



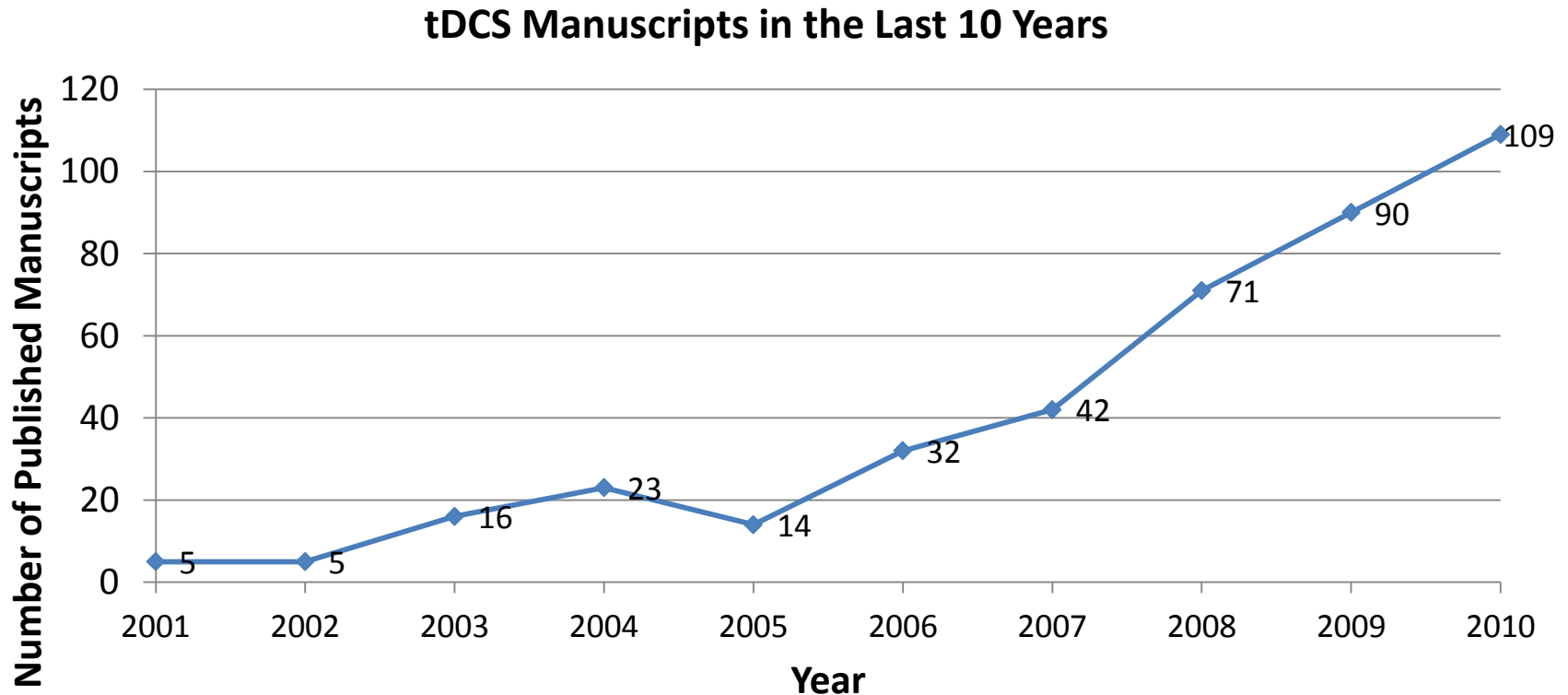
Laboratory for Cognition
and Neural Stimulation

tDCS Update: Recent Trends and Applications

Roy Hamilton, MD, MS

June 13, 2010

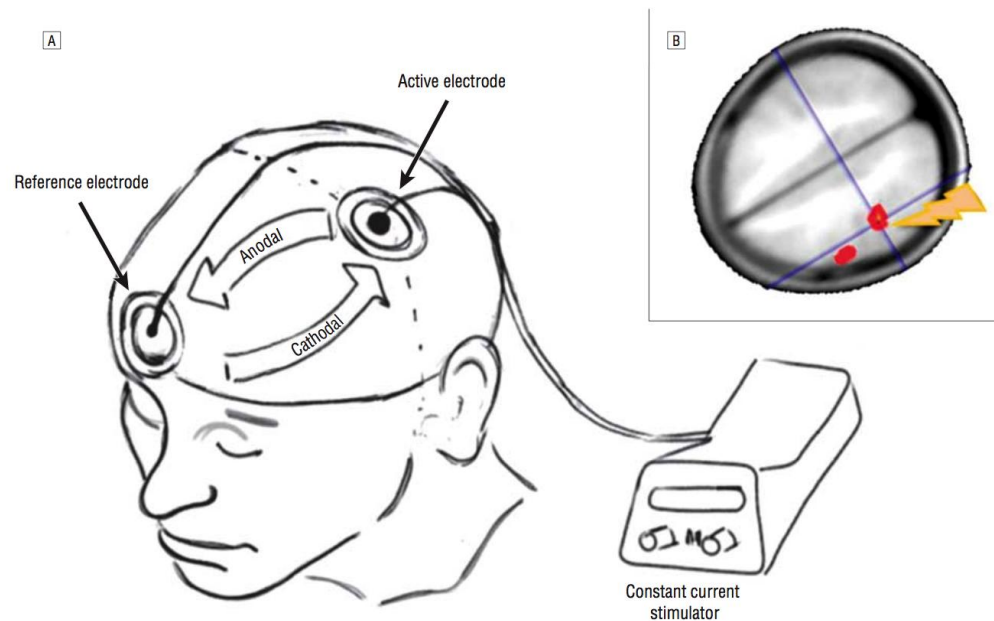
tDCS: A methodology on the move



- 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?

