Targeting of transcranial Direct Current Stimulation (tDCS)

Marom Bikson
Lucas Parra, Abhishek Datta, Jacek Dmochowski, Preet Minhas, Dennis Truong, Yu Huang, Mahtab Alam, Asif Rahman

Department of Biomedical Engineering, City College of New York of CUNY, New York, NY
$ Epilepsy Foundation, Wallace Coulter Foundation, DoD COI: Soterix Medical Inc.

Neuralengr.com
Transcranial Direct Current Stimulation (tDCS)

- Non-invasive, portable, well-tolerated neuromodulation.
- Low-intensity (mA) current passed between pad electrodes.
- Investigated for cognitive neuroscience and neuropsychiatric treatment.

- Specificity derives from control of tDCS electrode position and current intensity.
Transcranial Direct Current Stimulation (tDCS)

- Two pad electrodes placed on head and connected to DC current stimulator.
- Current passed between ANODE(+) and CATHODE(-).
- DC CURRENT FLOW across cortex.
- Current is INWARD under ANODE and OUTWARD under CATHODE.
MRI-derived computational model predict brain current flow during tDCS

Full work-flow developed to preserve accuracy and resolution

MRI sequences optimized for tDCS modeling (3T at 1x1x1 mm)

Special segmentation tools perverse resolution in generation of tissue masks

Mesh includes >10 million elements

Solution provides detail insight into brain modulation

Conjugate gradient solver with <1E-8 tolerance

Model physics/domains include explicit consideration of electrode properties.
Pharmacologic activity (efficacy and safety) is determined by drug concentration at tissue.

Clinical dose is set by systemic application (tablets, ...)

Electrical activity (efficacy and safety) is determined by electric fields at tissue.

tDCS dose is set by surface application (stimulators and pads/coils).

Computational models predict the electric field generated in the brain for a specific stimulation configuration/settings.

tDCS “Dose” is those parameters controlled by operator. Electrode number, size, current at each electrode.
Transcranial Direct Current Stimulation (tDCS)

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MRI derived computational model
High-Definition Transcranial Direct Current Stimulation (HD-tDCS)

- tDCS pads replaced with array of small High-Definition (HD) electrodes.
- HD-electrodes are gel based and positioned on the scalp analogous to EEG electrodes.

10/20 position coordinates
High-Definition Transcranial Direct Current Stimulation (HD-tDCS)

• Target brain region is selected.
• Current is applied to select HD electrodes to optimize current flow to target.

• Given a brain region of interest, which electrodes should be activated?
High-Definition Transcranial Direct Current Stimulation (HD-tDCS)

• Given a brain region of interest, which electrodes should be activated?
• Many degrees of freedom (current at each electrode)

• “Best” solution depends on trial objectives / criterion
  Efficacy: Focality at target (s)
  Size of target
  Superficial or deep target location
  Maximize intensity at target
  Direction of current (modulation).
  Tolerability: Minimize total current
  Minimize total current per electrode
  Limit intensity at brain
High-Definition Transcranial Direct Current Stimulation (HD-tDCS)

Goal: target a single cortical brain region, with single direction of current (excitability change) while maintaining all intensity parameters (total current, maximum intensity at brain) within conventional norms.

4x1-Ring HD-tDCS Montage (total 5 electrodes)
- Center active electrode (2 mA) over cortical target
- Four surround return electrodes (0.5 mA each)
- Ring radius circumscribes underlying cortical region of interest
High-Definition tDCS 4x1-Ring Montage

- Center electrode determines polarity (anode, cathode)
- Ring radius determines modulation area

Outward current direction

Center electrode: CATHODE
Outward current direction (inhibitory)

Center electrode: ANODE
Outward current direction (excitatory)
High-Definition tDCS 4x1-Ring Montage

10 minutes of 2 mA 4x1 HD-tDCS produces >2 hour of after-effects
High-Definition tDCS 4x1-Ring Montage

Dylan Edwards
Mar Cortes

Transcranial Electrical Stimulation (TES) – short high-intensity pulse that triggers motor response (MEP)

Comparable focality to TMS
Subject specific modeling and experiments
Inter-subject variation in susceptibility >2x

- Change TES intensity to give same MEP response (left)
- Same TES intensity giving different MEP responses (right)
High-Definition Transcranial Direct Current Stimulation (HD-tDCS)

- Given a brain region of interest, which electrodes should be activated?
- If subject anatomy effects susceptibility, should “best” electrode montage be individually optimized?
High-Definition Transcranial Direct Current Stimulation (HD-tDCS)

- Given a brain region of interest, which electrodes should be activated?
- If subject anatomy affects susceptibility, should “best” electrode montage be individually optimized?

- At extremes of age
- In stroke
- In head injury / skull defects
- In morbid obesity
- Health adults - Normalize outcomes
tDCS for stroke rehabilitation

Subject X: Aphasia

Julius Fridriksson
Julie Baker
tDCS for stroke rehabilitation

Brain Electric Field

Brain and CSF Current Density
HD-tDCS for stroke rehabilitation

4x2 HD-tDCS

Prospective Individually Optimized Trial
Targeting of Transcranial Direct Current Stimulation

- Optimization of tDCS based on brain regions of interest.
- Increased degrees of freedom with HD-tDCS (current at every electrode) providing flexibility and specificity.
- Computer modeling tools enhance targeting precision.
- “Best” solution depends on trial objectives including targeting, intensity, tolerability.
- Individual optimization feasible (in cases warranted)
General computational modeling methods


Dose design for stroke and injury

M. Halko, A. Datta, E. Plow, J. Scaturro, M. Bikson, L. Merabet. Neuroplastic changes following rehabilitative training correlate with regional electrical field induced with tDCS. Neuroimage 2011
*A. Datta, M. Bikson, F. Fregni. Transcranial direct current stimulation in patients with skull defects and skull plates: High-resolution computational FEM study of factors altering cortical current flow. Neuroimage 2010

Dose design for cognitive neuroscience


Dose validation

“Deep” tDCS

Alex DaSilva
Felipe Fregni
White matter neuromodulation

Salman Shahid
Conventional and High-Definition Electrodes

Conventional bipolar large electrodes

High-Definition electrodes in “4x1” configuration
Optimized electrotherapy in rehabilitation
Targeting based on functional changes

Vision Rehabilitation
PI: Lotfi Merabet
Targeting and model validation

Post-mortem “fMRI”

Walter Paulus
Andrea Antal
Targeting and model validation

Walter Paulus
Andrea Antal