



Conventional and Focal tDCS

A review of tDCS focality

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Overview



1. Introduction
2. Current Modelling and Experimental Data
3. Orthogonal versus Parallel Montages
4. Latest Systematic Review
5. Conclusion

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Introduction

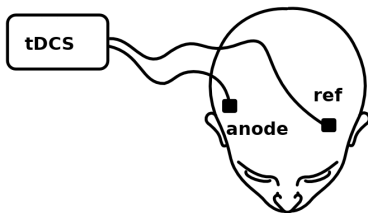
Introduction

Current flow and tDCS results



Outcomes of transcranial direct current stimulation (tDCS) are influenced by the current flow between the electrodes (Rawji et al., 2018) [9]

To target the motor cortex (M1), the conventional tDCS montage calls for a large (e.g. 5x5 cm) anode electrode to be positioned over the M1 hotspot of the right hand, while a large cathode electrode is placed over the right supra-orbital area (Woods et al., 2016) [10]



Introduction

State of the Art-2008



Nitsche MA, Cohen LG, Wassermann EM, Priori A, Lang N, Antal A, Paulus W, Hummel F, Boggio PS, Fregni F, Pascual-Leone A. Transcranial direct current stimulation: state of the art 2008. Brain stimulation. 2008 Jul 1;1(3):206-23.[7]

Introduction

Nitsche et al., 2008



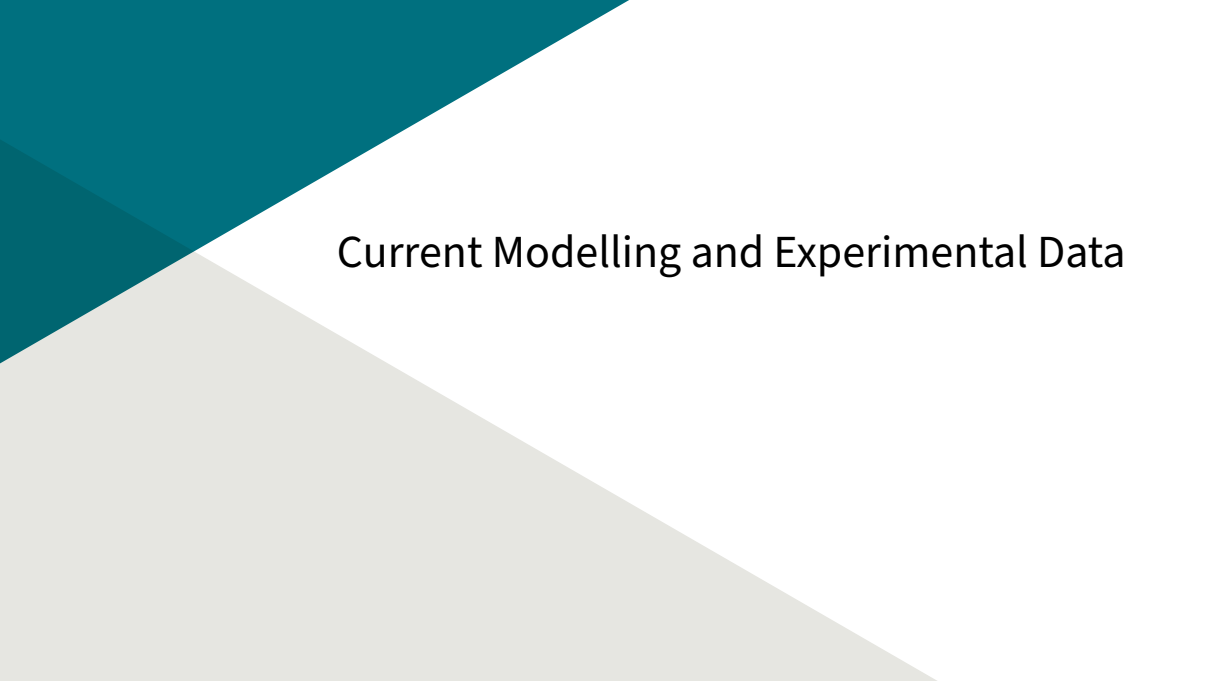
Transcranial direct current stimulation (tDCS) of different cortical areas has been shown, in various studies, to result in modifications of perceptual, cognitive, and behavioral functions.[7]