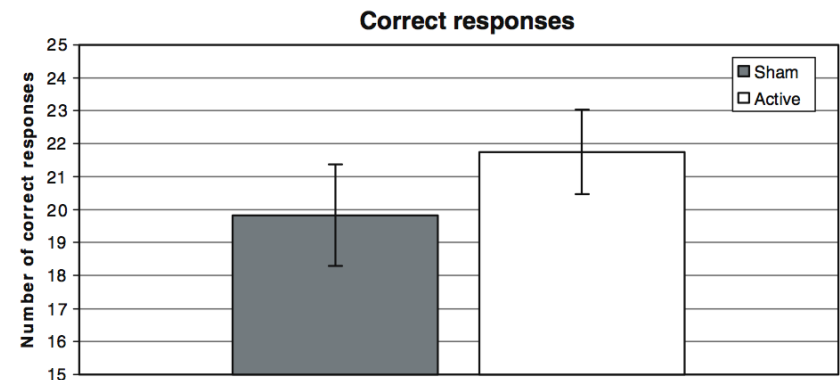
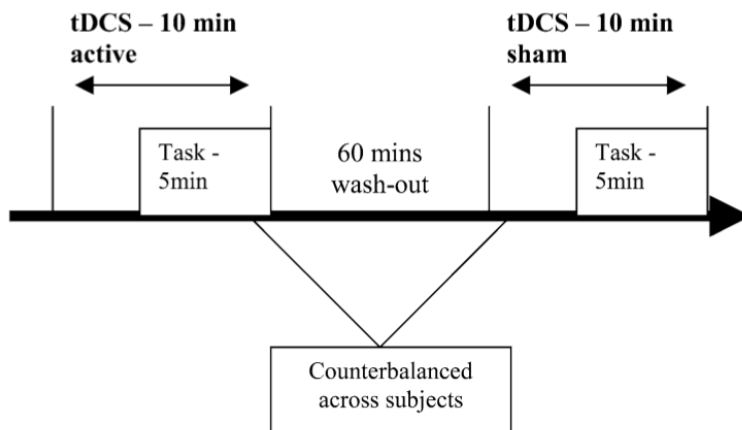
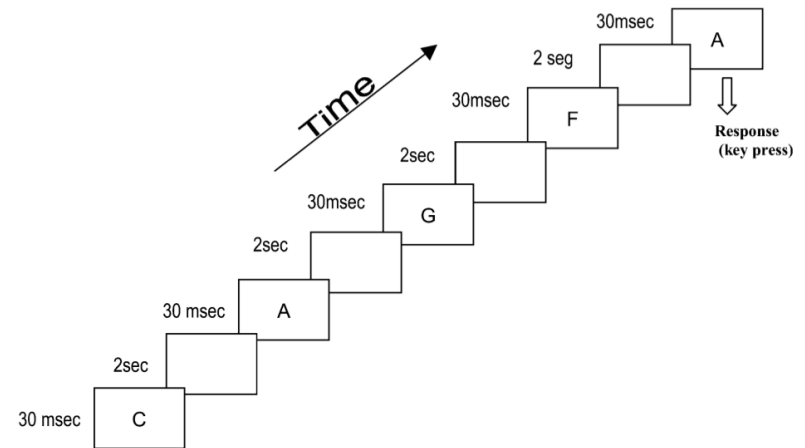
- Cognitive Neuroscience
 - Frontal lobe functions
 - Language
 - Motor learning
 - Cognitive enhancement
- Clinical Applications
 - Stroke rehabilitation
 - Depression
 - Pain



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 Lavidor^{1,3}

JOCN,
2011



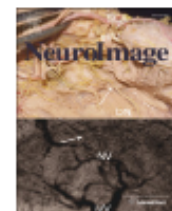
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NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

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



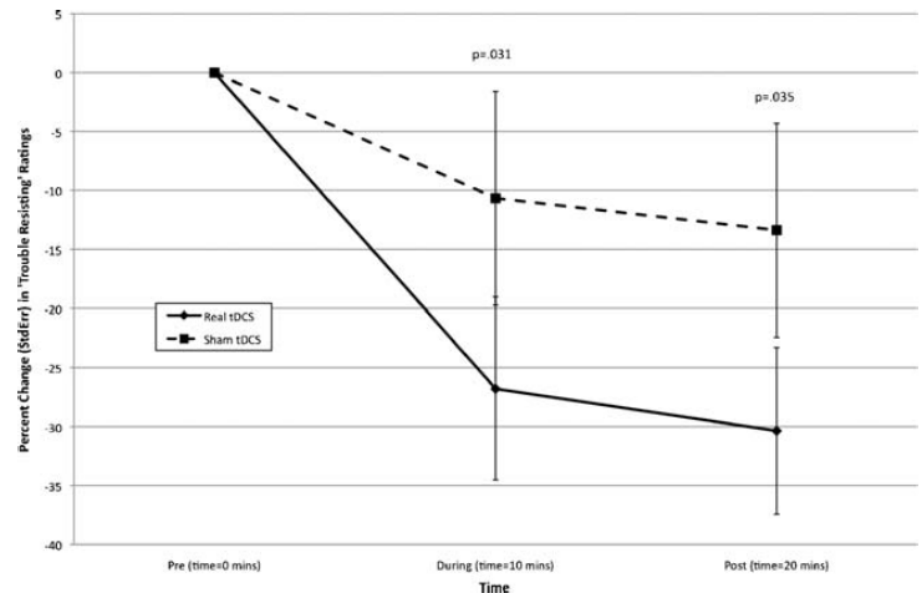
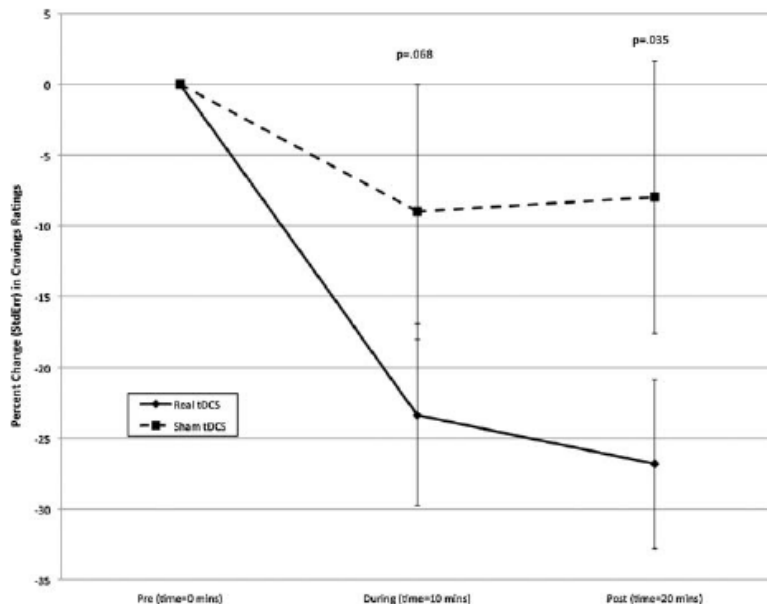
Research report

Prefrontal cortex transcranial direct current stimulation (tDCS) temporarily reduces food cravings and increases the self-reported ability to resist food in adults with frequent food craving[☆]

Rachel L. Goldman^{a,*}, Jeffrey J. Borckardt^{a,b}, Heather A. Frohman^b, Patrick M. O'Neil^a, Alok Madan^a, Laura K. Campbell^a, Amanda Budak^a, Mark S. George^{a,c,d}

