How tDCS polarizes a highly folded cortex

Marom Bikson
Lucas Parra, Asif Rahman, Niranjan Khadka, Jacek Dmochowski, Doris Ling, Mark Jackson, Dennis Truong, Belen Lafon, Gregory Kronberg, Ole Seibt, Devin Adair, Nigel Gebodh, Thomas Radman
Disclosure:

Soterix Medical Inc. produces tDCS and High-Definition tDCS. Marom Bikson is founder and has shares in Soterix Medical. Marom Bikson serves on the scientific advisory board of Boston Scientific Inc.

Support:

NIH (NINDS, NCI, NIBIB), NSF, Andy Grove Foundation, Epilepsy Foundation, Wallace Coulter Foundation, DoD (USAF, AFOSR)

Slides at NeuralEngr.com
Concentric sphere models of tDCS

Rush & Driscoll (1968) Current distribution in the brain from surface electrodes

Analytical Solution
Concentric sphere models of tDCS

Rush & Driscoll (1968) Current distribution in the brain from surface electrodes

**Analytical Solution**

Miranda et al. (2006) Modeling the current distribution during transcranial direct current

**Finite Element Method**

Datta et al. (2008): Transcranial current stimulation focality using disc and ring electrode configurations: FEM analysis.

**Montage optimization**

Dmochowski et al. (2012): The point spread function of the human head - implications for transcranial current stimulation.

neuralengr.com/spheres
Concentric sphere models of tDCS

Rush & Driscoll (1968) Current distribution in the brain from surface electrodes

Analytical Solution

Miranda et al. (2006) Modeling the current distribution during transcranial direct current

Finite Element Method

Datta et al. (2008) : Transcranial current stimulation focality using disc and ring electrode configurations: FEM analysis.

Montage optimization


neuralengr.com/spheres
Datta et al. (2008)
• Complete current path from Anode to Cathode
• Complete current path from Anode to Cathode
• Inward under Anode, Outward under Cathode
• Complete current path from Anode to Cathode
• Inward under Anode, Outward under Cathode
• Tangential between electrodes
• Asymmetric pyramidal neurons in cortical columns
• Directional current flow relevant to cortical surface (columns and pyramidal neurons)
• Tangential current flow polarizes afferent axons
• Neuromodulation at all directions of current flow

Datta et al. (2008)
Datta et al. (2008)
Datta et al. (2008) Focal tDCS using concentric ring electrode configurations. 3rd International Conference on TMS/tDCS conference

• Current between and around electrodes
• Clustering of intensity based of idiosyncratic anatomy
• Peak between electrodes

Datta et al. (2008) Focal tDCS using concentric ring electrode configurations. 3rd International Conference on TMS/tDCS conference
• Majority of current tangential
• Directionality inversion within Gyri (under electrode)

How can polarity specific (or any) effects result with mixed polarization?

• Input / Output sensitive to anodal polarization only

Lafon et al. (2016) Direct Current Stimulation alters neuronal input/output function. Brain Stimulation
• Input / Output sensitive to anodal polarization only

• On a population level net change in mixed polarization

Lafon et al. (2016) Direct Current Stimulation alters neuronal input/output function. Brain Stimulation
Network activity “binds” opposite polarized regions to produce a coherent effects.

Reato et al. (2013) Transcranial electrical stimulation accelerates human sleep homeostasis. PLOS Computation Biology
• Preferential enhancement of plasticity by anodal tDCS

Rahman et al. (2016) In Revision
# NYC Neuromodulation 2017
January 13th – 15th (New York City, USA)

**Abstract or 1-Page Proceedings** - Published in Brain Simulation Journal

**Talks – Practical Demos – Panel Discussions – Breakout Sessions – Awards**

<table>
<thead>
<tr>
<th>Category</th>
<th>Title</th>
<th>Presenter/Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical Demo on Modern tDCS/tACS methodology</td>
<td>Emerging concepts in Spinal Cord Stimulation: high rate and collision approaches</td>
<td>Keynote: John Rothwell – Does rTMS really effect synaptic plasticity?</td>
</tr>
<tr>
<td>Awards Presentation</td>
<td>1) NYC Neuromodulation Pioneer Award</td>
<td>Sarah Lisanby - The NIH Brain Initiative: Opportunities and Priorities for Non-invasive Neuromodulation</td>
</tr>
<tr>
<td></td>
<td>2) Neuromodulation Young Investigator Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3) NYC Neuromodulation Clinical Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4) NYC Neuromodulation Best Poster Award: $1000 prize</td>
<td></td>
</tr>
<tr>
<td>Biophysics of tACS and tDCS for clinicians</td>
<td>Practical Demo on HD-tDCS plus EEG</td>
<td>The limits of focality</td>
</tr>
<tr>
<td>Perspectives on Neuromodulation in Neurology: Are we ready yet for clinic?</td>
<td>Is neuromodulation better than drugs? (treating depression, tDCS for OCD)</td>
<td>Neuromodulation at Home</td>
</tr>
<tr>
<td>Continuum of clinical care and research: from noninvasive to invasive Neuromodulation</td>
<td>Panel – Off label use of neuromodulation and individualized therapy</td>
<td>Practical Demo on tDCS plus TMS</td>
</tr>
<tr>
<td>Updates on Safety of Neuromodulation (tDCS, TMS, DBS, ECT, ultrasound)</td>
<td>Panel – Pediatric Neuromodulation</td>
<td>Human Performance</td>
</tr>
<tr>
<td>New frontiers in tDCS mechanisms (tDCS metaplasticity and synaptic plasticity)</td>
<td>Panel – Frontiers of Electroceuticals:</td>
<td>Keynote: Mark George - Does rTMS work in the treatment of depression and other neuropsychiatric disorders?</td>
</tr>
<tr>
<td>Using Neuroimaging and EEG to individualized neuromodulation</td>
<td>Panel – tDCS in sport: Industry and academic perspectives.</td>
<td></td>
</tr>
<tr>
<td>New Protocols and Application for Neuromodulation (obesity, aging, ECT, TMS)</td>
<td>Regulation of tDCS and related technology</td>
<td>Variability in Neuromodulation</td>
</tr>
</tbody>
</table>