
NAH CONGRES
Niet-aangeboren hersenletsel
in Vlaanderen vandaag
Welkom
Niet-invasieve hersenstimulatie
C. Lafosse & S. De Witte
Hersenletsel Liga
INCLUSIE IN-ZICHT

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NAH CONGRES
Niet-aangeboren hersenletsel
in Vlaanderen vandaag
Tijd voor
een getuigenis

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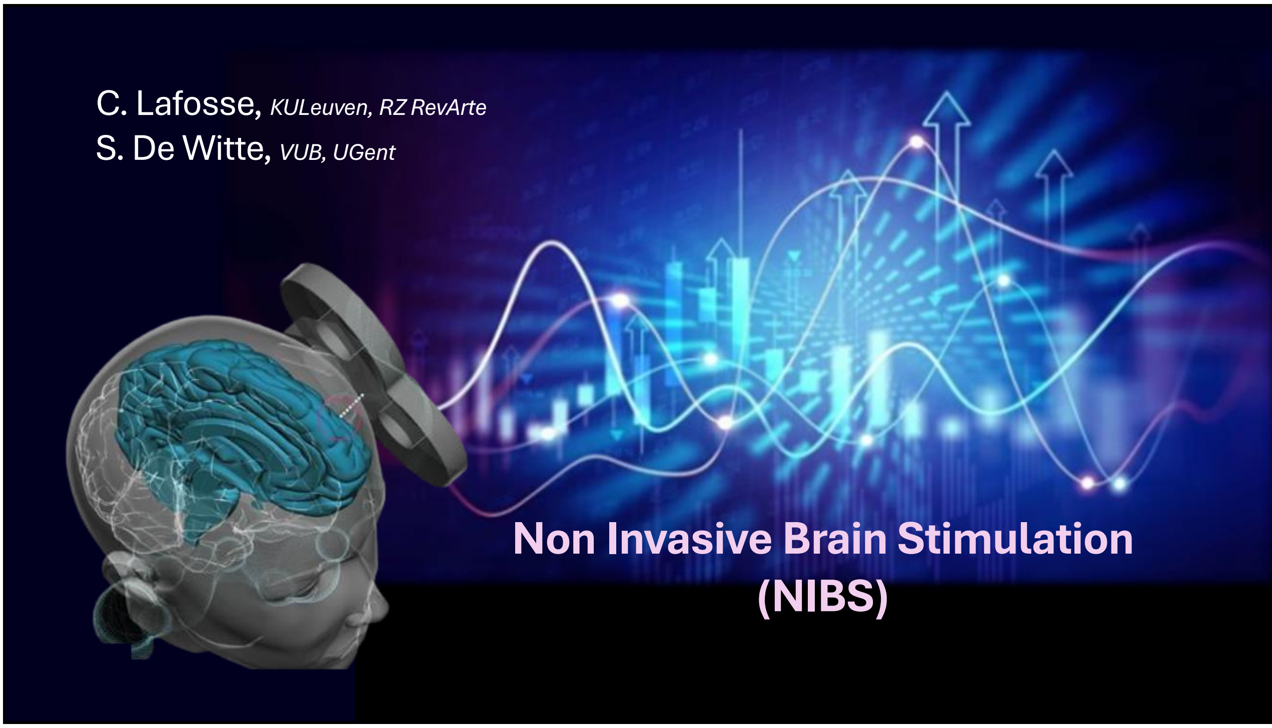

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Non-Invasive Brain Stimulation (NIBS)

Publications

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Non-Invasive Brain Stimulation (NIBS)
Societies

ins International Neuromodulation Society

CLINICAL TMS SOCIETY

ESBS European Society for Brain Stimulation

STICHTING HERSENSTIMULATIE

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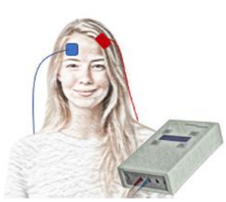
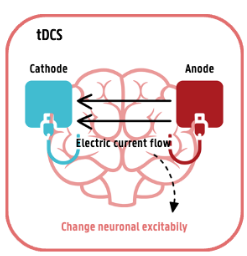
Non-Invasive Brain Stimulation (NIBS)
Overview

Transcranial Electric Stimulation (TES)





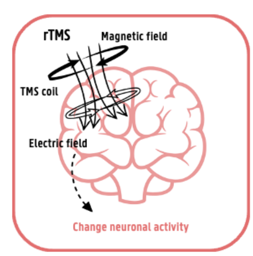
tDCS (Transcranial direct current stimulation)

tACS (Transcranial alternating current stimulation)

TRNS (Transcranial Random Noise Stimulation)

TENS (Transcutaneous electrical nerve stimulatie)

Transcranial Magnetic Stimulation (TMS)



rTMS (repetitive Transcranial Magnetic Stimulation)

TBS (Theta Burst Stimulation)

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Non-Invasive Brain Stimulation (NIBS)
Overview

	rTMS	TBS	tDCS	tACS
Stimulation method	Magnetic pulses applied to the brain	Magnetic pulses applied to the brain	Electrical current applied to the brain	Electrical current applied to the brain
Mechanism of action	Induces electrical currents in neural tissue	Induces electrical currents in neural tissue	Modulates neuronal resting membrane potential	Uses a rhythmic electrical current to synchronize the brain's natural activity patterns
Frequency of stimulation	Low-frequency (1 Hz or lower) High frequency (5 Hz or higher)	Burst patterns (three pulses at 50 Hz, given every 200ms)	Constant low current (typically 1-4 mA)	Constant low current (typically 1-4 mA)
Duration of session	Typically 20-30 minutes	Typically 3-5 minutes	Typically 20-30 minutes	Typically 20-30 minutes
Side effects	Scalp discomfort, headache, seizures (very rare)	Scalp discomfort, headache, seizures (very rare)	Mild tingling or itching, rare adverse effects	Mild tingling or itching, rare adverse effects
Costs	High	High	Low to moderate	Low to moderate

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Non-Invasive Brain Stimulation (NIBS)
Overview

	rTMS	TBS	tDCS	tACS
Advantage	Most widely studied method Approved by FDA for the treatment of depression	Shorter sessions possible Approved by FDA for the treatment of depression	Easy use, low cost, possible home-based application, mobile	Easy use, low cost, possible home-based application, mobile
Disavantage	Expensive, specialized medical staff is needed, treatment can only be given in hospital	Expensive, specialized medical staff is needed, treatment can only be given in hospital	Not specifically approved yet, often off-label use	Not specifically approved yet, often off-label use

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Non-Invasive Neuromodulation

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Transcranial Magnetic Stimulation (TMS)

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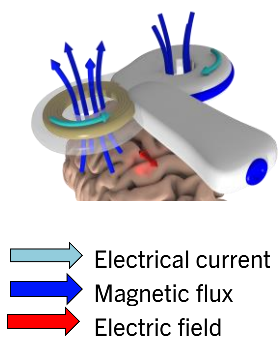
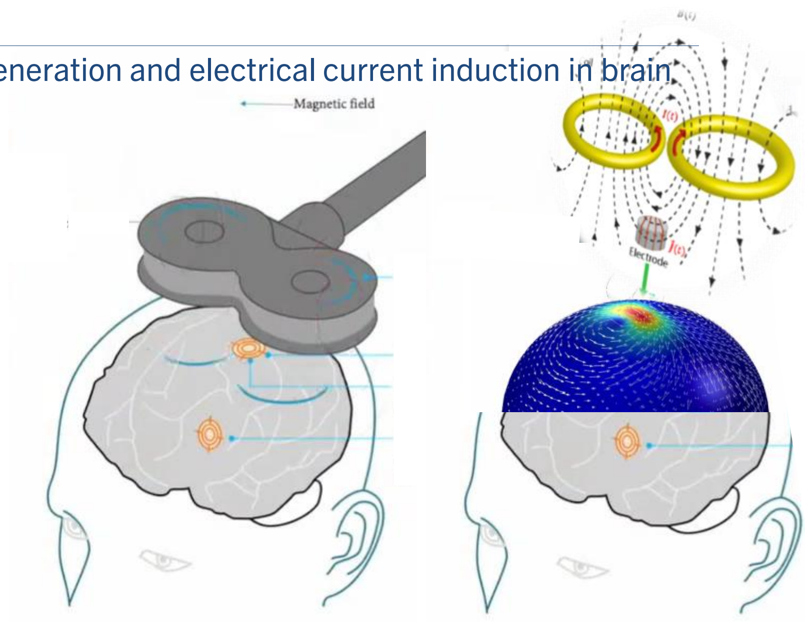
Transcranial Magnetic Stimulation (TMS)
Biophysics

Magnetic field generation and electrical current induction in brain
(Faraday principle)





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Transcranial Magnetic Stimulation (TMS)
Biophysics

TMS coil designs

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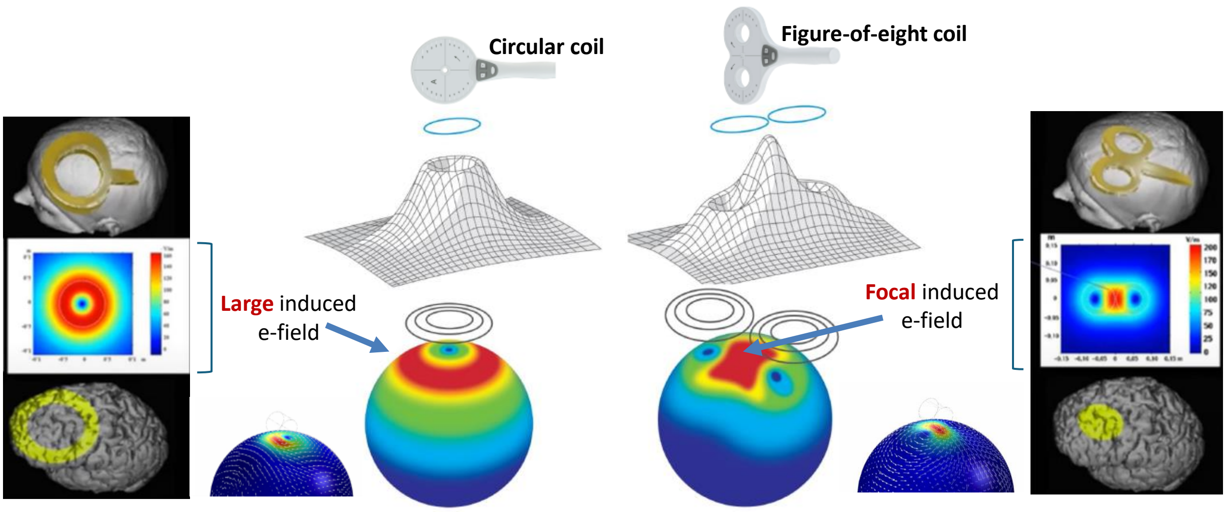
Transcranial Magnetic Stimulation (TMS)
Biophysics

Effect of coil shape on induced electrical field



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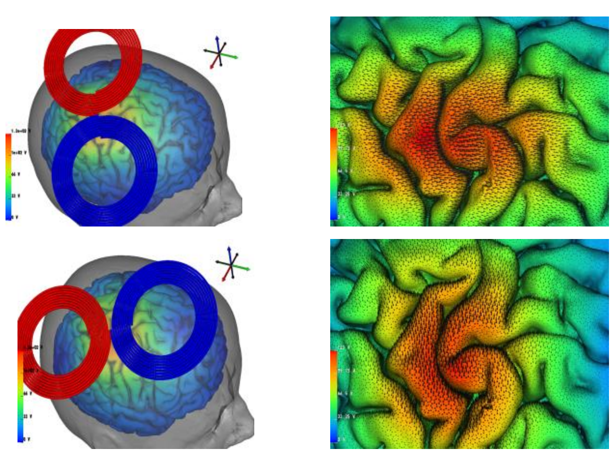
Transcranial Magnetic Stimulation (TMS)
Biophysics

