NAH CONGRES
Niet-aangeboren hersenletsel in Vlaanderen vandaag

Welkom

Niet-invasieve hersenstimulatie

C. Lafosse & S. De Witte

Hersenletsel Liga
Samen voor mensen met NAH

sig
INCLUSIE IN-ZICHT

1

NAH CONGRES
Niet-aangeboren hersenletsel in Vlaanderen vandaag

Getuigenis







2

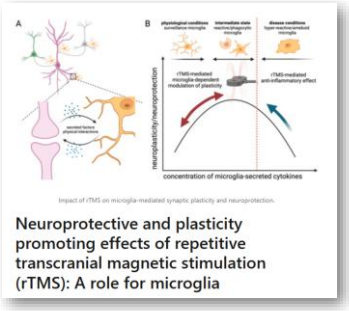


Werkingsmechanisme van niet-invasieve neuromodulatie

3

All neuromodulation techniques have same underlying principle

Neuromodulation changes activity of neurons and glia and bloodvessels
thereby changes functional and effective connectivity
modulates neural networks functioning (e.g. efficiency)
thereby changing the network's emergent function
and has an anti-inflammatory effect



Neuroprotective and plasticity promoting effects of repetitive transcranial magnetic stimulation (rTMS): A role for microglia

4



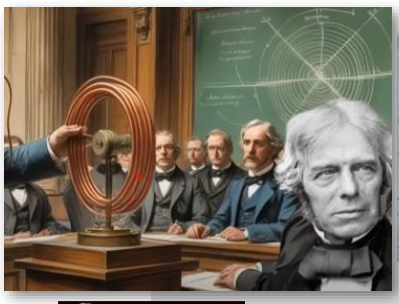
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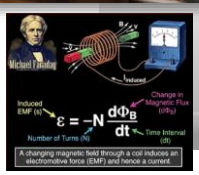
Transcranial Magnetic Stimulation (TMS)

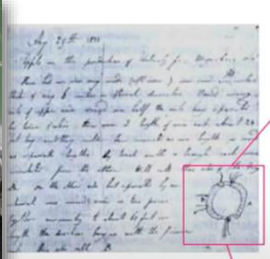
Biophysics

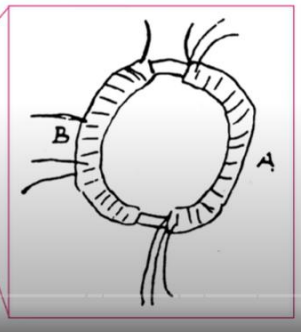
Magnetic field generation and electrical current induction in brain
(Faraday's Law of electromagnetic induction)

wanneer een stroom door lussen van metaaldraad (zoals een magnetische spoel) loopt, ontstaat er een tijdelijk magnetisch veld, dat op zijn beurt een elektrisch veld opwekt









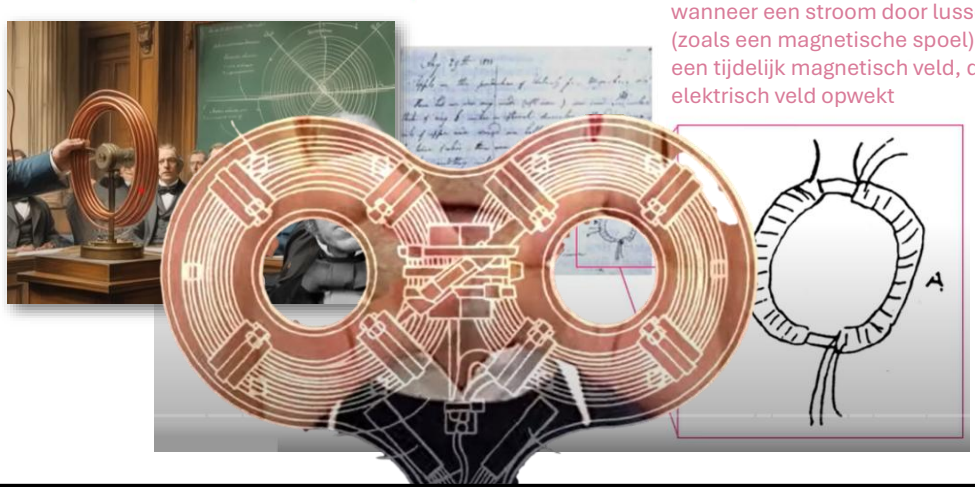
M. Faraday
August 29, 1831

6

Transcranial Magnetic Stimulation (TMS)
Biophysics

Magnetic field generation and electrical current induction in brain
(Faraday's Law of electromagnetic induction)

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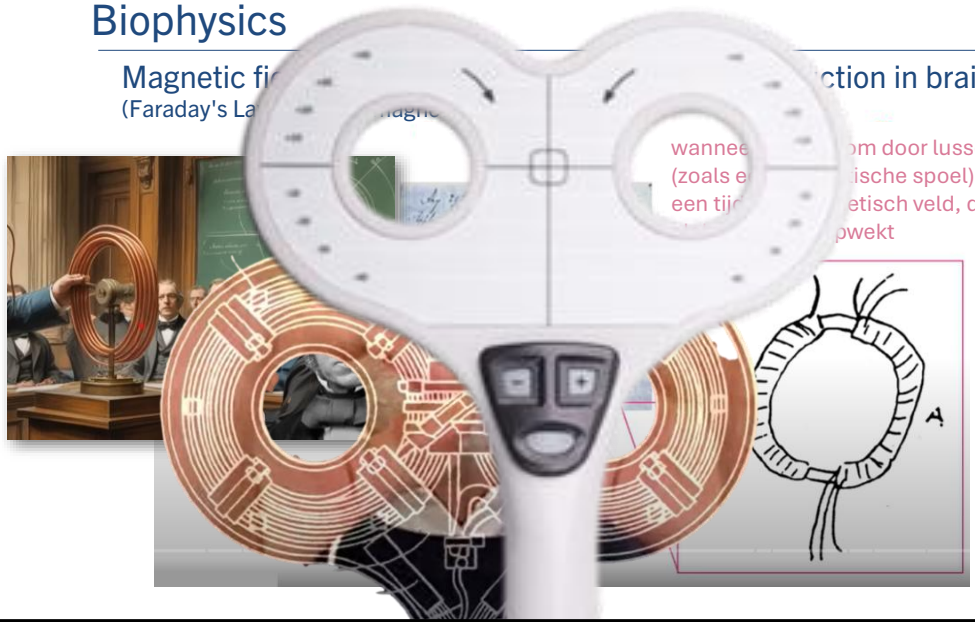


7

Transcranial Magnetic Stimulation (TMS)
Biophysics

Magnetic fi ction in brain
(Faraday's La

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8

Transcranial Magnetic Stimulation (TMS)
Biophysics

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(Faraday's Law of electromagnetic induction)

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9

Transcranial Magnetic Stimulation (TMS)
Biophysics

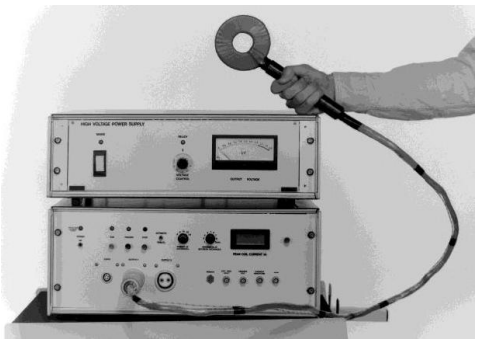
Magnetic field generation and electrical current induction in brain
(Faraday's Law of electromagnetic induction)



dr. Anthony Barker
February 12, 1985
Institute of Neurology London



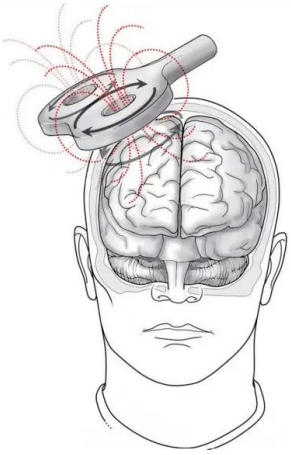
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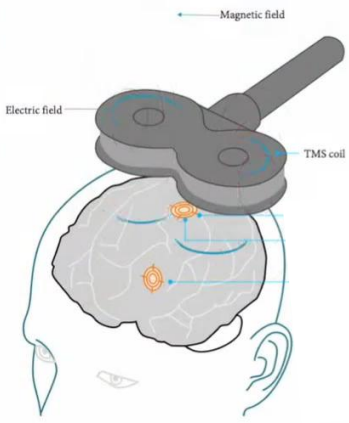
Transcranial Magnetic Stimulation (TMS)
Biophysics

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





een veranderende magnetische flux zorgt voor een elektrische spanning en stroom

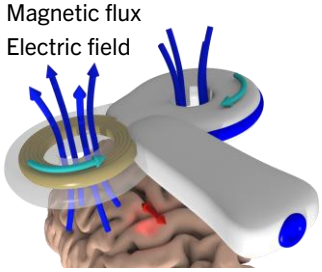


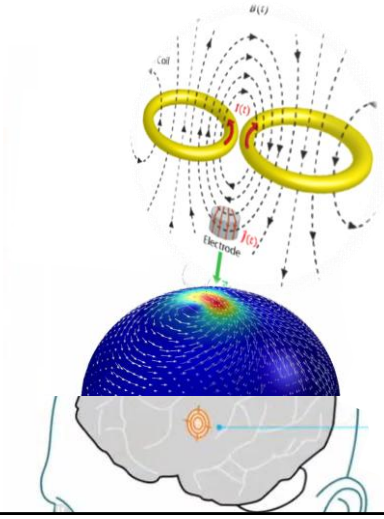
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Transcranial Magnetic Stimulation (TMS)
Biophysics

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

Electrical current
Magnetic flux
Electric field

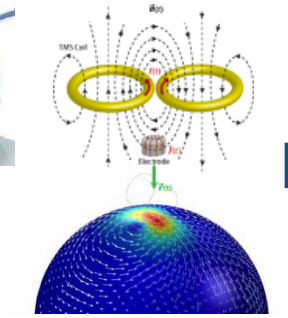
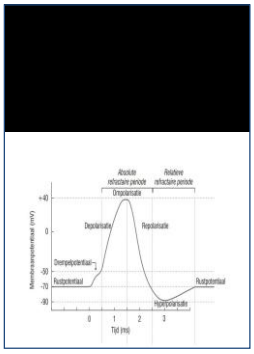
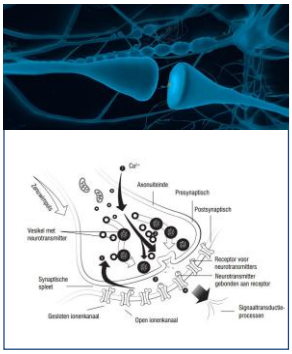




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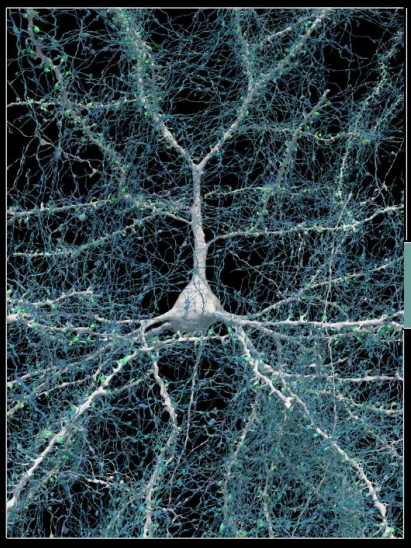
Transcranial Magnetic Stimulation (TMS)
Biophysics

From stimulus to response

13

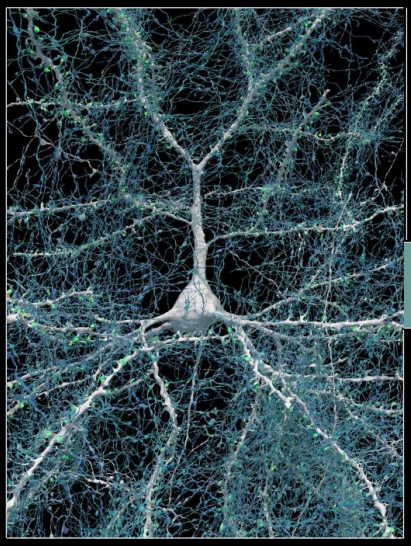
From stimulus to response


neuron



14

From stimulus to response



neuron



TMS coil induces a magnetic field (2-Tesla magnitude)

↓

creates an electric field in the brain

↓

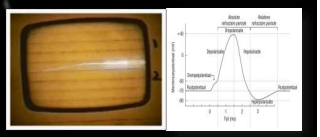
neuronal membrane potential changes

↓

when it reaches a certain threshold (-50mV)

