Effect of tDCS on motor learning

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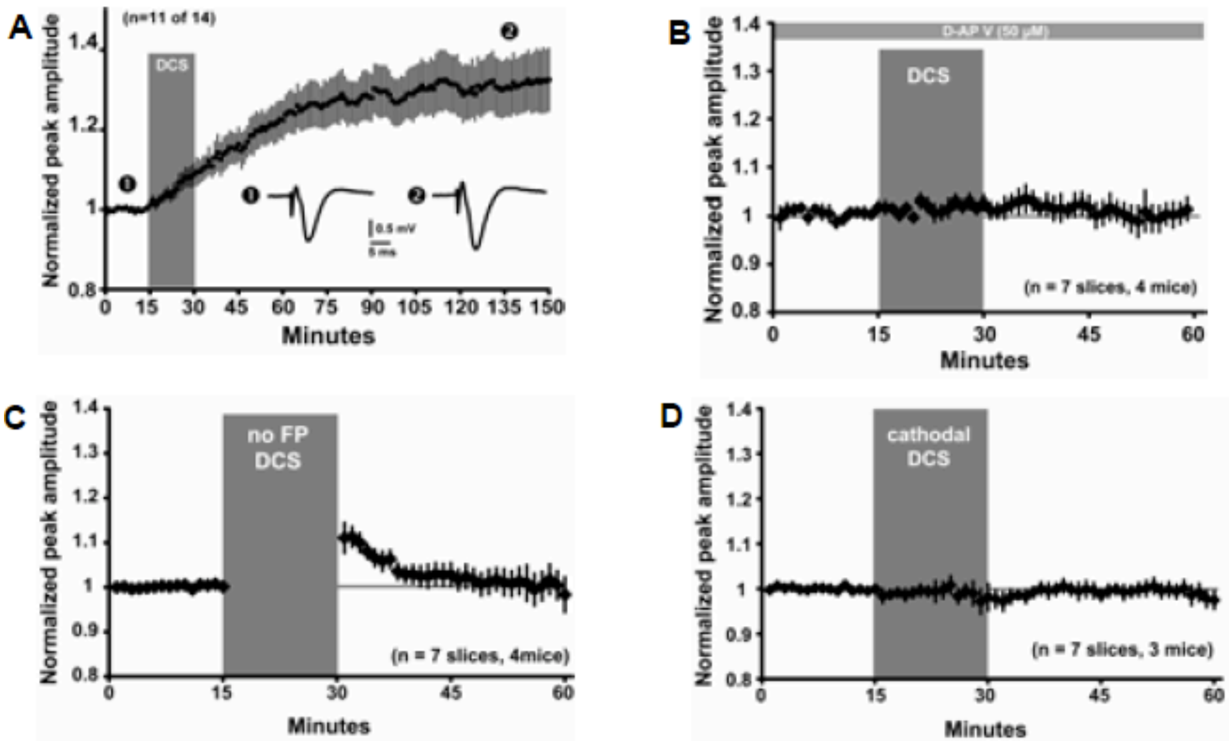
Mechanisms of tDCS effects



15-min of anodal DCS (10 μA) applied in the direction of vertical fibers in M1:

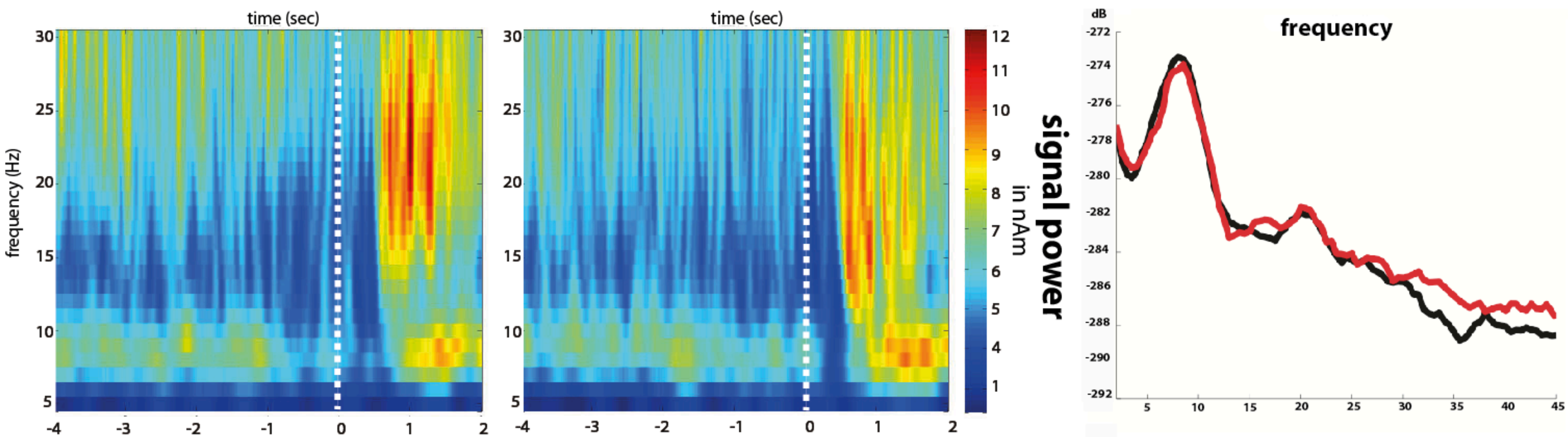
- Enhanced synaptic efficacy by 30% (Fig. 2 A).