Introduction

Increasing focality- Nitsche et al, 2008



Increasing focality of tDCS can be achieved by: (1) reducing electrode size, but keeping current density constant, for the electrode that is intended to affect the underlying cortex; (2) increasing the size, and thus reducing current density, of the electrode, which should not affect the underlying cortex; or (3) using an extracephalic reference. Each of these approaches implies methodologic differences that might lead to qualitatively different effects of the stimulation.[7]

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Current Modelling and Experimental Data

Current Modelling and Experimental Data

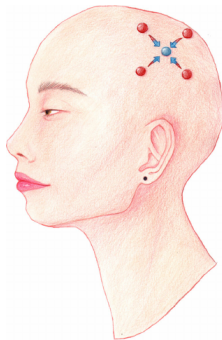
Kuo et al. 2013



- ▶ The authors compared the effects of conventional anodal and cathodal motor cortex stimulation on subsequent MEPs with those produced by 4X1 high definition anodal and cathodal tDCS
- ▶ Both anodal and cathodal stimulation induced the expected increase and decrease in M1 excitability
- ▶ High definition tDCS induced more gradual and prolonged after-effects [5]

Current Modelling and Experimental Data

Leiros Costa et al., 2013 [2]



Current Modelling and Experimental Data

Hogeveen et al., 2016



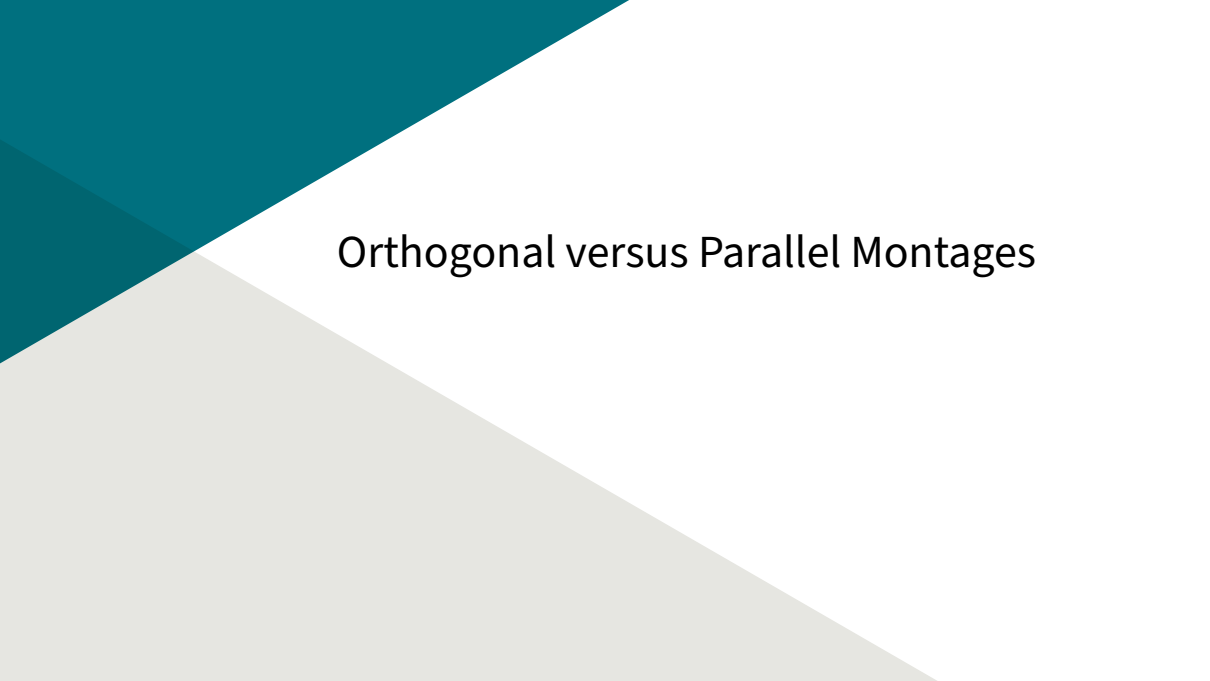
Hogeveen, J., Grafman, J., Aboseria, M., David, A., Bikson, M., Hauner, K. K. (2016). Effects of high-definition and conventional tDCS on response inhibition. Brain stimulation, 9(5), 720-729. [4]