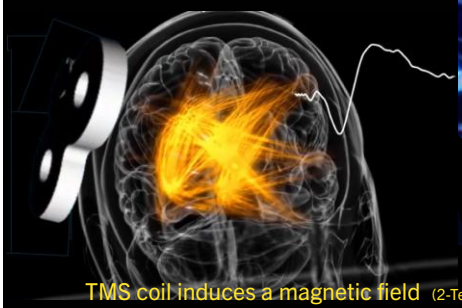
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action potential



15

From stimulus to response





TMS coil induces a magnetic field (2-Tesla magnitude)

↓

creates an electric field in the brain

↓

neuronal membrane potential changes

↓

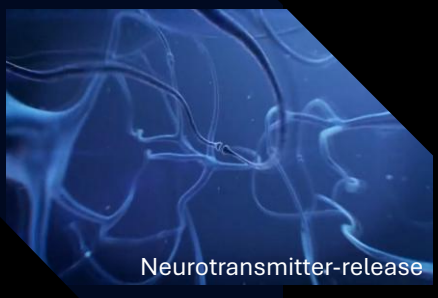
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↓

action potential

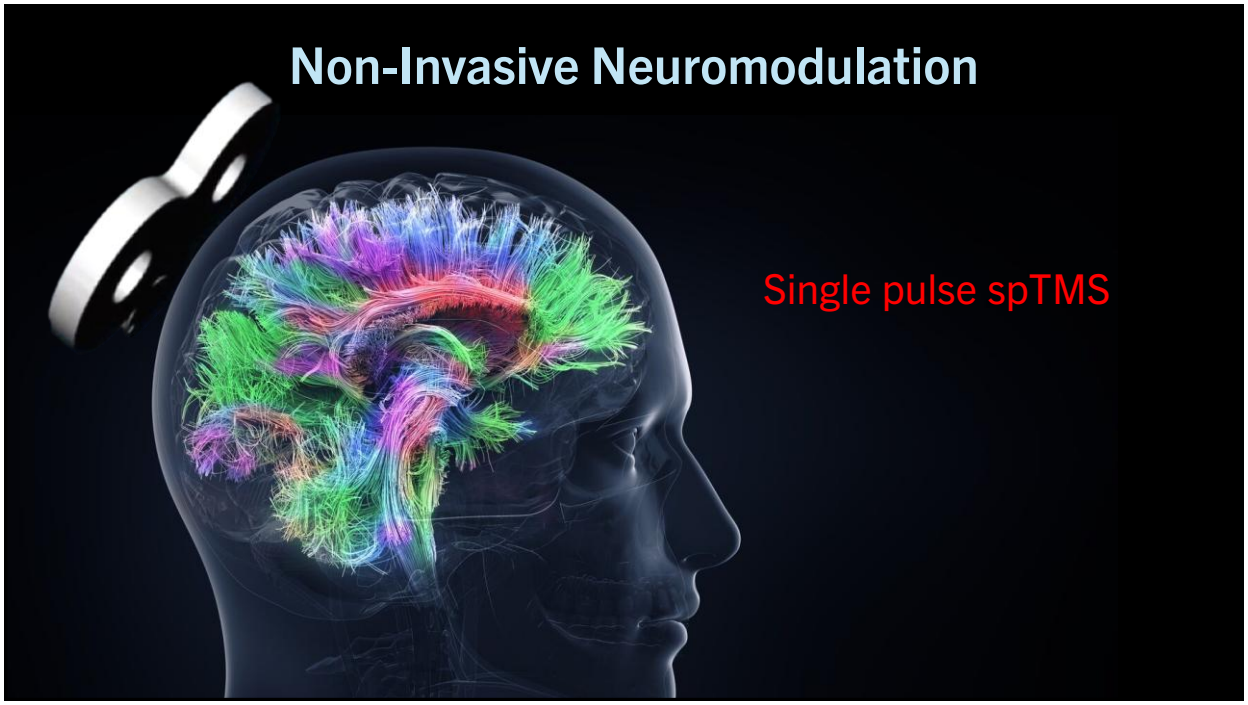
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signal propagation



Neurotransmitter-release

16

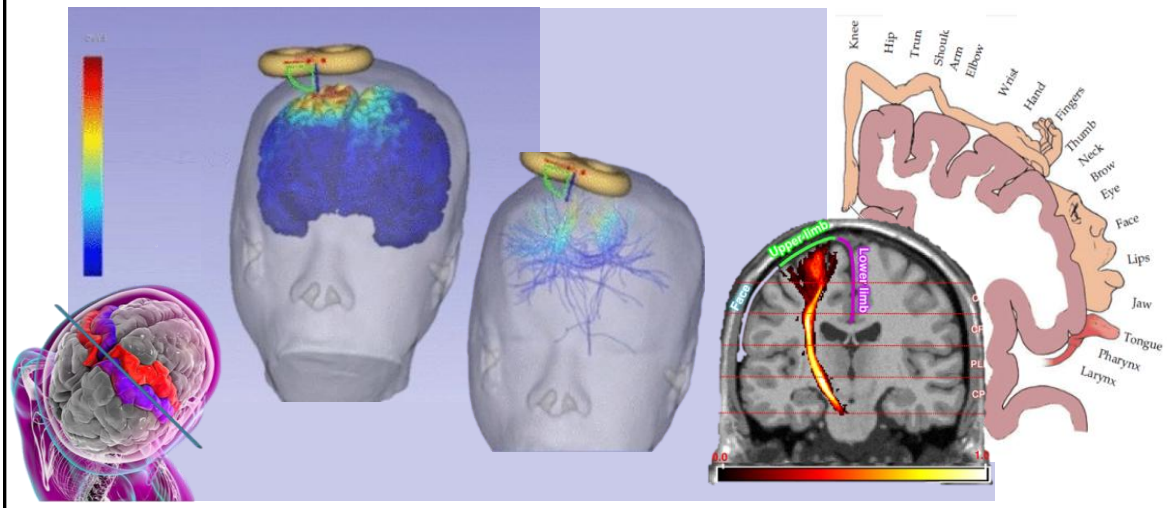


17

Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

Single pulse stimulation Motor Cortex M1

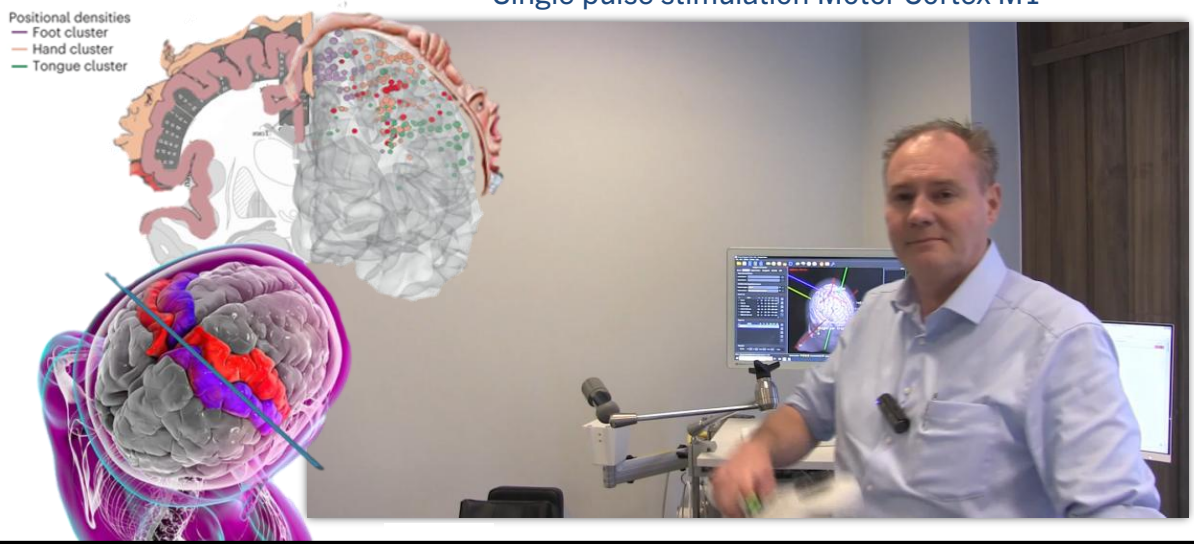


18

Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

Single pulse stimulation Motor Cortex M1

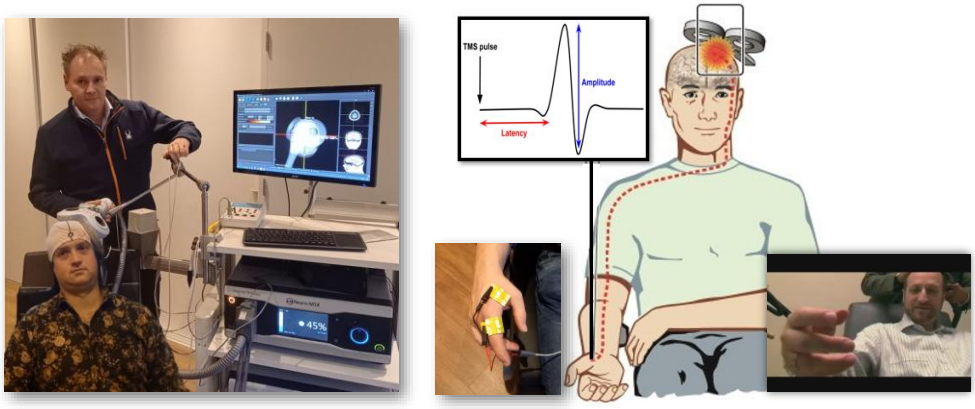


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Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

Motor Evoked Potential (MEP)



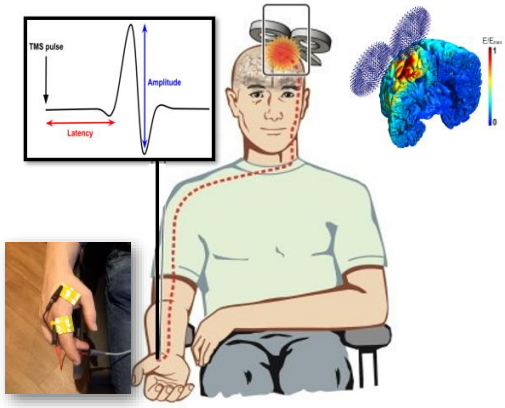
A single TMS pulse can evoke activity in the motor cortex resulting in a muscular motor response (MEP) that can be measured with EMG. TMS also activates different intracortical circuits within the M1 and connections from other cortical areas to the M1. These intracortical circuits interact with each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

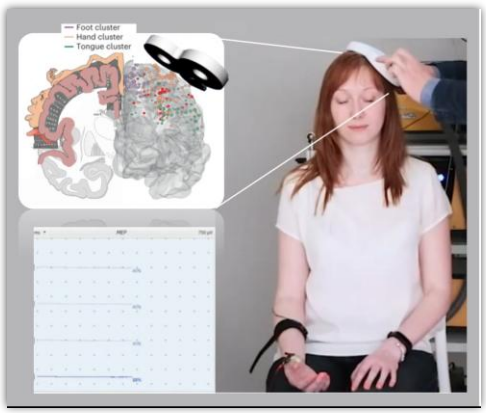
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Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

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





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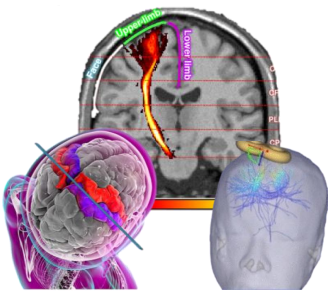
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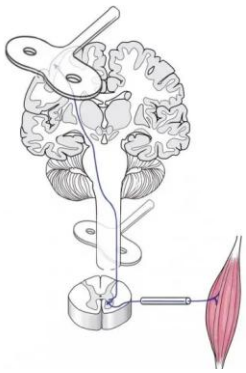
KLINISCH

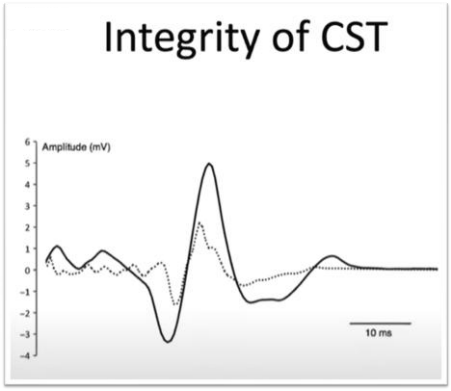
Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

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







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KLINISCH

Transcranial Magnetic Stimulation (TMS)

Magnetic Stimulation Modes

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



Cerebrovascular disease
Original research

The relationship between corticospinal excitability and structural integrity in stroke patients

Lina Daghsen [1, 2], Thomas Checkouri [1, 2], Aymric Wittwer [2, 3], Romain Valabregue [1, 4], Damien Galanaud [1, 4, 5], François-Xavier Lejeune [1, 6], Mohammed Doulazmi [7], Jean-Charles Lamy [1, 4], Pierre Pouget [1], Emmanuel Roze [1, 8], Charlotte Rosso [1, 2, 3]

