

**Intensive Course in TMS - June 2026**

**Translational value of TMS studies  
in healthy subjects into clinical populations**

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**Deputy editor royalties from Elsevier**

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**Repetitive Transcranial Magnetic Stimulation (rTMS) and transcranial Direct Current Stimulation (tDCS) over the dorsolateral Prefrontal Cortex (dlPFC) can modulate behaviours in healthy adults.**



**Impair  
(virtual lesion)**



***Can this be a concern for our patients?***



**Improve  
(neuroenhancement)**

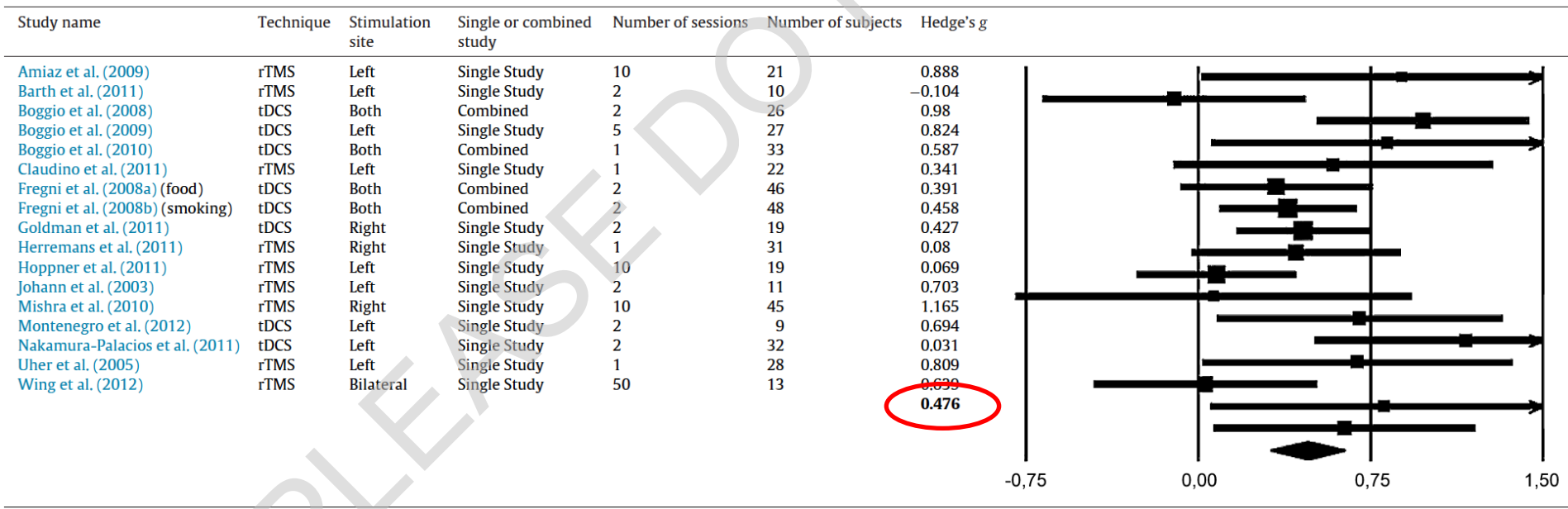
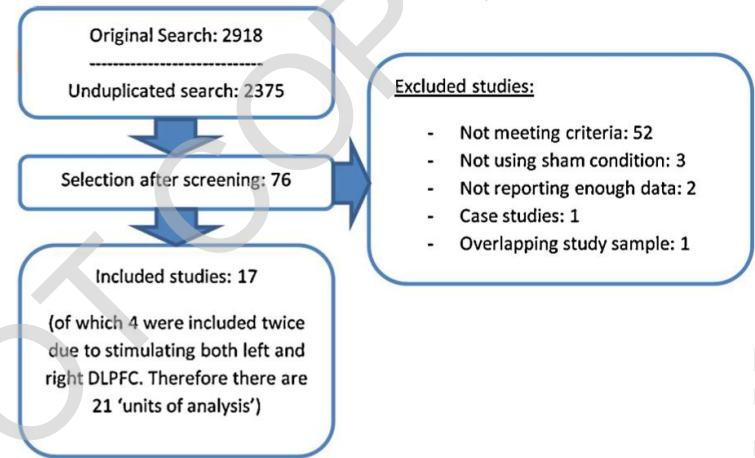


***Can this be beneficial for our patients?***

**Example with substance-related and addictive disorders.**

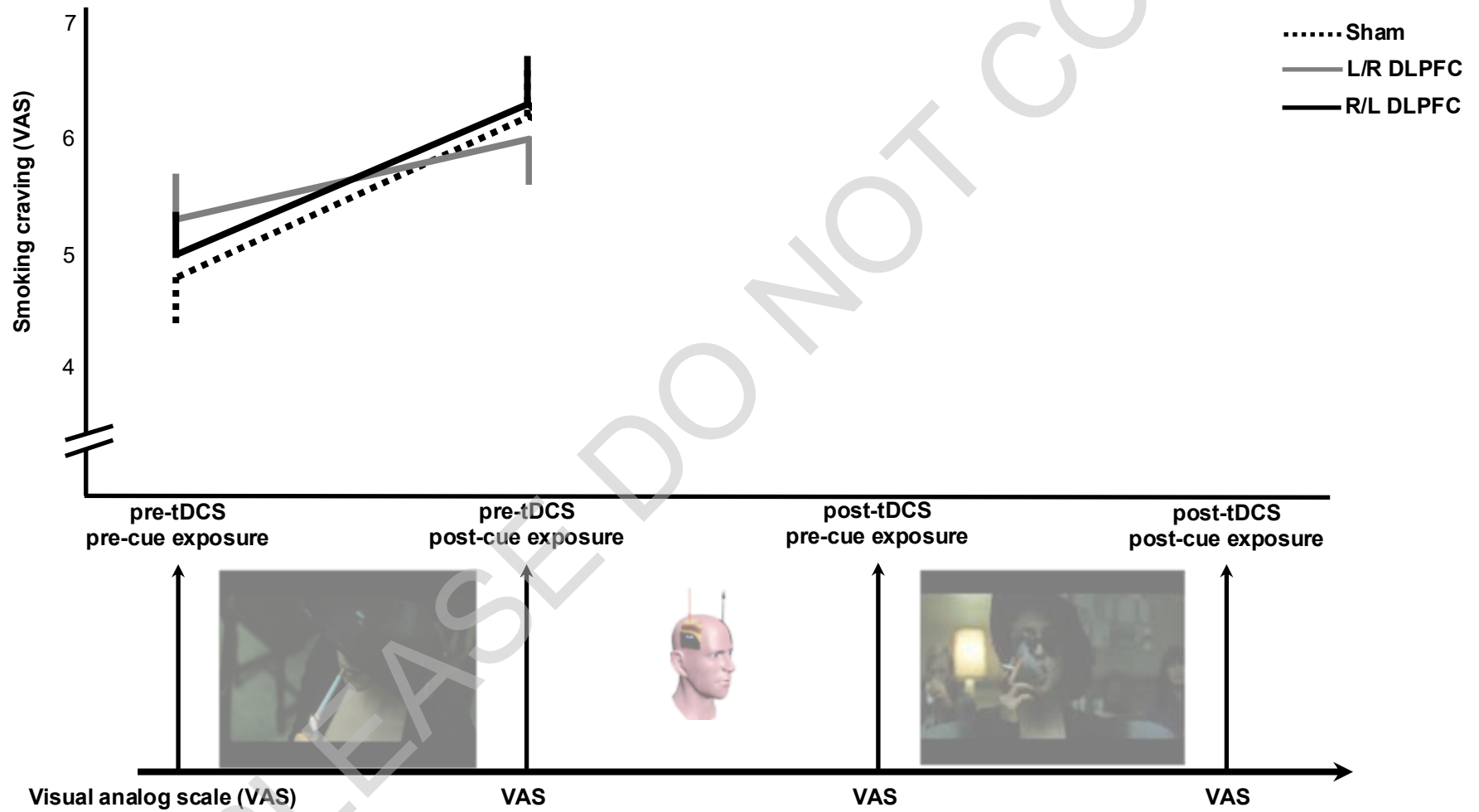
# NIBS can reduce craving for:

- Nicotine
- Alcohol
- Food
- Marijuana
- Psychostimulant



## tDCS over the dlPFC on craving in adults with Tobacco Use Disorder.

This was a 3-arm, crossover, sham controlled, blind at 3 levels (subjects, tDCS provider, outcome assessors) study with smokers receiving 3 single tDCS sessions.



## **rTMS on smoking in Tobacco Use Disorder.**

**The US FDA cleared the use of rTMS as an aid in short-term smoking cessation in adults**

- **Daily rTMS, 5 days/week, for 3 weeks, followed by 1 weekly rTMS session for 3 weeks.**
- **Each 10Hz rTMS session is preceded by a 5-min provocation procedure to induce craving.**
- **Each rTMS session is followed by a 2-min motivational language to encourage smoking cessation.**

# Individual sham-controlled rTMS trials on smoking and craving.

	Primary outcomes of smoking	Craving
Amiaz et al. 2009	↓ reduction cig/d	↓
Dinur-Klein et al. 2014	↓ reduction cig/d, cotinine	↓
Li et al. 2020	↓ 2-d abstinence cig/d, CO, cotinine	↓
Zangen et al. 2021	↓ 4-wk abstinence cig/d, cotinine	↓
Abdelraham et al. 2021	↓ reduction cia/d	↓
Eichhammer et al. 2003	↓ reduction cig ad libitum	n.s.
Sheffer et al. 2019	↓ continuous abstinence cig/d, CO	n.s.
Ibrahim et al. 2023	↓ 7-d abstinence cig/d, cotinine	n.s.
Trojak et al. 2015	↓ continuous abstinence cig/d, CO	n.s.
Dieler et al. 2014	↓ continuous abstinence	n.s.
Lechner et al. 2022	n.s. delay to smoking analog task	n.s.
Addicott et al. 2024	n.s. 7-d abstinence cotinine	n.s.
Bellini et al. 2024	n.s. 2-wk abstinence cig/d, CO, cotinine	n.s.