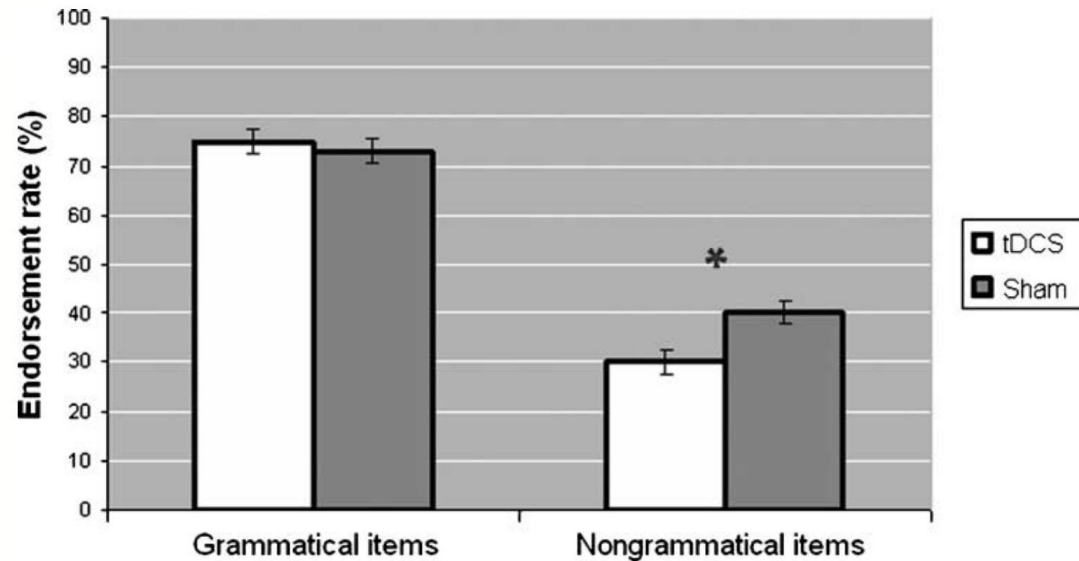
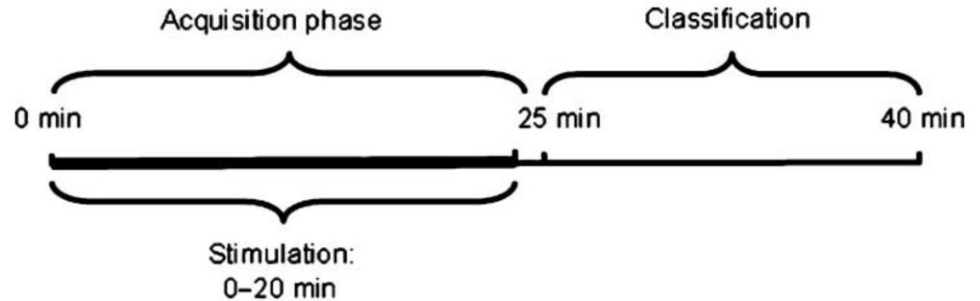
Goldman et al., 2011

- 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

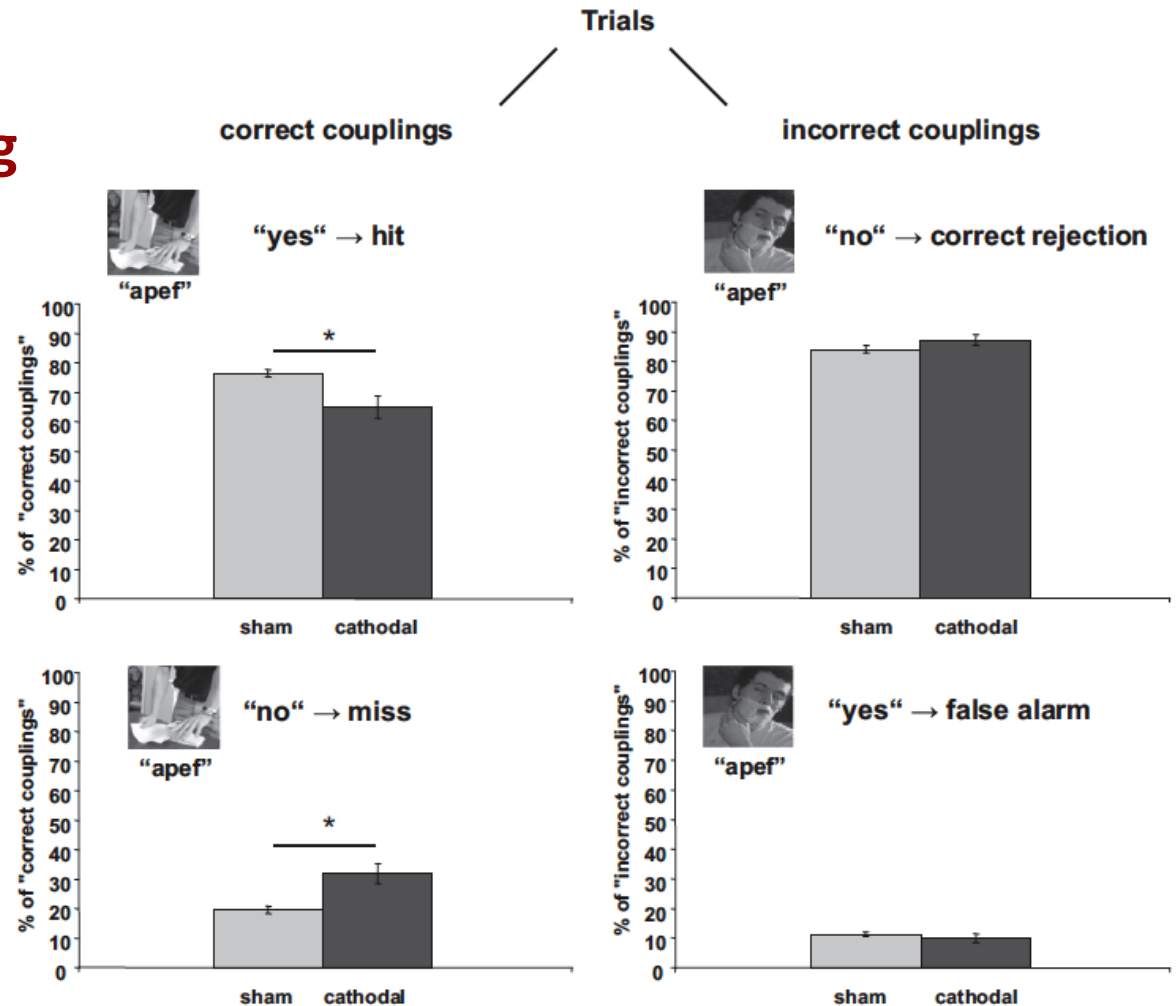
- tDCS: Faster naming (e.g. Sparing et al., 2007)
- tDCS: Improved acquisition of novel names (Flöel et al., 2009)
- tDCS: Increased verbal fluency (Iyer et al 2005)
- **tDCS: Better acquisition of grammar** (de Vries et al, 2009)