Effect of coil orientation



total induced electrical field
orthogonal and parallel to precentral gyrus

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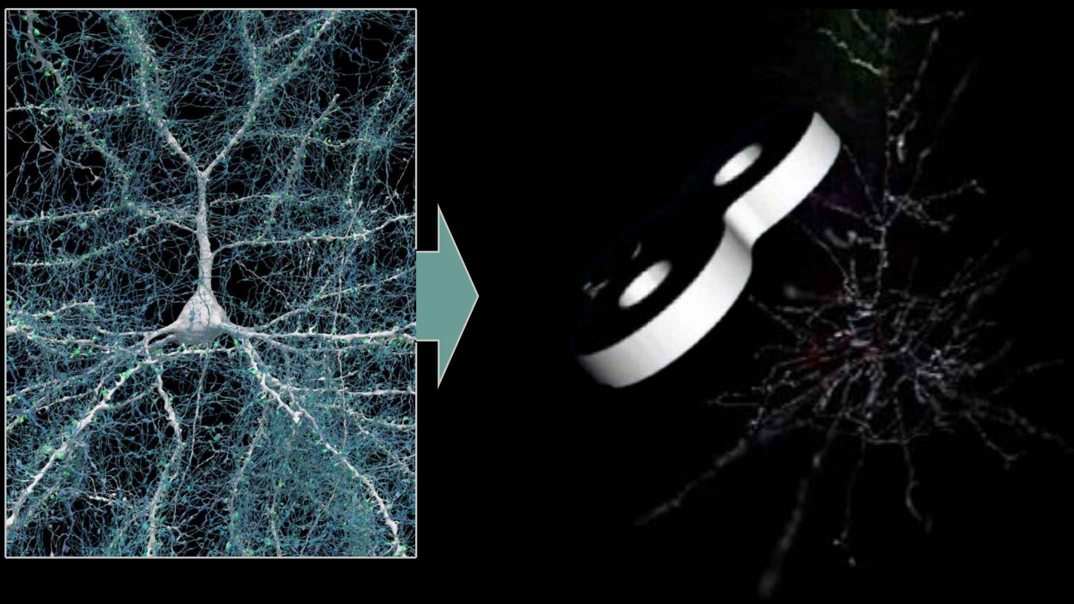
From stimulus to response



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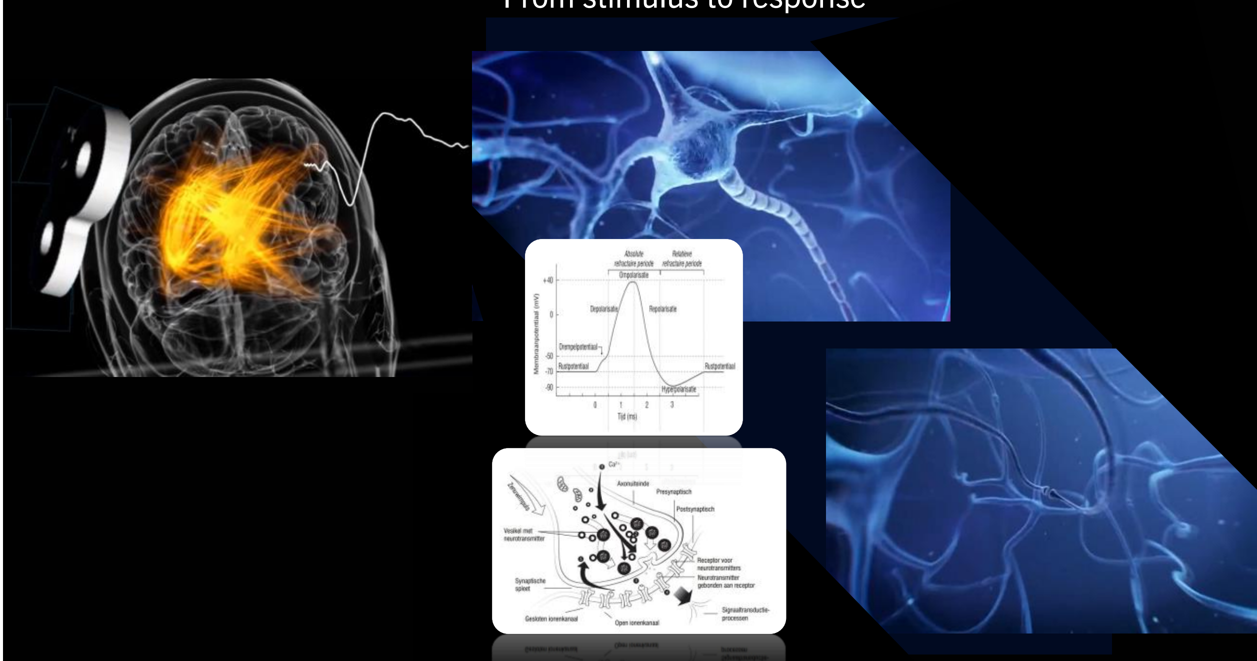
From stimulus to response



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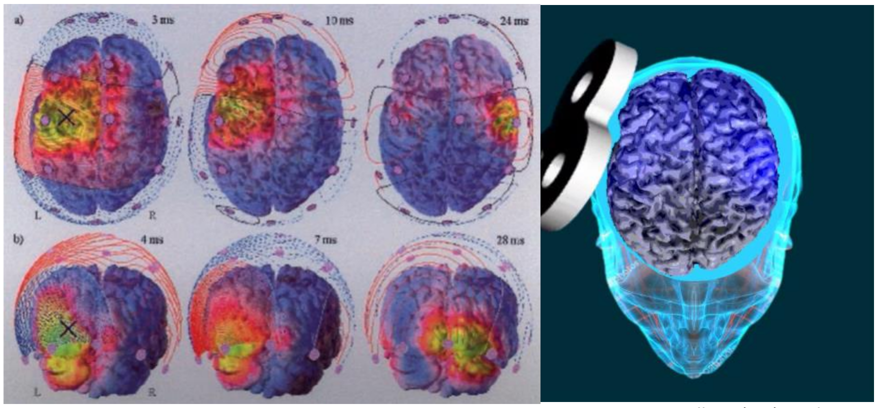
Transcranial Magnetic Stimulation (TMS)
Signal propagation

After local activation, induced neuronal activation propagates to distal areas



Ilmoniemi, et al. 1997

TMS-induced activity is not restricted to the target brain region but spreads to remote brain regions

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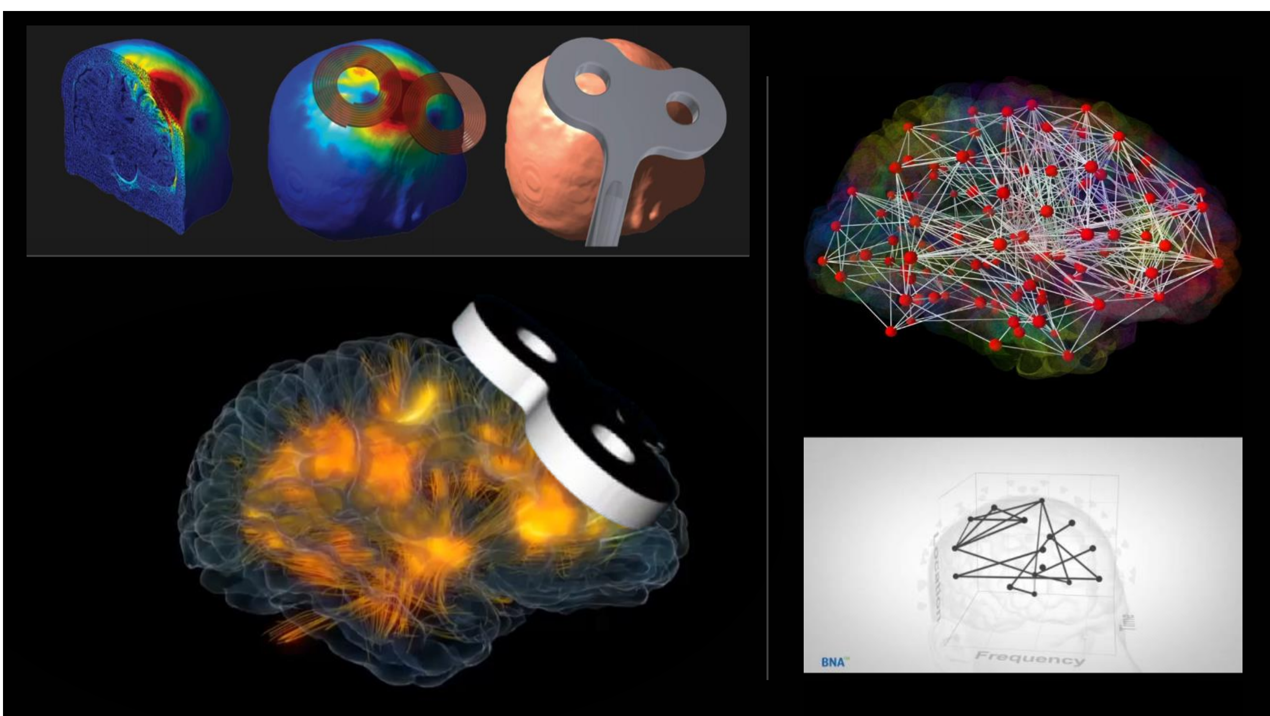

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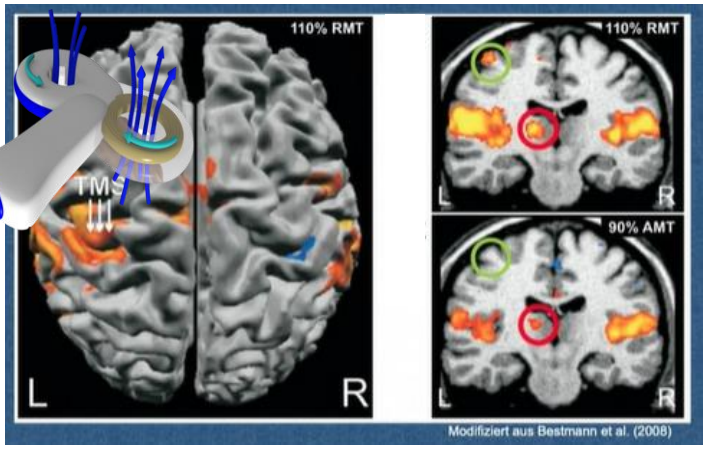
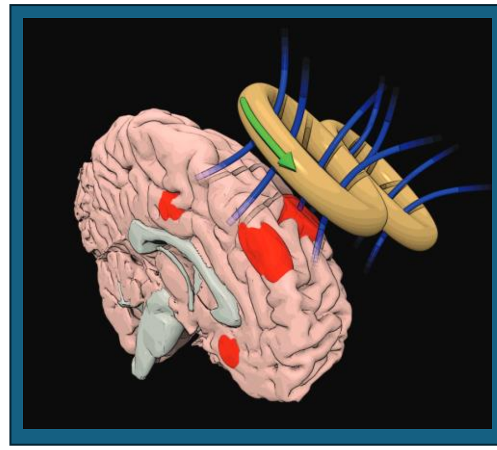
Transcranial Magnetic Stimulation (TMS)
Stroke