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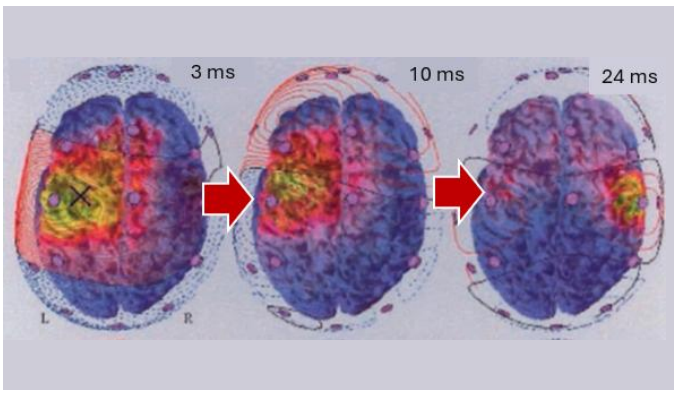
23

Transcranial Magnetic Stimulation (TMS)

Signal propagation

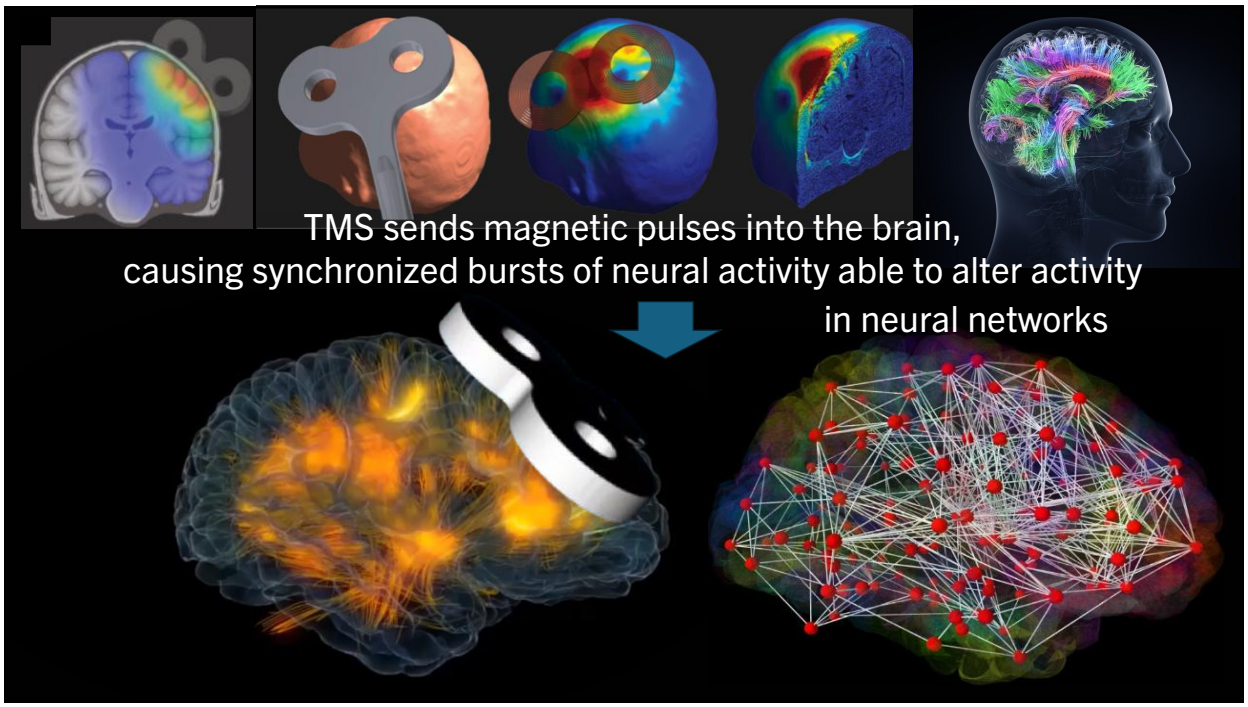
After local activation, induced neuronal activation propagates to distal areas



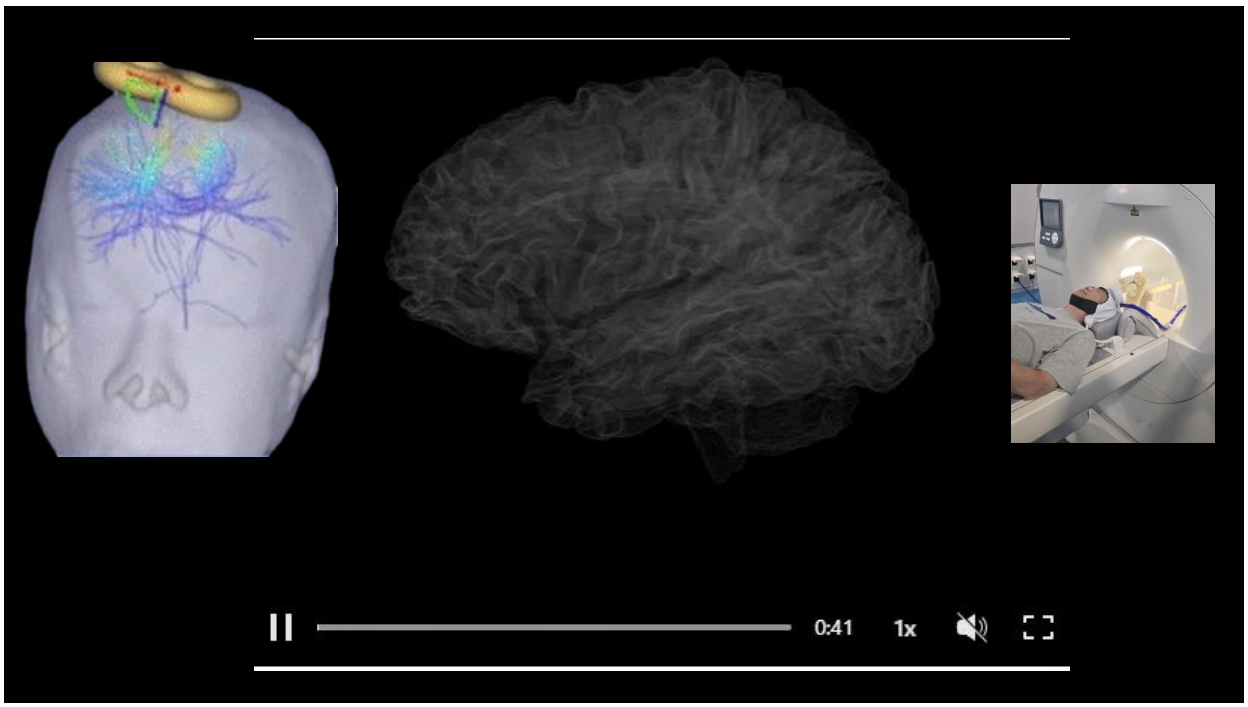


TMS-induced activity is not restricted to the target brain region but spreads to remote brain regions

24


TMS sends magnetic pulses into the brain,
causing synchronized bursts of neural activity able to alter activity
in neural networks

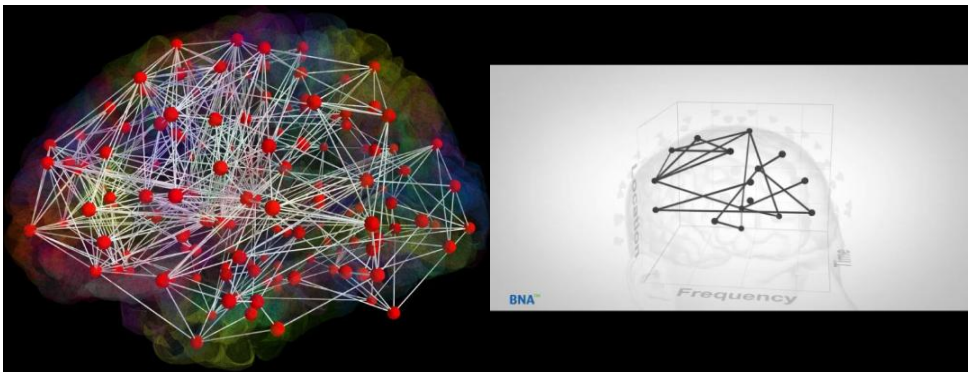
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0:41
1x

26

Transcranial Magnetic Stimulation (TMS)
Signal propagation

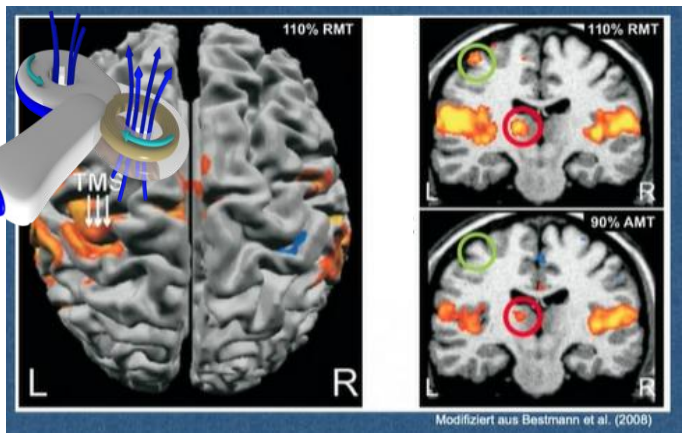
Full effect of TMS signal propagation can only be understood in terms of full networks of neuron activation

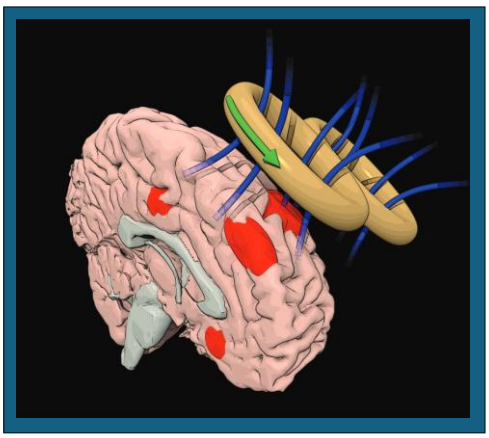


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Transcranial Magnetic Stimulation (TMS)
Stroke

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

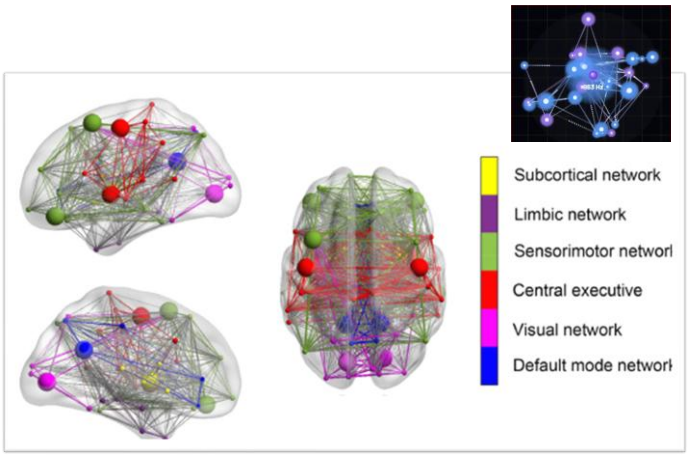




28

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





Increased or decreased brain connectivity can be modulated by TMS

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Non-Invasive Neuromodulation

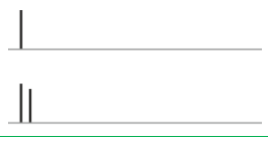


Therapeutic rTMS

30

Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

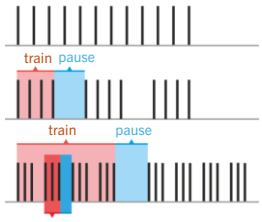
DIAGNOSTIC



Single pulse

Paired pulse

THERAPEUTIC



Continuous rhythmical stimulation

Stimulation by trains

Burst stimulation (TBS or Theta Burst Stimulation)

repetitive TMS (rTMS)

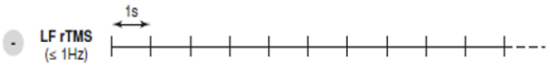
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Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

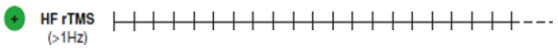
repetitive TMS protocols can either temporarily **increase** or **decrease** neuronal **excitability**