This synaptic potentiation:

- Was long-lasting (>2 hours, Fig. 2 A)
- Was NMDA receptor-dependent (Fig. 2 B)
- Required simultaneous DCS and synaptic activation (Fig. 2 C)
- Was polarity specific (Fig. 2 D)

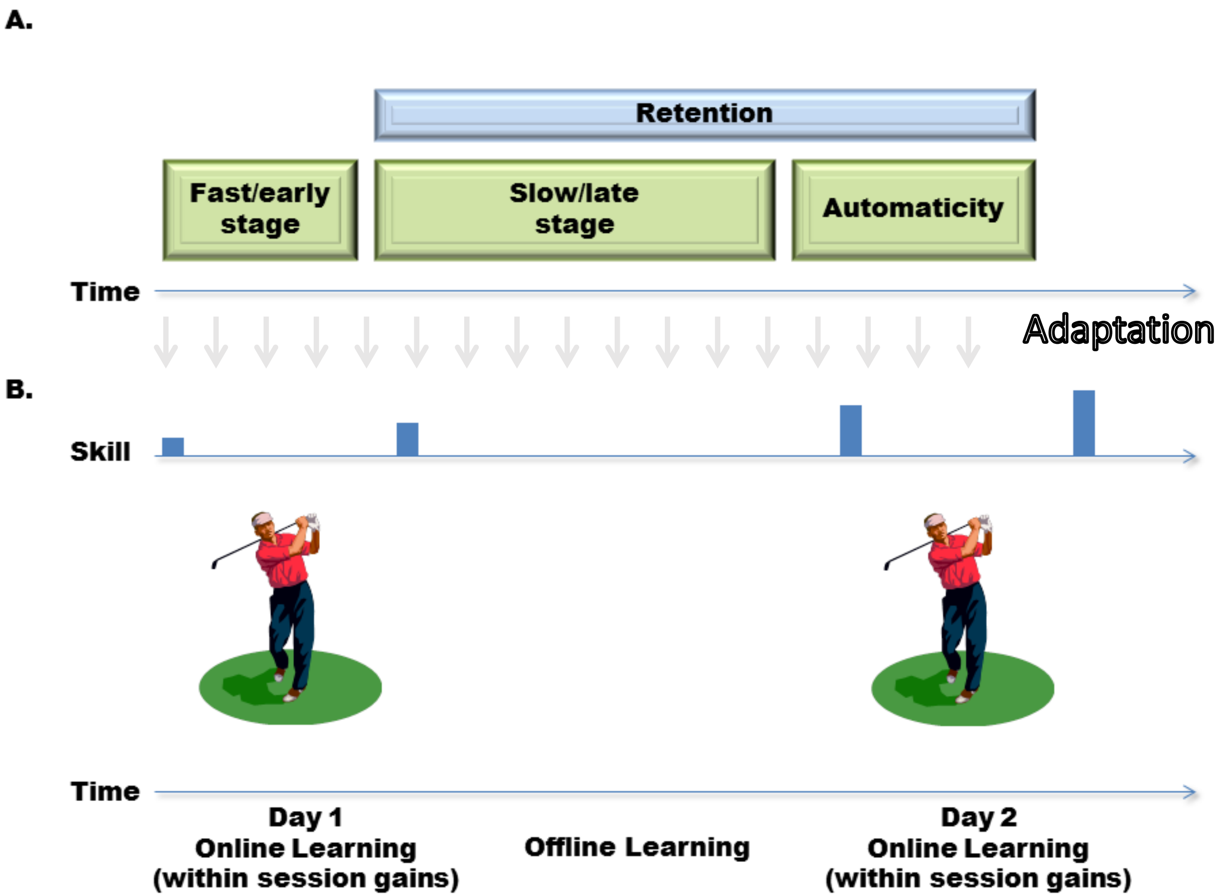
Fritsch et al, *Neuron* (2010)

