tDCS Update: Recent Trends and Applications

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June 13, 2010
tDCS: A methodology on the move

- 460 PubMed manuscripts with keywords “transcranial direct current stimulation”
- 136/460 (29.6%) manuscripts published in the last 12 months
tDCS: What’s trending in 2010/11?

• Cognitive Neuroscience
  – Frontal lobe functions
  – Language
  – Motor learning
  – Cognitive enhancement

• Clinical Applications
  – Stroke rehabilitation
  – Depression
  – Pain
Frontal lobe functions

Working memory

• Fregni et al. 2005
  – Left DLPFC
  – 1 mA x 10 min
  – Anodal vs Sham
  – 3-back task
Frontal lobe functions

Inhibition, Impulse Control, Behavioral Control

Activation of Inhibition: Diminishing Impulsive Behavior by Direct Current Stimulation over the Inferior Frontal Gyrus

Liron Jacobson¹, Daniel C. Javitt², and Michal Lavidor¹,³

JOCN, 2011

Modulating inhibitory control with direct current stimulation of the superior medial frontal cortex

Tzu-Yu Hsu a,b,c, Lin-Yuan Tseng a,b,c, Jia-Xin Yu a,b,c, Wen-Jui Kuo a,b,c, Daisy L. Hung a,b,c, Ovid J.L. Tzeng a,b,c,d, Vincent Walsh e, Neil G. Muggleton b,e, Chi-Hung Juan b,c,*
Frontal lobe functions

Inhibition, Impulse Control, Behavioral Control

Goldman et al., 2011

- 19 subjects with cravings
- VAS of food craving and ability to resist
- Anode right; cathode left PFC
- 2.0 mA x 20 min or Sham
Language

• tDCS: Faster naming (e.g. Sparing et al., 2007)

• tDCS: Improved acquisition of novel names (Flöel et al., 2009)

• tDCS: Increased verbal fluency (Iyer et al 2005)

• tDCS: Better acquisition of grammar (de Vries et al, 2009)
Language

Motor Cortex in Action Word Learning

- Liuzzi et al., 2011
  - 30 subjects
  - Novel action word training
  - 1 mA x 15 min
  - Cathodal effect
  - DLPFC site & Object word control conditions NS
Motor learning

Noninvasive cortical stimulation enhances motor skill acquisition over multiple days through an effect on consolidation

Janine Reis\textsuperscript{a,b}, Heidi M. Schambra\textsuperscript{a}, Leonardo G. Cohen\textsuperscript{a,1}, Ethan R. Buch\textsuperscript{a}, Brita Fritsch\textsuperscript{a,b}, Eric Zarahn\textsuperscript{a}, Pablo A. Celnik\textsuperscript{a,1,2}, and John W. Krakauer\textsuperscript{a,2}

\textsuperscript{a}Human Cortical Physiology Section and Stroke Neurorehabilitation Clinic, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, MD 20892; \textsuperscript{b}Department of Neurology, Albert-Ludwigs-University, Freiburg 79106, Germany; \textsuperscript{1}Motor Performance Laboratory, Department of Neurology, Columbia University College of Physicians and Surgeons, New York, NY 10032; and \textsuperscript{2}Department of Physical Medicine and Rehabilitation, Johns Hopkins University, Baltimore, MD 21287

Edited by Emilio Bizzi, Massachusetts Institute of Technology, Cambridge, MA, and approved November 25, 2008 (received for review June 5, 2008)
Cognitive enhancement

Facilitation of “Numerical Competence”

Cohen Kodosh et al. (Current Biol., 2011)

- 6 Days training with artificial number symbols
- Biparietal stimulation (RA-LC vs RC-LA) vs sham
- Numeric Stroop & Number-to-space tasks
- Enhanced acquisition of number-space relationship after RA-LC stimulation
- Persistent effects 6 months later
Manipulation of semantic processing with tDCS has been linked to multiple enhancements associated with stimulation of the anterior temporal lobes.
Stroke rehabilitation: aphasia

Anodal tDCS (1mA, 20 minutes for 5 days) to the left frontal lobe resulted in improvements in naming accuracy among 10 patients with left hemisphere strokes and chronic aphasia