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



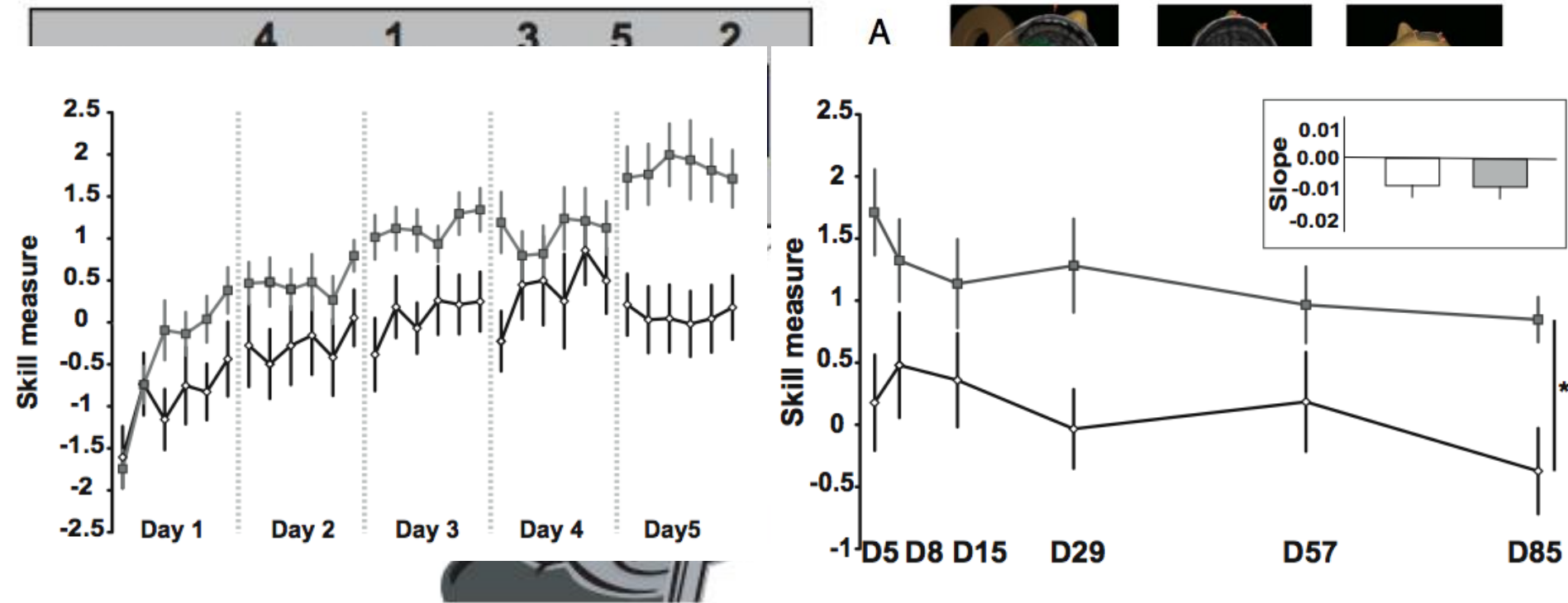
Motor learning

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

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

^aHuman Cortical Physiology Section and Stroke Neurorehabilitation Clinic, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, MD 20892; ^bDepartment of Neurology, Albert-Ludwigs-University, Freiburg 79106, Germany; ^cMotor Performance Laboratory, Department of Neurology, Columbia University College of Physicians and Surgeons, New York, NY 10032; and ^dDepartment 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)

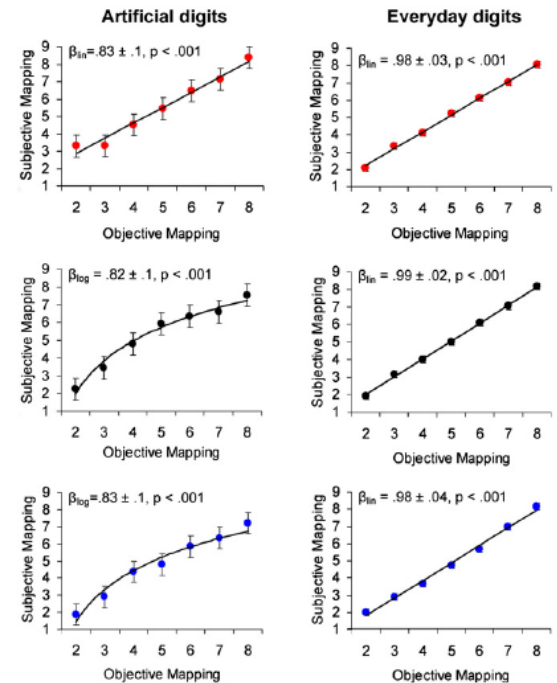
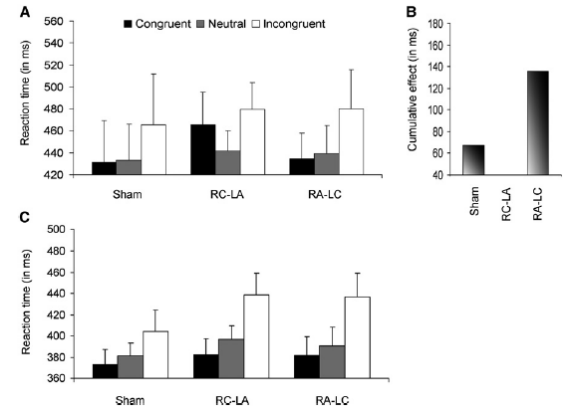
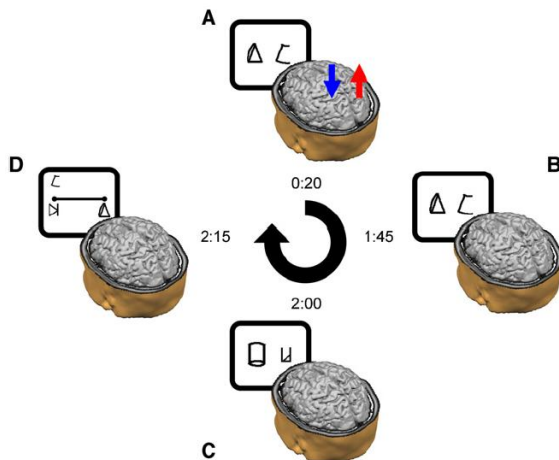


Cognitive enhancement

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




Temporal lobes and cognitive enhancement

Manipulation of semantic processing with tDCS has been linked to multiple enhancements associated with stimulation of the anterior temporal lobes.



available at www.sciencedirect.com



www.elsevier.com/locate/brainres

BRAIN RESEARCH

Research Report

Visual memory improved by non-invasive brain stimulation

Richard P. Chi^{a,b}, Felipe Fregni^b, Allan W. Snyder^{a,*}

^aCentre for the Mind, Main Quadrangle (A14), University of Sydney, NSW 2006, Australia
^bLaboratory of Neuromodulation, Spaulding Rehabilitation Hospital, Harvard Medical School, Boston, MA, USA

OPEN ACCESS Freely available online



Facilitate Insight by Non-Invasive Brain Stimulation

Richard P. Chi, Allan W. Snyder*

Centre for the Mind, University of Sydney, Sydney, Australia

Neuropsychology
2011, Vol. 25, No. 2, 185–192

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0894-4105/11/\$12.00 DOI: 10.1037/a0021102

Noninvasive Brain Stimulation Reduces Prejudice Scores on an Implicit Association Test

Jason Gallate, Cara Wong, Sophie Ellwood, Richard Chi, and Allan Snyder
University of Sydney