Full effect of TMS signal propagation can only be understood in terms of full **networks** of neuron activation





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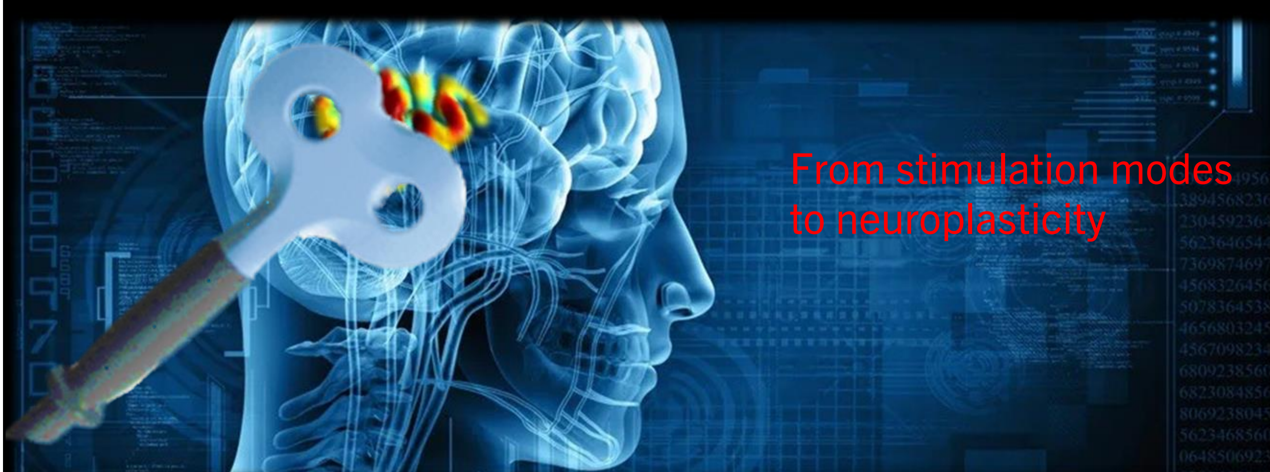
Non-Invasive Neuromodulation



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Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

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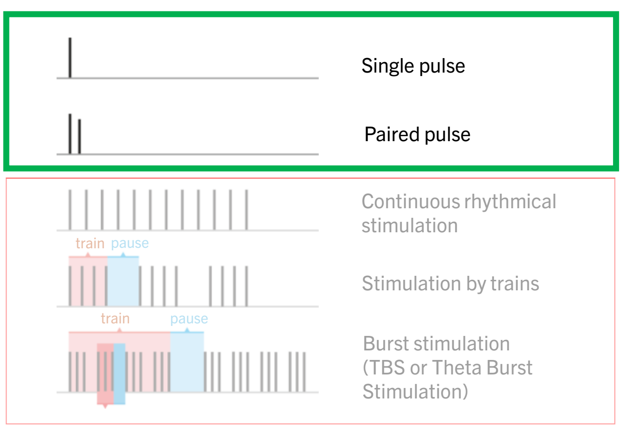
Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

DIAGNOSTIC

THERAPEUTIC



1 pulse

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Transcranial Magnetic Stimulation (TMS)
Effects on neural systems

Neuron level and neural signaling

Single-pulse TMS induced a highly (**spatial**) **localized** excitation of single neurons which interfere with normal task-related activity

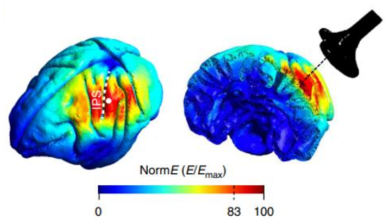
nature COMMUNICATIONS

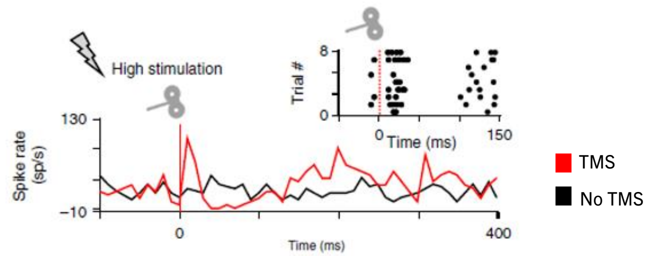
ARTICLE

https://doi.org/10.1038/s41467-019-10638-7

Neural effects of transcranial magnetic stimulation at the single-cell level

Maria C. Romero[1,2,3,4], Marco Davare[2,3,4], Marcelo Armendariz[1,3] & Peter Janssen[1,3]





Single-pulse TMS induce strong **oscillations** in the firing rate of these neurons seen on the oscillatory activity in EEG

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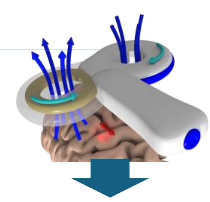
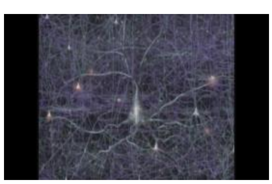
Transcranial Magnetic Stimulation (TMS)
Effects on neural systems

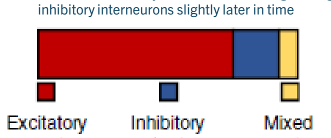
Neuron level and neural signaling

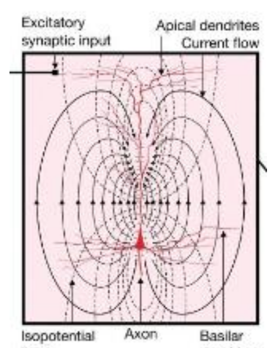




excitation and **inhibition**

Inhibition caused by the activation of neighboring inhibitory interneurons slightly later in time





The balance of these excitatory and inhibitory influences determines the overall "**excitability**" or activity level of a brain circuit or structure, or even of the whole brain

Single-pulse TMS induce strong oscillations in the firing rate of these neurons seen on the oscillatory activity in EEG

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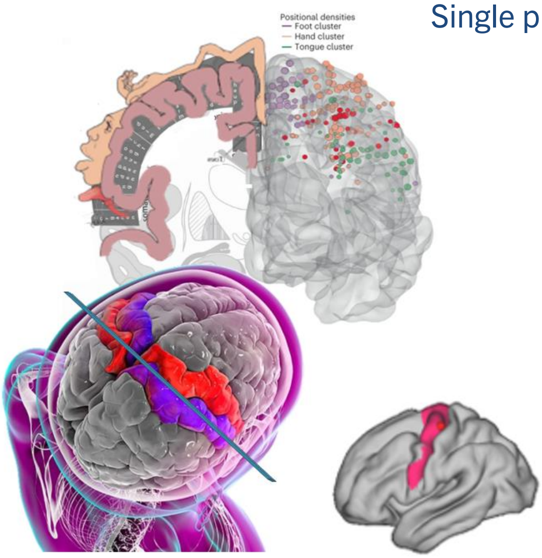
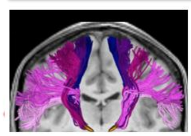
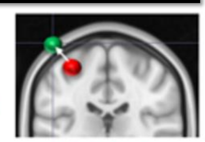
Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes



Single pulse stimulation Motor Cortex M1





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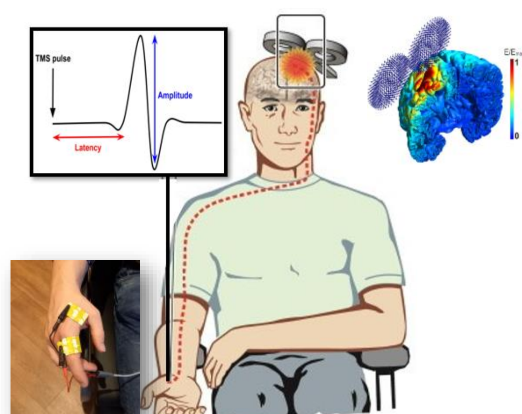
Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

Single pulse stimulation Motor Cortex M1 and Motor Evoked Potential (MEP)



A single TMS pulse can evoke activity in the motor cortex resulting in a muscular motor response (MEP) that can be measured with EMG. TMS also activates different intracortical circuits within the M1 and connections from other cortical areas to the M1. These intracortical circuits interact with each other.

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Transcranial Magnetic Stimulation (TMS)

Clinical applications

Single pulse TMS protocols can be used to:

(a) assess the presence and severity of neurological impairments
(b) investigate the pathophysiology of the disease
(c) monitor disease progression
(d) evaluate the mechanism of actions of various therapeutic approaches

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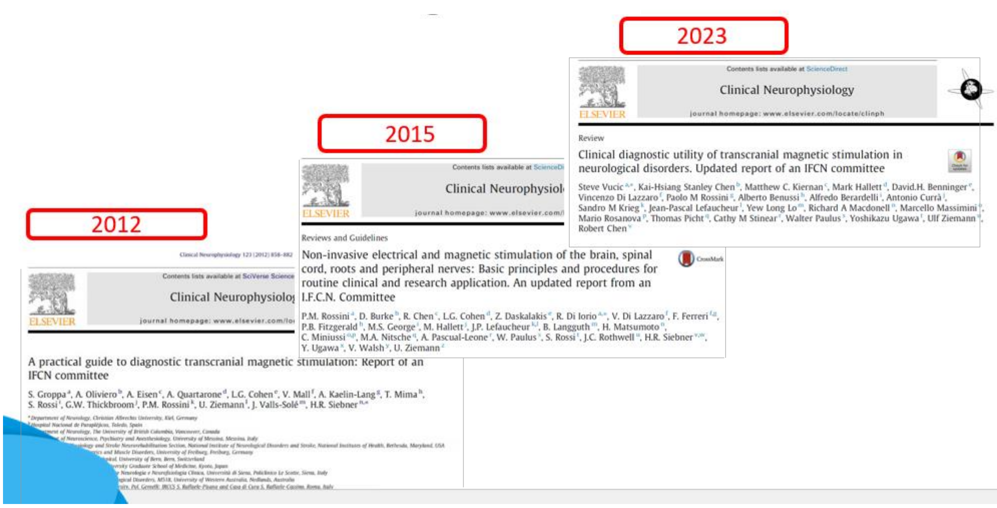
Transcranial Magnetic Stimulation (TMS)

Guidelines Diagnostic TMS



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Transcranial Magnetic Stimulation (TMS)

Clinical applications

frontiers | Frontiers in Neurology

REVIEW
published: 20 May 2022
doi: 10.3389/fneur.2022.793253

Check for updates

Transcranial Magnetic Stimulation in the Treatment of Neurological Diseases

Fahad A. Somaa[1], Tom A. de Graaf[2,3] and Alexander T. Sack[2,3,4]*

[1] Department of Occupational Therapy, Faculty of Medical Rehabilitation, King Abdulaziz University, Jeddah, Saudi Arabia, [2] Section Brain Stimulation and Cognition, Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, Netherlands, [3] Center of Integrative Neuroscience, Maastricht University, Maastricht, Netherlands, [4] Department of Psychiatry and Neuropsychology, School for Mental Health and Neuroscience, Brain + Nerve Centre, Maastricht University Medical Centre+, Maastricht, Netherlands

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Transcranial Magnetic Stimulation (TMS)