Continuous rhythmical stimulation

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



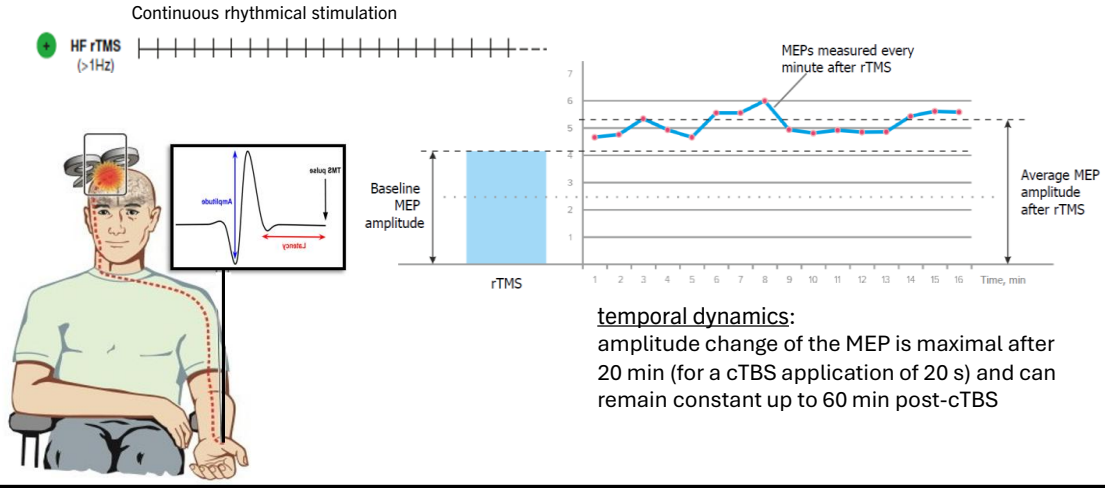
- High frequency rTMS stimulation (> 3Hz)
  - Excitatory effect



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Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

Effect of HF-rTMS on the amplitude of evoked potentials



temporal dynamics:
amplitude change of the MEP is maximal after 20 min (for a cTBS application of 20 s) and can remain constant up to 60 min post-cTBS

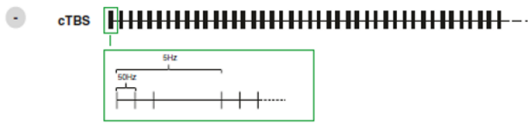
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Transcranial Magnetic Stimulation (TMS)
Magnetic Stimulation Modes

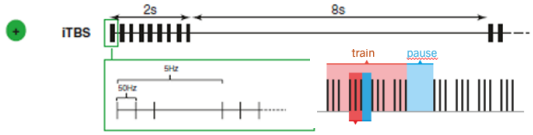
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Theta burst stimulation

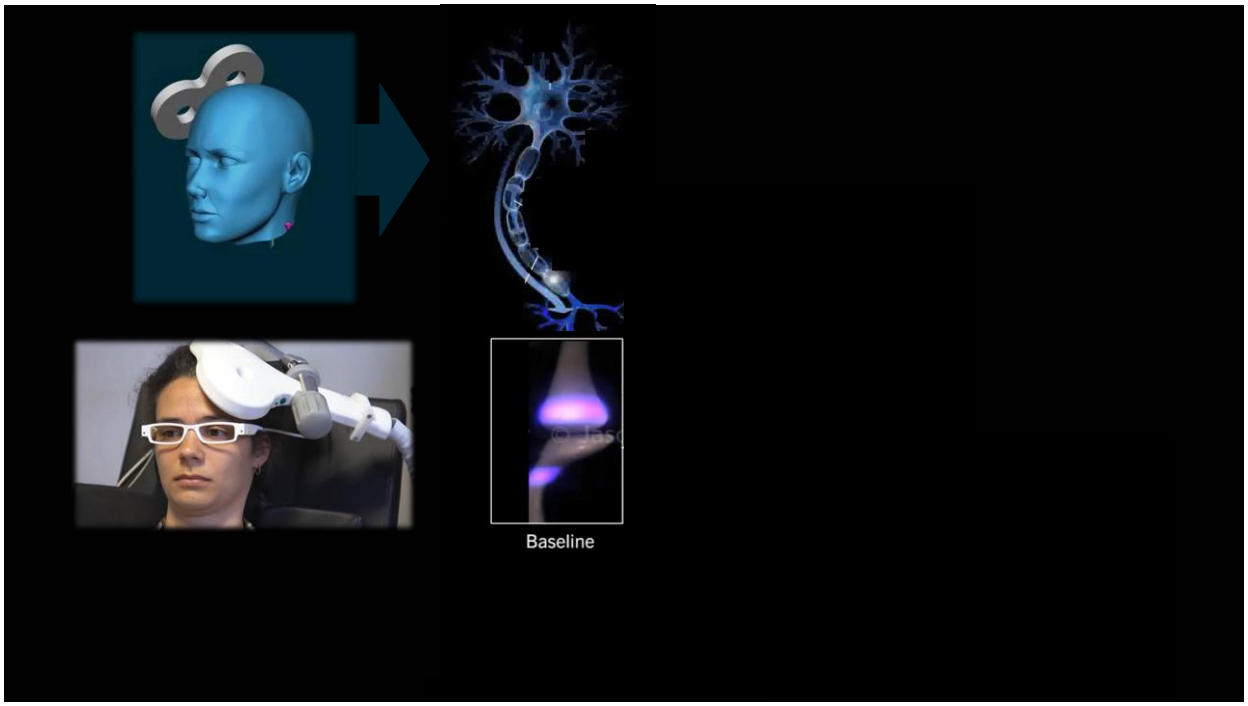
- Continuous theta burst stimulation
  - Inhibitory effect



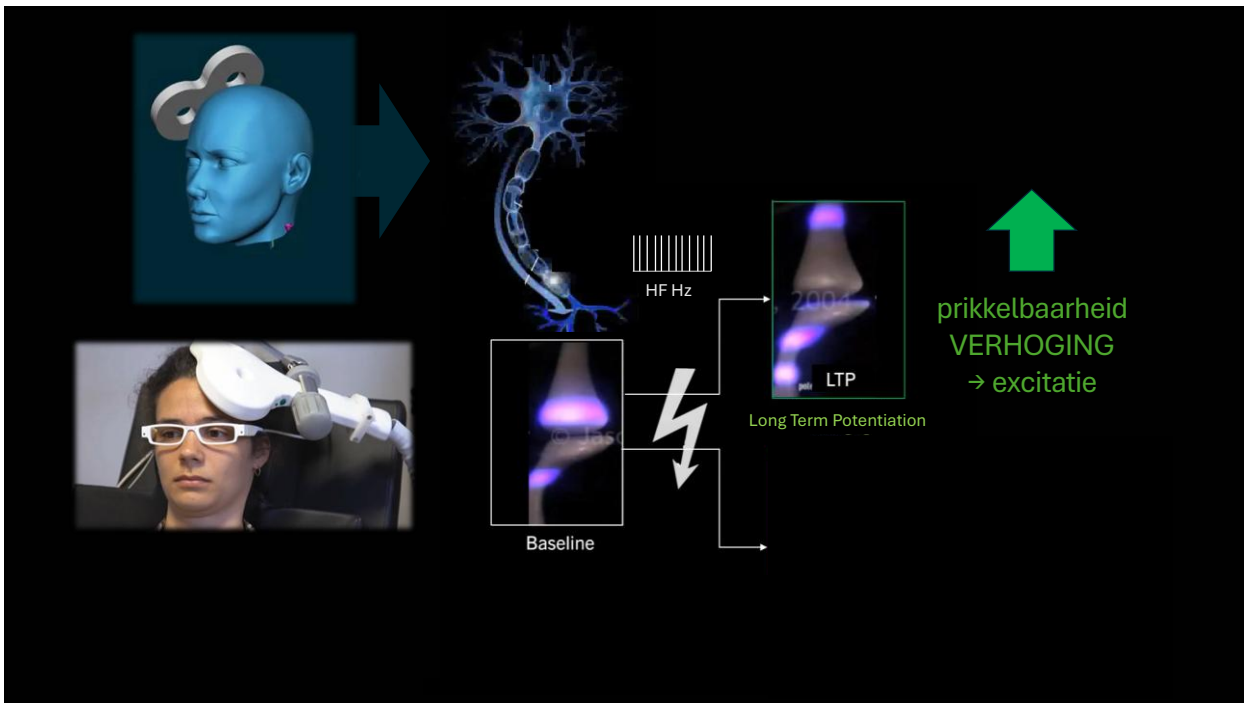
- Intermittent theta burst stimulation
  - Excitatory effect



