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How to get smart and even cure disease with electrical brain stimulation

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Disclosure:
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 tDCS?
transcranial Direct Current Stimulation

Weak direct current applied across the head

To change brain function in healthy and sick individuals

To make us smarter and better
What is tDCS?

transcranial Direct Current Stimulation
Why tDCS?

• To probe the brain for science.
• To treat the brain: neurological, psychiatric, rehabilitation.
• To enhance mental performance (neuro-enhancement).
What is all the hype about?

Can You Download Knowledge Into Your Brain With Electricity?

tDCS Brain Hacking Tech Boosts Stroke Recovery

Study tests electrical stimulation to treat depression in pregnancy eye

Spark of Genius

Jumper Cables for the Mind

HELP YOU LOSE WEIGHT

DIY Brain-Shock Kits Jump Start Users' Day

Have You Tried to Zap Fibromyalgia Pain Away?
Accelerated Training

HRL

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA
Electro-doping
Electroceuticals: Brain healing
Clark began working on tDCS in 2007, shortly after being named scientific director of the Mind Research Network at the University of New Mexico. Funded by DARPA, the research division of the Department of Defense, his first study determined that tDCS can help subjects learn to detect hidden threats in complex images. The researchers used images from DARWARS, a video game

Witkiewitz put an anode over my right temple. In a trancelike tone, she instructed me to think about my breath, to imagine a balloon slowly filling in the empty space behind my eyes, to focus all my attention on the area directly above my head. She told me to watch my thoughts come and go. In previous
How to get it?

Available at Amazon

“Like a futuristic espresso, or a wearable technology whiskey on-the-rocks”

-WEARABLE
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.

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, Reality Filtering, IQ, Prejudice...
Transcranial Direct Current Stimulation (tDCS)

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

How is specificity of action achieved?

tDCS Publications
Depression, pain, migraine, epilepsy, PTSD, schizophrenia, tinnitus, neglect, rehabilitation (motor, aphasia), TBI, OCD, autism, accelerated learning (reading, motor skills, math, threat detection), memory, creativity, lucid dreaming…
Is there anything tDCS does not work for?

Vince Walsh
Hype, positive or negative, is still hype.  

Sven Bestmann
How can a 9V battery do anything for the complex brain?
How is specificity of action achieved?
How could Pharmaceuticals treat so many disorders?
It’s not one thing.
Many formulations.

How could 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 (HD) tDCS “formulation”
“4x1” montage of High-Definition tDCS

✓ Allows targeting of selected cortical regions
Customized tDCS for Stroke Rehabilitation

4x2 HD-tDCS
**tDCS montages for treatment of Depression**

- Brunoni et al.
  - SELECT / ELECT
  - target: DPLPC
  - 2.0 mA
  - Double blind RCT

- Loo et al.
  - Multi-Center Trial
  - target: DPLPC
  - 2.5 mA
  - Double blind RCT

- Target stimulated but not specifically !!
Transcranial Direct Current Stimulation (tDCS)

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, Jelousy, Reality Filtering, IQ, Prejudice…

Majority of trials use diffuse 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 tDCS treat many disorders?

It’s a tool to enhance cognitive training and therapy.
tDCS combined with training (tasks)
How does tDCS just enhance the trained task?

What is the cellular mechanism of “Task Targeting”
What makes tDCS so special?

- May devices use electricity to “zap” the brain
- Name of each method is defined by how electricity is delivered (some letters ending with “s”)

Deep Brain Stimulation (DBS)  Transcranial Magnetic Stimulation (TMS)  tDCS
What makes tDCS so special?
What makes tDCS so special?

High-intensity Pulses

Low-intensity Direct Current

TMS

Invasive cortical

DBS
What makes tDCS so special?

High-intensity Pulses  Low-intensity Direct Current
What makes tDCS so special?

High-intensity Pulses

Low-intensity Direct Current
What makes tDCS so special?

High-intensity Pulses  Low-intensity Direct Current

tDCS
The organization of cortex by columns
Cortical columns received information from different brain regions (input) and processes this information (output).
Direct Current stimulation of columns: tDCS

Transcranial Direct Current Stimulation

Application of weak Direct Current using electrodes on the scalp: produces Direct Current flow through the cortex
How does Direct Current change cortical processing?
How does Direct Current change neurons?

Optical Mapping with voltage sensitive dyes

How does Direct Current change neurons?

Intracellular recording and morphology

Radman, Bikson et al. Role of cortical cell type and morphology in subthreshold and suprathreshold uniform electric field stimulation. Brain Stimulation. 2009
Direct Current stimulation of columns: tDSC

How does Direct Current change cortical processing?
Direct Current stimulation of columns: tDCS

How does Direct Current change cortical processing?
How does Direct Current change cortical processing?
Direct Current stimulation of columns: tDCS

How does Direct Current change cortical processing?
From Anatomical Targeting to Task Targeting
From Anatomical Targeting to Task Targeting

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

Current flow across entire region

 Preferential modulation of selected active neurons
Biophysical basis of tDCS task selectivity

Fritsch 2010: BDNF dependent + activity dependent induction

Specific ongoing synaptic activity (no plasticity)

(tDCS induces plasticity)

Rahman 2015: Pathways specific + plasticity dependent modulation

Ongoing Plasticity

(tDCS modulates plasticity)

“None-active” synapse

No tDCS synaptic plasticity

Synaptic Plasticity in brain slice
① tDCS produces a sustained weak polarization of neuronal membranes

② Weak polarization modulates cortical processing related to active tasks, and can promote plasticity (learning)
tDCS combined with training (tasks)
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
tDCS is tested for so (too?) many things.

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

tDCS generates weak current across specific parts of the brain. Neurons in those parts are polarized. Tasks applied at same time. tDCS changes how those specific parts process this activity boosting training and learning.
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