Stroke rehabilitation: aphasia

Patient	Immediate Posttreatment >Baseline				1 Week Posttreatment >Baseline			
	A-tDCS Treated Items	S-tDCS Treated Items	A-tDCS Untreated Items	S-tDCS Untreated Items	A-tDCS Treated Items	S-tDCS Treated Items	A-tDCS Untreated Items	S-tDCS Untreated Items
1	5	0	17	-2	8	-2	10	1
2	5	4	6	1	3	2	9	-1
3	10	10	3	-1	5	5	5	0
4	1	0	1	2	1	0	1	2
5	6	0	6	-1	6	-2	2	0
6	0	0	0	0	0	0	0	0
7	1	1	1	1	1	0	1	-1
8	2	2	2	-1	3	0	3	-1
9	3	-3	-1	2	5	2	1	6
10	3	1	5	2	3	6	10	9
Total	36	15	40	3	35	11	42	15

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

Stroke rehabilitation: aphasia

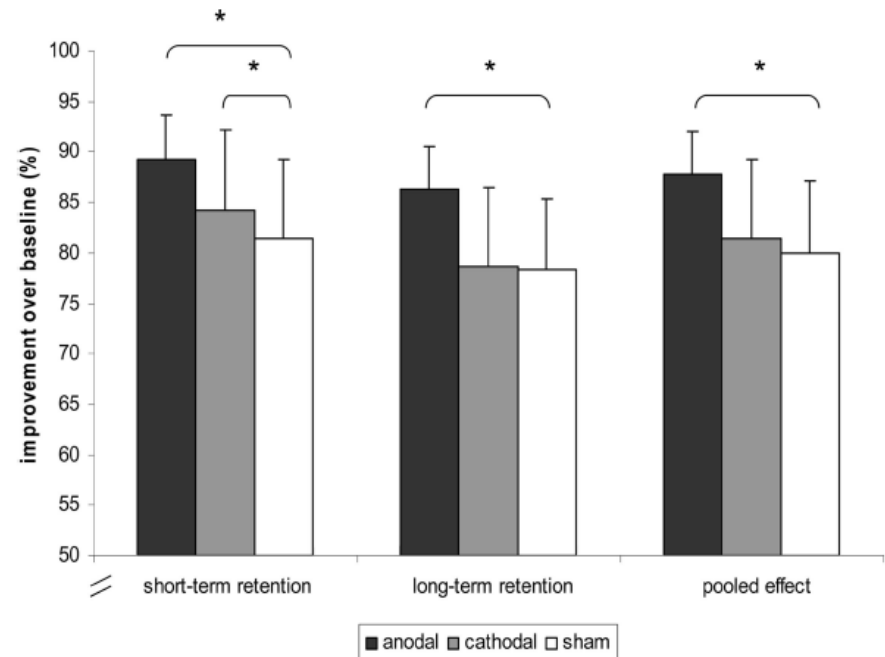
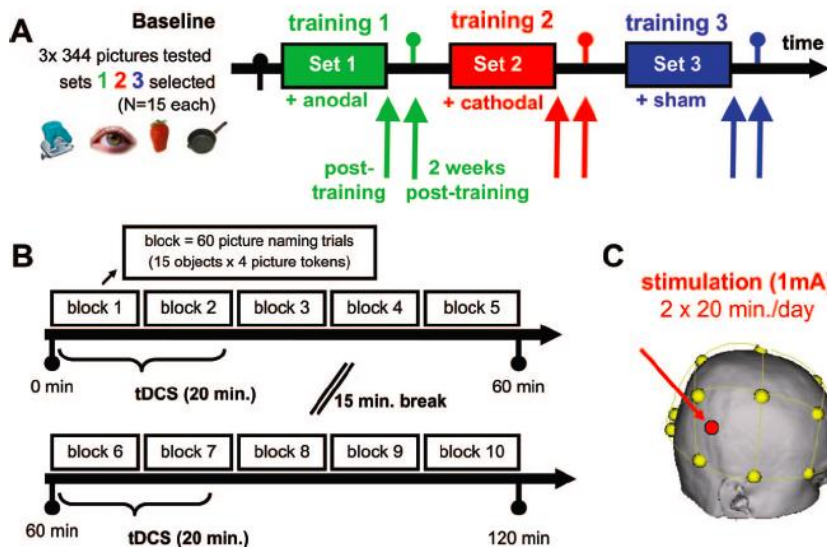
Short-Term Anomia Training and Electrical Brain Stimulation

Agnes Flöel, Marcus Meinzer, Robert Kirstein, Sarah Nijhof, Michael Deppe, Stefan Knecht and Caterina Breitenstein
Stroke published online Jun 2, 2011;

Stroke

American Stroke Association
A Division of American Heart Association

- 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

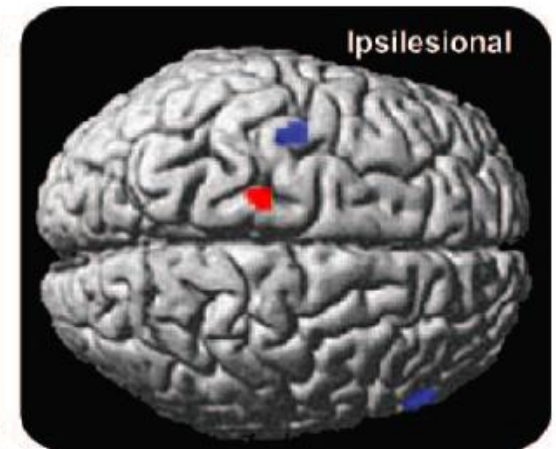
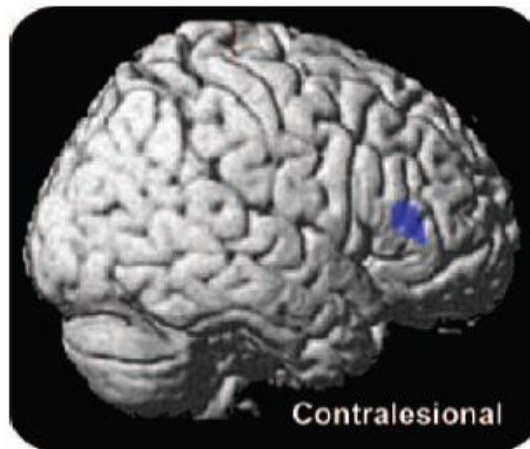
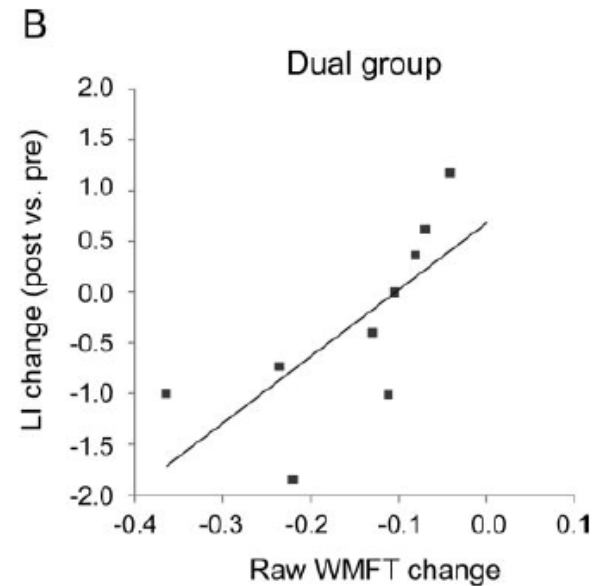
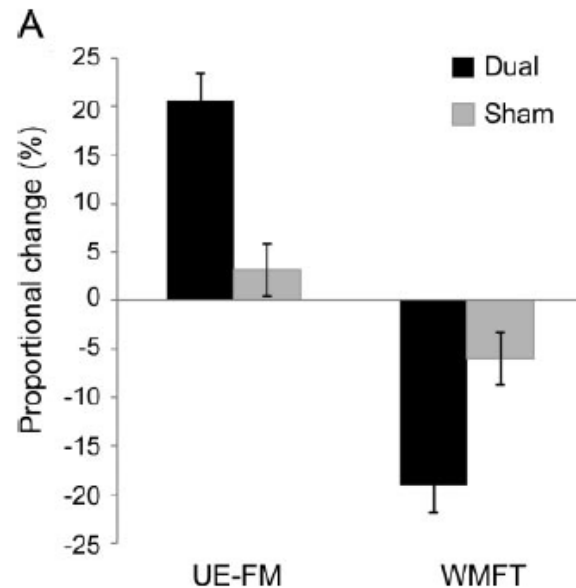


