

# Are we ready to boost the riders' brain to enhance cycling performance?

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Starting the 7th of July 2018, the Tour de France will again be in the spotlight of the world of cycling. The three-week race is one of the main instances of endurance sports, pushing the riders' leg muscles, lungs, and heart to the limit. But, above all, the Tour de France is an overwhelming challenge for the riders' brain. The brain is indeed a primary, if not the ultimate, responsible for achieving the goals of such a complex and challenging behavior like endurance cycling (cf. Walsh, 2014). Hence, a current objective of Sports Scientists is to unveil how the neural systems organize, control and respond to such gargantuan efforts. Athletes will of course benefit from such endeavour, as it can help developing means of improving performance without turning to prohibited substances. But, has research reached the necessary status to apply the laboratory evidence to the sports field? My quick answer is "no", but, please allow me to give my personal view on the current state of affairs.

The study of the brain has pervaded Sports Science. This has gone hand in hand with the achievements of Cognitive Neuroscience and the emergence of novel techniques of acquisition and analysis of indexes of brain functioning related to physical effort. As a result, we now know that a self-paced exercise like endurance cycling impacts brain oscillatory activity (Ciria et al., 2018) and involves more than the obvious activation of the motor cortex. The insula, for example, has been proposed as the principal interface between the peripheral body systems and high-order cortical areas responsible for the control, monitoring, and perception of the effort (McMorris, Barwood, & Corbett, 2018). The study of that centro-peripheral bidirectional communication could lead to the comprehension of central fatigue and the prediction of the abrupt decline in performance that happens at exhaustion. We are, however, far from the full understanding of brain functioning related to sports performance.

Yet, if the brain is of paramount importance for physical exercise, why not stimulating it to enhance performance? The rationale is straightforward and based on findings from Neuroscience: there is substantial empirical evidence showing that selective stimulation of the brain results in measurable effects at both the neural and cognitive levels (Luber & Lisanby, 2014). Amongst the methods utilized in the field (e.g., single cell stimulation, transcranial magnetic stimulation-TMS-, or transcranial direct current stimulation-tDCS), tDCS seems the ideal candidate for

its application in Sports, as it is non-invasive, with minor side-effects, and inexpensive.

A cursory look to the scientific literature shows that tDCS research is indeed a current topic in Sports Science. The few narrative reviews to date, highlight its potential to enhance physical performance, even if some researchers are cautious about the interpretation of the outcomes given the sometimes mixed results and heterogeneity in fundamental methodological aspects such as the locus of the stimulation (Angius, Hopker, & Mauger, 2017). The seemingly successful use of tDCS has even raised concerns about whether Sports is facing a new form of doping, the so-called "brain doping" or "Neurodoping" (Davis, 2013). Notably, the impact of tDCS in Sports goes beyond the domain of empirical (basic) research, for this investigation has propelled the development of new cheap and portable "do it yourself" devices. All good science with direct practical (and profitable) implications. However, after reading the next paragraphs, the reader might end up sharing my skepticism about the "virtues" of tDCS in light of the existing evidence.

Cognitive Neuroscience (and psychology in general) has come under scrutiny in recent years (Barch & Yarkoni, 2013). Thoughtful evaluations of the available empirical evidence conclude that many (not all!) published reports are not as reliable as they may appear given the sophisticated technology and methodology used in the majority of them and the purportedly trustworthy peer-review system of scientific publication. I ought to say, before continuing, that this scientific "crisis" is not restricted to brain and cognition or more general psychology research, as many other disciplines are suffering from it (Nosek & Errington, 2017). The good news is that we now know more about the causes that undermine research (e.g., p-hacking, hypothesis harking, low statistical power, conflict of interests, publication bias), and that there are interesting proposals to remedy them (e.g., pre-registration, multi-lab replications, open data sharing etc.). Unfortunately, I am convinced that tDCS research in the Sports domain is by no means immune to that lack of credibility.

In my opinion, tDCS investigation in Sports Science is a topic that has gained popularity sharing some (if not all) of the pitfalls suggested above. Particularly relevant (and directly measurable) is the low sample size of the majority of studies, which negatively affects statistical power. The lower the statistical power, the higher the probability of false negatives and the lower the



probability that an observed effect that passes the threshold of statistical significance (typically  $p < .05$ ) actually reflects a true effect (Button et al., 2013). A low sample size would provide the statistical power to detect an effect if it is rather large, which I think are unlikely in this research domain given the disparate published (and, I would say, unpublished negative) results and the inherent variability of any measure related to human behaviour and neurophysiology (Szucs & Ioannidis, 2017). Hence, a significant result from a tDCS-Sport study that tested a sample of 8, 10 or 12 participants may well be a false positive.

Angius et al. (2017), as already noted, underlined methodological factors that could explain the mixed results they summarized in their review article, such as the cortical site of stimulation or the test used to evaluate physical performance. They did not mention, however, what, in view of a recent study, might be a major flaw in all these previous studies: the use of a maximum of 2mV to stimulate the brain. Although they tested transcranial alternating current stimulation instead of tDCS, which may undermine the comparison, Vöröslakos et al. (2018) reported that higher intensities (up to at least 4mV) than those currently used in brain and cognition research are needed to induce effects in neuronal circuits. Note that 2mV are innocuous, which in part explains the success and interest on tDCS as an ergogenic aid, but larger (effective) intensities might result in adverse effects. The intensity of the stimulation or the low sample size are easily prompted when scrutinizing the methods of the published tDCS-Sports performance literature. Issues like p-hacking or publication bias are more difficult to identify (although there are helpful meta-analytical tools for that), but that does not mean they are not present.

The issues raised above appear to call into question many of the extant findings of tDCS in Sports Science. It does not mean, however, that all this research is flawed and that the topic should be abandoned. I would argue, instead, that tDCS is an easy-to-use and affordable technique that may provide relevant information about brain function related to exercise and has potential applications as ergogenic aid. As I mentioned above, tDCS investigation shares similar issues with other disciplines and would therefore benefit from the solutions proposed to increase their reliability and credibility (Manufò et al, 2017). Increasing the sample size (based on a priori power analysis) seems particularly necessary. Study pre-registration and public data sharing appear to reduce the likelihood of p-hacking, hypothesis harking and publication bias. This latter issue concerns not only authors but scientific journals that should encourage the submission of negative results.

To end on a positive note, I am still convinced of the value of tDCS-Sports research, provided we as investigators endorse sound scientific practice.

## Conflict of interest

None

## Keywords

brain; performance; behaviour; road cycling.

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