Brain oscillatory activity during tDCS



Soekadar et al. _Nature Communications_ 2013

Motor learning



Dayan and Cohen *Neuron* 2011

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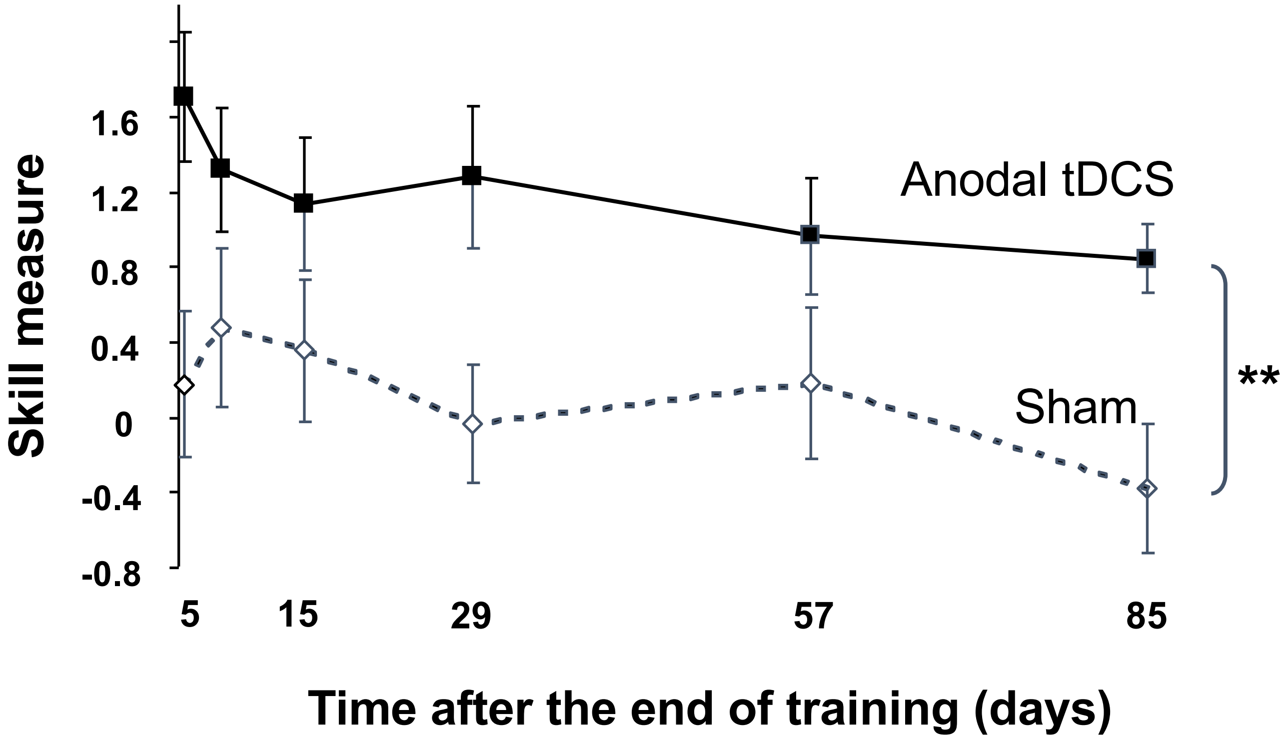
Background

- Motor skills are required for activities of daily living
- Physiological effects of tDCS suggest it could interact with training effects
- Proof of principle studies pointed in this direction for years.