Clinical applications

frontiers in Human Neuroscience

SYSTEMATIC REVIEW
published: 27 August 2020
doi: 10.3389/fnhum.2020.00306

Check for updates

The Neurophysiological Responses of Concussive Impacts: A Systematic Review and Meta-Analysis of Transcranial Magnetic Stimulation Studies

Emily Scott[1], Dawson J. Kidgell[2], Ashlyn K. Frazer[2] and Alan J. Pearce[1]*

[1] College of Science, Health and Engineering, La Trobe University, Melbourne, VIC, Australia, [2] Department of Physiotherapy, Faculty of Medicine, Nursing and Health Science, School of Primary and Allied Health Care, Monash University, Melbourne, VIC, Australia

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Transcranial Magnetic Stimulation (TMS)

Clinical applications

Transcranial magnetic stimulation confirms hyperexcitability of occipital cortex in migraine

S.K. Aurora, MD; B.K. Ahmad, MD; K.M.A. Welch, MD; P. Bhardhwaj, MD; and N.M. Ramadan, MD

TMS for Migraine (abortive)

Single-pulse transcranial magnetic stimulation for acute treatment of migraine with aura: a randomised, double-blind, parallel-group, sham-controlled trial

Richard B Lipton, David W Dodick, Stephen D Silberstein, Joel R Saper, Sheena K Aurora, Starr H Pearlman, Robert E Fischell, Patricia L Ruppel, Peter J Goadsby

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Transcranial Magnetic Stimulation (TMS)

Clinical applications

https://doi.org/10.1093/brain/awad395 BRAIN 2024: 147; 1423–1435 | 1423

BRAIN
ORIGINAL ARTICLE

The pathobiology of psychomotor slowing in psychosis: altered cortical excitability and connectivity

Stephanie Lefebvre,[1,2] Gwendolyn Gehrig,[1] Niluja Nadesalingam,[1,2] Melanie G. Nuoffer,[1,2,3] Alexandra Kyrou,[1] Florian Wüthrich[1,2] and Sebastian Walther[1,2]

the TMS data suggest a specific inhibitory deficit in patients with schizophrenia and hypokinetic motor abnormalities, i.e. psychomotor slowing and catatonia

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Transcranial Magnetic Stimulation (TMS)

Clinical applications


Contents lists available at ScienceDirect

Clinical Parkinsonism & Related Disorders

journal homepage: www.sciencedirect.com/journal/clinical-parkinsonism-and-related-disorders

ELSEVIER

Transcranial and muscular single-pulse magnetic stimulation is efficient on motor functional neurological disorders by the feedback of induced muscle contractions — A retrospective case series

Bonnan Mickael

Service de Neurologie, Centre Hospitalier de Pau, 64000 PAU, France PRDOA 5 (2021)

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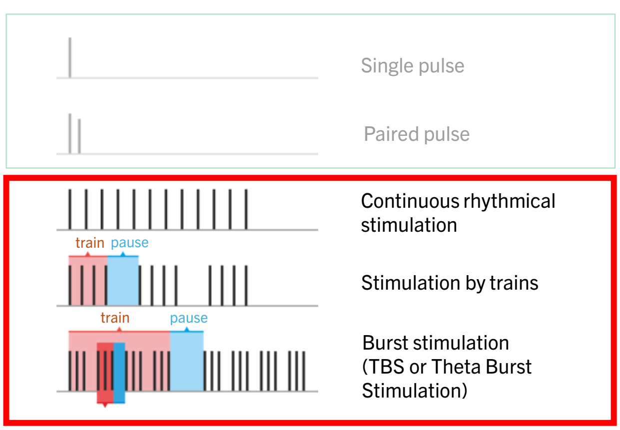
Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

DIAGNOSTIC

THERAPEUTIC



10 pulses / sec

9 pulses / train
3 sec train
2 sec pause

Burst van 3 pulses

repetitive TMS (rTMS)
Theta Burst Stimulation

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Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

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Transcranial Magnetic Stimulation (TMS)

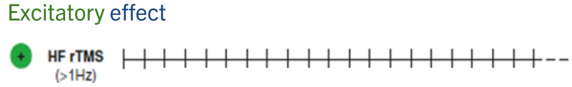
Magnetic Stimulation Modes

repetitive TMS protocols can either temporarily increase or decrease neuronal **excitability**

Continuous rhythmical stimulation

- Low frequency rTMS stimulation (< 3Hz)
  - Inhibitory effect

- High frequency rTMS stimulation (> 3Hz)
  - Excitatory effect



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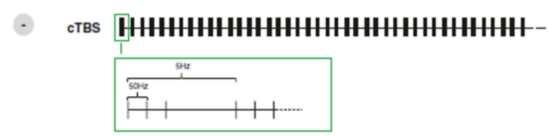
Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

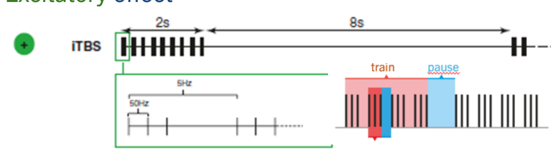
repetitive TMS protocols can either temporarily **increase** or **decrease** neuronal **excitability**

Theta burst stimulation

- Continuous theta burst stimulation
  - Inhibitory effect



- Intermittent theta burst stimulation
  - Excitatory effect



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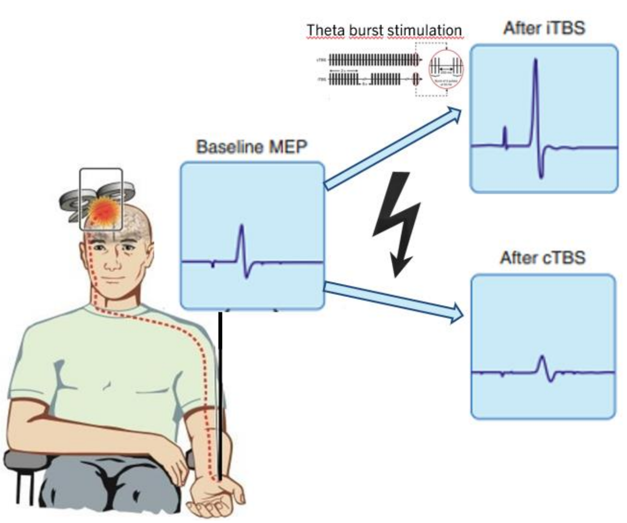
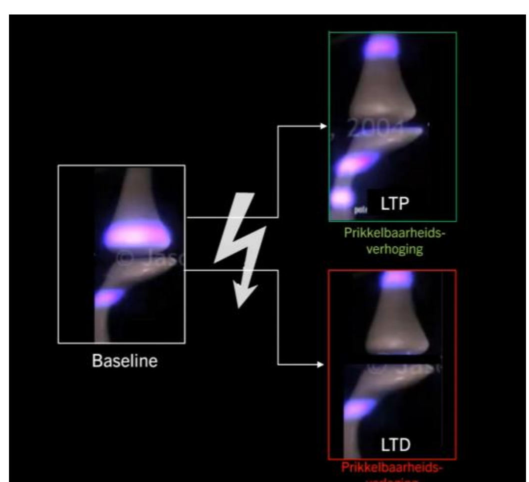
Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

Neuroplasticity (LTP and LTD)





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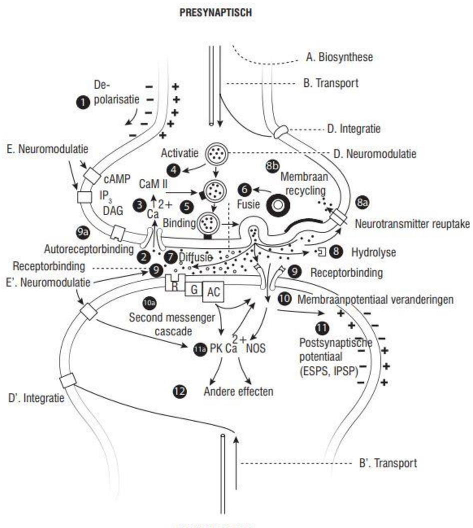
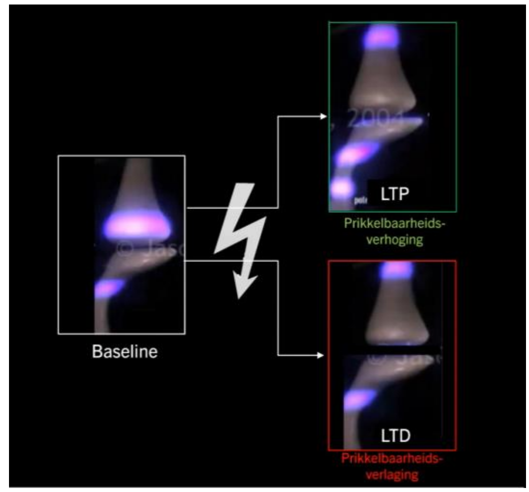
Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

Neuroplasticity (LTP and LTD)





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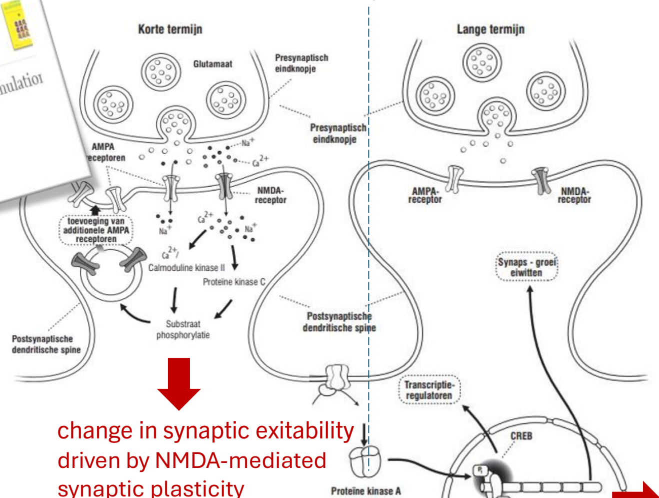
Transcranial Magnetic Stimulation (TMS)

Effects on neural systems

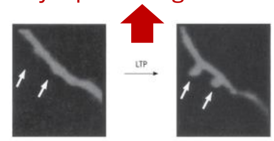
Neuroplasticity (LTP)


Clinical Neurophysiology
Volume 118, Issue 5, May 2007, Pages 1028-1032
The after-effect of human theta burst stimulation is NMDA receptor dependent
Show more

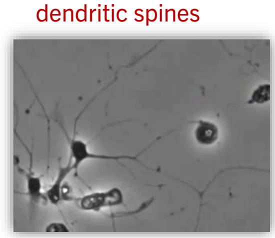


change in synaptic exitability driven by NMDA-mediated synaptic plasticity

synaptic changes



modification of dendritic spines



gene transcription

protein synthesis

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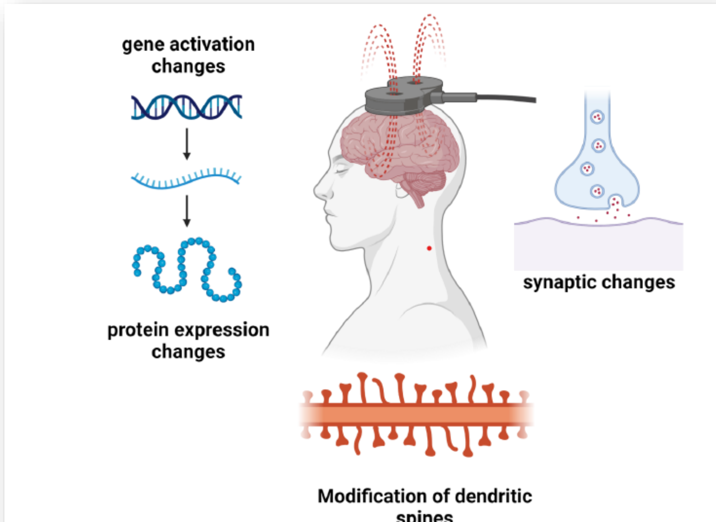
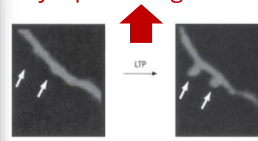
Transcranial Magnetic Stimulation (TMS)