Current Modelling and Experimental Data

Hogeveen et al., 2016



Bayesian estimation of the effects of HD- and conventional tDCS to IFC relative to control site stimulation demonstrated enhanced response inhibition for both conditions. No improvements were found after control task (CRT) training in any tDCS condition.[4]

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Orthogonal versus Parallel Montages

Orthogonal versus Parallel Montages

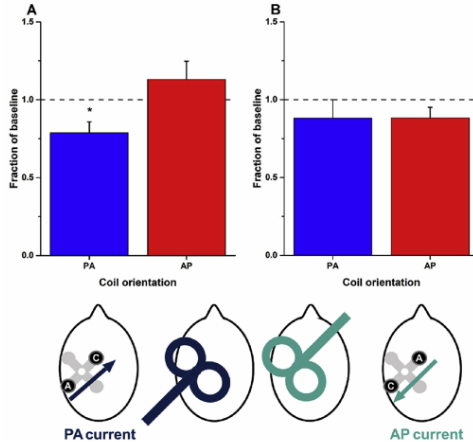
Rawji et al. 2018



- ▶ Current flow models predicted that the orthogonal electrode montage produces consistently oriented current across the hand region of M1 that flows along cortical columns, while the parallel electrode montage produces non-uniform current directions across the M1 cortical surface [9]
- ▶ TMS with a monophasic pulse that induces an electric current flowing from approximately posterior to anterior across the central sulcus (perpendicular to the line of the individual's central sulcus at that point) evokes MEPs (PA-TMS-MEPs) that have a shorter latency and lower threshold than stimulation with an anterior-posterior induced current (AP-TMS-MEPs). [9][1]

Orthogonal versus Parallel Montages

Rawji et al. 2018



Orthogonal versus Parallel Montages

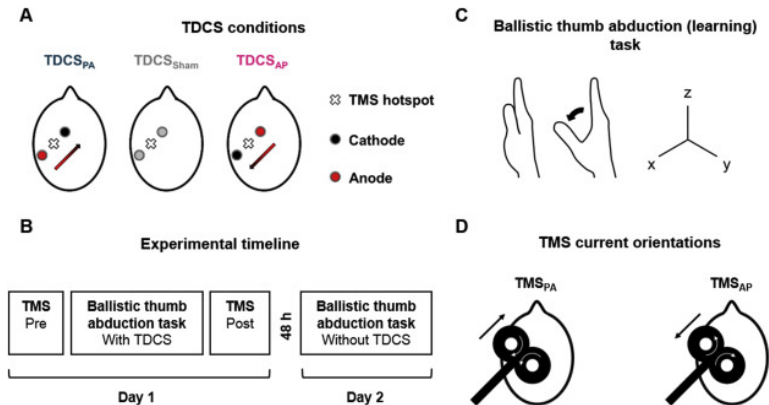
Hannah et al, 2019



- ▶ The authors applied tDCS during the practice of a ballistic movement task to test whether it affected learning or the retention of learning 48h later.
- ▶ TDCS electrodes were oriented perpendicular to the central sulcus and two current orientations were used (posterior-anterior, tDCSPA; and anterior-posterior, tDCSAP)
- ▶ Directional tDCSAP impaired the retention of learning on the ballistic movement task compared to tDCSPA and a sham condition [3]