Long term retention effects in healthy subjects

Reis et al. *Proc Nat Acad Sci* 2009

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Consensus document

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New Results

Effects of tDCS on motor learning and memory formation: a consensus and critical position paper

Ethan R Buch, Emiliano Santarnecchi, Andrea Antal, Jan Born, Pablo A Celnik, Joseph Classen, Christian Gerloff, Mark Hallett, Friedhelm C Hummel, Michael A Nitsche, Alvaro Pascual-Leone, Walter J Paulus, Janine Reis, Edwin M Robertson, John C Rothwell, Marco Sandrini, Heidi M Schambra, Eric M Wassermann, Ulf Ziemann, Leonardo G Cohen

doi: http://dx.doi.org/10.1101/064204

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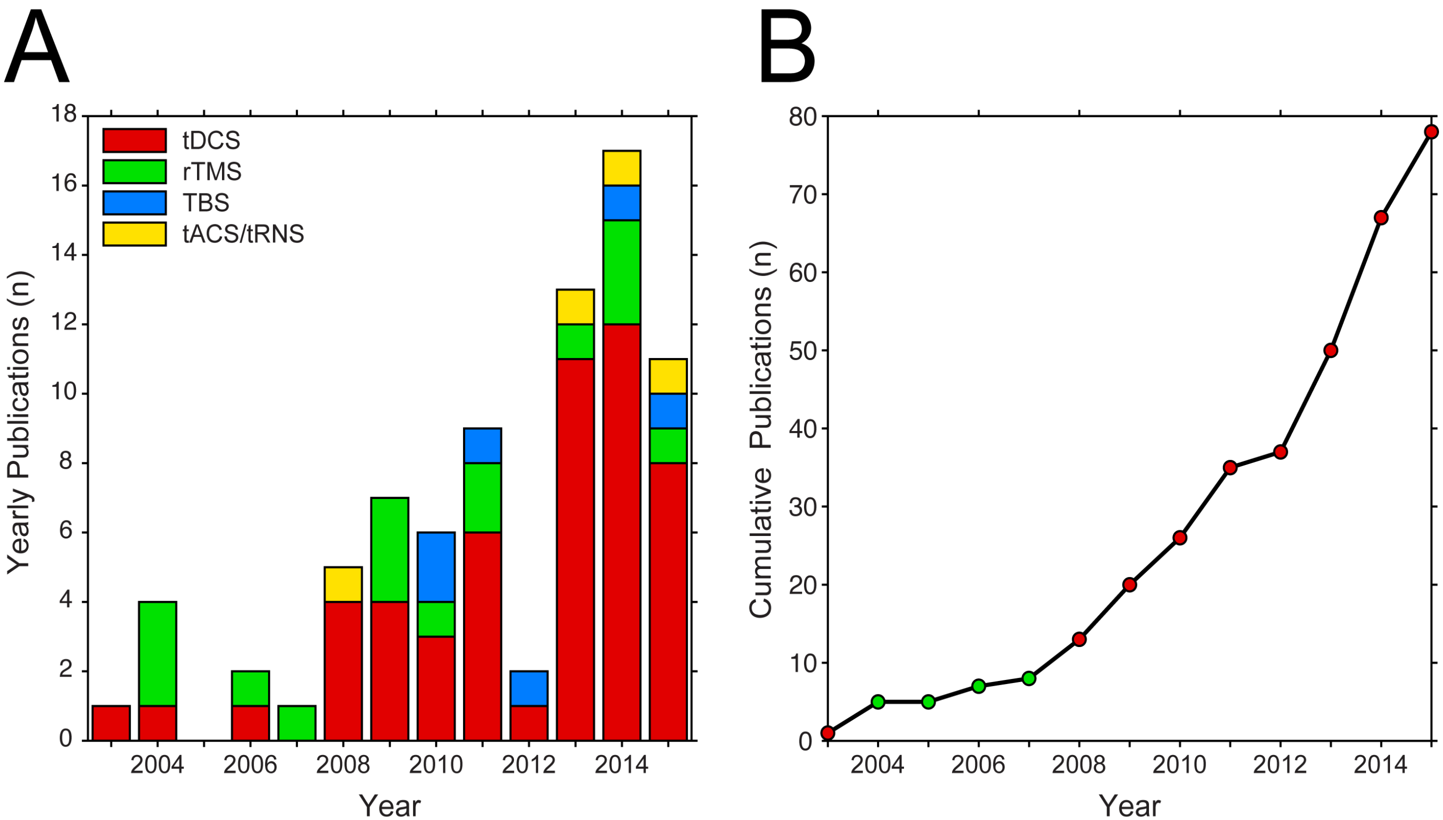
http://biorxiv.org/content/early/2016/07/18/064204