<table>
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<th>Patient</th>
<th>Immediate Posttreatment &gt; Baseline</th>
<th>1 Week Posttreatment &gt; Baseline</th>
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Baker et al., 2010
Stroke rehabilitation: aphasia

Short-Term Anomia Training and Electrical Brain Stimulation
Agnes Flöel, Marcus Meinzer, Robert Kirstein, Sarah Nijhof, Michael Deppe, Stefan Knecht and Caterina Breitenstein
Stroke published online Jun 2, 2011;

• 12 chronic poststroke fluent aphasia patients
• Randomized, double-blind, sham-controlled crossover trial
• Anodal vs cathodal vs sham tDCS of temporo-parietal cortex
• Paired with short-term high-frequency anomia training.
• Naming outcome assessed after training and 2 weeks later
Stroke rehabilitation: paresis

Paresis

Lindenberg et al. (*Neurology*, 2010)

- 20 chronic stroke patients
- 5 consecutive sessions anodal-ipsilesional/cathodal-contralesional tDCS over M1 or sham
- Simultaneous PT/OT
- Outcome measures: changes in Upper Extremity Fugl-Meyer & Wolf Motor Function Test
- fMRI used to identify neural correlates of motor improvement
23 patients with major depressive disorder or bipolar disorder

- tDCS for 5 days, two sessions/day
- 2.0 mA x 20 min per session
- Anodal L-DLPFC, Cathodal R-DLPFC
- Measured HAM-D and MADRS scores

Three time-points: T0 (baseline), T1 (endpoint tDCS) and T2 (end of the first week of follow-up).
**Depression**

Contemporary Clinical Trials, 2011

Sertraline vs. EElectrical Current Therapy for Treating Depression Clinical Trial - SELECT TDCS: Design, rationale and objectives

Andre Russowsky Brunoni a,b,* Leandro Valiengo a,e, Alessandra Baccaro a, Tamires Araujo Zanao a,b, Janaina Farias de Oliveira a,b, Giselly Pereira Vieira a, Viviane Freire Bueno a,b, Alessandra C. Goulart a,e, Paulo Sérgio Boggio c, Paulo Andrade Lotufo a,e, Isabela Martins Bensenor a,e, Felipe Fregni b,d,*

- Enrolling 120 subjects

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Pain

Numerous recent small studies:

• **Refractory orofacial pain**
  Antal & Paulus, 2010

• **Neuropathic pain in SCI**
  Soler et al., 2010

• **Fibromyalgia**
  Mendonca et al., 2011

• **Migraine**
  Antal et al., 2011

• **Post-Procedural Pain**
  Borckardt et al., 2011

Hydromorphone use after Endoscopic Retrograde Cholangiopancreatography (ERCP) and tDCS

• 21 patients hospitalized overnight for ERCP for unexplained right upper quadrant pain.
• Cathodal tDCS over sensorimotor cortex, 20 min x 2.0 mA, immediately after ERCP.
• 22% reduction in narcotic use in first 24 hours
Converging methodologies

fMRI

- Block design: 20s tDCS on/20s tDCS off
- 1 mA anodal and cathodal stim over the left M1 at rest and during finger tapping (FT).
- No detectable BOLD signal change during rest.
- Decreased BOLD in SMA only during Anodal-FT
- Results may reflect difference between MEPs and BOLD as indicators of neural activity

Antal et al. (NeuroImage, 2011)
Converging methodologies

**EEG/ERP**

- Zaehle et al., 2011
  - 16 subjects
  - Left DLPFC/1 mA x 15 min
  - 2-back task
  - Event-related spectral pertubation
    - Anodal: $\uparrow \theta & \alpha$
    - Cathodal: $\downarrow \theta & \alpha$
Converging methodologies

**fNIRS**

Prefrontal hemodynamic changes produced by anodal direct current stimulation

Mertzagora et al. (*NeuroImage*, 2010)
Conclusions

• Despite limited spatial resolution, tDCS studies are increasingly being used for investigations of structure-function relationships in the brain.

• Owing to its ease of use and safety profile tDCS is being investigated increasingly for diseases across various disciplines that are thought to have a cortical component.

• Future studies will combine technologies to validate tDCS effects, elucidate mechanisms of brain stimulation, & provide converging methodologies to strengthen investigations.