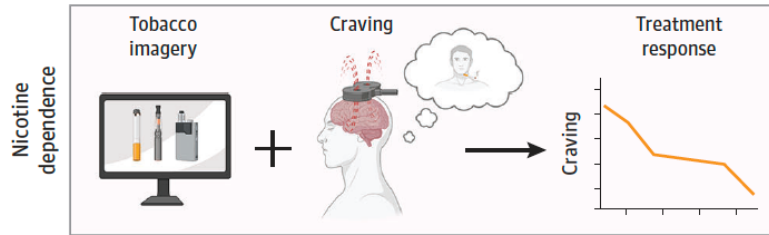
When NIBS reduces smoking, it does not always reduce craving.



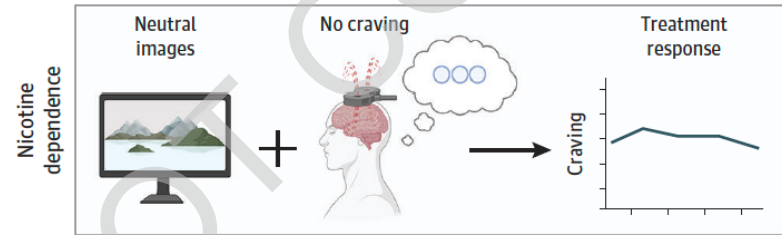
# Should NIBS be combined with symptom provocation?

Figure 1. Model of Hypothesized Effects of Symptom Provocation on Clinical Response to Transcranial Magnetic Stimulation (TMS)

**A** rTMS with symptom provocation



**B** rTMS without symptom provocation



**rTMS for nicotine dependence:**

There was no statistical difference in effect size between rTMS with and without symptom provocation (95%CI, -1.00 to 0.58;  $p = .57$ ).

(similar result for OCD)

# When NIBS reduces smoking, what does it modulate if it is not craving?

	smoking	craving	rTMS protocol		
			N sessions	Hz	coil site
Li et al. 2020	↓	↓	10	10	l dIPFC

**10 sessions of 10Hz rTMS over the left dIPFC of adults with tobacco use disorder:**

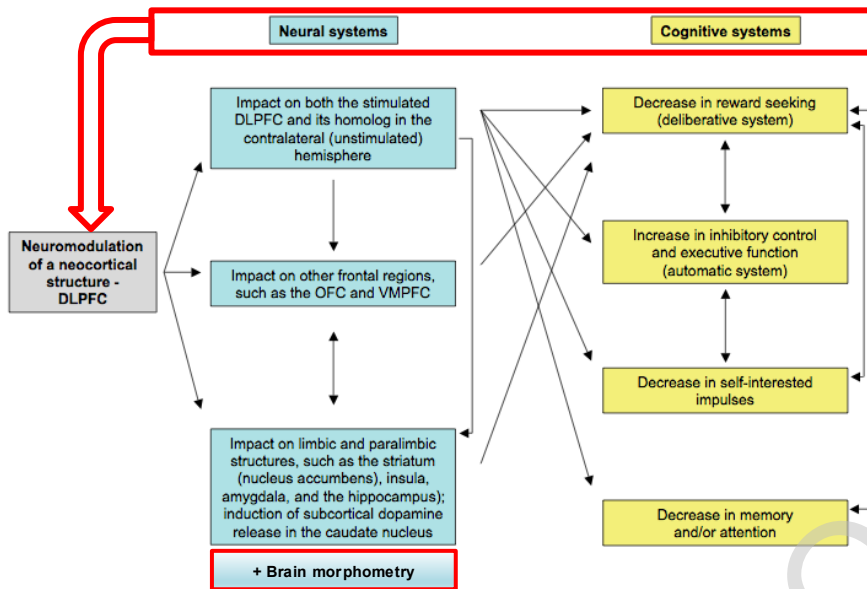
- **Quitting smoking:**  
lower connectivity between the dorsal anterior cingulate cortex (dACC) and medial orbitofrontal cortex
- **Reduced cigarette consumption:**  
increased activity in the dACC
- **Craving:**  
no changes in functional connectivity
- **Impact of rTMS on the balance between drive-reward and executive control?**

1. Noninvasive brain stimulation (NIBS) to treat substance-related and addictive disorders (SRAD).

**2. Effects of NIBS when applied over the dlPFC on cognitive functions and their translational values in individuals with SRAD.**

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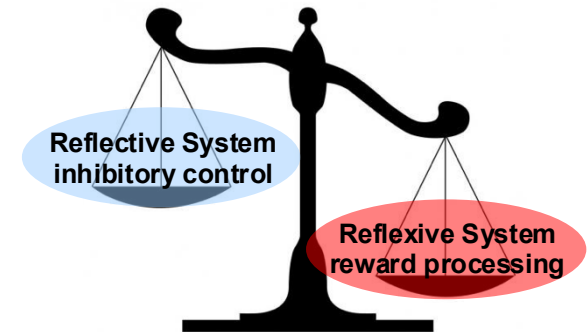
# What do we modulate when we apply NIBS over the dlPFC?



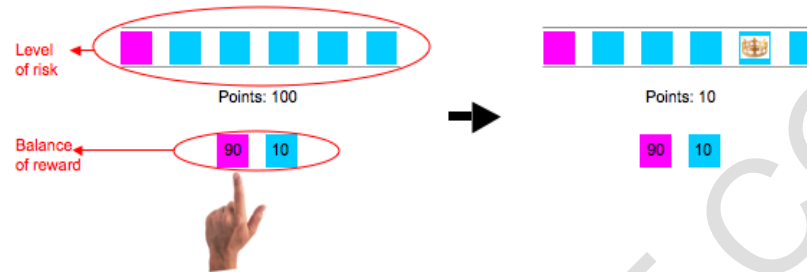
There are several ways to induce cognitive and clinical benefits, and they are not mutually exclusive.

Risky decision-making, a characteristic behavioural phenotype in addictions:

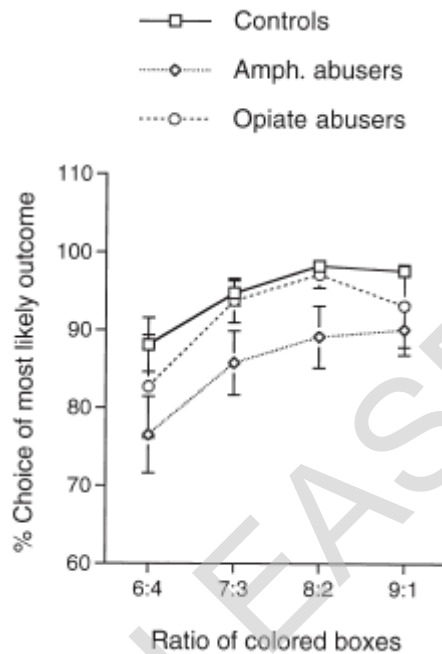
- risk taking;
- reward seeking;
- impulsivity;
- delayed gratification;
- attention.



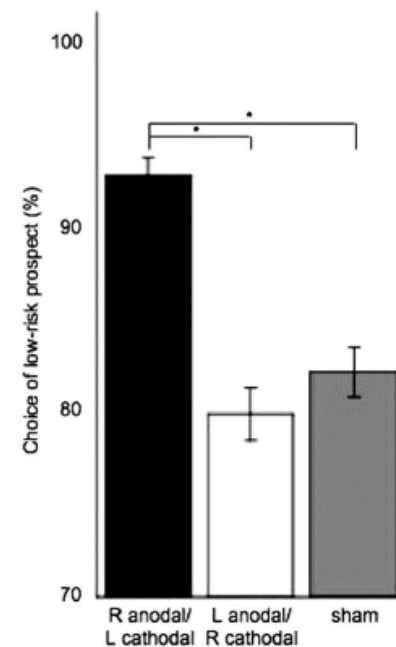
# Risk taking, reward seeking



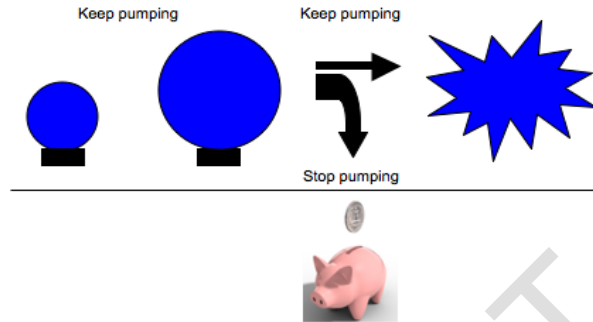
**Patients with substance use disorders take greater risk at the Risk Task.**



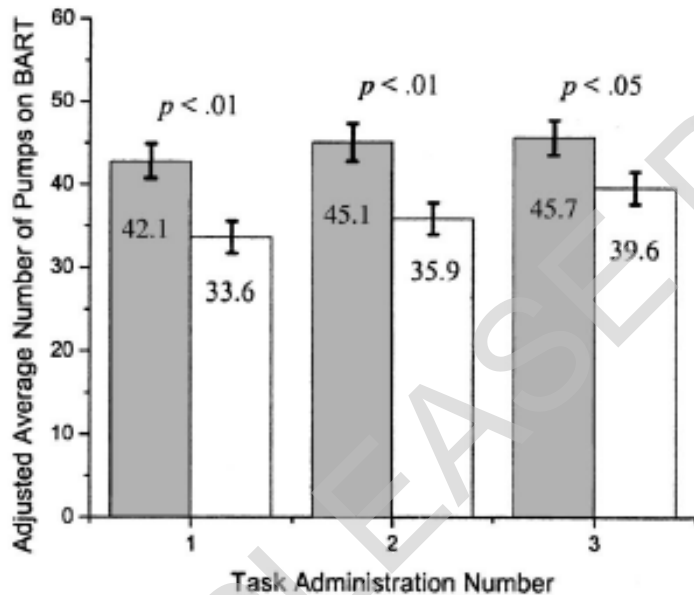
**tDCS over the DLPFC can decrease risk taking and reward seeking at the Risk Task.**



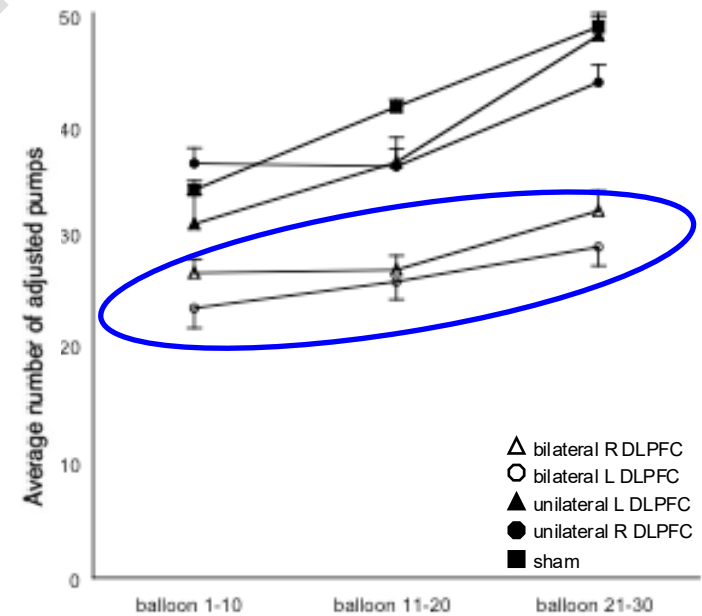
# Risk taking, reward seeking



Patients with tobacco use disorders take greater risk at the BART.



tDCS over the dlPFC can decrease risk taking at the BART task.