Effects on neural systems

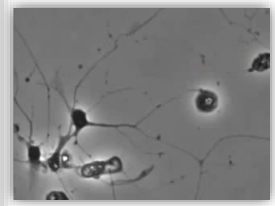


Cirillo, G., di Pino, G., Capone, F., Ranieri, F., Florio, L., Todisco, V., Tedeschi, G., Funke, K., & di Lazzaro, V. (2017). Neurobiological after-effects of non-invasive brain stimulation. *Brain Stimulation*, *10*(1), 1–18.

synaptic changes



modification of dendritic spines



gene transcription

protein synthesis

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Non-Invasive Brain Stimulation

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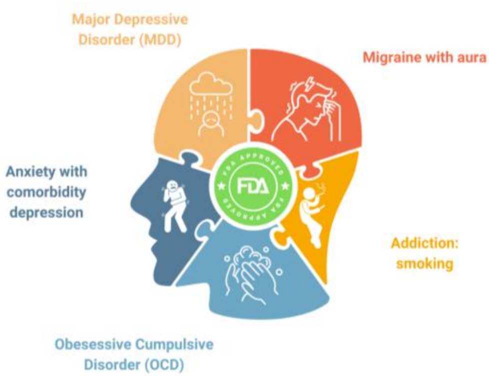
Transcranial Magnetic Stimulation (TMS)

What is it used for?

FDA APPROVED



POTENTIALLY EFFECTIVE

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Transcranial Magnetic Stimulation (TMS)

Depression

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Transcranial Magnetic Stimulation (TMS)
Depression

In Belgium, 1 in 3 people feels bad in their skin

9% of the population experiences depression

33% of those people do not respond to treatment

Belgium ranks 3rd in Europe in terms of the highest number of suicides per year

Deep TMS

Conventional TMS

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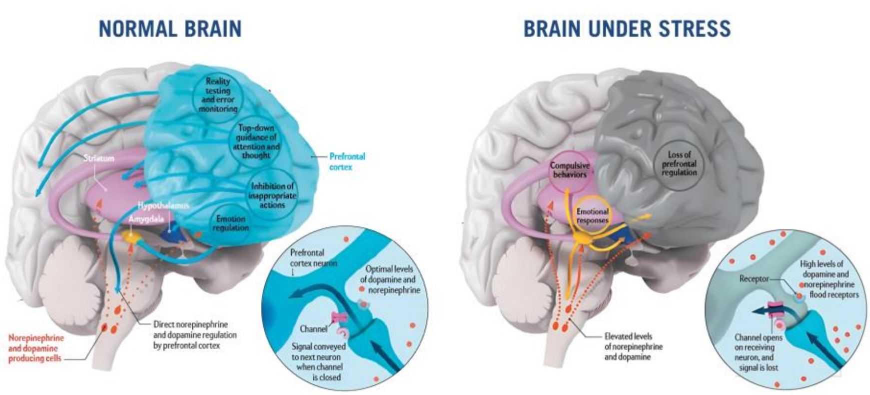
Transcranial Magnetic Stimulation (TMS)
Depression



Arnsten, 2009

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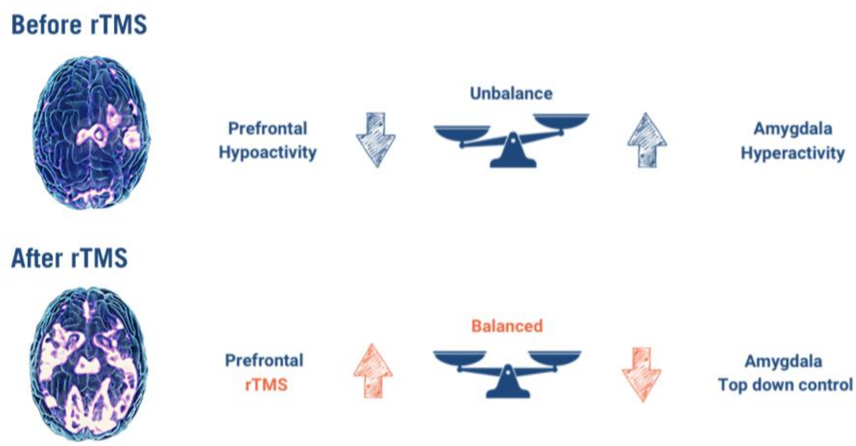
Transcranial Magnetic Stimulation (TMS)
Depression



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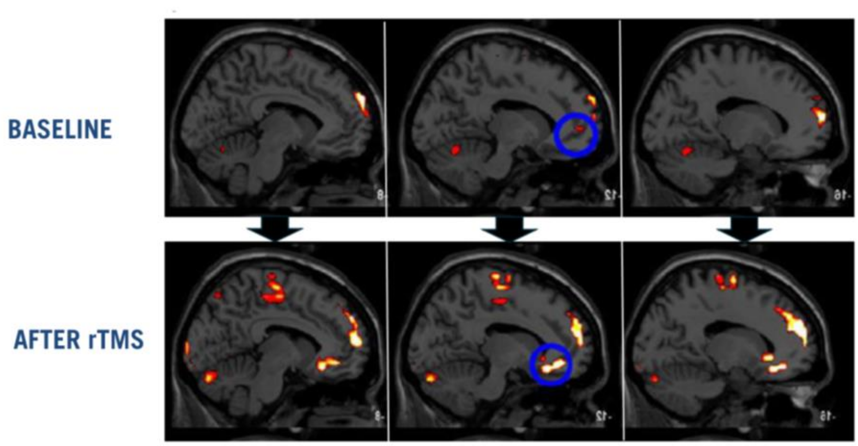
Transcranial Magnetic Stimulation (TMS)
Depression



Vink et al. 2018

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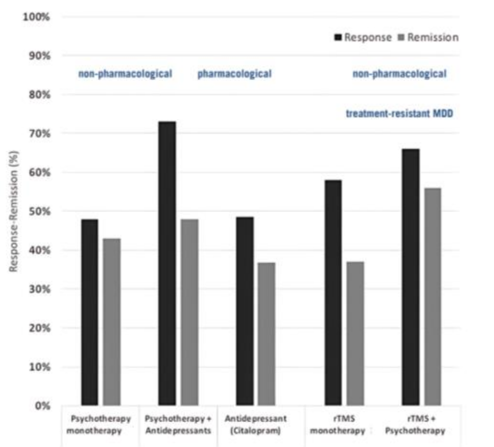
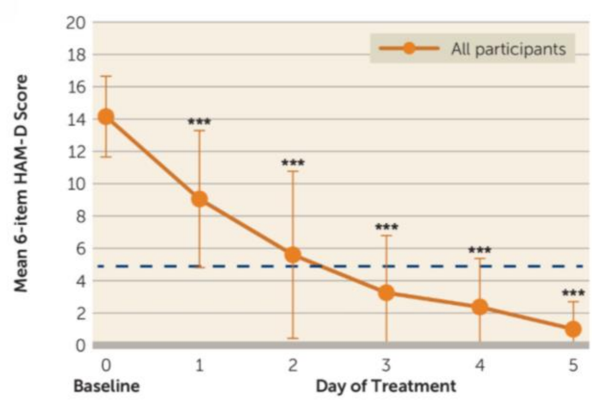
Transcranial Magnetic Stimulation (TMS)
Depression



Baeken et al., 2019



Cole et al., 2020

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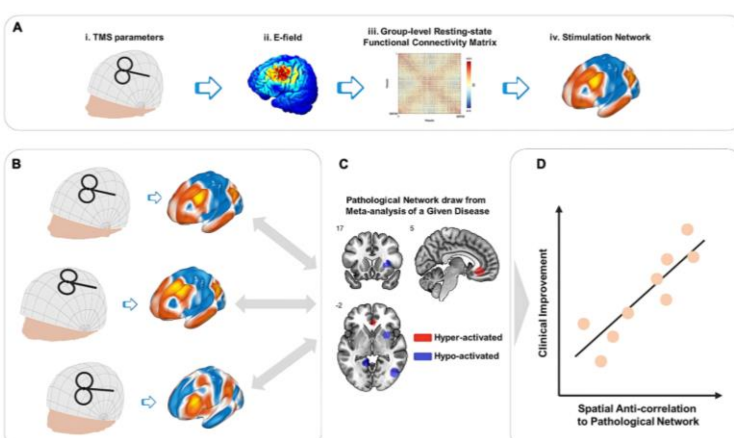
Transcranial Magnetic Stimulation (TMS)
Depression



Cao et al., 2023

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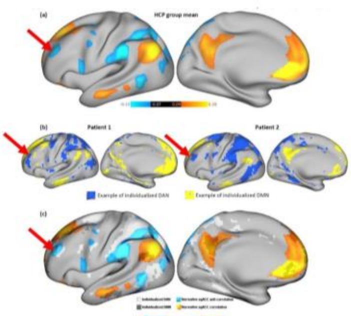
Transcranial Magnetic Stimulation (TMS)

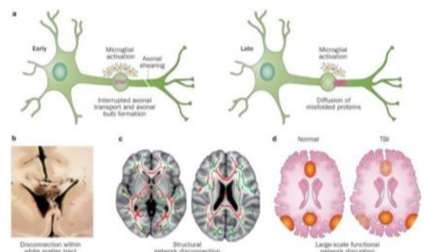
Depression after a traumatic brain injury

Article | Open access | Published: 11 March 2023

Individualized precision targeting of dorsal attention and default mode networks with rTMS in traumatic brain injury-associated depression

Shan H. Siddiqi, Sridhar Kandala, Carl D. Hacker, Nicholas T. Trapp, Eric C. Leuthardt, Alexandre R. Carter & David L. Brody





Sharp et al., 2014

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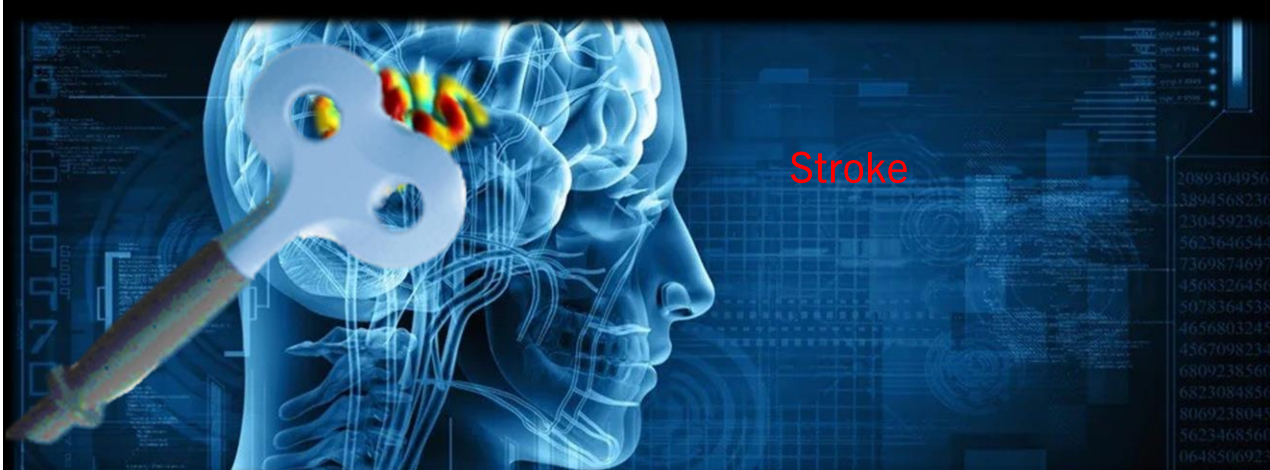
Non-Invasive Neuromodulation