Effects of NIBS on motor learning



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What is known

- Anode M1, cerebellum, PMd.
- Tasks
  - Sequential finger tapping tasks (implicit or explicit) (Ghilardi, Moisello, Silvestri, Ghez, & Krakauer, 2009; Nitsche et al., 2010; Reis et al., 2015; Song & Cohen, 2014)
  - Sequential visuomotor tasks (Reis et al., 2009)
  - Adaptation ((Avila et al., 2015; Galea et al., 2011; Herzfeld et al., 2014; Hunter, Sacco, Nitsche, & Turner, 2009; Orban de Xivry et al., 2011)
- Learning stages
  - Online (Amadi, Allman, Johansen-Berg, & Stagg, 2015; Ambrus et al., 2016; Cuypers et al., 2013; Kang & Paik, 2011; Kantak, Mummidisetty, & Stinear, 2012; Karok & Witney, 2013; M. F. Kuo et al., 2008; Nitsche et al., 2010; Nitsche et al., 2003; Reis et al., 2015; Reis et al., 2009; Stagg, Jayaram, et al., 2011; Tecchio et al., 2010; Vines, Cerruti, & Schlaug, 2008; Wade & Hammond, 2015)
  - Offline (Cantarero et al., 2015; Naros et al., 2016; Reis et al., 2015; Reis et al., 2009; Saucedo-Marquez, Zhang, Swinnen, Meesen, & Wenderoth, 2013; Schambra et al., 2011; Waters-Metenier et al., 2014)
  - Long-term retention

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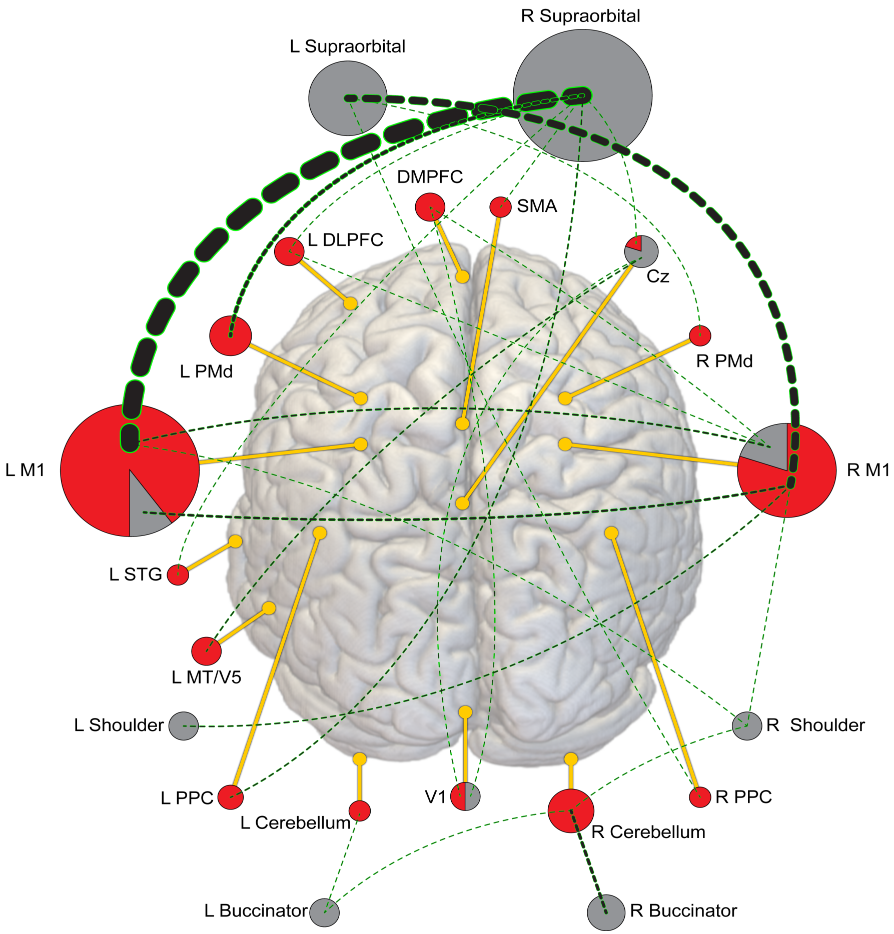
Montages



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What is known. Meta-analyses