Lejuez, Aklin, Jones, Richards, Strong, Kahler, Read, *Exp Clin Psychopharmacol* 2003.

Fecteau, Pascual-Leone, Zald, Liguori, Theoret, Boggio, Fregni, *J Neurosci* 2007b.

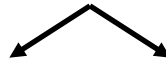
# Self-interest



Ultimatum Game

If you accept :  
The proposer gets \$8 and you get \$2

The proposer has \$10 and offers you \$2



If you reject :  
The proposer gets \$0 and you get \$0

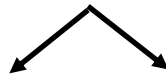
**Smokers (and nonsmokers) reject most of the time unfair offers of money at the Ultimatum Game.**



Ultimatum Game

If you accept :  
The proposer gets 8 and you get 2 cigarettes

The proposer has 10 cigarettes and offers you 2 cigarettes

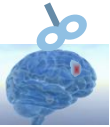
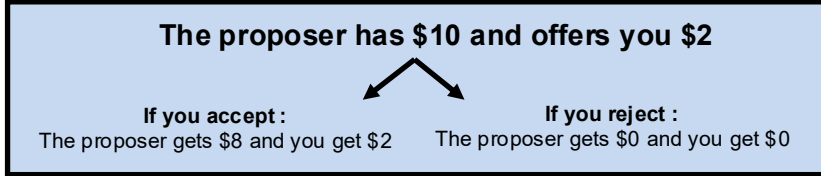


If you reject :  
The proposer gets 0 and you get 0 cigarette

**Smokers accept most of the time unfair offers of cigarette.**

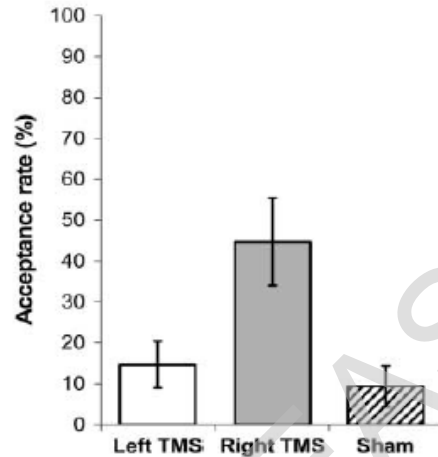
# Self-interest

## The Ultimatum Game

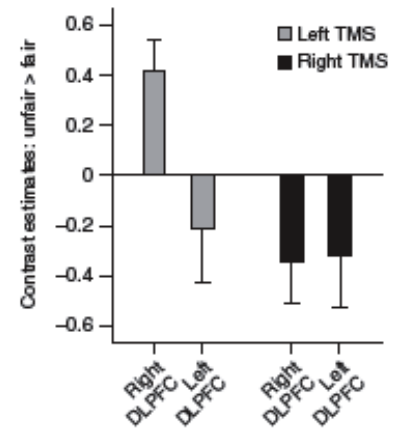
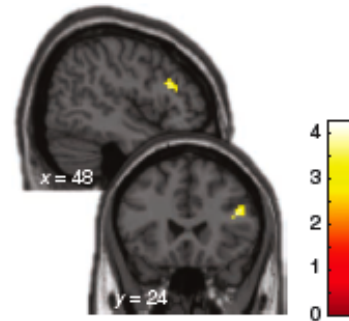


1Hz rTMS over the R dIPFC

Accepted more often unfair offers

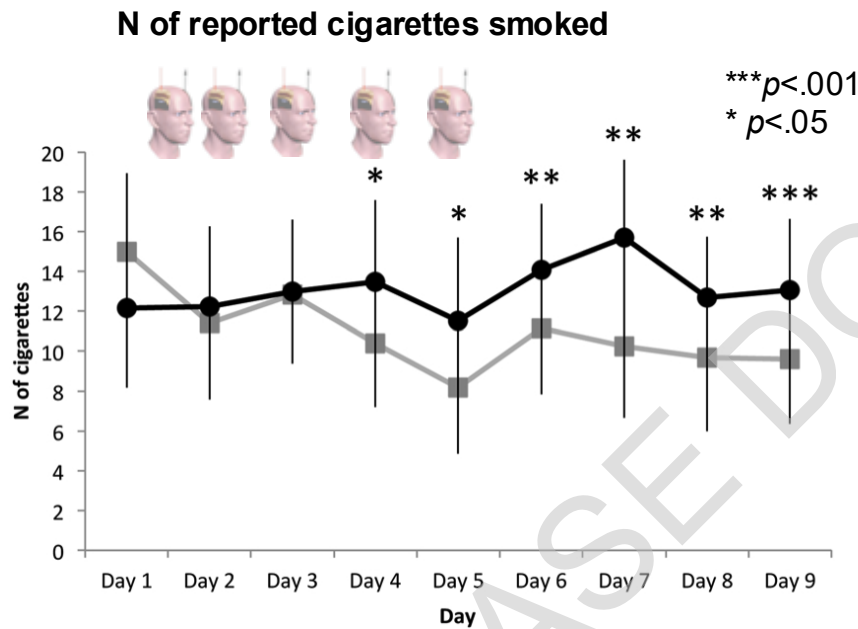


Elicited activity in both dIPFCs when contrasting unfair > fair offers

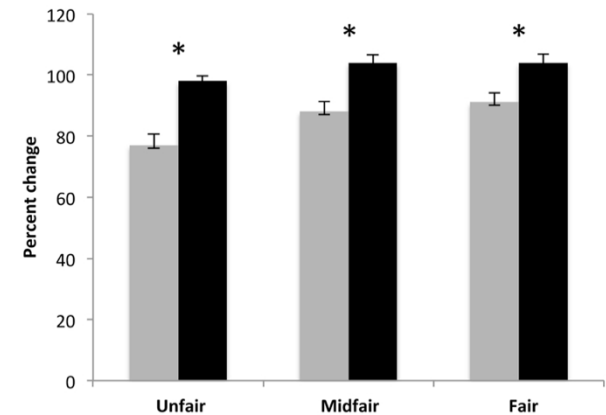


# Self-interest, smoking

This was a 2-arm, crossover, sham controlled, blind at 3 levels (subjects, tDCS provider, outcome assessors) study with smokers receiving two 5-day tDCS regimens (real, sham).



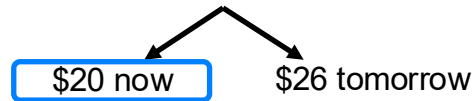
**Ultimatum Game**



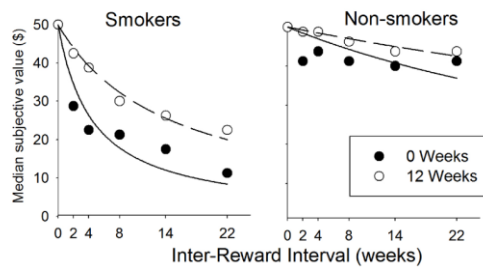
- Real tDCS (anode and cathode over the R and L DLFPC)
- Sham tDCS (anode and cathode over the R and L DLFPC)

# Impulsivity, delayed gratification, craving

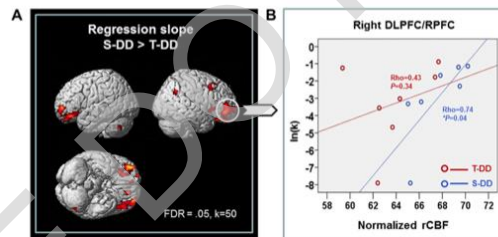
Would you prefer to receive:



Smokers choose more often the smaller, immediate offer of money

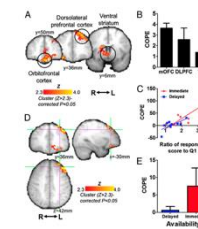


cTBS over the R dIPFC in healthy subjects

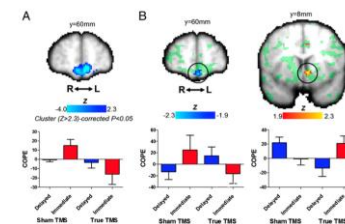


1Hz rTMS over the L dIPFC in smokers

Delayed gratification



Decreased craving



1. Noninvasive brain stimulation (NIBS) to treat substance-related and addictive disorders (SRAD).

2. Effects of NIBS when applied over the dlPFC on cognitive functions and their translational values in individuals with SRAD.

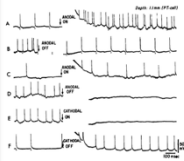
**3. Effects of NIBS when applied over the dlPFC on brain substrates. Let's not go back to a century ago.**

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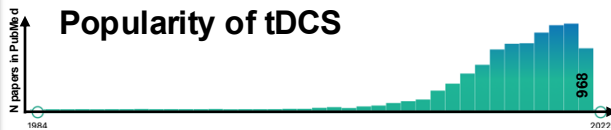
# A lesson from history? Do we reach the cortex?



