Background notes for Hand-On Modeling tDCS Current Distribution using Soterix Medical HD-Explore

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Marom Bikson
Intuition **without models** is faulty

Small changes in montage: change brain current flow between and under **both** electrodes.
Current flow models of tDCS

Montovani Montage (tested for OCD)
“Active” electrode over the pre-Supplementary Motor Area
“Return” on the right shoulder
Current does not stop at cortex

Physics
• Hot-spots around deep structures
• Cellular morphology is varied

Physics
• Difficult to predict “increase” or “decrease” in deep structures
• Details idiosyncratic

Diagram: Illustration of brain structures with labels for Nucleus Accumbans, Fornix, and Mamillary Bodies.
tDSC “Dose” is those parameters controlled by operator
Electrode number, size, current at each electrode

Current flow models only predict the electric field generated in the brain for a specific stimulation configuration/settings

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

Peterchev AV Wagner T, Miranda P, Nitsche M, Paulus W, Lisanby SH, Pascual-Leone A, Bikson M
Transcranial Direct Current Stimulation (tDCS)

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

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.

Gyri-precise head model of transcranial direct current stimulation: improved spatial focality using a ring electrode versus conventional rectangular pad. 

*Brain Stimulation* 2009 Datta A, Bansal V, Diaz J, Patel J, Reato D, Bikson M.
High-Definition tDCS (HD-tDCS)

- tDCS pads replaced with array of small High-Definition (HD) electrodes.
- **Categorical** change in brain current flow control.
- Optimization problem “solved” given a MRI + head model

Optimized multi-electrode stimulation increases focality and intensity at target.

Given a brain region of interest, which tDCS or HD-tDCS electrodes should be activated?

- Target brain region is selected.
- Current is applied to select HD electrodes to optimize current flow to target.
- Need to specify “what” is optimized since no perfect solution

*Optimized multi-electrode stimulation increases focality and intensity at target.*

Given a brain region of interest, which tDCS or HD-tDCS electrodes should be activated?

“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

Optimized multi-electrode stimulation increases focality and intensity at target.

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

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High-Definition tDCS 4x1-Ring Montage

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

Outward current direction
- (inhibitory) for CATHODE
- (excitatory) for ANODE
Reasons NOT to use models

- The increased control over current flow (e.g. great targeting, great intensity) is not what I wanted all along.
  
  Diffuse current flow is good.

- Models are just models. Rather use my intuition then rely on math.

- I don’t have access to models.
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Clinician accessible tools for GUI computational models of transcranial electrical stimulation: BONSAI and SPHERES. *Brain Stimulation* 2014

Truong, Huber, Xie, Datta, Rahman, Parra, Dmochowski, Bikson.
Soterix Medical HD-Explore