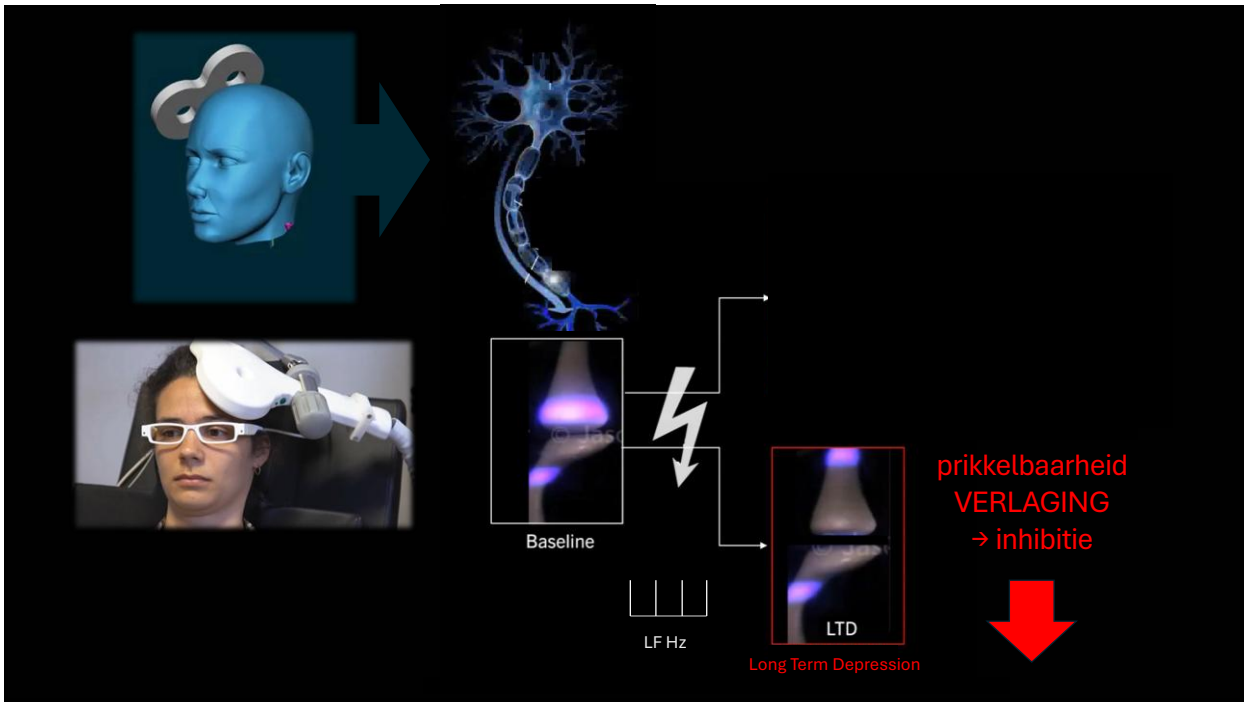
34


Baseline

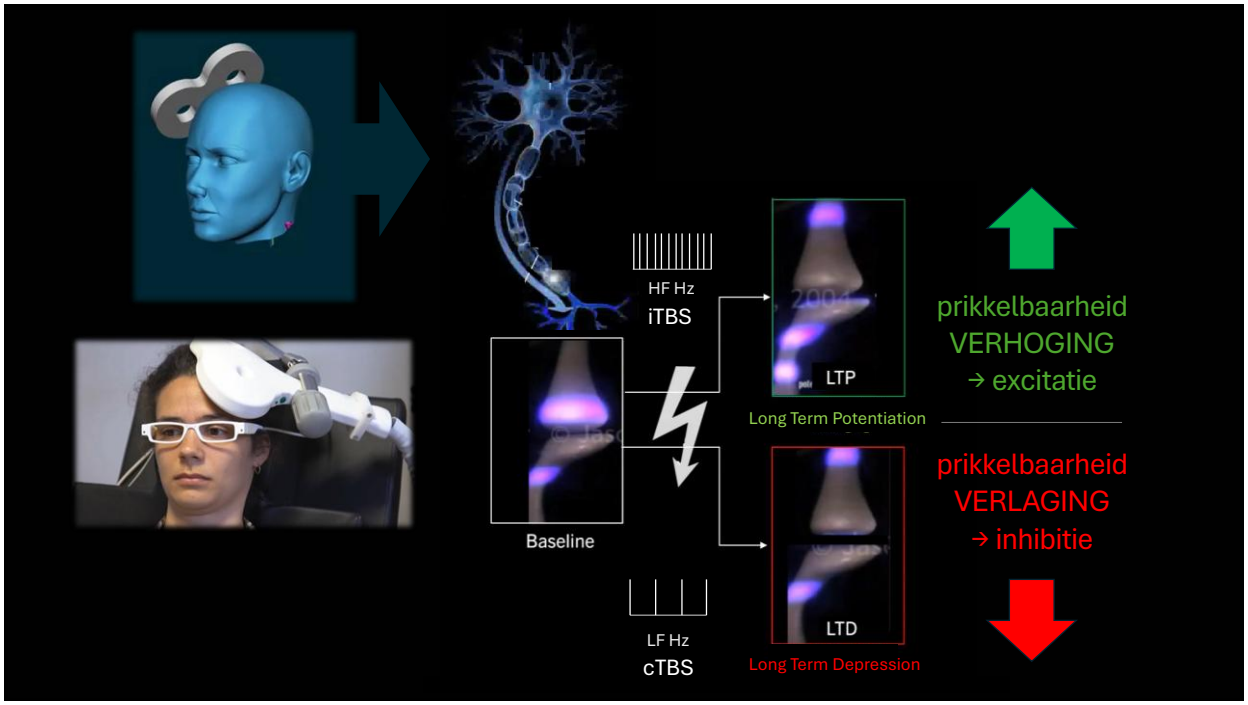
35


HF Hz
LTP
Long Term Potentiation
Baseline
prikkelbaarheid
VERHOGING
→ excitatie

36

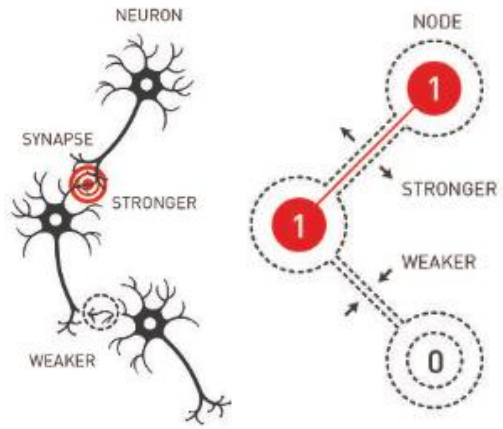

Baseline
LF Hz
LTD
Long Term Depression
prikkelbaarheid
VERLAGING
→ inhibitie

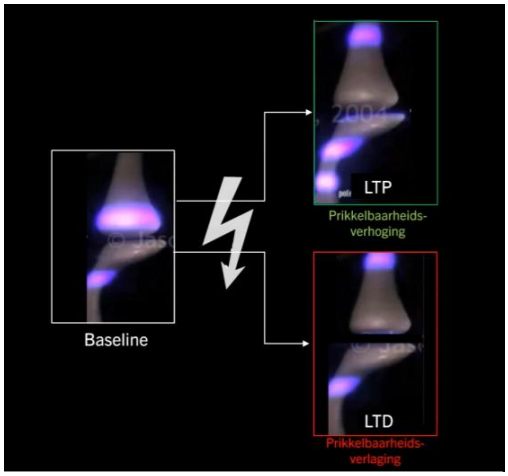
37


HF Hz
iTBS
LTP
Long Term Potentiation
prikkelbaarheid
VERHOGING
→ excitatie
Baseline
LF Hz
cTBS
LTD
Long Term Depression
prikkelbaarheid
VERLAGING
→ inhibitie

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Neuroplasticiteit



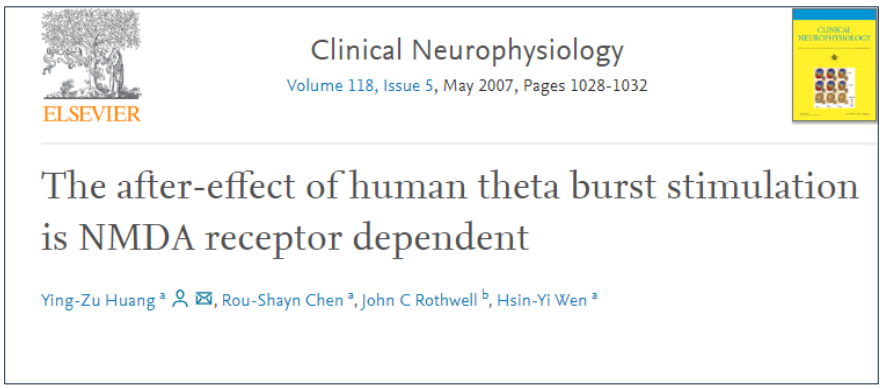


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Transcranial Magnetic Stimulation (TMS)

Effects on neural systems

Neuroplasticity (LTP and LTD)



ELSEVIER

Clinical Neurophysiology

Volume 118, Issue 5, May 2007, Pages 1028-1032

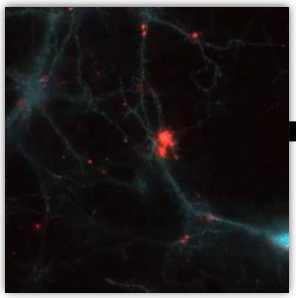
The after-effect of human theta burst stimulation is NMDA receptor dependent

Ying-Zu Huang [a], Rou-Shayn Chen [a], John C Rothwell [b], Hsin-Yi Wen [a]

40

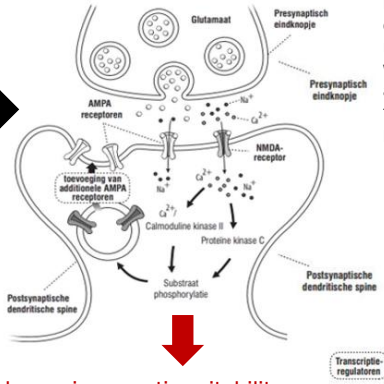
Transcranial Magnetic Stimulation (TMS)

Effects on neural systems



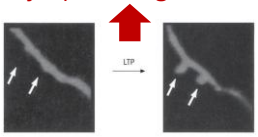


Neuroplasticity (LTP)

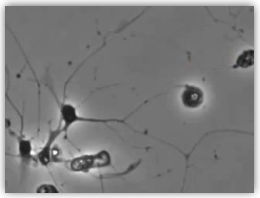


Its landing place on neurons is a channel called an AMPA receptor, which interacts with glutamate, and then acts like a pore that takes in charged particles.

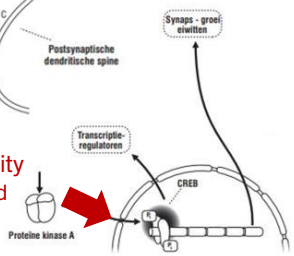
synaptic changes



modification of dendritic spines



change in synaptic exitability driven by NMDA-mediated synaptic plasticity

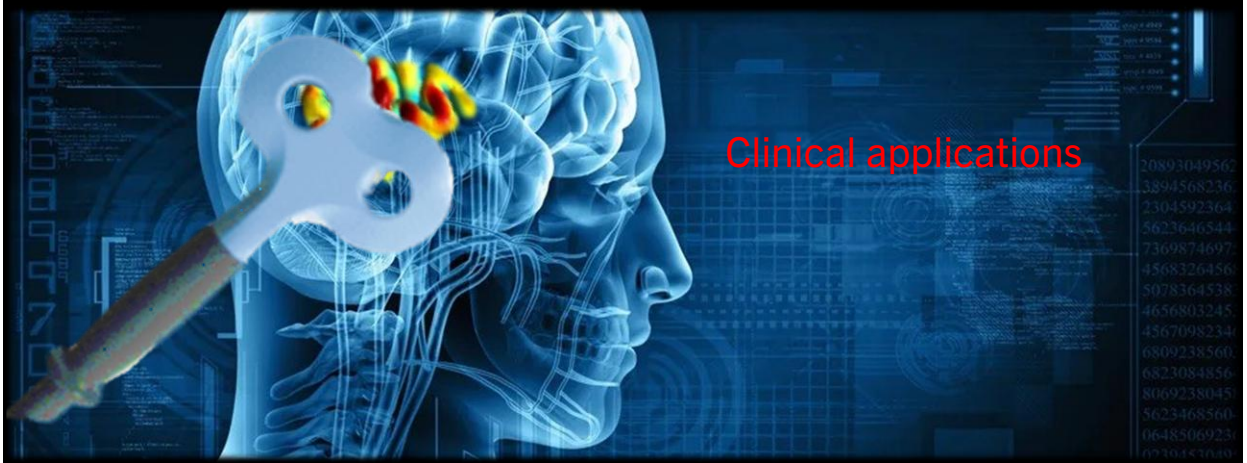


gene transcription

protein synthesis

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Non-Invasive Neuromodulation



Clinical applications

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KLINISCH

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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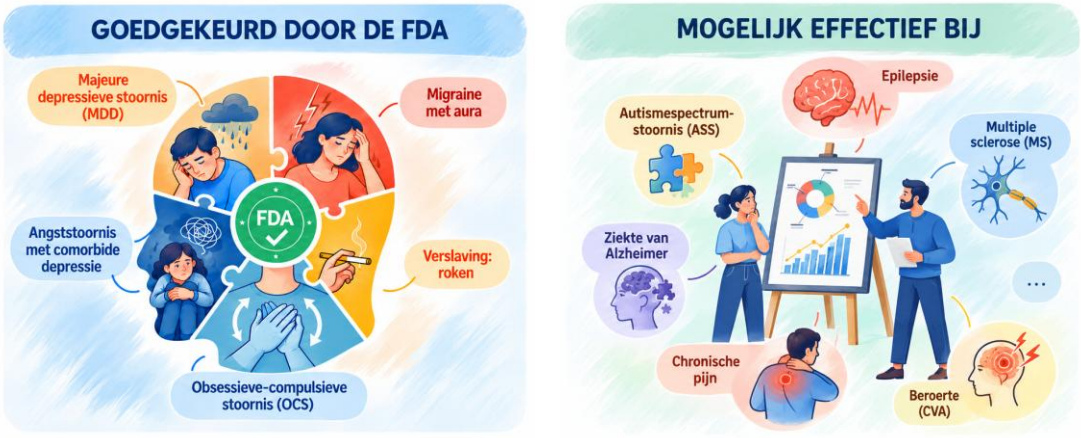
44

Leven met een hersenletsel



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TMS: klinische toepassingen en onderzoek



Lefaucheur et al., 2020

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Emotioneel welbevinden na hersenletsel



Depressie komt vaak voor na een hersenletsel

- Na beroerte: ongeveer 30% in het eerste jaar
- Na traumatisch hersenletsel: ongeveer 25–28%

Verminderd dagelijks functioneren

Is soms moeilijk te herkennen

Conroy, Brownlowe & McAllister, 2020; Dehbozorgi et al., 2024

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rTMS en emotioneel welbevinden

Resultaten zijn bemoedigend

- Depressieve klachten nemen af

Nog beperkt onderzocht

- Kleine studies, wisselende resultaten en onzekerheid over het langetermijneffect

Mogelijk nog meer maatwerk nodig

- Hersenletsels verschillen sterk. Individuele hersennetwerken kunnen aanknopingspunten bieden



Chang et al., 2023; Tsai et al., 2021; Siddiqi et al., 2019

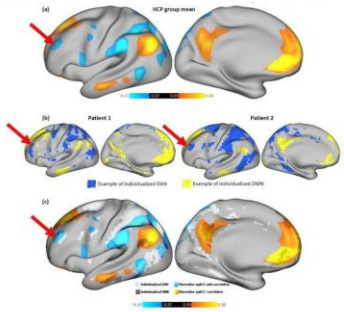
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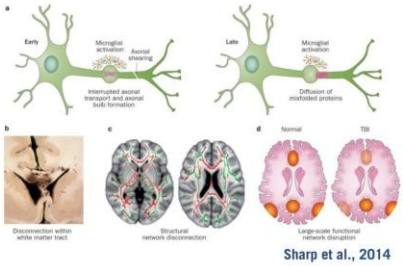
rTMS en emotioneel welbevinden

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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Cognitie na hersenletsel

- **Aandacht**
  - Concentreren en omgaan met afleiding
- **Geheugen**
  - Nieuwe informatie onthouden
- **Verwerkingssnelheid**
  - Informatie verwerken en reageren
- **Plannen en organiseren**
  - Overzicht houden en schakelen tussen taken
- **Overprikkeling en vermoeidheid**
  - Prikkels kunnen sneller te veel worden en denken kost meer energie



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rTMS en cognitie



Aandacht

- Concentreren en omgaan met afleiding

Visuele informatie onthouden

- verbetering in het onthouden van beelden en locaties.

