An overview of the applications and mechanisms of transcranial Direct Current Stimulation (tDCS)

Marom Bikson, Ph.D.
The City College of New York

Slides and References at NeuralenGR.com
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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. Marom Bikson serves on the scientific advisory board of Boston Scientific Inc.

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What is Neuromodulation?

- Application of electricity to change brain function
- “Electroceuticals”
- Many techniques: Name of each method is defined by how electricity is delivered
  (some letters ending with “s”).

Deep Brain Stimulation (DBS)
Transcranial Magnetic Stimulation (TMS)
Transcranial Direct Current Stimulation (tDCS)
Why Neuromodulation?

- To probe the brain for science
- To treat the brain: neurological, psychiatric, rehabilitation
- To enhance mental performance (neuro-enhancement)

Deep Brain Stimulation (DBS)

Transcranial Magnetic Stimulation (TMS)

Transcranial Direct Current Stimulation (tDCS)
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.

How can a 9V battery do anything for the complex brain?
How is specificity of action achieved?
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TDCS Publications
Depression, pain, migraine, epilepsy, PTSD, schizophrenia, incontinence, neglect, rehabilitation (motor, aphasia), TBI, OCD, attention, Accelerated learning (reading, motor skills, math, threat detection), memory, creativity, lucid dreaming...

THE ORIGINAL
CURE ALL

RELIEVES INSTANTANEOUSLY
And Cures: Headaches, Nueralgia, Cough, Cold, Sneezing, Hiccups, Goat, Gonorrhea, Dysentery, Daunplung, Mumps, Measles, Whooping cough, Tuberculosis, And even Bowden's Malady.

FOR BLINDNESS TRY OUR RATTLESNAKE OIL!
Regulatory Status

• tDCS has not been approved by the FDA for the treatment of any medical condition.

• Human trials in the US proceed typically under “non-significant risk”
  (including healthy college students)

• tDCS is available in the US under the Investigational Device Exemption

  or on Amazon…

• tDCS is available in the EU under CE mark.
Current home use

USA FDA home-use devices
Current home use

USA FDA home-use devices
tDCS Safety and Tolerability

- **60,000+ sessions** applied in controlled human trials (healthy and sick subjects)
- **2,000+ subjects** had repeated sessions over weeks
- No case of causal serious adverse event
- **Common-side effects mild**: itching, tingling, skin-redness that all resolve within minutes
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How can a 9V battery do anything for the complex brain?
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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, Beauty, Reality Filtering...
How could Pharmaceuticals treat so many disorders?
It’s not one thing.
Many formulations.

How could Electroceuticals (tDCS) treat many disorders?
It’s not one thing.
Many “formulations”.
tDCS electrode position on the head determines which regions are stimulated.

Specific brain regions are associated with specific functions / disease.

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

✓ Allows targeting of selected cortical regions

Datta et al. Gyri-precise model of tDCS: Improved spatial focality using a ring versus conventional pad. *Brain Stimulation* 2009
High Definition tDCS for Stroke Rehabilitation

Dmochowski et al. Targeted transcranial direct current stimulation for rehabilitation after stroke. *Neuroimage* 2013

4x2 HD-tDCS
tDCS montage for treatment of Depression

- Multi-center double-blind controlled clinical trials
- Monotherapy or with drugs
- target: left DPLPC

And

Vigilance
Impulsivity
Attention

... 

• Targeting of brain regions not enough

Seibt al. The pursuit of DLPFC. *Brain Stimulation* 2015
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Majority of trials use poorly targeted tDCS

➢ How can a 9V battery do anything for the complex brain?
➢ How is specificity of action achieved?
How could weights help with so many sports?

It’s a tool to enhance specific training.

How could Electroceuticals (tDCS) treat many disorders?

It’s a tool to enhance cognitive training and therapy.
tDCS is a tool for the mind that enhances activity and plasticity from cognitive training and therapy

- Human trials with tDCS use brain stimulation as adjunct to the brain training (e.g. math, game)
- Changes in mood that facilitate training (vigilance, relaxation)
- Boosting placebo – real and specific physiological response associated with expectation

Schambra et al. It’s all in your head: reinforcing the placebo response with tDCS. Brain Stimulation 2014
How does tDCS just enhance the trained task?

Cellular mechanism: Functional Targeting

Bikson et al. Origins of specificity during tDCS: anatomical, activity-selectivity, and input-bias mechanisms. *Front Human Neuro 2013*
From Anatomical Targeting to Functional Targeting

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

Preferential modulation of selected active network (activity dependent)

Current flow across entire region
tDCS changes endogenous synaptic plasticity in animals

- Four sessions of endogenous plasticity (learning) without tDCS
- Four sessions of endogenous plasticity (learning) with tDCS

мышечная пропитанность (обучение) на tDCS

Calculated Plasticity (Learning)

Accelerated Plasticity (Learning)

Enhanced Maximum

✓ tDCS boosts ongoing plasticity (learning)
The mechanisms of tDCS changing the brain are the mechanisms of endogenous plasticity.
tDCS is a tool for the mind that boosts ongoing brain plasticity and learning

✓ Cellular mechanisms of tDCS exhaustively studied.
✓ “Functional Targeting” means only paired tasks are boosted.
✓ Effects of tDCS can last as long as normal learning and plasticity would last.

• Decades of animal studies on mechanisms and safety.
• 15 years of safety and tolerability data including on healthy college students.
• 10 years of human trials including for patients with devastating neuropsychiatric disorders who failed drug options.
• Medical grade stimulators only available in US through IDE. Available in EU*.
• “DIY-tDCS” community (in response to lack of available medical grade stimulators).
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