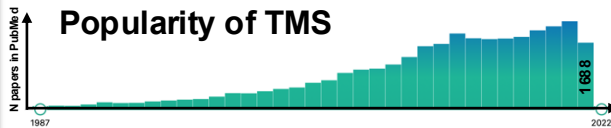
- More than a century ago... There were some behavioral changes, but the effects were unreliable.
- The current was presumably not going through the brain.



- If applied to the brain, current can modulate brain activity (Purpura & McMurtry, 1964).
- Thus, with appropriate stimulation parameters, behavioral changes should be due to brain modulation and should be replicable.



- Ruff et al. 2013 Changing social norm compliance with noninvasive brain stimulation. *Science*
- Brunoni et al. 2017 Trial of electrical direct-current therapy versus escitalopram for depression. *N Engl J Med*



- Yesavage et al. 2018 Effect of rTMS on treatment-resistant major depression in US veterans: a randomized clinical trial. *JAMA Psychiatry*
- Romero et al. 2019 Neural effect of TMS at the single-cell level. *Nat Commun*

## - Negative findings: a lesson from history?

### tDCS:

- Tremblay et al. 2014 The uncertain outcome of prefrontal tDCS. *Brain Stimul*
- Horvath et al. 2015 Quantitative review finds no evidence of cognitive effects in healthy populations from single-session tDCS. *Brain Stimul*
- Horvath et al. 2016 No significant effects in tDCS found on simple motor reaction time comparing 15 different stimulation protocols. *Neuropsychologia*

### rTMS:

- Novak et al. 2006 The double-blind sham-controlled study of high-frequency rTMS (20 Hz) for negative symptoms in schizophrenia: negative results. *Neuro Endocrinol Lett*
- Slotema et al. 2011 Can rTMS really relieve medication-resistant auditory verbal hallucinations? Negative results from a large randomized controlled trial. *Biol Psychiatry*
- Paz et al. 2018 Randomised sham-controlled study of high-frequency bilateral dTMS to treat adult ADHD: negative results. *World J Biol Psychiatry*

... and this is considering publication bias of positive findings.

- In order to move forward, we need to deepen mechanistic knowledge to induce reliable and replicable effects.

# Sham-controlled rTMS and tDCS trials on substance use and craving.

## Alcohol use disorder (AUD)

rTMS	Drinking	Craving
Addolorato et al. 2017	↓	n.s.
Perini et al. 2020	n.s.	n.s.
Harel et al. 2022	↓	↓
McCalley et al. 2022	n.s.	↓
Zhang et al. 2022	↓	↓
Hoven et al. 2023	n.s.	n.s.
Selim et al. 2024	↓	↓

tDCS	Drinking	Craving
Claus et al. 2019	n.s.	n.s.
Witikiewitz et al. 2019	n.s.	n.s.
Holla et al. 2020	↓	n.s.
Dubuson et al. 2021	↓	n.s.
Camchong et al. 2023	↓	n.s.
Dayal et al. 2024	n.s.	n.s.

## Cocaine use disorder (CUD)

rTMS	Use	Craving
Bolloni et al. 2016	n.s.	
Martinez et al. 2018	↓	n.s.
Lolli et al. 2021	n.s.	↓
Garza-Villarreal et al. 2021	n.s.	↓
Martinotti et al. 2022	n.s.	n.s.
McCalley et al. 2024	n.s.	↓

tDCS	Use	Craving
Verveer et al. 2020	n.s.	n.s.
Gaudreault et al. 2022	n.s.	n.s.
Verveer et al. 2022	n.s.	n.s.

**What do we know about brain morphometry of these patients?**

Reduced gray matter volume in the frontal cortex (including the prefrontal cortex) and insula in AUD<sup>1</sup> and CUD.<sup>2</sup>

<sup>1</sup> Spindler, Trautmann, Alexander, Broning, Bartscher, Stuppe, Muellhan, Sci Rep 2021; Yang, Tian, Zhang, Zeng, Chen, Wang, Jia, Gong, *Neurosci Biobehav Rev* 2016.

<sup>2</sup> Poireau, Segobin, Maillard, Clergue-Duval, Icick, Azuar, Volle, Delmaire, Bloch, Pitel, Vorspan, *Psychiatry Res Neuroimaging* 2024.

**Let's start with the "simplest" question...:**

**Do we reach the cortex?**

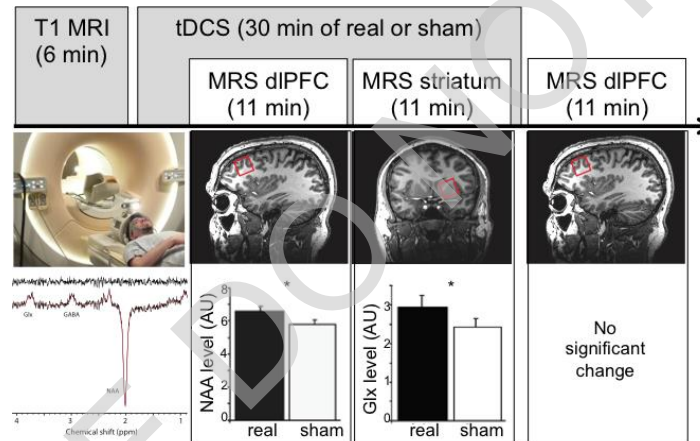
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# Can NIBS reach the cortex?

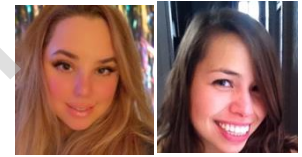


Concurrent tDCS-MRI, sham controlled, blind at 3 levels studies to identify the neural effects of tDCS in healthy adults.

## Concurrent tDCS-MRSI

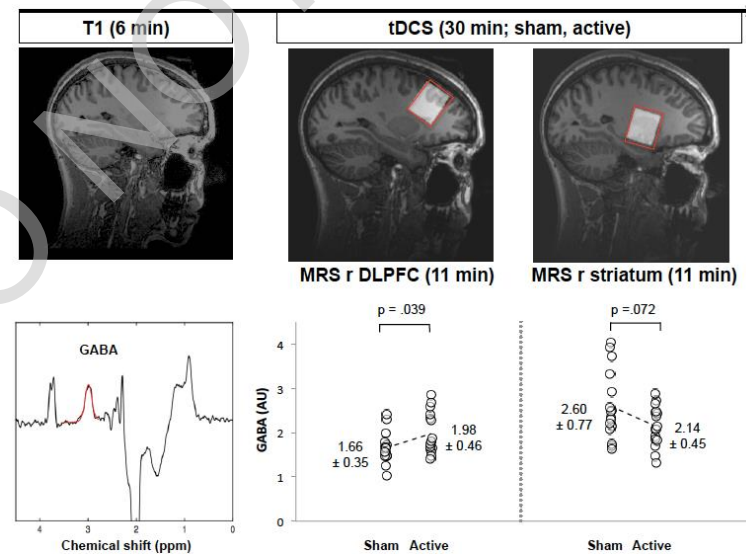
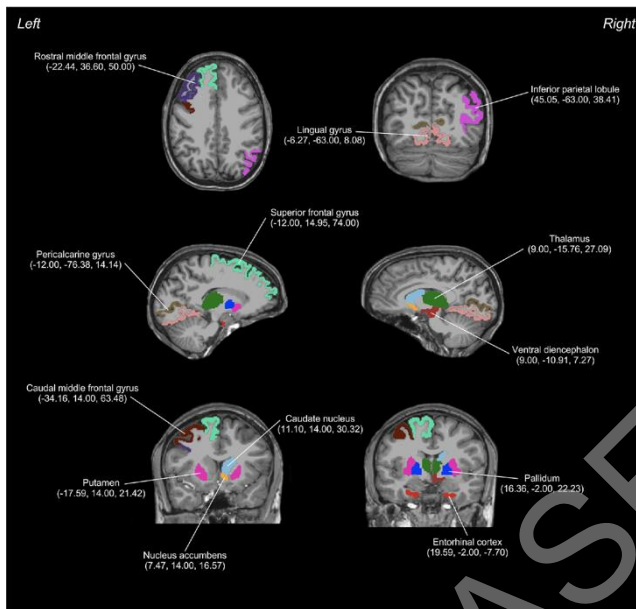


# Can NIBS modulate neurotransmitter levels of adults with gambling disorder?



Adults with gambling disorders compared to healthy controls displayed smaller volume of the left DIPFC<sup>1</sup>.

Concurrent tDCS-MRI, sham controlled, blind at 3 levels studies to identify the neural effects of tDCS applied over the DIPFC<sup>2</sup>.

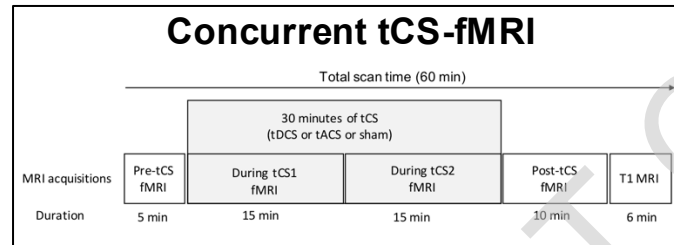
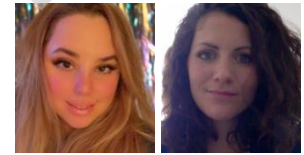


Potential intervention targeting the GABAergic system?

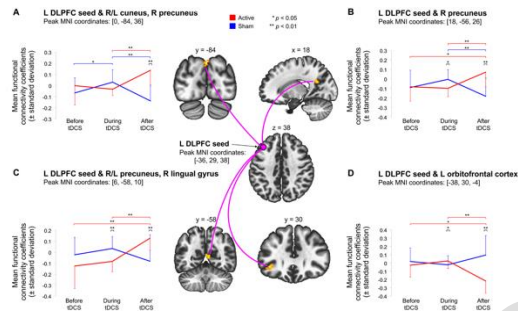
<sup>1</sup>Bouchard, Dickler, Renaud, Lenglos, Ferland, Rouillard, Leblond, Fecteau. *J Psychiatr Res* 2021.

<sup>2</sup>Dickler, Lenglos, Renaud, Ferland, Edden, Leblond, Fecteau, *Neuropharmacology* 2018.