Informatie vasthouden en ermee werken

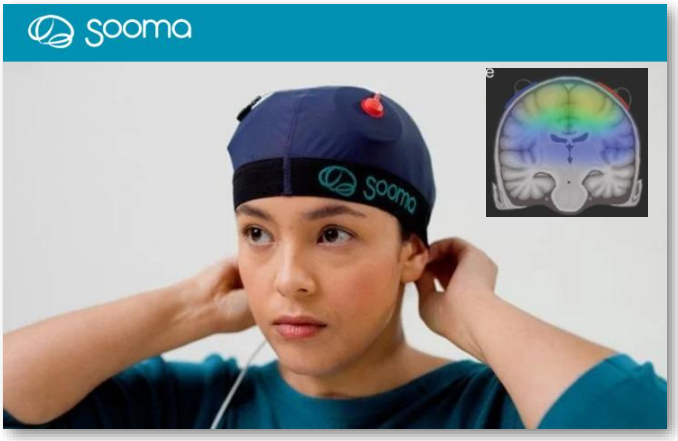
- Potentieel verbeteren van het werkgeheugen

Schakelen en automatische reacties onderdrukken

- Automatische reacties remmen en vlotter schakelen

51

Onderhoudsbehandeling via tES





52



Niet invasieve hersenstimulatie: neurorevalidatie

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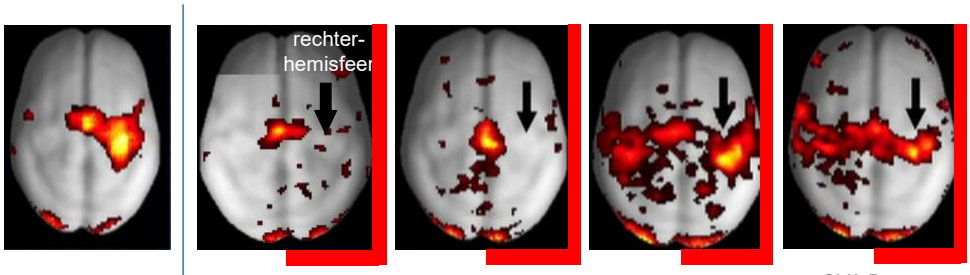
Non-Invasive Neuromodulation



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Transcranial Magnetic Stimulation (TMS)
Stroke

Imbalanced interhemispheric activity



VOOR | CVA Dag 2 | CVA Dag 6 | CVA Dag 9 | CVA Dag 11

toenemende handbewegingen

Grefkes et al. 2008

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Academia
Neuroscience and Brain Research
10.20935/AcadNeurosci8408

Review Article

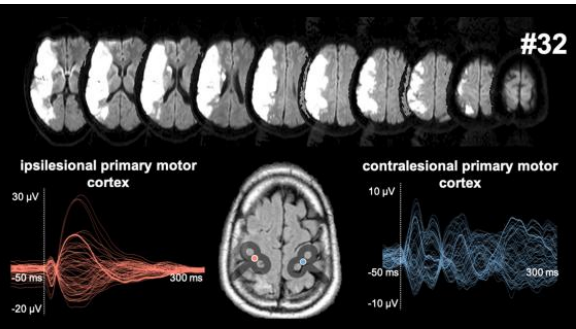
Neurophysiological assessment of stroke recovery after repetitive transcranial magnetic stimulation

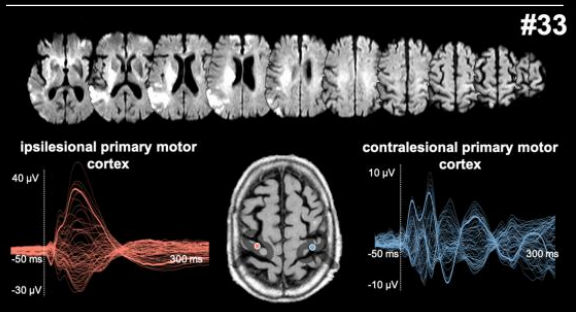
Devisree Dhanachezhiyan[1], Subasree Ramakrishnan[2], Deepak Menon[2], Anupam Gupta[3], Selva Ganapathy[3], Talakad Narsappa Sathyaprabha[1], Kaviraja Udupa[1]*

[1] Department of Neurophysiology, National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore, India
[2] Department of Neurology, National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore, India
[3] Department of Neurorehabilitation, National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore, India
* Correspondence: kaviraja.e03234@nimhans.net

Received: 2 January 2026 | **Accepted:** 25 June 2026 | **Published:** 9 July 2026

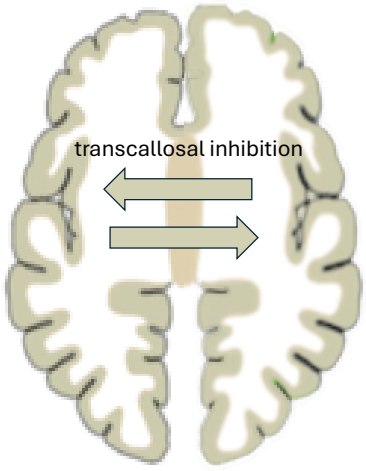






56

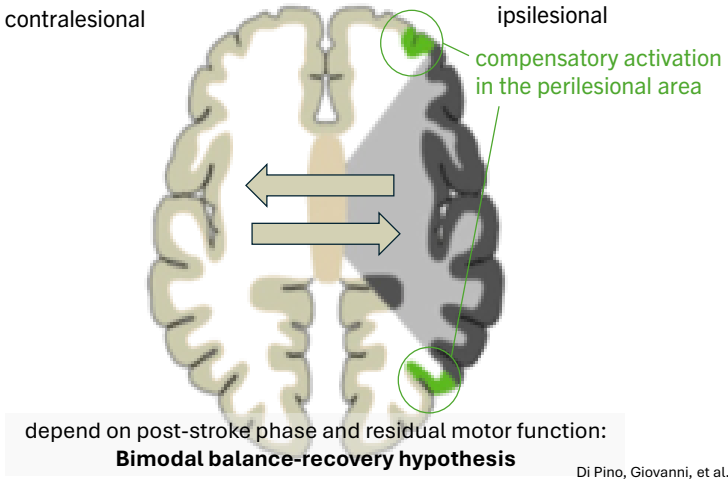
Transcranial Magnetic Stimulation (TMS)
Stroke



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Transcranial Magnetic Stimulation (TMS)
Stroke

Paradoxal Functional Facilitation in the subacute phase



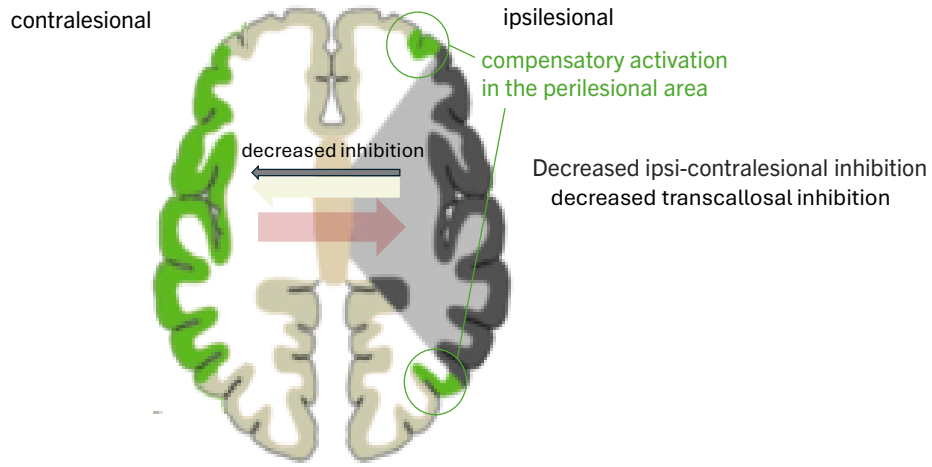
depend on post-stroke phase and residual motor function:
Bimodal balance-recovery hypothesis

Di Pino, Giovanni, et al. Nature Reviews Neurology, 2014

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Transcranial Magnetic Stimulation (TMS)
Stroke

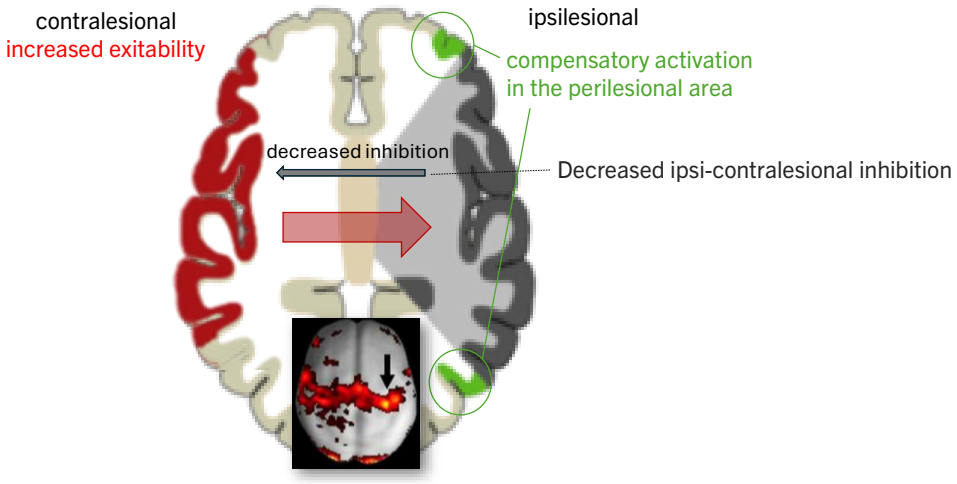
Paradoxal Functional Facilitation



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Transcranial Magnetic Stimulation (TMS)
Stroke

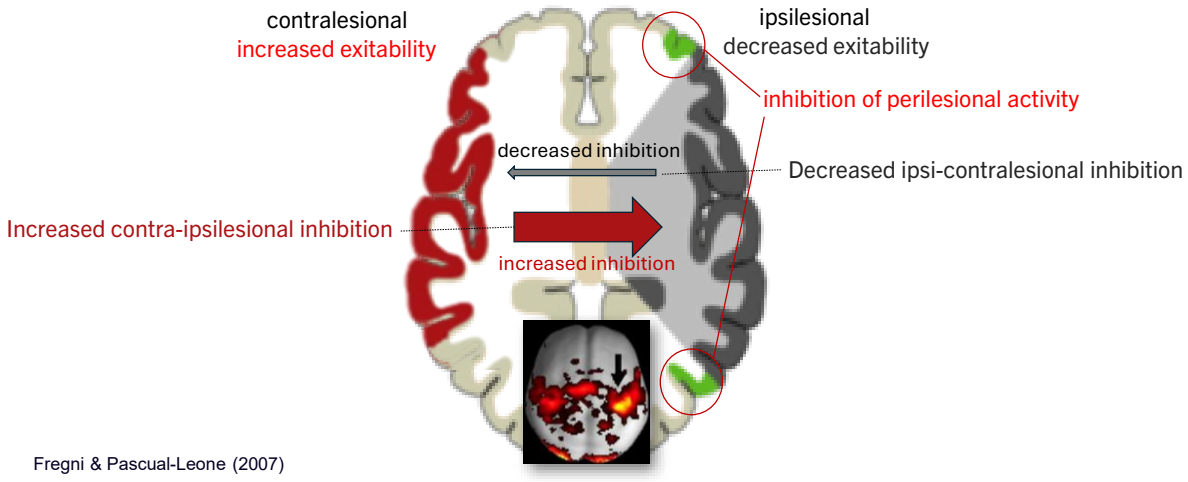
Paradoxal Functional Facilitation



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Transcranial Magnetic Stimulation (TMS)
Stroke

Paradoxal Functional Facilitation

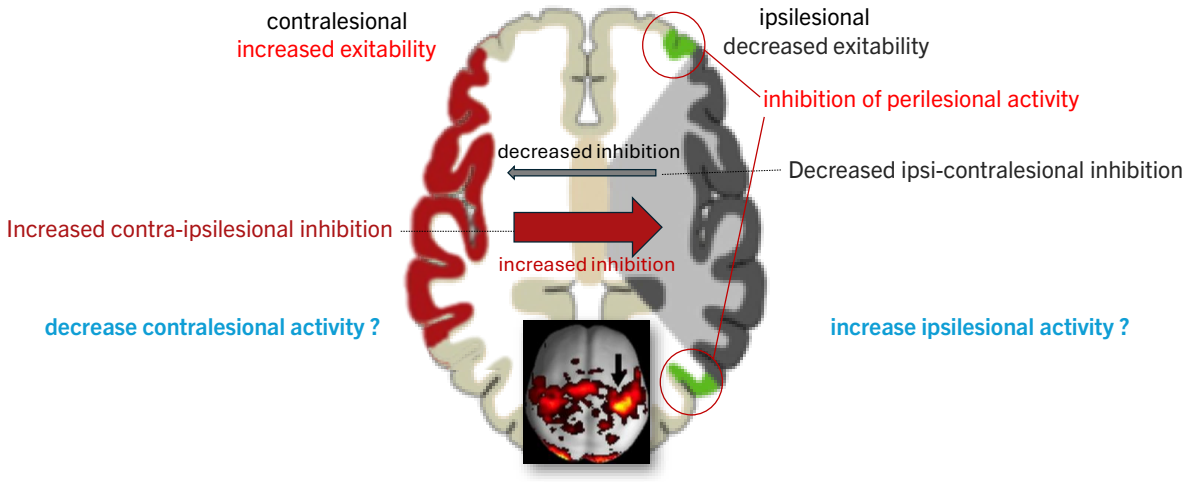


Fregni & Pascual-Leone (2007)

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Transcranial Magnetic Stimulation (TMS)
Stroke