Stroke rehabilitation: paresis

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



Depression

Journal of European Psychiatry, 2011

Original article

Transcranial direct current stimulation for the outpatient treatment of poor-responder depressed patients

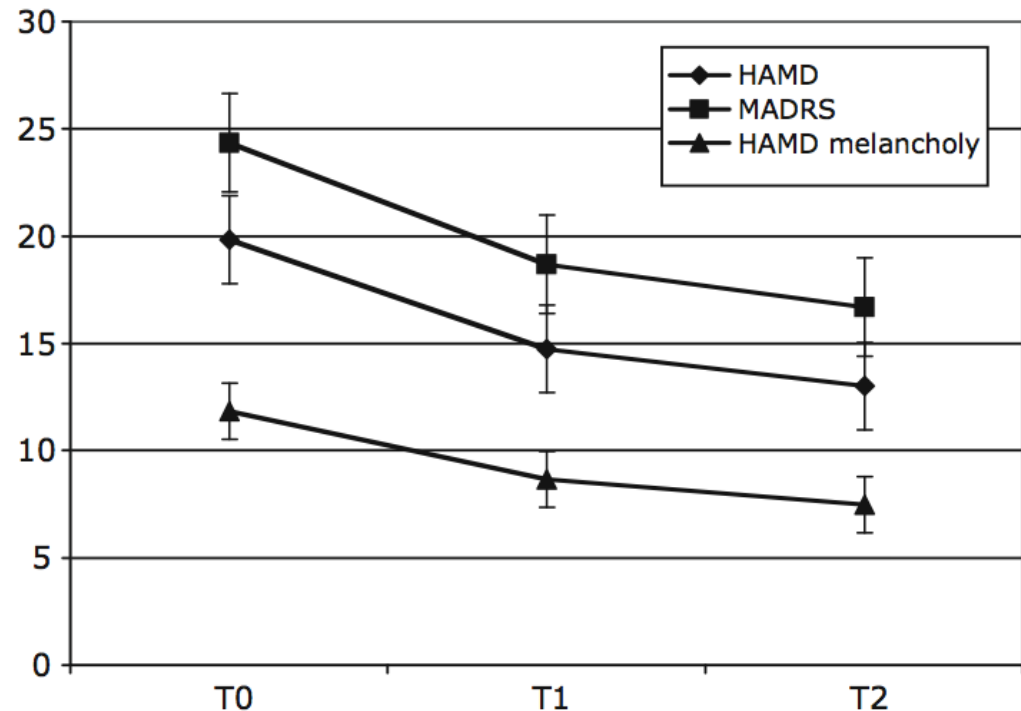
B. Dell'Osso^{a,*}, S. Zanoni^a, R. Ferrucci^{b,c}, M. Vergari^{b,c}, F. Castellano^a, N. D'Urso^a, C. Dobrea^a, B. Benatti^a, C. Arici^a, A. Priori^{b,c}, A.C. Altamura^a

^a Dipartimento di Neuroscienze, Università degli Studi di Milano, Dipartimento di Salute Mentale Fondazione IRCCS Ca' Granda, Ospedale Maggiore Policlinico, Via Francesco Sforza 35, 20122 Milano, Italy

^b Centro Clinico per le Neuroanotecnologie e la Neurostimolazione, Università degli Studi di Milano, Fondazione IRCCS Ca' Granda, Ospedale Maggiore Policlinico, Milano, Italy

^c U.O. Neurofisiopatologia, Fondazione IRCCS Ca' Granda, Ospedale Maggiore Policlinico, Milano, Italy

- 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. Electrical 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

Schedule of SELECT TDCS.

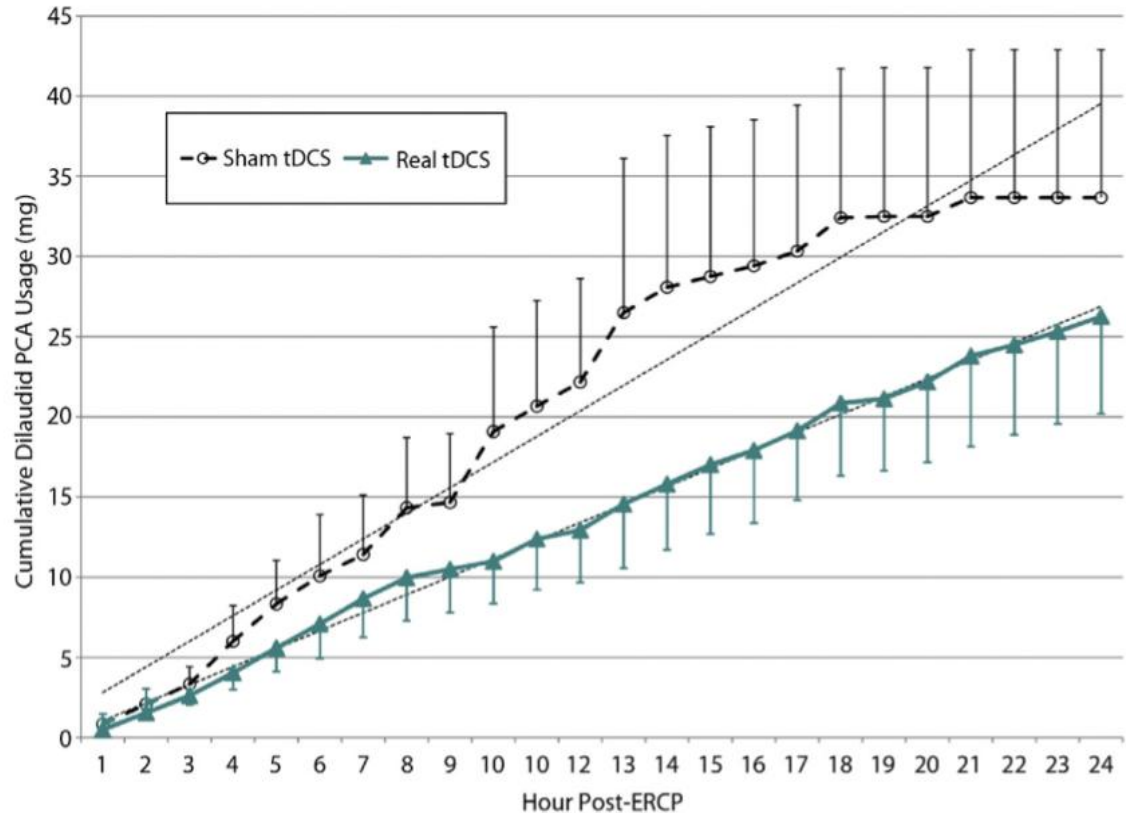
Visit	Screening visit	Baseline visit	Daily stimulation	D2	D4	Endpoint visit
Trial week	Pre-trial	Day 0	0-2 weeks	Week 2	Week 4	Week 6
Eligibility criteria	X					
Non-structured interview	X					
Drug washout	X					
Informed consent	X					
<i>Diagnostics</i>						
M.L.N.I.		X				
HDRS/MADRS		X		X	X	X
BDI/IDS		X		X	X	X
CGI - P/CGI - C		X		X	X	X
YMRS		X		X	X	X
<i>Safety</i>						
SAFTEE			X	X	X	X
tDCS questionnaire			X	X	X	X
<i>Neuropsychological evaluation</i>						
MEEM/MOCA		X				X
Stroop test		X				X
Digit span		X				X
Trail making		X				X
<i>Biological markers</i>						
BDNF polymorphism		X				
BDNF serum levels		X		X		X
HRV		X				X
<i>Procedures</i>						
Stimulation session			X	X	X	X