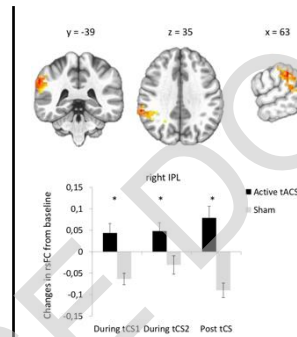
# Can NIBS modulate functional connectivity?



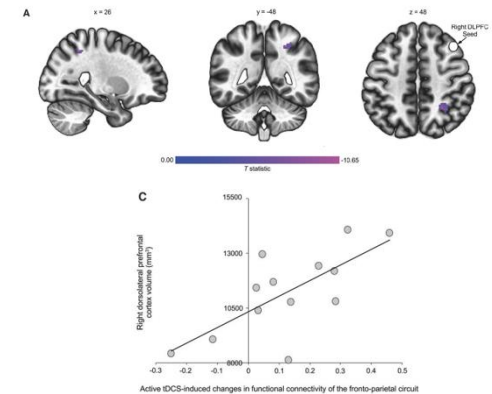
## Healthy adults tDCS-fMRI<sup>1</sup>



## tACS-fMRI<sup>2</sup>



## Adults with gambling disorder tDCS-fMRI<sup>3</sup>



Potential intervention targeting the fronto-parietal circuit, known to be involved in attentional processes?

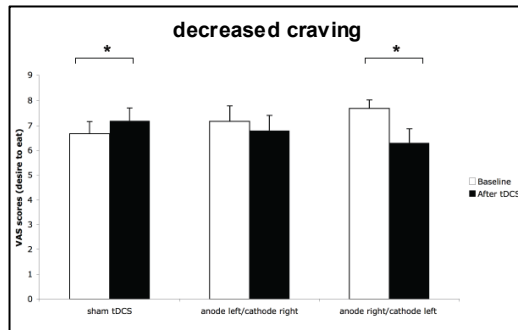
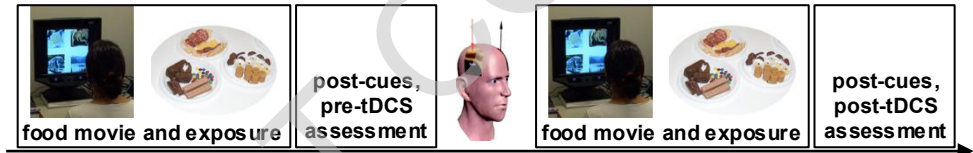
<sup>1</sup>Bouchard, Renaud, Fecteau, *Front Hum Neurosci* 2023.

<sup>2</sup>Mondino, Ghumman, Gane, Renaud, Whittingstall, Fecteau, *Front Hum Neurosci* 2020.

<sup>3</sup>Bouchard, Dickler, Renaud, Lenglos, Ferland, Rouillard, Leblond, Fecteau, *Brain Connect* 2021.

# NIBS can modulate fronto-parietal connectivity, known to be involved in attentional processes: impact on craving and consumption?

This was a 3-arm, crossover, sham controlled, blind at 3 levels study with adults with abnormal food craving receiving single tDCS sessions.



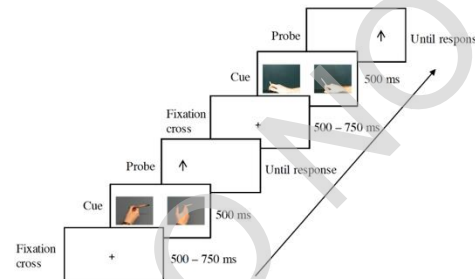
**tDCS induced an attentional shift from food to non-food related items.**



# NIBS can modulate fronto-parietal connectivity, known to be involved in attentional processes: impact on decision-making processes?



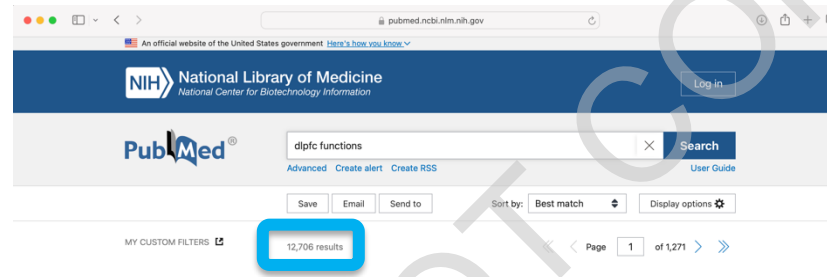
This was a crossover, sham controlled, blind at 3 levels study with adults with tobacco use disorder receiving tACS over the dlPFC.



- tACS induced an attentional shift from smoking to non-smoking related items.
- tACS reduced impulsive decision-making to smoke cigarettes.
- tACS did not change craving level.

# NIBS over the dIPFC can modulate decision-making processes and...?

## Functions related to the dIPFC



The US FDA cleared protocol of rTMS as an aid in short-term smoking cessation in adults

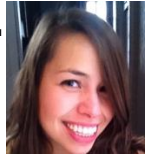
- Each 10Hz rTMS session is preceded by a 5-min provocation procedure to induce craving.

Is craving the best option to prime the brain for all?

rTMS applied over the dIPFC for... depression, anxiety, chronic pain, etc.

1. Noninvasive brain stimulation (NIBS) to treat substance-related and addictive disorders (SRAD).
2. Effects of NIBS when applied over the dlPFC on cognitive functions and their translational values in individuals with SRAD.
3. Effects of NIBS when applied over the dlPFC on brain substrates.
4. **Effects of NIBS applied over the dlPFC can be impacted by:**
  - a. behavioural trait and state
  - b. functional connectivity
  - c. brain morphometry

# The impact of behavioural trait and state on the neural effects of NIBS.

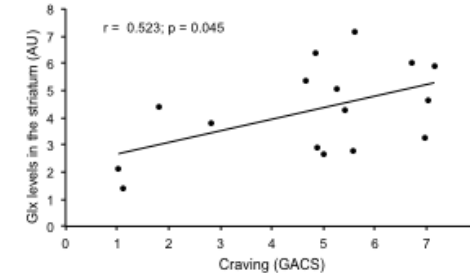
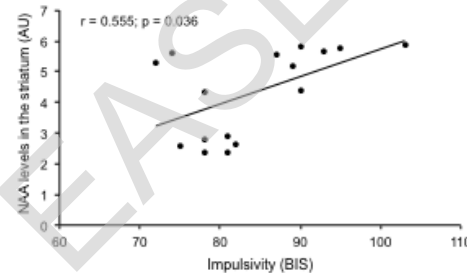
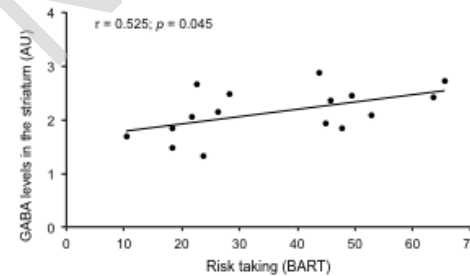
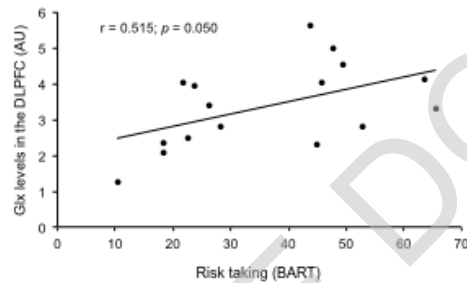


Concurrent tDCS-MRI, sham controlled, blind at 3 levels design to identify the neural effects of tDCS in adults with gambling disorder.

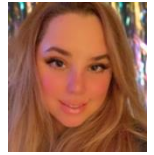
Greater risk taking, impulsivity, craving levels

=

Greater tDCS impact on neurotransmitter levels in the dlPFC and striatum

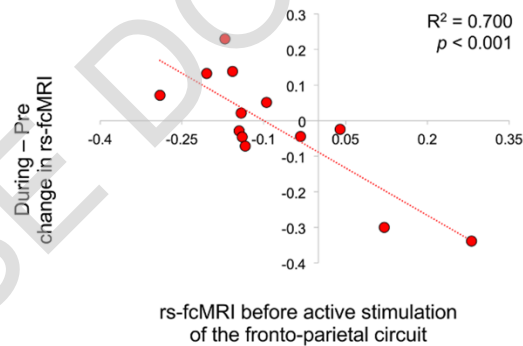


# The impact of functional connectivity on the neural effects of NIBS.

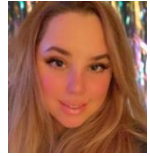


Concurrent tDCS-fMRI : instantaneous and subsequent tDCS effects in a sham controlled, blind at 3 levels study with healthy adults.

Stronger baseline functional connectivity  
=  
stronger tDCS impact on functional connectivity



# The impact of brain morphometry on the neural effects of tDCS.



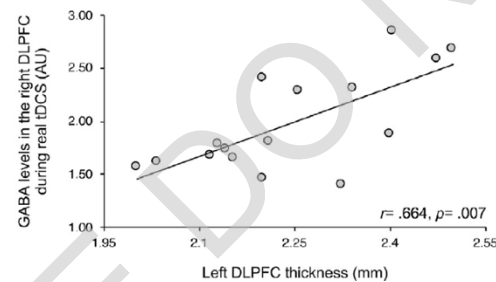
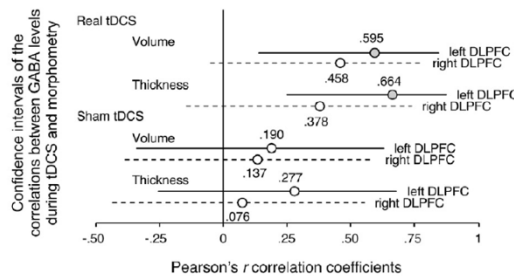
tDCS applied over the dlPFC in adults with gambling disorder.

Greater dlPFC volume and thickness

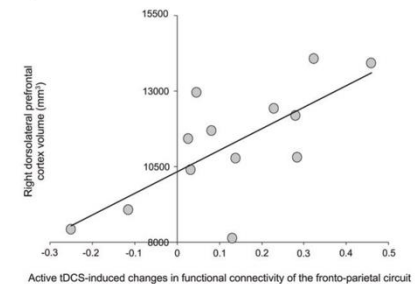
=

Greater tDCS related changes in neurotransmitter levels and functional connectivity strength.

