Specificity of tDCS: High-Definition tDCS and Functional Targeting

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Soterix Medical Inc. produces tDCS and High-Definition tDCS. Marom Bikson is founder and has shares in Soterix Medical. Some of the clinical data presented may be supported by Soterix Medical.
Transcranial Direct Current Stimulation (tDCS)

- Non-invasive, portable, well-tolerated neuromodulation.
- Low-intensity (mA) current passed between anode and cathode electrodes.

Depression, pain, migraine, epilepsy, PTSD, schizophrenia, tinnitus, neglect, rehabilitation (motor, aphasia), TBI, OCD, attention, accelerated learning (reading, motor skills, math, threat detection), memory…

- Can a “simple” intervention modulate brain function?
- How is specificity of action achieved?
Specificity of tDSCS

• tDCS specificity through **anatomical targeting** of brain regions

• tDCS specificity through "**functional targeting**" of tasks / behaviours
Anatomical Specificity of tDCS

• tDCS montage (electrode position) determines brain current flow pattern.

• Combined with waveform (duration, intensity) determines dose.
Anatomical Specificity of HD-tDCS

- High-Definition tDCS (HD-tDCS) array provides high degree of current flow control.
- Current at each electrode controlled to steer targeting
- Single system with wide configurations: low-cost
- Superficial or deep target(s)

Datta, Bikson, Alam
HD-tDCS Optimization

• Given target and head anatomy ➔ optimal montage is close-form solution

Dmochowski, Bikson, Parra

• ✔ Target selected and optimal montage given
4x1 HD-tDCS

- 4x1 High-Definition tDCS (HD-tDCS) optimized for cortical targeting

Datta, Bikson, Alam

- Ring radius determines cortical focality

7 cm radius

3 cm radius
Neuromodulation Technologies: Anatomical Targeting

- Neuromodulation (brain stimulation) technology based on anatomical targeting (DBS, TMS…)
- Trade-off between complexity (invasiveness) and focality
- Focality is “relative” for suprathreshold stimulation
tDCS mechanisms: Neuromodulation

High-intensity Pulses

Low-intensity DC

Over-driving a neural network
tDCS mechanisms: Neuromodulation

High-intensity Pulses

Low-intensity DC

Over-driving a neural network
tDCS mechanisms: Neuromodulation

High-intensity Pulses

Low-intensity DC

Over-driving a neural network
tDCS mechanisms: Neuromodulation

High-intensity Pulses

Over-driving a neural network

Low-intensity DC

Interacting with specific activity in a neural network
Specificity of tDCS

- tDCS specificity through anatomical targeting of brain regions

- tDCS specificity through “functional targeting” of tasks / behaviours
Neuronal Polarization under tDCS

Electrode

Head Surface

Cortical Neuron
Neuronal Polarization under tDCS

Optical Mapping with voltage sensitive dyes

Bikson, Inoue, Arkiyama, Miyakawa, Jefferys
Neuronal Polarization under tDCS

Brain slice intracellular recording + morphological reconstruction

Layer I Interneuron
Layer II/III Pyramidal
Layer V/VI Bursting Pyramidal

0 mV polarization
0.03 mV polarization
0.1 mV polarization

Anode Current Flow

Radman, Ramos, Bikson
Neuronal Polarization under tDCS

- tDCS is too weak to produce neuronal firing ➔ How does it modulate processing of (synaptic) input?
- Dendrites and terminals are polarized 3x of soma.

Radman, Parra, Bikson, Lafon
Modulation of sensitivity to synaptic input under DCS

DC stimulation + evoked response

Jefferys, Bikson

fEPSP: metric of cellular synaptic efficacy

Cathodal stimulation (soma Hyperpolarized)
Control
Anodal stimulation (soma Depolarized)

- Extensive characterization of acute synaptic processing across brain regions and synaptic pathways
• Higher sustained synaptic inputs under anodal stimulation (substrate for plasticity)
• Input specific neuromodulation – “functional” targeting
Specificity of tDCS

- tDCS specificity through **anatomical targeting** of brain regions
  - Tremendous flexibility in dose / targeting

- tDCS specificity through “**functional targeting**” of tasks / behaviours
  - Combination of tDCS with training / therapy
  - State and activity dependent modulation