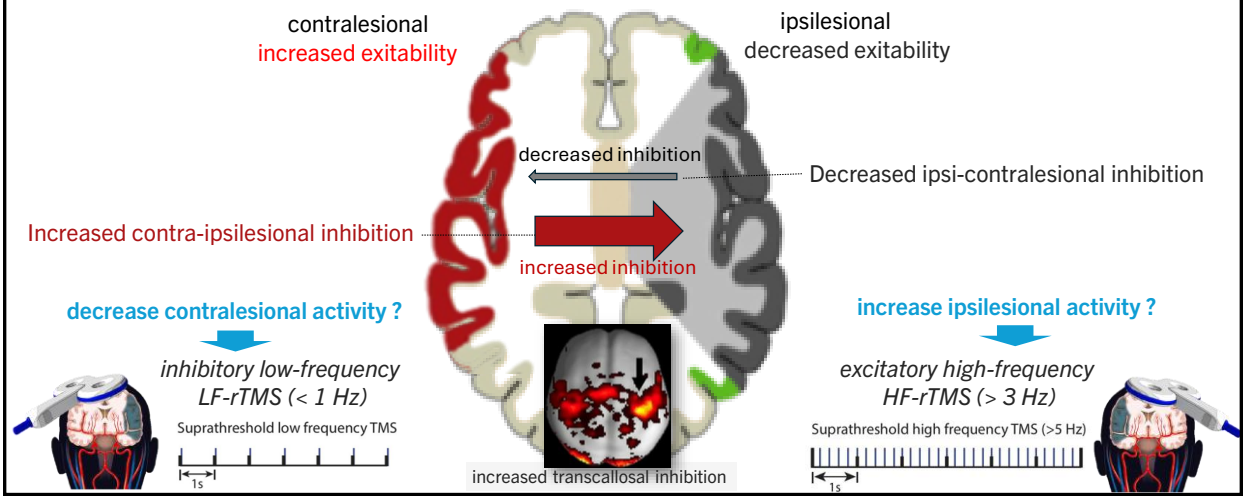
Paradoxal Functional Facilitation



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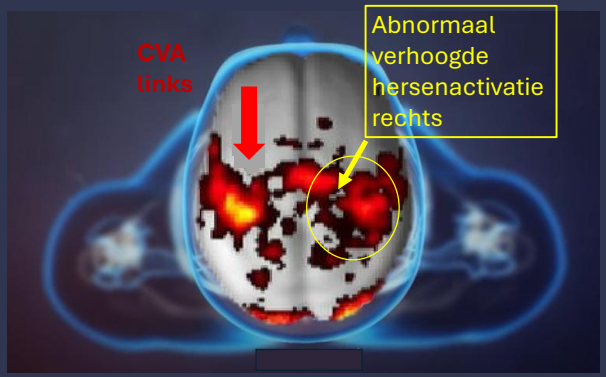
Transcranial Magnetic Stimulation (TMS)
Stroke

Paradoxal Functional Facilitation



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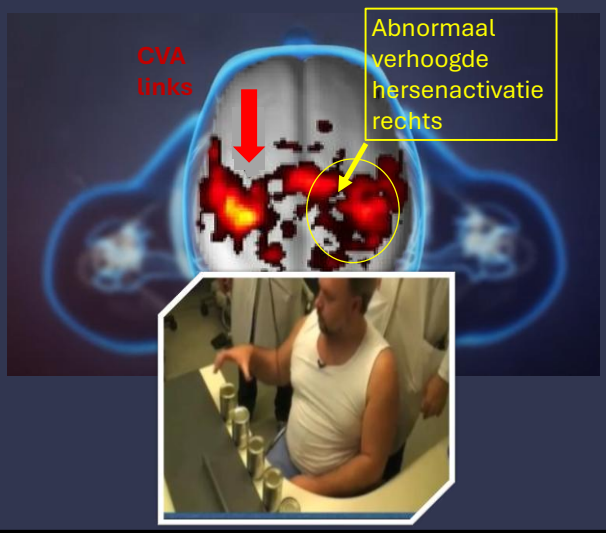
BEROERTE (CVA)



abnormaal verhoogde hersenactivatie in de rechter hersenhelft bij een beweging rechterhand door activatie linker motorisch hersengebied

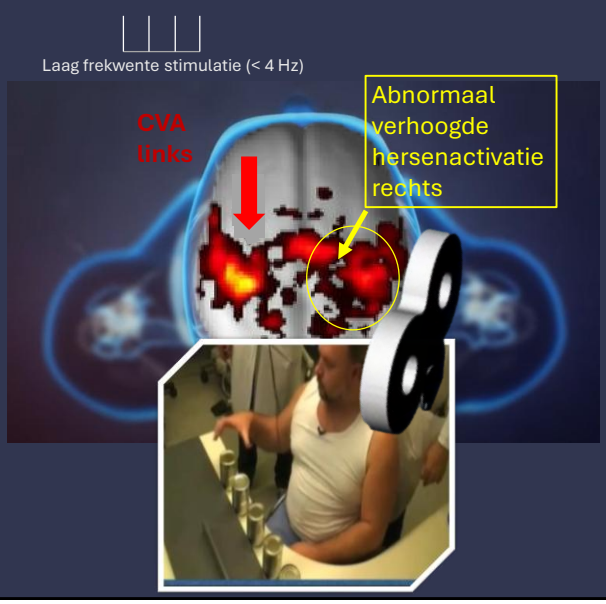
64

BEROERTE (CVA)

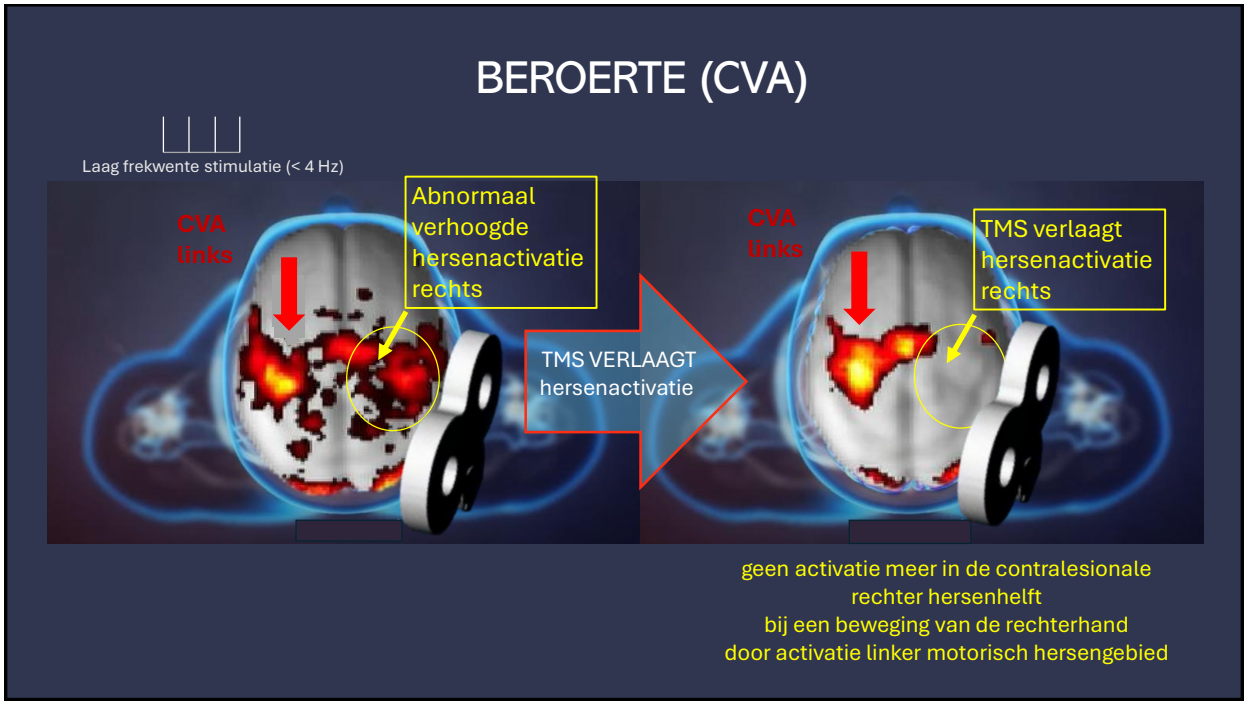


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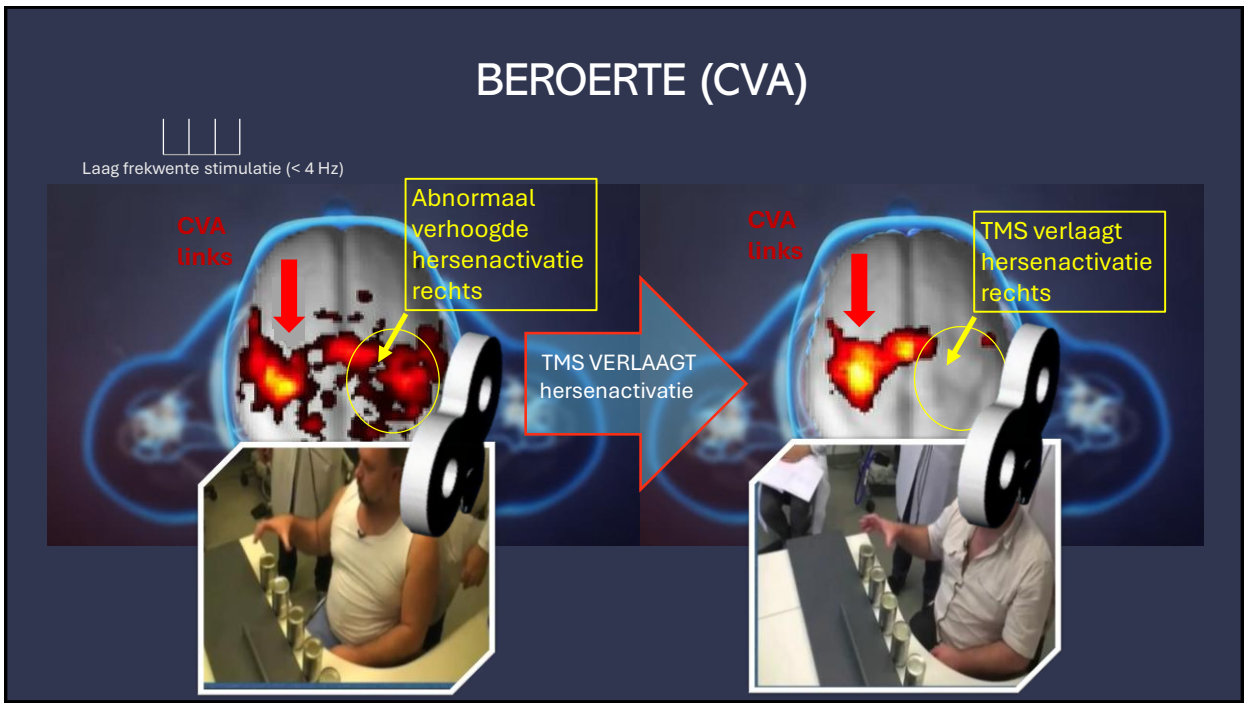
BEROERTE (CVA)



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BEROERTE (CVA)
Laag frekwente stimulatie (< 4 Hz)
CVA links
Abnormaal verhoogde hersenactivatie rechts
TMS VERLAAGT hersenactivatie
CVA links
TMS verlaagt hersenactivatie rechts
geen activatie meer in de contralesionale rechter hersenhelft
bij een beweging van de rechterhand
door activatie linker motorisch hersengebied

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BEROERTE (CVA)
Laag frekwente stimulatie (< 4 Hz)
CVA links
Abnormaal verhoogde hersenactivatie rechts
TMS VERLAAGT hersenactivatie
CVA links
TMS verlaagt hersenactivatie rechts

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Transcranial Magnetic Stimulation (TMS)
Stroke





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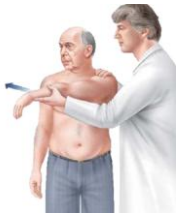
Transcranial Magnetic Stimulation (TMS)
Stroke



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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

CLINICAL TRIALS

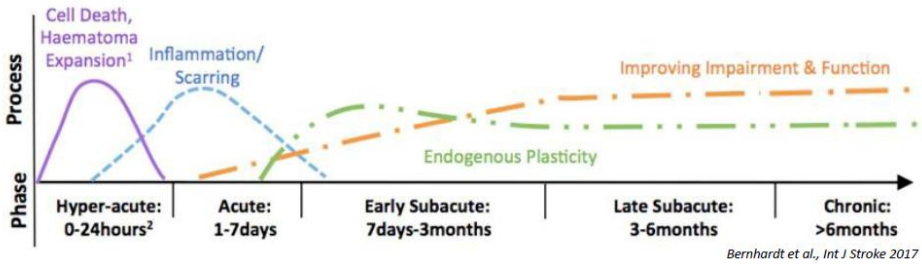
Continuous Theta-Burst Stimulation of the Contralesional Primary Motor Cortex for Promotion of Upper Limb Recovery After Stroke: A Randomized Controlled Trial