## Concurrent tDCS-MRSI<sup>1</sup>



## Concurrent tDCS-fMRI<sup>2</sup>



*Should we adjust the stimulation parameters based on patient's morphometry of the stimulation site (dlPFC morphometry)?*

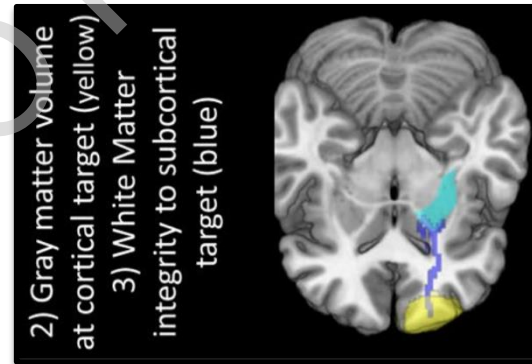
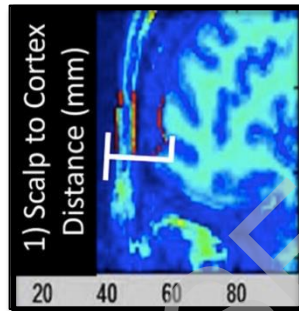
<sup>1</sup>Bouchard, Dickler, Renaud, Lenglos, Ferland, Edden, Rouillard, Leblond, Fecteau, *Brain Stimul* 2020.

<sup>2</sup>Bouchard, Dickler, Renaud, Lenglos, Ferland, Rouillard, Leblond, Fecteau, *Brain Connect* 2021.

# The impact of scalp-to-cortex distance on the neural effects of rTMS.

cTBS applied over the left frontal pole on functional connectivity fMRI in adults with Alcohol Use Disorder.

cTBS related change in fronto-striatal connectivity was influenced by the scalp-to-cortex distance (strongest predictor).

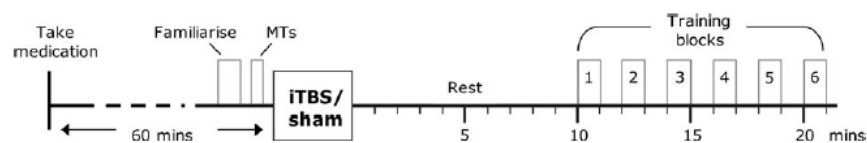


1. Noninvasive brain stimulation (NIBS) to treat substance-related and addictive disorders (SRAD).
2. Effects of NIBS when applied over the dlPFC on cognitive functions and their translational values in individuals with SRAD.
3. Effects of NIBS when applied over the dlPFC on brain substrates.
4. Effects of NIBS applied over the dlPFC can be impacted by:
  - a. behavioural trait and state
  - b. functional connectivity
  - c. brain morphometry
5. **What's next?**

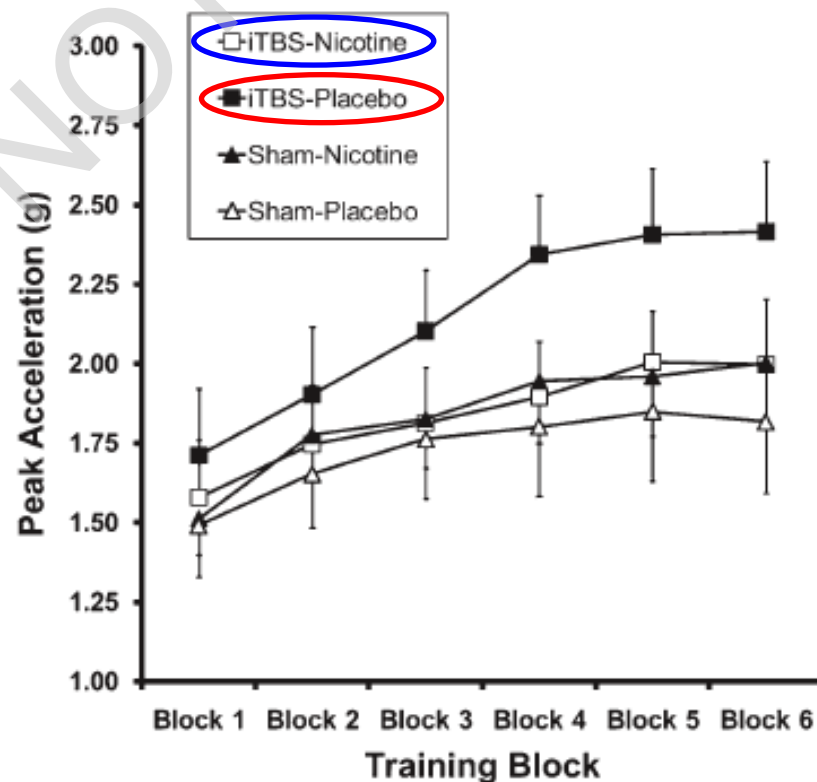
In which brain state we should stimulate?

Nicotine intake can cancel the effects of iTBS on motor function.

↑ thumb acceleration with iTBS over the contralateral M1.



Nondominant thumb abduction



## When to prime the brain?

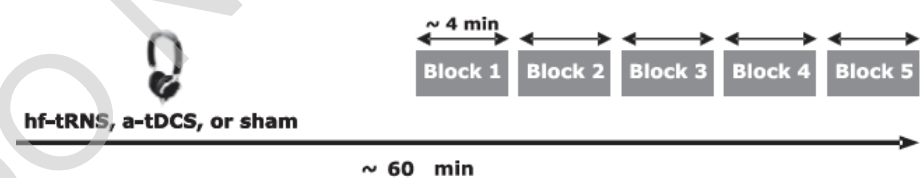
Effects of NIBS on an orientation discrimination task testing:

- online tDCS, offline tDCS,
- online tRNS, offline tRNS,
- online sham, offline sham.

### Online protocol



### Offline protocol



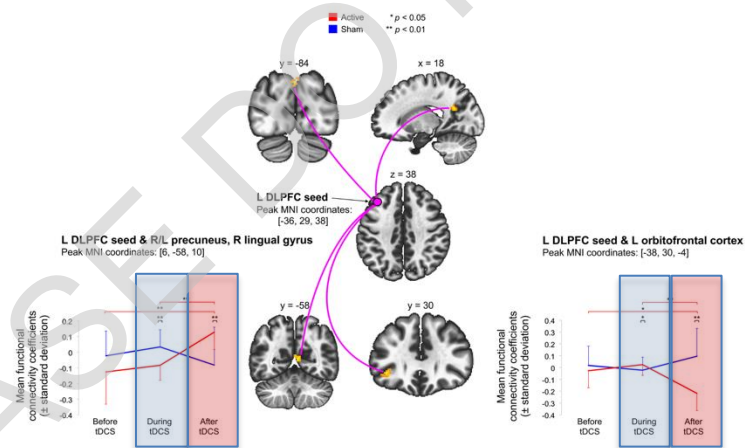
- Improvement with offline, but not with online tDCS.

- Improvement with online, but not with offline tRNS.

# When to prime the brain?

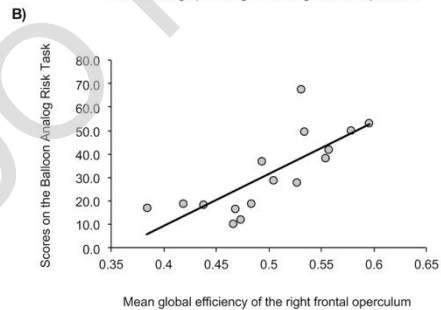
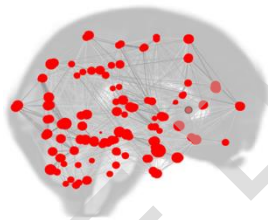
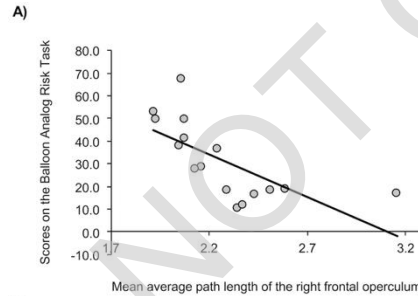
Concurrent tDCS-fMRI : instantaneous and subsequent tDCS effects in a sham controlled, blind at 3 levels study with healthy adults.

tDCS induced changes in functional connectivity  
during  $\neq$  after tDCS



# The relevance of resting state functional connectivity for behavioural trait.

## Efficiency of the right frontal cortex correlated with risk taking level in patients with gambling disorders



*If we want to reduce risk taking,  
should we adjust the stimulation parameters according to  
patient's individual frontal connectivity?*

## **What's next?**

**Is there translational value of NIBS studies in healthy subjects into clinical applications? Yes, but to some extent.**

**The effects of NIBS can be impacted by:**

- behavioural trait and state**
- brain activity**
- brain morphometry.**

**Behaviours, brain activity and morphometry can be different:**

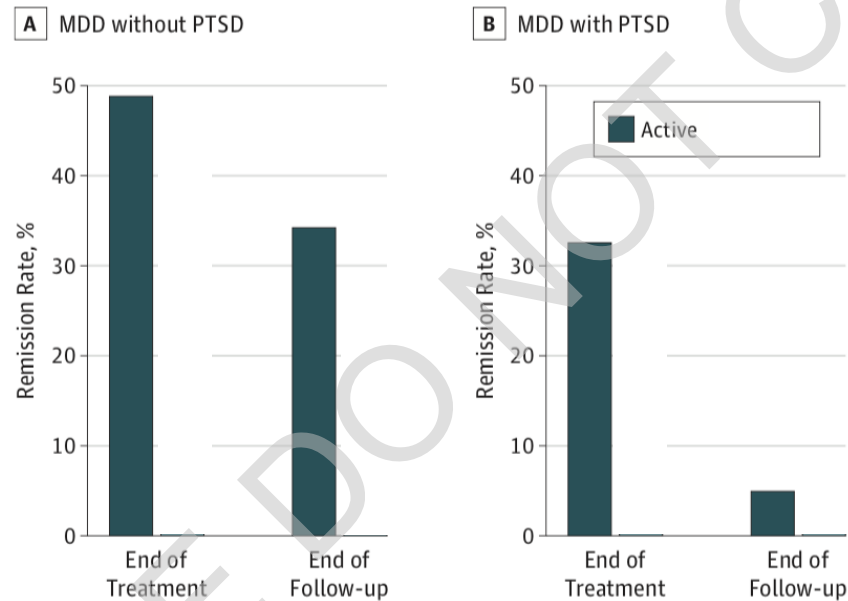
- between groups (e.g., healthy subjects and patients)**
- within a clinical population (e.g., patients with comorbid MDD and AUD)**
- within an individual (e.g., sobriety).**