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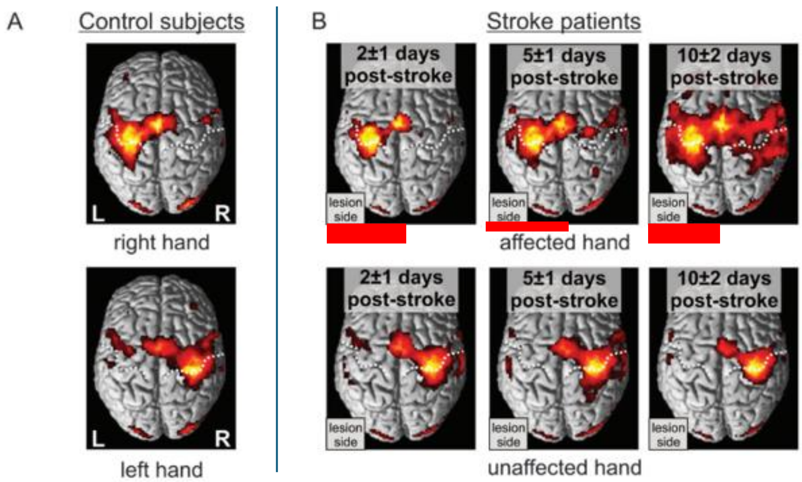
Transcranial Magnetic Stimulation (TMS)
Stroke

Imbalanced interhemispheric activity



Grefkes et al. 2008

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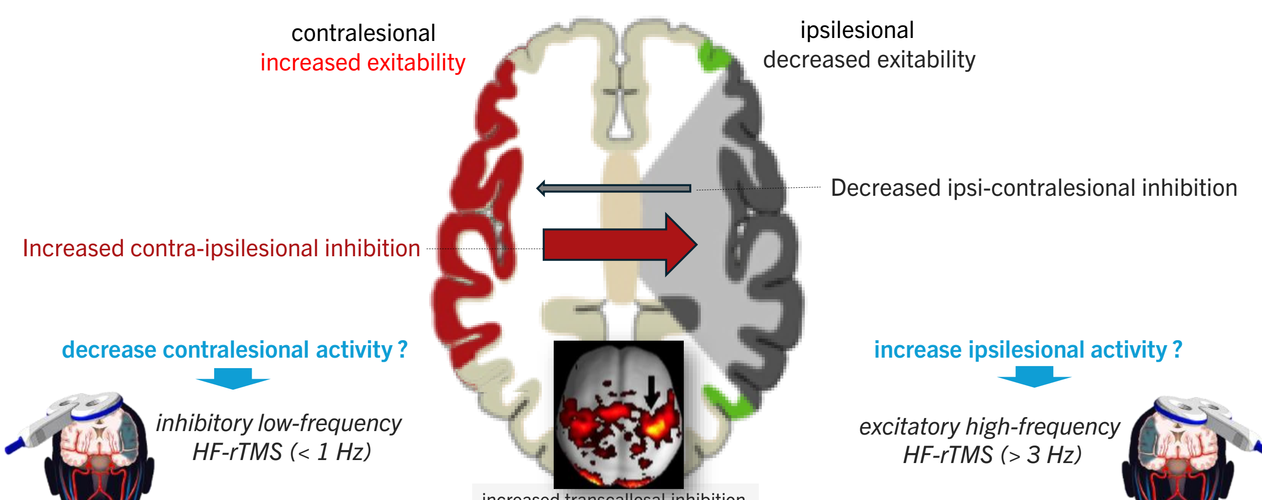
Transcranial Magnetic Stimulation (TMS)
Stroke

Paradoxal Functional Facilitation



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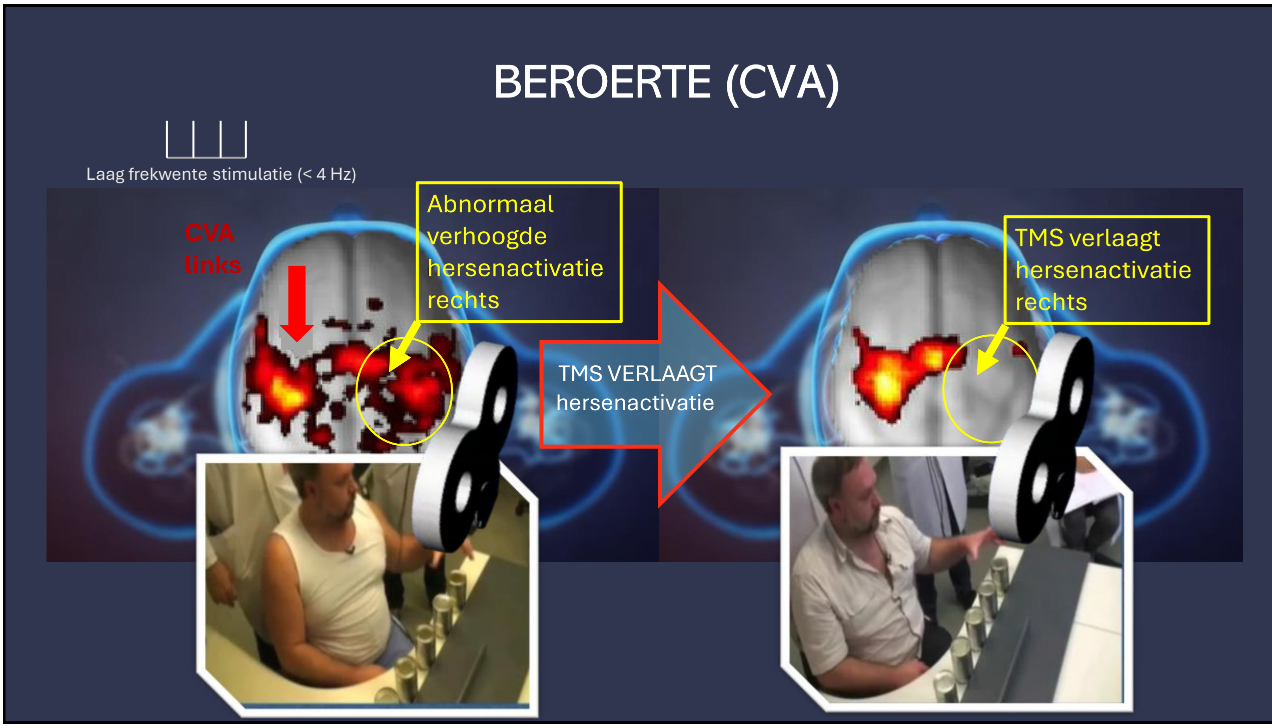

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Transcranial Magnetic Stimulation (TMS)
Stroke

Clinical study

Stroke
Volume 54, Issue 8, August 2023; Pages 1962-1971
https://doi.org/10.1161/STROKEAHA.123.042924

American Heart Association.

CLINICAL TRIALS

Continuous Theta-Burst Stimulation of the Contralesional Primary Motor Cortex for Promotion of Upper Limb Recovery After Stroke: A Randomized Controlled Trial

Jord J.T. Vink, MSc *, Eline C.C. van Lieshout, PhD *, Willem M. Otte, PhD, Ruben P.A. van Eijk, PhD, Mirjam Kouwenhoven, MD, Sebastiaan F.W. Neggers, PhD, H. Bart van der Worp, MD, PhD, Johanna M.A. Visser-Meily, MD, PhD, and Rick M. Dijkhuizen, PhD

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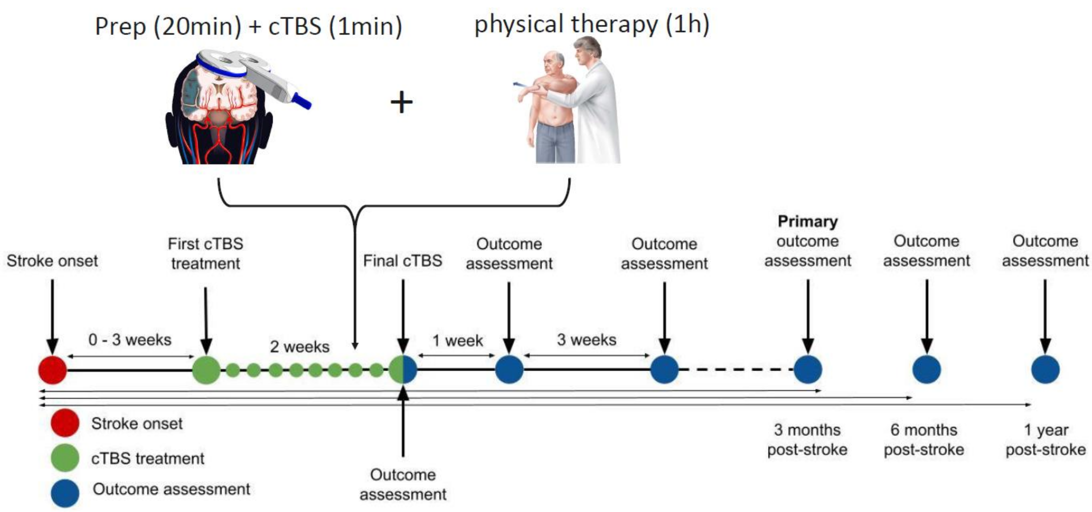
Transcranial Magnetic Stimulation (TMS)
Stroke

Clinical study



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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Federatie **Medisch Specialisten**

Herseninfarct en hersenbloeding

Non-invasieve hersenstimulatie met rTMS

Vooral stimulatie van de contralaterale, gezonde hemisfeer met LF rTMS of iTBS binnen drie maanden na een herseninfarct of –bloeding is herhaaldelijk geassocieerd met een beter herstel van uiteenlopende functies.

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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Editorial

ASNR AMERICAN SOCIETY OF NEUROREHABILITATION

International Stroke Recovery and Rehabilitation Roundtable Consensus Statements Are Driving Growth and Progress in Our Field

Neurorehabilitation and Neural Repair
2024, Vol. 38(1) 3–6
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DOI: 10.1177/15459683231223648
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Sage

Kathryn S. Hayward, PhD[1], Gert Kwakkel, PhD[2], and Julie Bernhardt, PhD[3]

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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

International Stroke Recovery and Rehabilitation Roundtable Consensus Statements Are Driving Growth and Progress in Our Field

Kathryn S. Hayward, PhD[1], Gert Kwakkel, PhD[2], and Julie Bernhardt, PhD[3]

Table 1. Topics for Which Consensus Recommendations Were Established in the First, Second, and Third Stroke Recovery and Rehabilitation Roundtable efforts.