- Relatively small number of studies fitting the inclusion criteria
  - challenges faced when attempting to perform quantitative reviews of tDCS effects on motor learning (Antal, Keeser, Priori, Padberg, & Nitsche, 2015; Nitsche, Bikson, & Bestmann, 2015)

- 13/140 reviewed articles (9.2%) (Hashemirad et al., 2016):
  - One or more sessions of tDCS over M1 + training
  - A negative control group (either sham tDCS plus task training or training only)

- Single tDCS sessions showed lesser physiological (Horvath, Forte, & Carter, 2015a) and or cognitive (Horvath, Forte, & Carter, 2015b) effects (questions on methodology) (Antal et al., 2015)

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Effect size

- Effect size: up to d 0.5

Hashemirad et al *Brain Cogn* 2016

Scientific caveats

- Claims of focality of stimulation (Dayan et al., 2013)
- Infrequent use of modelling to guide stimulation (de Berker et al., 2016)
- Iteratively refine experimental parameters and modelling assumptions. (Manenti, Sandrini, Brambilla, & Cotelli, 2016; Martin, Liu, Alonzo, Green, & Loo, 2014) (Bestmann, 2015; Brunoni et al., 2012).
- Understand interindividual variability (López-Alonso et al., 2015)
- State-dependent effects (Silvanto et al., 2008) (Amadi et al., 2015; Muller-Dahlhaus & Ziemann, 2015).
- Differential effects on stages of learning and generalization (Waters-Metenier et al., 2014)
- Underreporting of negative results (Mancuso, Ilieva, Hamilton, & Farah, 2016; Shiozawa et al., 2014; Vannorsdall et al., 2016)

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Methodology caveats

(Jessica, Emily)

- Insufficient use of double blind designs
- Poor differentiation between exploratory (hypothesis-generating) and confirmatory (hypothesis-driven) research.
- Scarcity of preregistration of hypothesis, design, power analysis and data processing for research written up as hypothesis-driven and confirmatory (see for example https://blogs.royalsociety.org/publishing/registered-reports/);
- Insufficient prepublication and sharing of materials
- Insufficient post-publication repositories of data
- Seldom use of experimental designs with replications built in
- Insufficient use of appropriate sample size based on prospective power analysis for studies claimed to be hypothesis-driven.

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Reproducibility

- “expression of the general reproducibility problem in science (Collins & Tabak, 2014) to tDCS studies of motor learning. “

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Reporting checklist for tDCS effects on motor learning

Experimental Design Factors:			
Controls used	☐ None	☐ Sham	☐ Active
Blinding used	☐ None	☐ Single	☐ Double
Hypothesis statement	☐ Yes	☐ No	
If Hypothesis-based:			
Power-analysis statement	☐ Yes	☐ No	
Pre-registration	☐ Yes	☐ No	
Exploratory-based	☐ Yes	☐ No	

Participant Factors:	Reported?	Controlled?
Number of subjects	☐	☐
Age of subjects	☐	☐
Gender of subjects	☐	☐
Handedness of subjects	☐	☐
Subjects prescribed medication	☐	☐
Use of CNS active drugs (e.g. anti-convulsants)	☐	☐
Neuropsychological evaluation	☐	☐
Any medical conditions	☐	☐
History of specific repetitive motor activity	☐	☐
Years of Education completed	☐	☐

Stimulation Factors:	Reported?	Controlled?
Scalp position of tDCS electrodes	☐	☐
MRI-based localization of tDCS electrodes	☐	☐
Electrode type (size and geometry)	☐	☐
Current density of applied stimulation	☐	☐
Type of stimulator used (e.g. brand)	☐	☐
Stimulation intensity	☐	☐
Stimulation ramp time	☐	☐
Stimulation duration	☐	☐
Number of Sessions	☐	☐
If Multiple Sessions:		
Time interval between sessions	☐	☐
Subject attention (level of arousal) during testing	☐	☐
Subject activities during stimulation	☐	☐
tDCS-induced sensations (i.e. - itching, pain, heat, pinching, burning)	☐	☐

Analysis & Statistics factors:		
Effect-size(s) reported	☐ Yes	☐ No
Raw data uploaded to publicly accessible data repository	☐ Yes	☐ No
Analyzed data uploaded to publicly accessible data repository	☐ Yes	☐ No
Full analysis protocol including custom scripts uploaded to publicly accessible data repository	☐ Yes	☐ No

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