**Next, what does NIBS modulate when it induces cognitive and clinical benefits?**

**Value of neuroimaging and cognition in understanding the cognitive and clinical benefits of NIBS.**

# The value of neuroimaging in NIBS treatment.

## rTMS to treat depression in military veterans



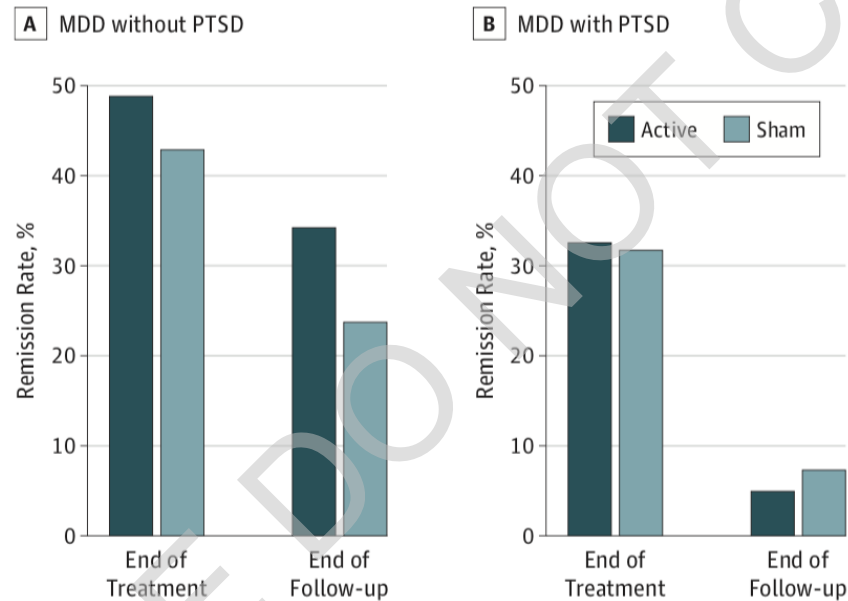
JAMA Psychiatry | [Original Investigation](#)

### Effect of Repetitive Transcranial Magnetic Stimulation on Treatment-Resistant Major Depression in US Veterans A Randomized Clinical Trial

Jerome A. Yesavage, MD; J. Kaci Fairchild, PhD; Zhibao Mi, PhD; Kousick Biswas, PhD; Anne Davis-Karim, PharmD; Ciaran S. Phibbs, PhD; Steven D. Forman, MD, PhD; Michael Thase, MD; Leanne M. Williams, PhD; Amit Etkin, MD, PhD; Ruth O'Hara, PhD; Gerald Georgette, RN; Tamara Beale, MA; Grant D. Huang, MPH, PhD; Art Noda, MS; Mark S. George, MD; for the VA Cooperative Studies Program Study Team

# The value of neuroimaging in NIBS treatment.

## rTMS to treat depression in military veterans



## The importance of sham-controlled trial

JAMA Psychiatry | [Original Investigation](#)

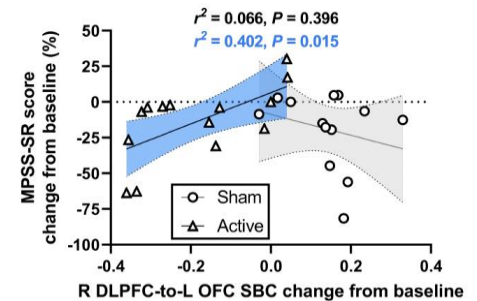
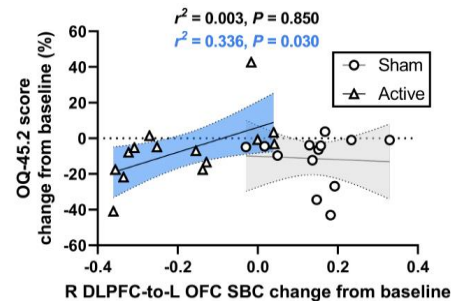
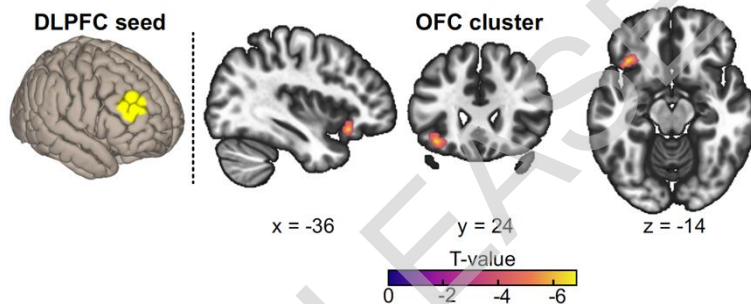
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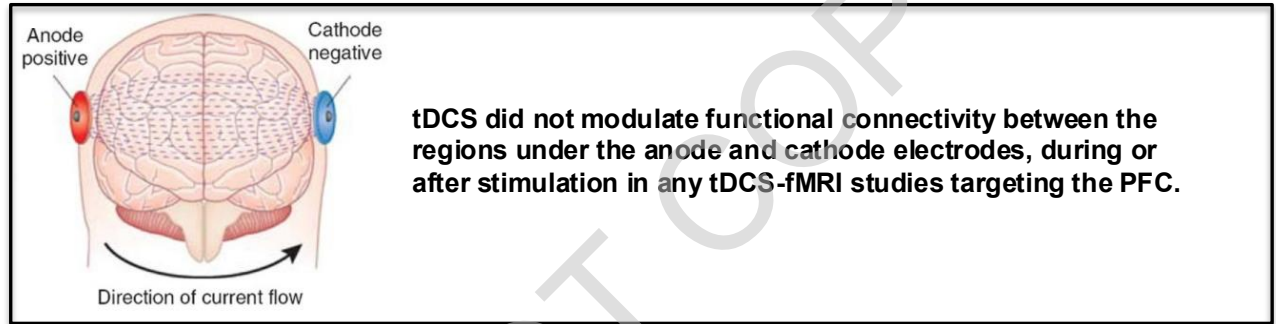
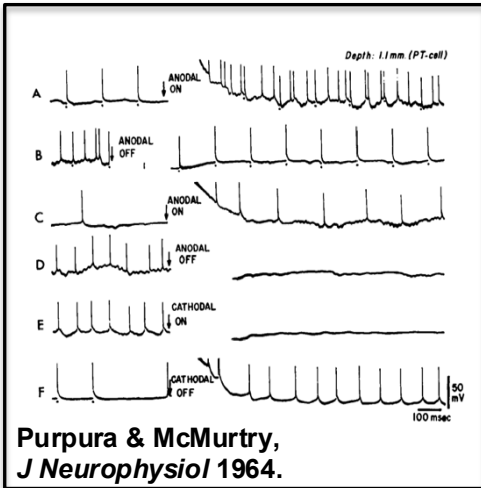
# The value of neuroimaging in NIBS treatment.

iTBS to treat posttraumatic stress disorder in military personnel

- 32% of remission 1-month after active or sham iTBS.
- Quality of Life improved 1-month after active, but not sham iTBS.
- Group differences of functional connectivity between the right DLPFC seed and the left orbitofrontal cortex.
- Alleviation of PTSD symptoms and improved Quality of Life correlated with reduced connectivity in the active, but not the sham group.



# Dosing dogma of NIBS



### The Pitfalls

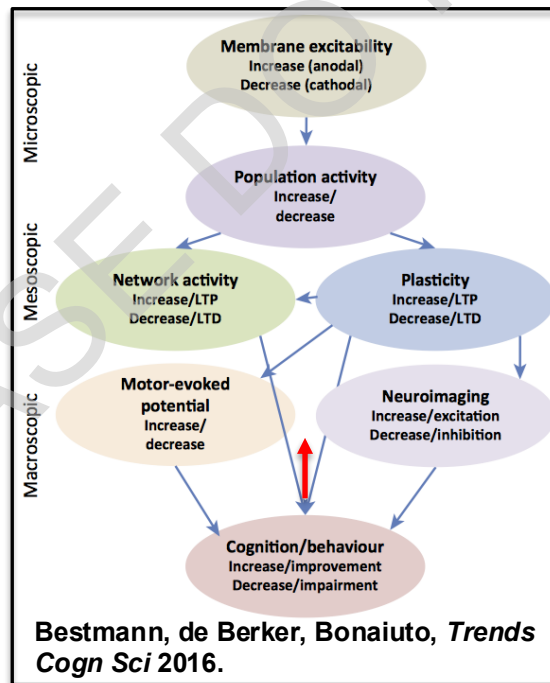
- Optimal dosing unknown, infinite parameter space
  - Conventional "Dosing dogma" is misleading

rTMS	High freq	Low freq
TBS	Intermittent	Continuous
tDCS	Anodal	Cathodal
	<b>Excitatory</b>	<b>Inhibitory</b>

↓

rTMS	High freq	Low freq
TBS	Continuous	Intermittent
tDCS	Anodal	Cathodal
	<b>Excitatory &amp; Inhibitory</b>	

Lisanby, Transcranial Electric Stimulation Workshop, NIH 2016.