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

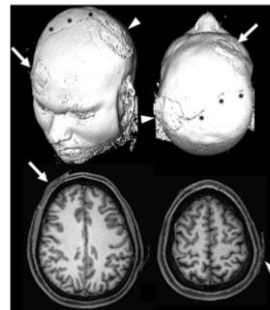
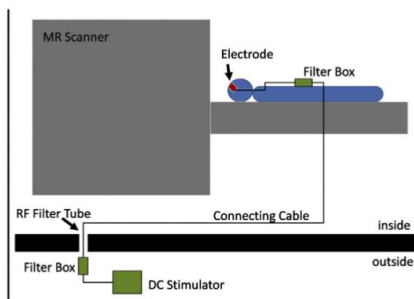


- 21 patients hospitalized overnight for ERCP for unexplained right upper quadrant pain.
- Cathodal tDCS over sensorimotor cortex, 20 min x 2.0 mA, immediately after ERCP.
- 22% reduction in narcotic use in first 24 hours

Converging methodologies

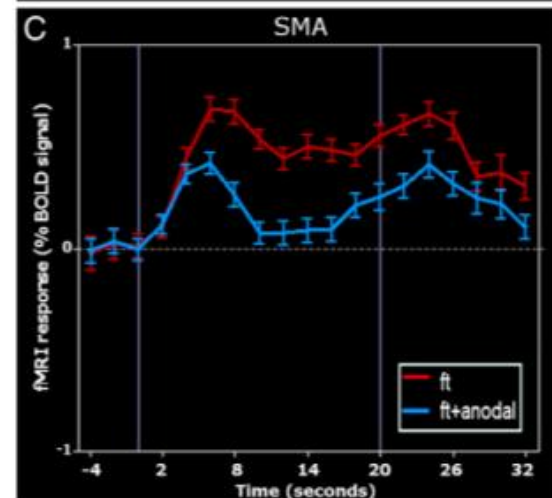
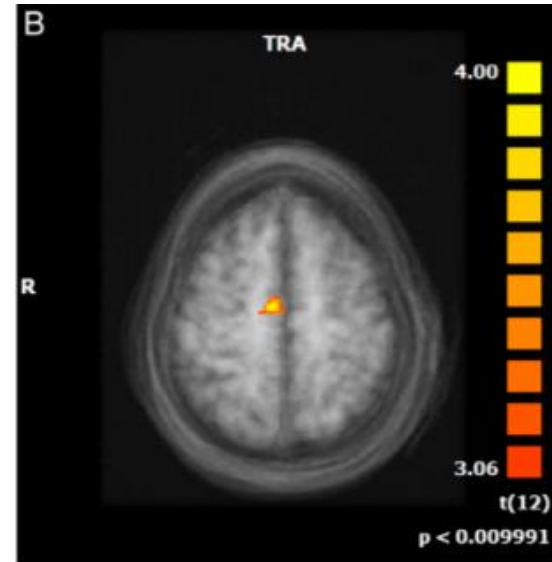
fMRI

- 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



The results of the statistical analysis with regard to the M1 stimulation.

VOIs	One-way repeated measures ANOVA			
	Stimulation only		ft + stimulation	
	F-value(1,12)	p-value	F-value(2,24)	p-value
SMA	1.6	0.21	6.77	0.005
Left M1	2.1	0.16	1.14	0.33
Left basal ganglia	1.7	0.22	1.4	0.26
Right basal ganglia	1.13	0.35	2.1	0.15

