), pp. 1–7. doi: <https://doi.org/10.3389/fpubh.2014.00046>.

Ohler, N. (2015): *Blitzed. Drugs in the Third Reich*, translated by Shaun Whiteside, Mariner Books, Houghton Mifflin Harcourt, Boston.

Outram, S.; Stewart, B. (2013): “Enhancement drug use in society and in sport: the science and sociology of stimulant use and the importance of perception”, *Sport in Society: Cultures, Commerce, Media, Politics* 16 (2013) 6, pp. 789–804, <http://doi.org/10.1080/17430437.2012.753529>.

Pelletier, S. J.; Cicchetti, F. (2015): “Cellular and molecular mechanism of action of transcranial direct current stimulation: evidence from in vitro and in vivo models”, *Int J Neuropsychopharmacol* 18 (2015) 2. doi: <https://doi.org/10.1093/ijnp/pyu047>.

Pérez Triviño, J. L. (2014): “Sport Enhancement: From Natural Doping to Brain Stimulation”, *Int J Technoethics* 5 (2014) 2, pp. 1–19. doi: <https://doi.org/10.4018/ijt.2014070106>.

Reardon, C. L. (2016): “The sports psychiatrist and psychiatric medication”, *International Review of Psychiatry* 28 (2016) 6, pp. 606–613, doi: <https://doi.org/10.1080/09540261.2016.1190691>.

Roesler, R.; Schröder, N. (2011): “Cognitive enhancers: focus on modulatory signaling influencing memory consolidation”, *Pharm. Biochem. Behav.* 99 (2011) 2, pp. 155–163. doi: <https://doi.org/10.1016/j.pbb.2010.12.028>.

Roskies, A. (2016): “Neuroethics”, *Stanford Encyclopedia of Philosophy*. Available at: <https://plato.stanford.edu/entries/neuroethics/> (accessed on 18 December 2018).

Rucker, M. (2017): “The Era of Pervasive Neurotechnology”, *Verywell Health* (27 June 2017). Available at: <https://www.verywellhealth.com/the-era-of-pervasive-neurotechnology-1739113> (accessed on 18 December 2018).

Saletan, W. (2009): “Doping deficit disorder. Need performance-enhancing drugs? Claim ADHD”, *Slate* (12 January 2009). Available at: <https://slate.com/technology/2009/01/need-performance-enhancing-drugs-claim-adhd.html> (accessed on 11 September 2019).

Schiess, A. (2016): “Digital Therapeutics vs Digiceuticals: defining the software-mediated healthcare landscape”, *HEALTH – LinkedIn* (17 February 2016). Available at: <https://www.linkedin.com/pulse/digital-therapeutics-vs-digiceuticals-defining-anya-schiess> (accessed on 18 December 2018).

Schleim, S.; Quednow, B. B. (2018): “How Realistic Are the Scientific Assumptions of the Neuroenhancement Debate? Assessing the Pharmacological Optimism and Neuroenhancement Prevalence Hypotheses”, *Frontiers in Pharmacology* 9 (2018) 3. doi: <https://doi.org/10.3389/fphar.2018.00003>.

Schleim, S.; Quednow, B. B. (2017): “Debunking the ethical neuroenhancement debate”, in: ter Meulen, R.; Mohammed, A. D.; Hall, W. (eds.), *Rethinking cognitive enhancement: A critical appraisal of the neuroscience and ethics of cognitive enhancement*, Oxford University Press, Oxford, pp. 164–175.

Sharma, N.; Classen, J.; Cohen, L. G. (2013): “Neuronal plasticity and its contribution to functional recovery”, *Handb Clin Neurol* 110 (2013), pp. 3–12. doi: <https://doi.org/10.1016/B978-0-444-52901-5.00001-0>.

SharpBrains (2018): “Market Report on Pervasive Neurotechnology: A Groundbreaking Analysis of 10,000+ Patent Filings Transforming Medicine, Health, Entertainment and Business”, *SharpBrains* (n. d.). Available at: <https://sharpbrains.com/pervasive-neurotechnology/> (accessed on 18 December 2018).

Smith, M. E.; Farah, M. J. (2011): “Are prescription stimulants ‘smart pills’? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals”, *Psychological Bulletin* 137 (2011) 5, pp. 717–747. doi: <https://doi.org/10.1037/a0023825>.

Sparing, R.; Mottaghy, F. M. (2008): “Noninvasive brain stimulation with transcranial magnetic or direct current stimulation (TMS/tDCS) – From insights into human mem-

ory to therapy of its dysfunction”, *Methods* 44 (2008) 4, pp. 329–337. doi: <https://doi.org/10.1016/j.ymeth.2007.02.001>.

Wagner, T.; Valero-Cabre, A.; Pascual-Leone, A. (2007): “Noninvasive Human Brain Stimulation”, *Annu Rev Biomed Eng* 9 (2007) 1, pp. 527–565. <https://doi.org/10.1146/annurev.bioeng.9.061206.133100>.

Woods, A. J. *et al.* (2016): “A technical guide to tDCS, and related non-invasive brain stimulation tools”, *Clin Neurophysiol* 127 (2015) 2, p. 412. doi: <https://doi.org/10.1016/j.clinph.2015.11.012>.