Cortex 139 (2021) 43–59

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**Review**

### Effects of rTMS on the brain: is there value in variability?

Mitchell R. Goldsworthy<sup>a,b,c,\*</sup>, Brenton Hordacre<sup>d,1</sup>, John C. Rothwell<sup>e</sup> and Michael C. Ridding<sup>d</sup>

<sup>a</sup> Lifespan Human Neurophysiology Group, Adelaide Medical School, University of Adelaide, Adelaide, Australia  
<sup>b</sup> Hopwood Centre for Neurobiology, Lifelong Health Theme, South Australian Health and Medical Research Institute (SAHMRI), Adelaide, Australia  
<sup>c</sup> Discipline of Psychiatry, Adelaide Medical School, University of Adelaide, Adelaide, Australia  
<sup>d</sup> Innovation, Implementation and Clinical Translation (IMPACT) in Health, University of South Australia, Adelaide, Australia  
<sup>e</sup> Department of Clinical and Movement Neurosciences, UCL Queen Square Institute of Neurology, London, United Kingdom

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 Variability

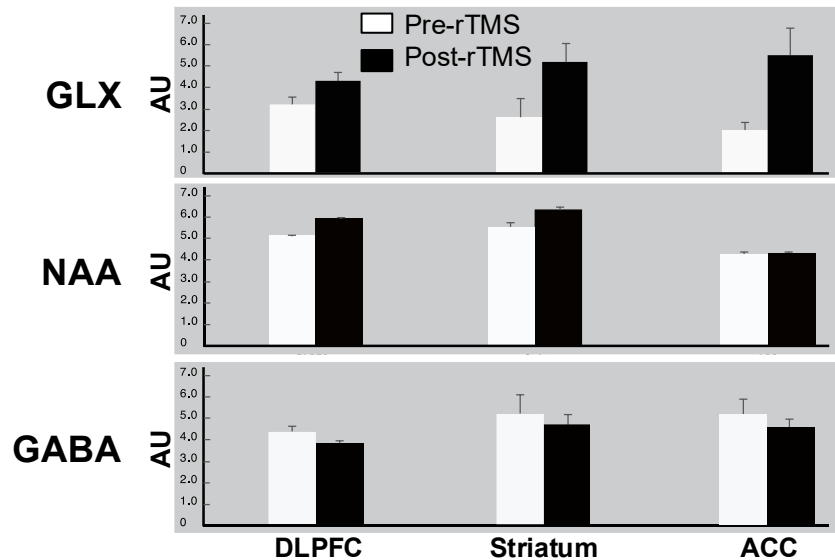
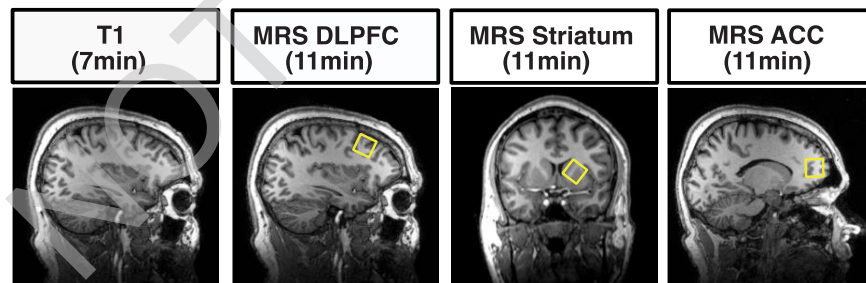
**ABSTRACT**

The ability of repetitive transcranial magnetic stimulation (rTMS) to non-invasively induce neuroplasticity in the human cortex has opened exciting possibilities for its application in both basic and clinical research. Changes in the amplitude of motor evoked potentials (MEPs) elicited by single-pulse transcranial magnetic stimulation has so far provided a convenient model for exploring the neurophysiology of rTMS effects on the brain, influencing the ways in which these stimulation protocols have been applied therapeutically. However, a growing number of studies have reported large inter-individual variability in the mean MEP response to rTMS, raising legitimate questions about the usefulness of this model for guiding therapy. Although the increasing application of different neuroimaging approaches has made it possible to probe rTMS-induced neuroplasticity outside the motor cortex to measure changes in neural activity that impact other aspects of human behaviour, the high variability of rTMS effects on these measurements remains an important issue for the field to address. In this review, we seek to move away from the conventional facilitation/inhibition dichotomy that permeates much of the rTMS literature, presenting a non-standard approach for measuring rTMS-induced neuroplasticity. We consider the evidence that rTMS is able to modulate an individual's moment-to-moment variability of neural activity, and whether this could have implications for guiding the therapeutic application of rTMS.

# The value of neuroimaging in NIBS treatment.

## Case study of a patient with severe polysubstance use and treatment refractoriness

		Pre-rTMS	Post-rTMS	3-mo follow up →
<b>OCDUS:</b>	Compulsion:	21	20	14
	Obsession:	16	12	5
<b>DASS:</b>	Stress:	19	16	18
	Depression:	16	6	5
	Anxiety:	14	10	2
<b>DDQ:</b>	Desire & Intention:	-12	10	
	Negative Reinforcement:	-2	-1	
	Control:	15	0	



1Hz rTMS: elevated NAA (excitatory effects?)

# How may NIBS induce enhancement?

## Conceptual framework of neuroenhancement

### Three potential mechanisms :

1. Zero-sum
2. Stochastic resonance
3. Entrainment enhancement

[Science](#). 2013 Oct 25;342(6157):482-4. doi: 10.1126/science.1241399. Epub 2013 Oct 3.

### **Changing social norm compliance with noninvasive brain stimulation.**

[Ruff CC](#), [Ugazio G](#), [Fehr E](#).

[Cereb Cortex](#). 2010 Jan;20(1):205-13. doi: 10.1093/cercor/bhp090.

### **The truth about lying: inhibition of the anterior prefrontal cortex improves deceptive behavior.**

[Karim AA](#), [Schneider M](#), [Lotze M](#), [Veit R](#), [Sauseng P](#), [Braun C](#), [Birbaumer N](#).

[Proc Natl Acad Sci U S A](#). 2009 Dec 8;106(49):20895-9. doi: 10.1073/pnas.0911619106. Epub 2009 Nov 30.

### **Disrupting the prefrontal cortex diminishes the human ability to build a good reputation.**

[Knoch D](#), [Schneider F](#), [Schunk D](#), [Hohmann M](#), [Fehr E](#).

[Soc Cogn Affect Neurosci](#). 2012 Mar;7(3):282-8. doi: 10.1093/scan/nsr008. Epub 2011 Apr 22.

### **Disrupting the right prefrontal cortex alters moral judgement.**

[Tassy S](#), [Oullier O](#), [Duclos Y](#), [Coulon O](#), [Mancini J](#), [Deruelle C](#), [Attarian S](#), [Felicjan O](#), [Wicker B](#).

[Curr Biol](#). 2012 Dec 4;22(23):2274-7. doi: 10.1016/j.cub.2012.10.018. Epub 2012 Nov 1.

### **Enhancing social ability by stimulating right temporoparietal junction.**

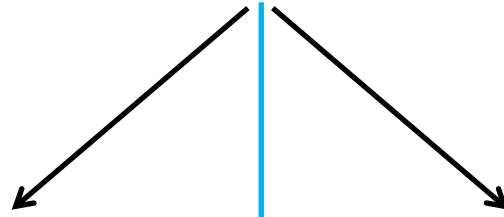
[Santesteban I](#), [Banissy MJ](#), [Catmur C](#), [Bird G](#).

[Soc Cogn Affect Neurosci](#). 2013 Oct 15. [Epub ahead of print]

### **The world can look better: enhancing beauty experience with brain stimulation.**

[Cattaneo Z](#), [Lega C](#), [Flexas A](#), [Nadal M](#), [Munar E](#), [Cela-Conde CJ](#).

**NIBS can modulate behaviors in healthy subjects.**



**Improve behaviors:**

- clinical relevance
- neuroenhancement

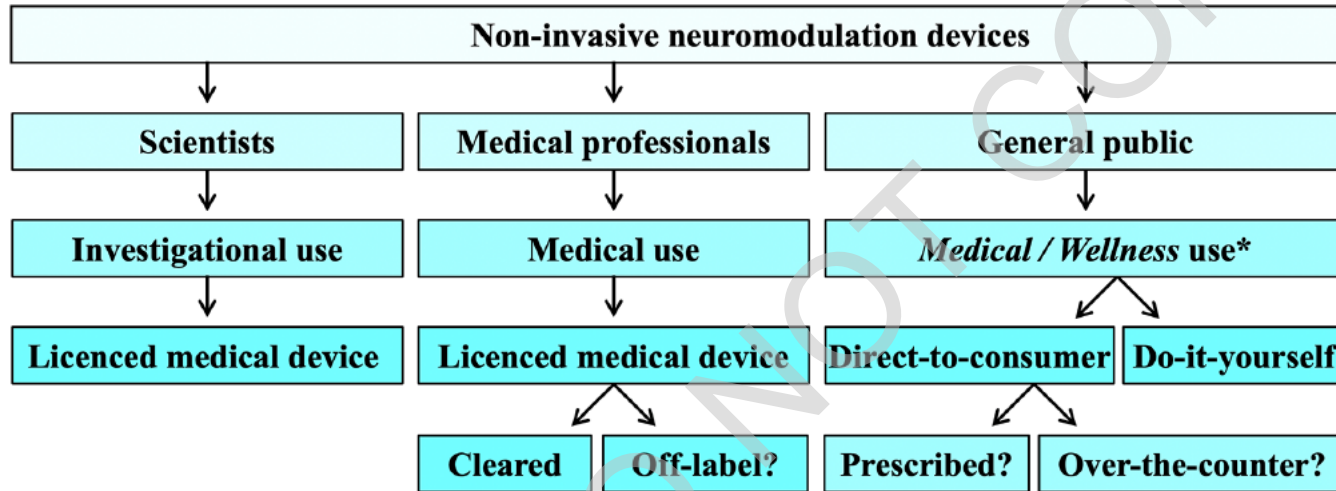
**Impair behaviors:**

- clinical relevance

**Ethical considerations**

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# Ethical considerations



Fecteau (2023) *The Neuroscientist*

Vulnerable populations: children, etc.

Special issue "Ethico-Legal Issues in Brain Stimulation" *Brain Stimulation*

## Take Home Message

NIBS over the dlPFC can modulate various behaviors

Impair (virtual lesion)

Improve (neuroenhancement)

*Can this be a concern for my patients?*

*Can this be beneficial for my patients?*

---

Translational value of studies in healthy subjects into clinical applications?

Yes, but the effects of NIBS can be influenced by:

- brain morphometry
- brain activity
- behavioral state

- Are they different between healthy subjects and patients?
- Are they different within a clinical population and within a patient?

The value of neuroimaging and cognition to understand the clinical benefits of NIBS.

**Thank you!**

**Questions?**

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