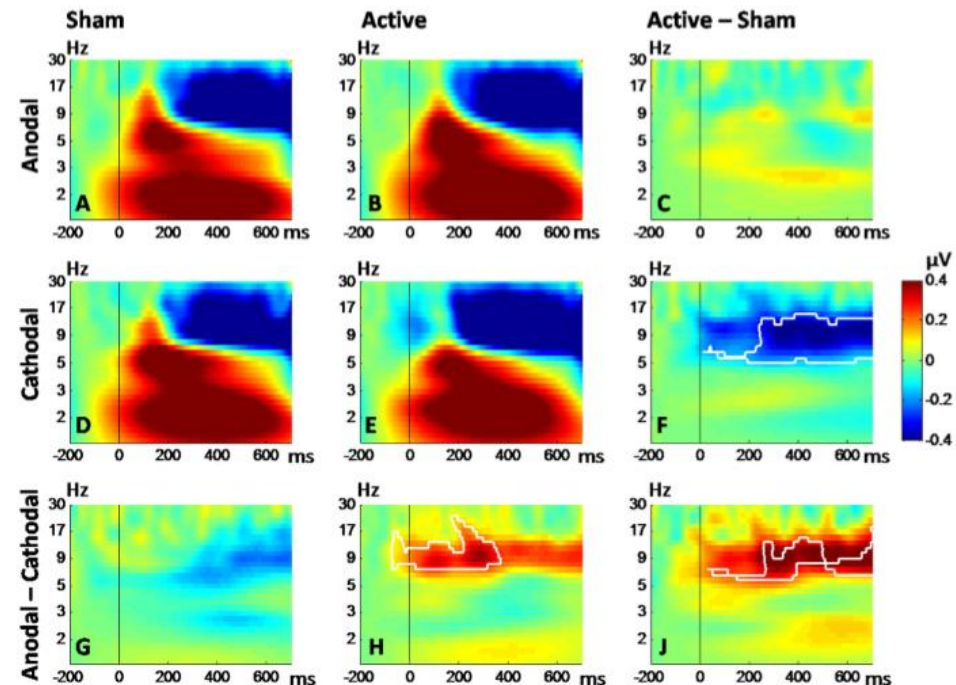
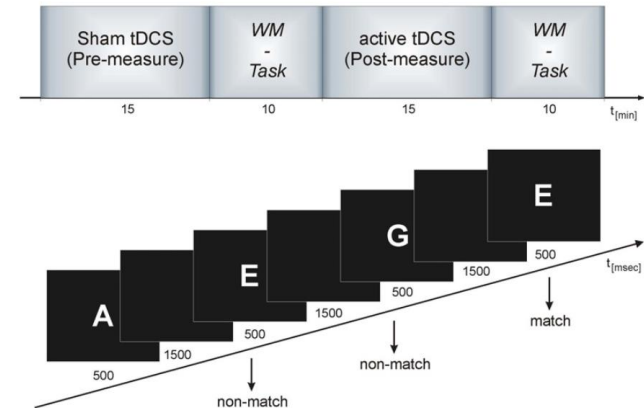
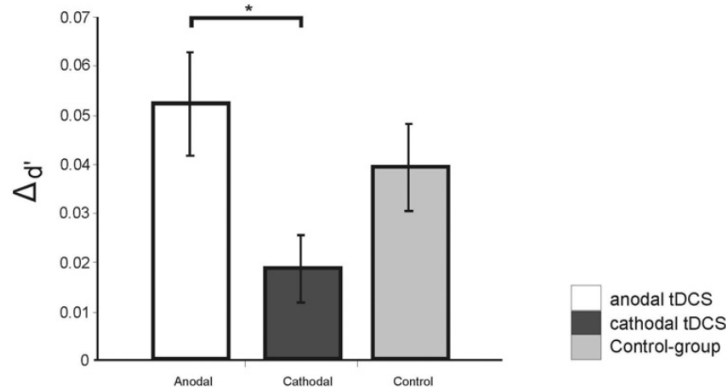


Antal et al. (*NeuroImage*, 2011)

Converging methodologies

EEG/ERP

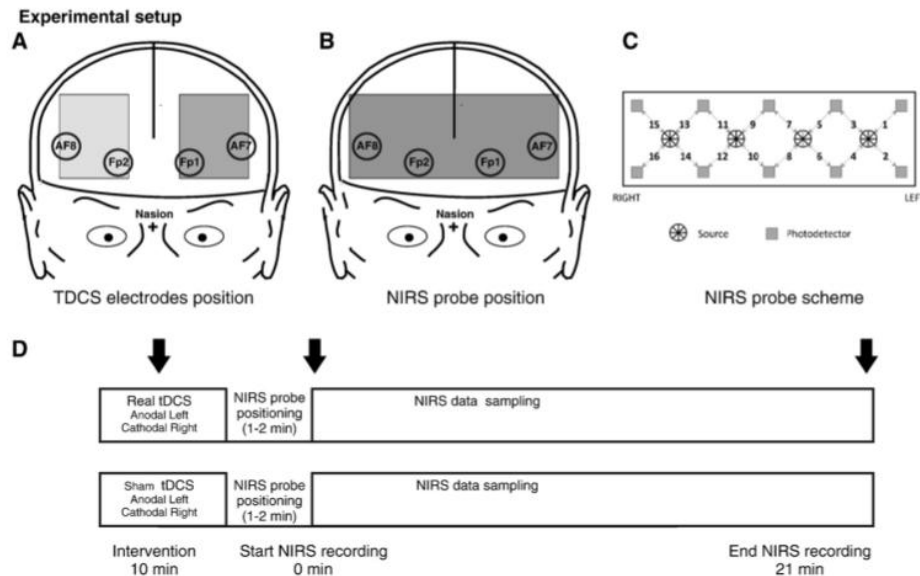
- Zaehle et al., 2011
 - 16 subjects
 - Left DLPFC/1 mA x 15 min
 - 2-back task
 - Event-related spectral perturbation
 - Anodal: \uparrow θ & α
 - Cathodal: \downarrow θ & α



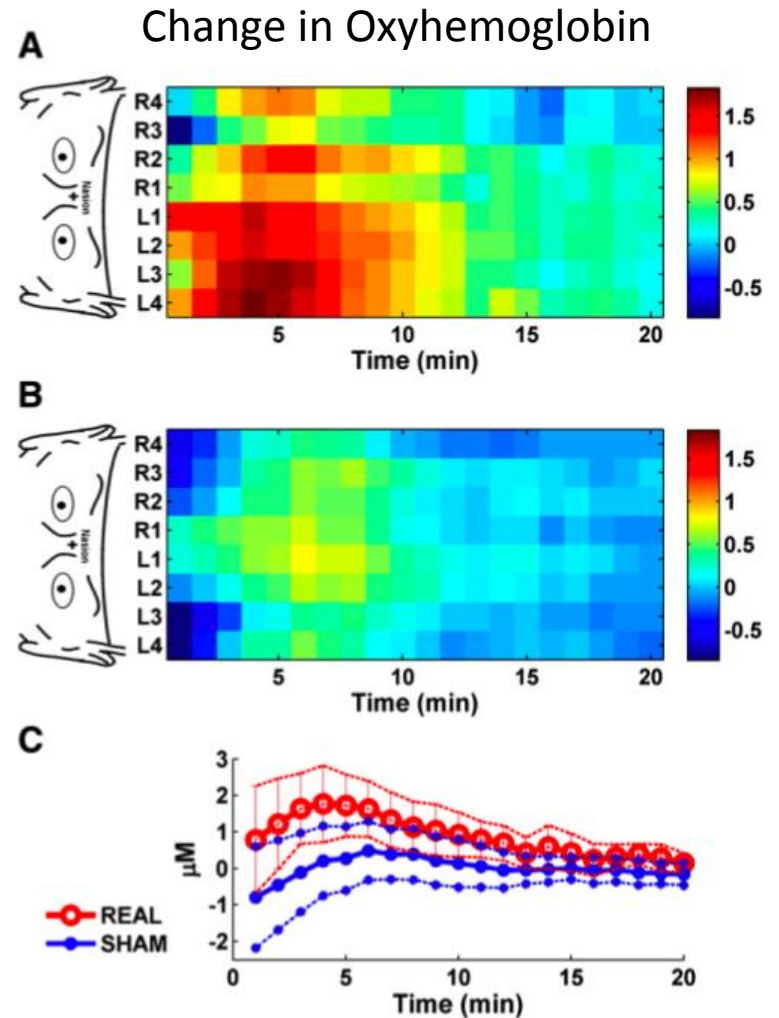
Converging methodologies

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.



