Principles and Technology of tDCS

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Continuum of Care from Wearables to Non-Invasive Brain Neuromodulation. NANS, Jan 21, 2018
Transcranial Direct Current Stimulation (tDCS)

- Non-invasive, portable (9V), well-tolerated neuromodulation.
- Low-intensity (mA) current passed between scalp electrodes.
- Tested for cognitive neuroscience and neuropsychiatric treatment and neurorehabilitation.

How can a 9V battery do anything for the complex brain?

How is specificity of action achieved?

Very abbreviated list of tDCS indications and applications:
Depression, Pain, Migraine, Epilepsy, PTSD, Schizophrenia, Tinnitus, Neglect, Rehabilitation (motor, aphasia), TBI, OCD, Attention / Vigilance, Accelerated learning (reading, motor skills, math, threat detection), Memory, Creativity, Sleep (SW, Lucid dreaming, Threat detection, Impulsivity, Compassion, Jealousy, IQ, Prejudice…
Target Engagement

- How can a 9V battery do anything for the complex brain?
- How is specificity of action achieved?

Through **anatomical targeting** of specific brain regions.

Can be studied using computational models of current flow.
tDCS electrode position on the head determines which regions are stimulated.

(?) Specific brain regions are associated with specific functions / disease

Truong et al. Clinician accessible tools for GUI computational models. “BONSAI” and “SPHERES”. Brain Stimulation 2014
"Cathodal" tDCS
Soma hyper-polarized
Apical dendrite depolarized

"Anodal" tDCS
Soma depolarized
Apical dendrite hyper-polarized

tDCS electrode position on the head determines which regions are stimulated

(!) Must consider both anode and cathode electrodes

Datta et al. Electrode montages for tDCS : Role of "return" electrode Clinical Neurophys. 2010
High-Definition tDCS uses arrays of electrodes to focus current to targets.

Software allows you to generate subject and target specific tDCS “formulation”

"4x1" montage of High-Definition tDCS

(!) Non-invasive electrical targeting of cortex

Datta et al. Gyri-precise model of tDCS: Improved spatial focality using a ring versus conventional pad. *Brain Stimulation* 2009
Target Engagement

- How can a 9V battery do anything for the complex brain?
- How is specificity of action achieved?

Through **functional targeting** of specific brain regions.

Can be studied using brain slices models of synaptic efficacy and plasticity.
From Anatomical Targeting to Task Targeting

Network of interest (e.g. depression, pain network)  Other networks – not targets for neuromodulation

Current flow across entire region

Preferential modulation of selected active neurons

Bikson et al. Origins of specificity during tDCS. *Front Human Neuro* 2013
Synaptic efficacy is modulated by Direct Current (polarity specific)

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- Direct Current stimulation does not generate synaptic activity or neuronal firing (Functional Targeting)

Direct Current has sustained effects on synaptic efficacy despite synaptic depression

- While Direct Current stimulation is on, ongoing synaptic activity boosted (Functional Targeting)

Theta Burst Stimulation (TBS) generates LTP which is modulated by concurrent Direct Current

Theta Burst Stimulation (TBS) generates LTP which is modulated by concurrent Direct Current

• Direct Current stimulation does not itself generate synaptic plasticity (Functional Targeting)

Repeated stimulation accelerates LTP and boosts the ceiling for synaptic learning

- **Hypothesis:** Combing Direct Current stimulation with repeated training of a task may enhance the rate and ceiling learning of that task *(Functional Targeting)*
• Any EEG can be automatically “inverted” to an optimal HD-tDCCS montage
• 50% reduction in VAS Pain + EEG Pain markers in 1/2 subjects within two weeks of optimization
Big picture - Target Engagement by tDCS

- Medical center: Transition from sponge-pad tDCS to High-Definition tDCS (HD-tDCS), with image-guided targeting. Individualized through close-loop.

- Home based: Extended therapy (repeated sessions) with “wearable guided targeting” + big data

- Training based functional targeting, moving beyond brain-as-a-sliding-scale models (e.g. anode = ‘up’).

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