World Anti-Doping Agency (2019). *World Anti-Doping Code*, International Standard. Available at: [https://www.wada-ama.org/en/resources/the-code/world-anti-doping-code?gclid=EAIaIqobChMIJK1wYbi5AIViNKyCh3mQg1uEAAYASAAEgJjIvD\\_BwE](https://www.wada-ama.org/en/resources/the-code/world-anti-doping-code?gclid=EAIaIqobChMIJK1wYbi5AIViNKyCh3mQg1uEAAYASAAEgJjIvD_BwE) (accessed on 18 December 2019).

Zhao, H. *et al.* (2017): “Modulation of Brain Activity with Noninvasive Transcranial Direct Current Stimulation (tDCS): Clinical Applications and Safety Concerns”, *Front Psychol.* 10 (2017) 8, pp. 1–17. doi: <https://doi.org/10.3389/fpsyg.2017.00685>.

Ziemann, U. (2017): “Thirty years of transcranial magnetic stimulation: where do we stand?”, *Exp Brain Res* 235 (2017) 4, pp. 973–984. doi: <https://doi.org/10.1007/s00221-016-4865-4>.

Ziemann, U. *et al.* (2015): “TMS and drugs revisited 2014”, *Clin Neurophysiol* 126 (2015) 10, pp. 1847–1868. doi: <https://doi.org/10.1016/j.clinph.2014.08.028>.

### Julija Erhardt

#### Neuroetika i sport – neuropoboljšavanje

##### **Sažetak**

*U potrazi za savršenstvom u sportu, uz pomoć znanosti o sportu i pratećih tehnologija, ljudi pomiču granice svojih tjelesnih sposobnosti. Međutim, granice ljudskog uma još nisu u potpunosti istražene. Iako većina sportova ima snažnu komponentu tjelesne snage i vještine, oni su čvrsto isprepleteni s percepcijom i kognitivnim procesima. Savršena izvedba zahtijeva »savršeni mozak« i u potrazi za izvrsnošću sportaši posežu za različitim načinima neuropoboljšavanja. Neki od korištenih metoda poboljšanja podliježu dopinškoj kontroli, no neki od njih su (još uvijek) izvan regulatornih granica. Integriranjem neuroznanstvenih znanja s etičkom i društvenom misli, članak će analizirati različite primjere neuropoboljšavanja i povezane etičke probleme.*

##### **Ključne riječi**

sport, poboljšavanje čovjeka, neuropoboljšavanje, neurodoping, farmakološko poboljšavanje, nefarmakološko poboljšavanje, digitalni terapeutici, tDCS, TMS

### Julija Erhardt

#### Neuroethik des Sports – Neuroverbesserung

##### **Zusammenfassung**

*Im Streben nach Perfektion in der Sportarena stießen die Menschen mithilfe der Sportwissenschaft und der dazugehörigen Technologien an die Grenzen ihres physischen Körpers. Die Grenzen des menschlichen Geistes sind jedoch noch nicht vollständig erforscht. Obwohl die große Mehrheit der Sportarten eine starke Komponente der körperlichen Stärke und Geschicklichkeit aufweist, ist sie dicht mit den perzeptiven und kognitiven Prozessen verwoben. Die perfekte Leistung erfordert das „perfekte Gehirn“ und auf der Suche nach Spitzenleistungen greifen die Sportler nach diversen Mitteln des Neuro-Enhancements. Einige der verwendeten Steigerungsmethoden unterliegen der Dopingkontrolle, einige von ihnen sind jedoch (immer noch) außer-*

*halb der regulativen Grenzen. Durch die Integration vom neurowissenschaftlichen Wissen mit dem ethischen und sozialen Gedanken analysiert der Artikel unterschiedliche Herangehensweisen dieser Verbesserungsmethoden als auch die damit zusammenhängenden ethischen Fragen.*

**Schlüsselwörter**

Sport, Verbesserung des Menschen, Neuroverbesserung, Neurodoping, pharmakologische Verbesserung, nicht pharmakologische Verbesserung, digitale Therapeutik, tDCS, TMS

**Julija Erhardt**

**Neuroéthique et sport – neuro-amélioration**

**Résumé**

*Étant à la recherche de la perfection dans l'arène sportive, et avec l'aide des sciences du sport et de ses technologies connexes, les hommes repoussent les limites de leurs capacités physiques. Toutefois, les limites de l'esprit humain n'ont pas encore fait l'objet d'une étude approfondie. Même si la majorité des sports requiert une forte composante de force physique et d'habileté, les processus de perception et de cognition y sont étroitement mêlés. La performance parfaite requiert « un cerveau parfait » et dans leur quête de l'excellence les athlètes recourent à différents moyens de neuro-amélioration. Certaines des méthodes d'amélioration utilisées sont soumises à un contrôle de dopage, alors que d'autres n'entrent pas (encore) dans les limites réglementaires. En intégrant la connaissance neuroscientifique à la pensée éthique et sociale, cet article va analyser les différentes approches de neuro-amélioration de ces méthodes d'amélioration et les problèmes éthiques qui y sont liés.*

**Mots-clés**

sport, amélioration de l'homme, neuro-amélioration, dopage cérébral, amélioration pharmacologique, amélioration non-pharmacologique, thérapies digitales, tDCS, TMS