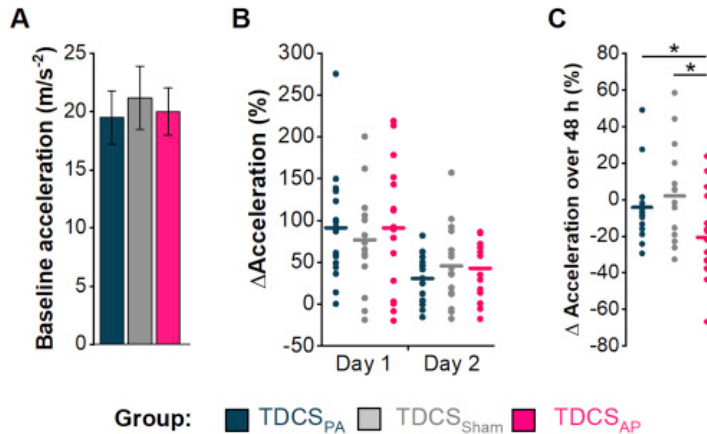
Orthogonal versus Parallel Montages

Hannah et al, 2019



Orthogonal versus Parallel Montages

Hannah et al, 2019



Orthogonal versus Parallel Montages

Hannah et al, 2019



...the retention of learning on a ballistic motor task appeared to be affected by AP, but not PA, directed current flow. [3]

Orthogonal versus Parallel Montages

Iannone et al, submitted



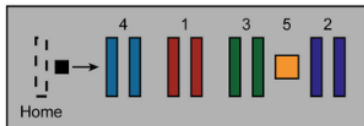
- ▶ 30 subjects practiced the sequential-visuomotor-isometric-pinch-force-task (SVIPT) while under conventional, high-definition or sham tDCS over M1
- ▶ 10 subjects in each group

Orthogonal versus Parallel Montages

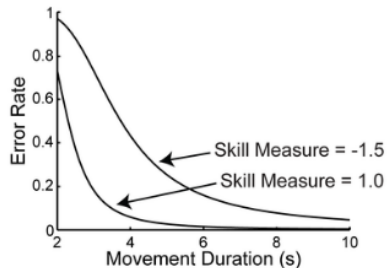
Iannone et al, submitted



A



B



Orthogonal versus Parallel Montages

Iannone et al, submitted



Focal tDCS led to greater motor skill performance in between-day retention but had no effect during training sessions

Orthogonal versus Parallel Montages

Mikonnen, 2020



- ▶ Interindividual variability of predicted EFs increased with EF focality for conventional M1- contralateral forehead and 4X1 HD montages.
- ▶ 4X1 HD-tDCS was found to have the highest EF focality and greatest variability. [6]

Orthogonal versus Parallel Montages

Mikonen, 2020



Bipolar HD montages targeting the region between two small electrodes... produced EF magnitudes comparable to those of 4X1 HD-TDCS, with a minor decrease in focality and lower interindividual variability.

— Mikonen et al, *Brain Stimulation* 13 (2020) 117-124 [6]

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Latest Systematic Review

Latest Systematic Review

Parlikar et al, 2021- a Review



Parlikar, R., Sreeraj, V. S., Shivakumar, V., Narayanaswamy, J. C., Rao, N. P., Venkatasubramanian, G. (2021). High definition transcranial direct current stimulation (HD-tDCS): A systematic review on treatment of neuropsychiatric disorders. Asian Journal of Psychiatry, 102542.[8]

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Conclusion

Conclusion

Results of a Systematic Review of HD-tDCS [8]



- ▶ more HD-tDCS studies are necessary
- ▶ experiments with bipolar orthogonal montages provide neurophysiological insights [9] [3][6]

Conclusion

HD-tDCS in Neurological Disorders [8]



- ▶ three randomized, controlled trials
- ▶ intensity of stimulation: tolerance is comparable across 1mA-3 mA
- ▶ strong sham arm advisable to avoid placebo effects
- ▶ different effects of HD-tDCS and conventional montages? uniform parameters are needed

Conclusion

HD-tDCS in Neurological Disorders [8]



All six studies, out of which three were randomized trials, showed significant outcomes with HD-tDCS. There is sufficient evidence to support the tolerability of HD-tDCS in these studies, but to ascertain its beneficial effects, certainly, more exploration is warranted. [8]

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