Taskforce topic	Provides consensus recommendations for
SRRR1	
Timeline definitions[3]	Common language and definitions for stroke recovery and rehabilitation field and an agreed vision for accelerating progress in stroke recovery research.
Biomarkers[4]	Biomarkers that were considered ready to be included in clinical trials, and others that were promising and represent a developmental priority.
Standardized measurement of sensorimotor recovery[5]	Core measurement standards and patient characteristics that should be collected in all future stroke recovery trials to help build our understanding of the trajectory of stroke recovery and aid discovery of new and more targeted treatments.
Preclinical and clinical alignment[6]	Appropriate preclinical stroke recovery research and to align preclinical to clinical stroke recovery studies to avoid past mistakes and maximize clinical translation.
Monitoring and reporting of stroke recovery research[7]	Issues identified as limiting stroke rehabilitation research in the areas of developing, monitoring, and reporting stroke rehabilitation interventions
SRRR2	
Preclinical and clinical trial development[8]	Key knowledge units to develop stroke recovery treatment trials that can be addressed within a framework that defines GO and NO-GO decision pathways to guide selection of the most appropriate trial (including phase) given current knowledge.
Cognition[9]	Cognitive assessments to be integrated into stroke recovery studies generally and defined priorities for ongoing and future research for stroke recovery and rehabilitation.
Translation into practice[10]	Research evidence to be prioritized for implementation into stroke rehabilitation practice to have maximal impact.
Standardized measurement of quality of movement[11]	Kinematic and kinetic movement quantification for standardized measurements of sensorimotor recovery in stroke trials.
SRRR3	
Control comparator trial design[12]	Challenges that impact control comparator design that can be addressed with a tool produced to guide control comparator selection, description, and reporting of preclinical and clinical trials in stroke recovery and rehabilitation.
Fatigue[13]	Definition, clinical screening tools, and outcome measurement for fatigue after stroke and provided a roadmap for future research.
Non-invasive brain stimulation[14]	Outstanding barriers for the translation of preclinical and clinical research using the non-invasive brain stimulation techniques, transcranial magnetic stimulation, and transcranial direct current stimulation and provided a roadmap for the integration of these techniques into clinical practice.
Standardized measurement of balance and mobility[15]	Standardized outcome instruments for measuring balance and mobility recovery after stroke to optimize the quality of stroke rehabilitation and recovery studies and to enable data synthesis across trials.

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Non-Invasive Neuromodulation

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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Level of Evidence A

Data derived from multiple randomized clinical trials or meta-analyses.

Level of Evidence B

Data derived from a single randomized clinical trial or large non-randomized studies.

Level of Evidence C

Consensus of opinion of the experts and/or small studies, retrospective studies, registries.

Table 20
Summary of recommendations on rTMS efficacy according to clinical indication.

Neuropathic pain	Definite analgesic efficacy of HF-rTMS of M1 contralateral to pain side (Level A), while LF-rTMS is probably ineffective (Level B)
CRPS type I	Possible analgesic efficacy of HF-rTMS of M1 contralateral to pain side (Level C)
Fibromyalgia	**Probable efficacy of HF-rTMS of the left M1 in improving quality of life of patients with fibromyalgia (Level B)**
Fibromyalgia	**Probable analgesic efficacy of HF-rTMS of the left DLPFC in patients with fibromyalgia (Level B)**
Parkinson's disease	**Probable efficacy of HF-rTMS of bilateral M1 regions in motor symptoms of PD patients (Level B)**
Parkinson's disease	Probable antidepressant efficacy of HF-rTMS of the left DLPFC in PD patients (Level B)
Motor stroke	**Definite efficacy of LF-rTMS of contralesional M1 in hand motor recovery at the postacute stage (Level A)**
Motor stroke	**Probable efficacy of HF-rTMS of ipsilesional M1 in hand motor recovery at the postacute stage (Level B)**
Motor stroke	**Possible efficacy of LF-rTMS of contralesional M1 in hand motor recovery at the chronic stage (Level C)**
Post-stroke aphasia	**Probable efficacy of LF-rTMS of right IFG in nonfluent aphasia recovery at the chronic stage (Level B)**
Hemispatial neglect	Possible efficacy of cTBS of the contralesional left parietal in visuospatial hemineglect recovery at the post-acute stage of stroke (Level C)
Multiple sclerosis	**Probable efficacy of iTBS of the leg area of M1 contralateral to the most affected limb (or both M1) in lower limb spasticity (Level B)**
Epilepsy	Possible antiepileptic efficacy of LF-rTMS of the epileptic focus (Level C)
Alzheimer's disease	**Possible efficacy of multisite rTMS-COG to improve cognitive function, memory and language level of AD patients, especially at a mild/early stage of the disease (Level C)**
Tinnitus	Possible efficacy of LF rTMS of the auditory cortex of the left hemisphere (or contralateral to the affected ear) in chronic tinnitus (Level C)
Depression	Definite antidepressant efficacy of HF-rTMS of the left DLPFC in major depression using a figure-of-8 coil or a H1-coil (Level A)
Depression	**Definite antidepressant efficacy of deep HF-rTMS over the left DLPFC in major depression (Level A)**
Depression	Probable antidepressant efficacy of LF-rTMS of the right DLPFC in major depression (Level B)
Depression	**Probable antidepressant efficacy of bilateral right-sided LF-rTMS and left-sided HF-rTMS of the DLPFC in major depression (Level B)**
Depression	**Probable antidepressant efficacy of bilateral right-sided cTBS and left-sided iTBS of the DLPFC in major unipolar depression (Level B), while unilateral right-sided cTBS is possibly ineffective (Level C)**
Depression	**Possibly no differential antidepressant efficacy between: right LF-rTMS vs. left HF-rTMS, bilateral vs. unilateral rTMS of the DLPFC, and rTMS performed alone vs. combined with antidepressants (Level C)**
Post-traumatic stress disorder	**Probable efficacy of HF-rTMS of the right DLPFC in PTSD (Level B)**
Obsessive compulsive disorder	**Possible efficacy of LF-rTMS of the right DLPFC in OCD (Level C)**
Schizophrenia:auditory hallucinations	Possible efficacy of LF-rTMS of the left TPC in auditory hallucinations in schizophrenia (Level C)
Schizophrenia: negative symptoms	**Possible efficacy of HF-rTMS of the left DLPFC on negative symptoms of schizophrenia (Level C)**
Addiction and craving	Possible efficacy of HF-rTMS of the left DLPFC on cigarette craving and consumption (Level C)

In all other conditions, there is "no recommendation", which means the absence of sufficient data to make a recommendation, but not the evidence for an absence of effect. Recommendations that change from our previous work (Lefaucheur et al., 2014) are shown in bold.

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Transcranial Magnetic Stimulation (TMS)
Indications

Depression
OCD
Motor stroke: contralesional motor cortex
Motor stroke: ipsilesional motor cortex
Stroke: hemispatial neglect
Post-stroke non-fluent aphasia
Stroke: Dysphagia
Concussion
Neuropathic pain
Non-neuropathic pain
MS
Parkinson's disease: movement disorders
Parkinson's disease: levodopa-induced dyskinesia
Parkinson's disease: depression

Epilepsy
Dementia Alzheimer's disease
Pelvic floor stimulation
Fibromyalgia
Visceral pain
Post-traumatic stress dsorder (PTSD)
Addictive disorders
Essential tremor (cerebellar stimulation)
Tinnitus
Addictive disorders
ASS
ADHD
Whiplash

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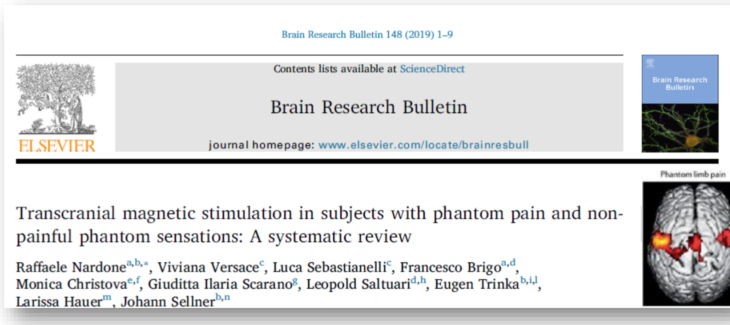
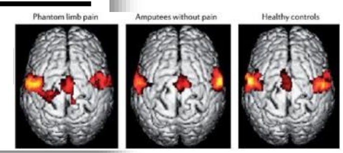
Transcranial Magnetic Stimulation (TMS)
Indications

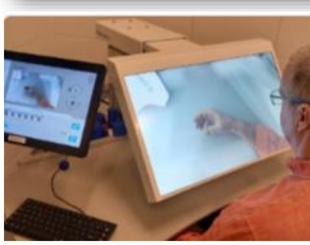


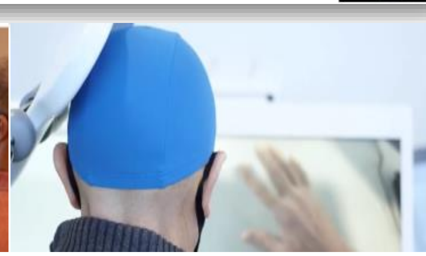
Brain Research Bulletin 148 (2019) 1–9
Contents lists available at ScienceDirect
Brain Research Bulletin
journal homepage: www.elsevier.com/locate/brainresbull

Transcranial magnetic stimulation in subjects with phantom pain and non-painful phantom sensations: A systematic review

Raffaele Nardone[a,b,*], Viviana Versace[c], Luca Sebastianelli[c], Francesco Brigo[a,d], Monica Christova[e,f], Giuditta Ilaria Scarano[g], Leopold Saltuari[d,h], Eugen Trinka[b,i,l], Larissa Hauer[m], Johann Sellner[b,n]







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Non-Invasive Neuromodulation

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Transcranial Magnetic Stimulation (TMS)
Safety

Expert Guidelines TMS

2009

Clinical Neurophysiology xxx (2009) xxx–xxx

Contents lists available at ScienceDirect

Clinical Neurophysiology

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

Guidelines

Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research ☆

Simone Rossi [a,*], Mark Hallett [b], Paolo M. Rossini [c,d], Alvaro Pascual-Leone [e] and The Safety of TMS Consensus Group [1]

[a] Dipartimento di Neuroscienze, Sezione Neurologia, Università di Siena, Italy
[b] Human Motor Control Section, NINDS, NIH, Bethesda, USA
[c] Università Campus Biomedico, Roma, Italy
[d] Casa di Cura S. Raffaele, Cassino, Italy
[e] Berenson-Allen Center for Noninvasive Brain Stimulation, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, USA

ARTICLE INFO

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Keywords:
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TMS
rTMS
Safety

ABSTRACT

This article is based on a consensus conference, which took place in Certosa di Pontignano, Siena (Italy) on March 7–9, 2008, intended to update the previous safety guidelines for the application of transcranial magnetic stimulation (TMS) in research and clinical settings.

Over the past decade the scientific and medical community has had the opportunity to evaluate the safety record of research studies and clinical applications of TMS and repetitive TMS (rTMS). In these years the number of applications of conventional TMS has grown impressively, new paradigms of stimulation have been developed (e.g., patterned repetitive TMS) and technical advances have led to new device designs and to the real-time integration of TMS with electroencephalography (EEG), positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Thousands of healthy subjects and patients with various neurological and psychiatric diseases have undergone TMS allowing a better assessment of relative risks. The occurrence of seizures (i.e., the most serious TMS-related acute adverse effect) has been extremely rare, with most of the few new cases receiving rTMS exceeding previous guidelines, often in patients under treatment with drugs which potentially lower the seizure threshold.

The present updated guidelines review issues of risk and safety of conventional TMS protocols, address the undesired effects and risks of emerging TMS interventions, the applications of TMS in patients with

2021

Clinical Neurophysiology 132 (2021) 269–306

Contents lists available at ScienceDirect

Clinical Neurophysiology

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

Review

Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines

Simone Rossi [a,*], Andrea Antal [b,c], Sven Bestmann [d], Marom Bikson [e], Carmen Brewer [f], Jürgen Brockmöller [g], Linda L. Carpenter [h], Massimo Cincotta [i], Robert Chen [j], Jeff D. Daskalakis [k], Vincenzo Di Lazzaro [l], Michael D. Fox [m,n,o], Mark S. George [p], Donald Gilbert [q], Vasilios K. Kimiskidis [r], Giacomo Koch [s], Risto J. Ilmoniemi [t], Jean Pascal Lefaucheur [u,v], Letizia Leocani [w], Sarah H. Lisanby [x,y,2], Carlo Miniussi [z], Frank Padberg [aa], Alvaro Pascual-Leone [ab,ac,ad], Walter Paulus [b], Angel V. Peterchev [ae], Angelo Quartarone [af], Alexander Rotenberg [ag], John Rothwell [d], Paolo M. Rossini [ah], Emiliano Santarnecchi [m], Mouhsin M. Shafi [m], Hartwig R. Siebner [ai,aj,ak], Yoshikatzu Ugawa [al], Eric M. Wassermann [am,2], Abraham Zangen [an], Ulf Ziemann [ao], Mark Hallett [ap,2,*],

The basis of this article began with a Consensus Statement from the IFCN Workshop on "Present, Future of TMS: Safety, Ethical Guidelines", Siena, October 17-20, 2018, updating through April 2020 [1]

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Transcranial Magnetic Stimulation (TMS)
Safety

Safety guidelines recommendations for TMS

- Patient screening
  - Medical history
  - Family history
  - Use of medication
- Treatment dose/duration
  - Max train duration of 4.2s for 10Hz rTMS at 120% RMT
  - Inter-train intervals
- Training

The Academy of Brain Stimulation ★ TMS Education and Certification ★

INTERNATIONAL
CLINICAL
TMS CERTIFICATION
COURSE

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Transcranial Magnetic Stimulation (TMS)
Safety

Contraindications

1. **The <u>only absolute contraindication</u>** to TMS/rTMS is the presence of metallic hardware in close contact to the discharging coil (such as cochlear implants, or Internal Pulse Generator or medication pumps).
2. **<u>All the rest contraindications are relative</u>** ones. In each individual case the benefit of the test should be weighed against possible adverse effects.
   - **Increased risk of inducing seizure:**
     - related to the protocol of stimulation;
     - related to the disease or patient's condition (epilepsy, lesion of the brain, administration of drugs that potentially lower seizure threshold, sleep deprivation, alcoholism).
   - **Increased risk of other events:**
     - related to patient's condition (implanted brain electrodes, pregnancy, severe or recent heart disease.

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Transcranial Magnetic Stimulation (TMS)
Safety

Neuropsychiatric Disease and Treatment
Neuropsychiatric Disease and Treatment 2020:16 2989–3000
Dovepress
open access to scientific and medical research

REVIEW

Transcranial Magnetic Stimulation (TMS) Safety with Respect to Seizures: A Literature Review

Debra J Stultz
Savanna Osburn
Tyler Burns
Sylvia Pawlowska-Wajswol
Robin Walton

This article was published in the following Dove Press journal:
Neuropsychiatric Disease and Treatment

- The risk of TMS-related seizures is < 1% overall.
- TMS has successfully been used in patients with epilepsy, traumatic brain injuries, and those with a prior TMS-related seizure.

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Transcranial Magnetic Stimulation (TMS)
Safety

Brain Neurorehabil. 2021 Mar;14(1):e6
https://doi.org/10.12786/bn.2021.14.e6
pISSN 1976-8753·eISSN 2383-9910

bnr
Brain & NeuroRehabilitation

Special Review

Check for updates

Safety Review for Clinical Application of Repetitive Transcranial Magnetic Stimulation

Won-Seok Kim, Nam-Jong Paik

Department of Rehabilitation Medicine, Seoul National University College of Medicine, Seoul National University Bundang Hospital, Seongnam, Korea

HIGHLIGHTS

- Repetitive transcranial magnetic stimulation (rTMS) conforming to the safety guideline is generally safe.
- Any precautions and risks for rTMS should be screened prior to starting rTMS.

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Transcranial Magnetic Stimulation (TMS)
Safety

Based on the vast amount of safety data collected over the past 30 years, several publications, meta-analyses, reviews, guidelines and consensus papers have provided peer-reviewed evidence-based assessments of the safety of TMS (see e.g., Rossi et al., 2020) as well as low output transcranial electric stimulation, TES (see e.g., Antal et al., 2017; 2022; Bikson et al., 2018a; b; Caulfield et al., 2022; Zewdie et al., 2020). Based on these data, **the current scientific and clinical evidence suggests both rTMS and low intensity TES are safe treatment and research interventions with few and mild adverse effects.**

The prominent mentioning of rTMS/TES-related seizure risks contradicts the most recent consensus statement in the field based on actual clinical data which demonstrated that observed seizure rates are so much lower than previous guidelines advised, that the prior caution about seizure risk is no longer supported by scientific evidence (Rossi et al., 2020).

To put this into perspective, the likelihood of a seizure from rTMS (0.003%) is lower than that associated with the use of antidepressants and antipsychotics (0.1-1, 5%), which are one of the most frequently prescribed treatments for depression (George et al., 2013).

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Transcranial Magnetic Stimulation (TMS)
Safety

B-STARS²
Brain STimulation for Arm Recovery after Stroke

De Hoogstraat Revalidatie | UMC Utrecht

Uit het onderzoeksprotocol voor B-STARS2:
The most serious adverse effect is the occurrence of a seizure at a crude risk of approximately **0.02%** per stimulation session, as reported in a systematic review of 67 studies with 1,040 subjects and >4,500 sessions. **(1/4500 sessions)**
More common adverse events during and after TBS are transient headache and neck pain, reported by <3% of subjects.
CTBS treatment **did not lead to seizures** in our phase II trial (B-STARS). We only observed mild side effects, such as headache (<4%) and muscle pain (<1%) and the intervention was reported to be tolerable and comfortable.

Oberman, Lindsay, et al. "Safety of theta burst transcranial magnetic stimulation: a systematic review of the literature." Journal of Clinical Neurophysiology 28.1 (2011): 67.

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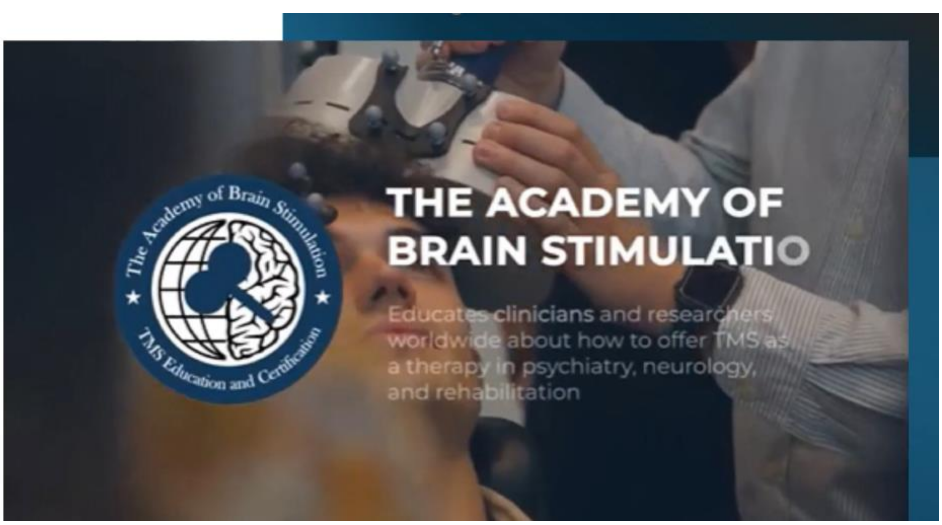
Transcranial Magnetic Stimulation (TMS)
Training



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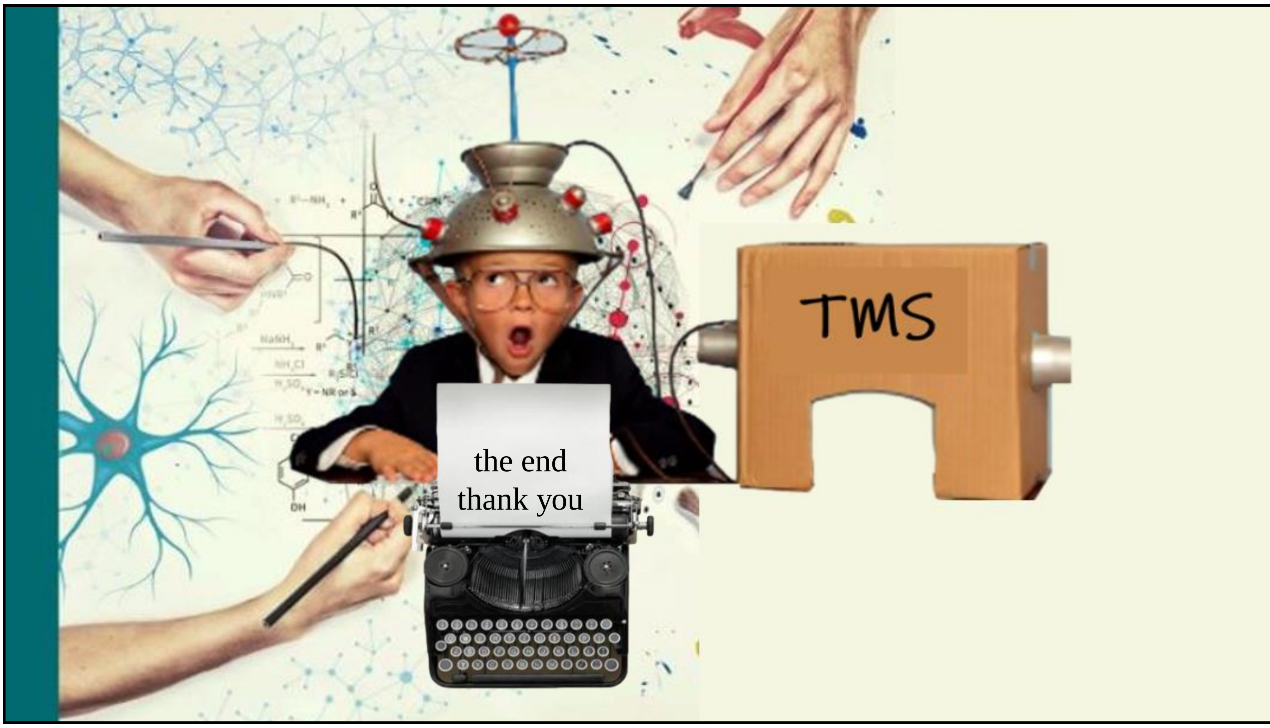

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