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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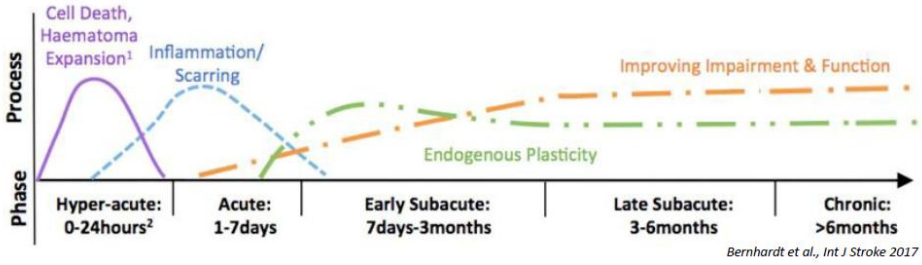
Transcranial Magnetic Stimulation (TMS)
Stroke



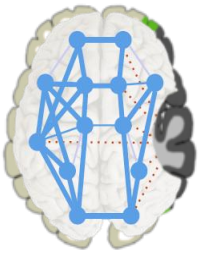
Bernhardt et al., Int J Stroke 2017

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Transcranial Magnetic Stimulation (TMS)
Stroke

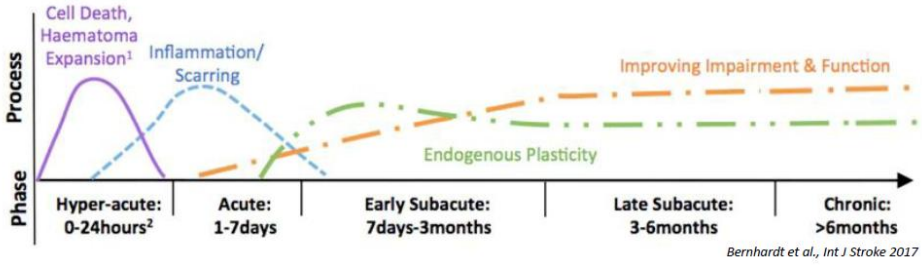


Bernhardt et al., Int J Stroke 2017

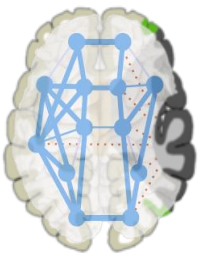


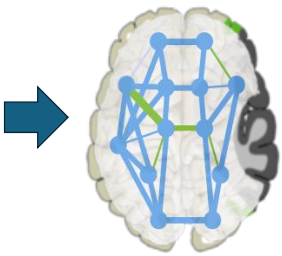
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Transcranial Magnetic Stimulation (TMS)
Stroke



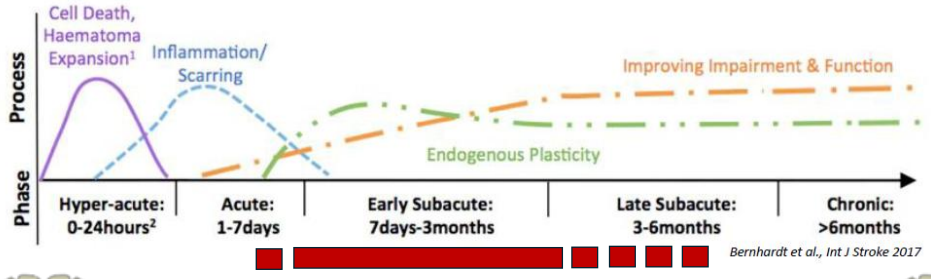
Bernhardt et al., Int J Stroke 2017





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Transcranial Magnetic Stimulation (TMS)
Stroke

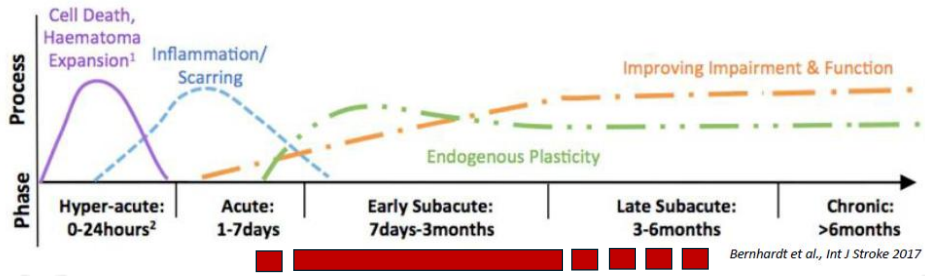


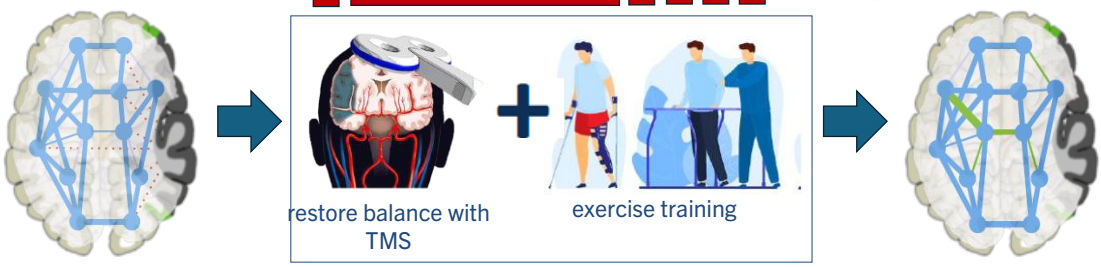


exercise training

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Transcranial Magnetic Stimulation (TMS)
Stroke

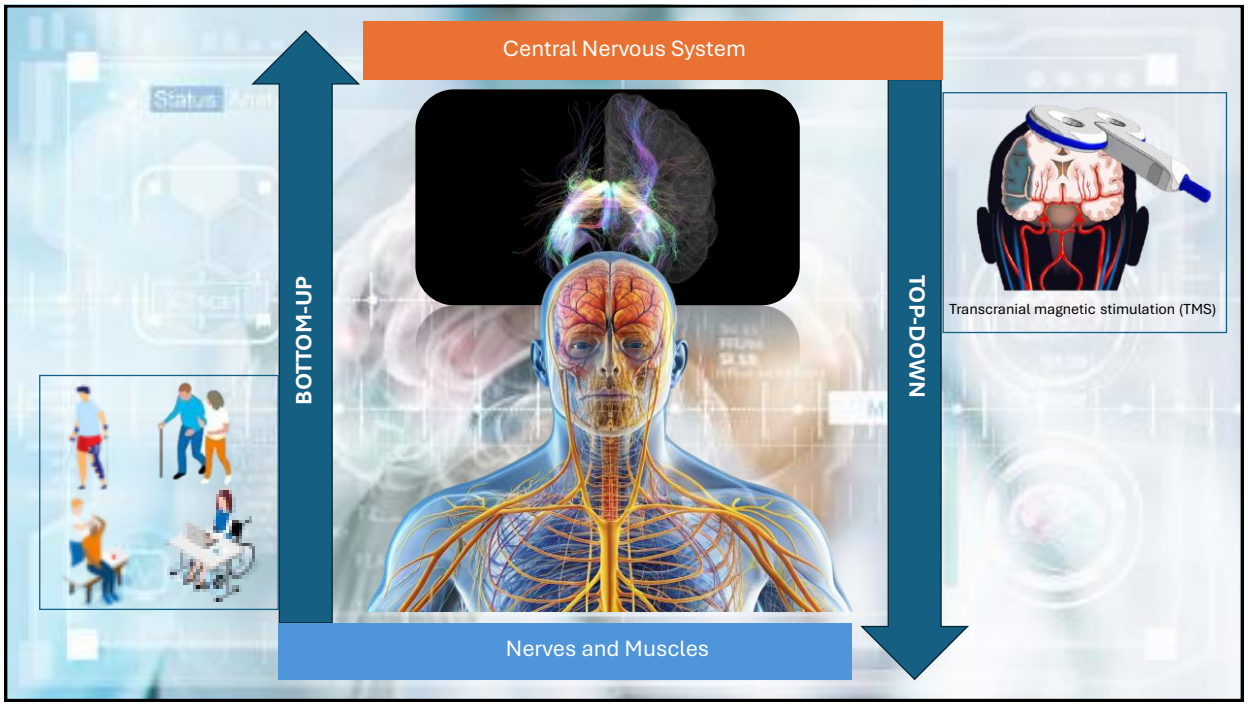




restore balance with TMS

exercise training

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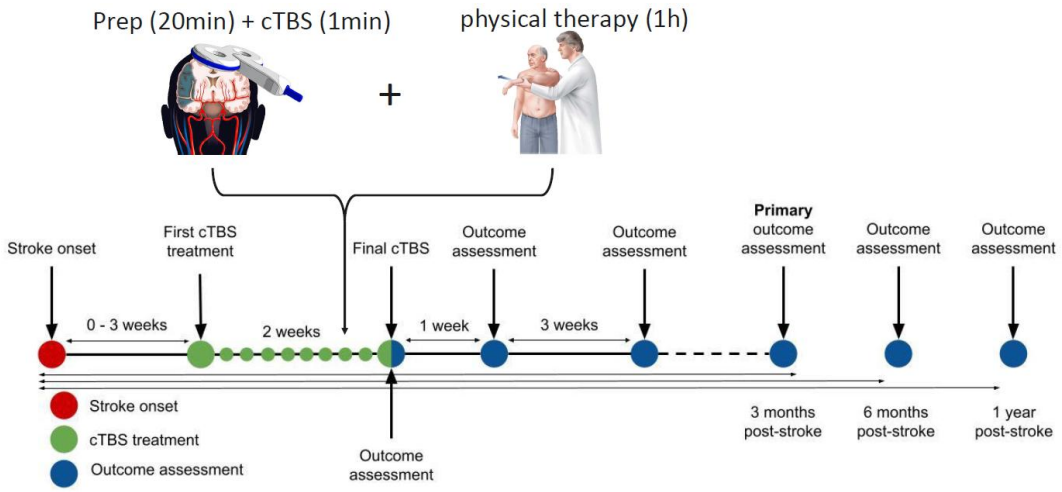


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Transcranial Magnetic Stimulation (TMS)

Stroke

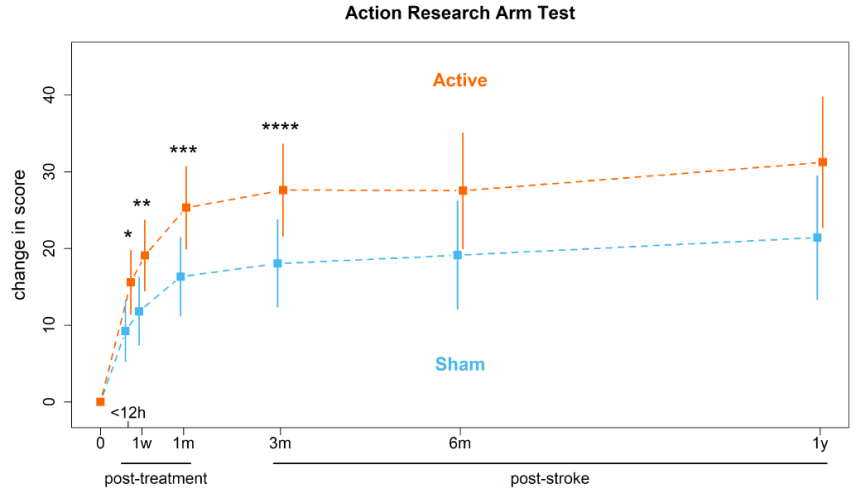
Clinical study



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Transcranial Magnetic Stimulation (TMS)
Stroke

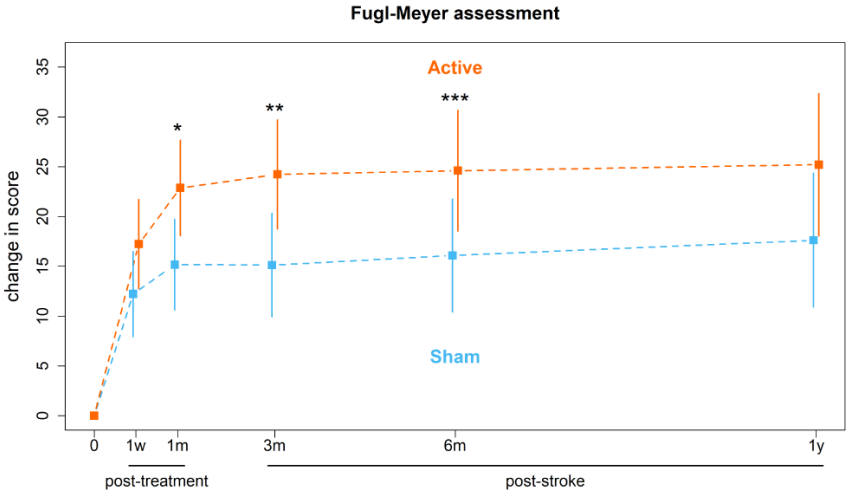
Clinical study



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Transcranial Magnetic Stimulation (TMS)
Stroke

Clinical study

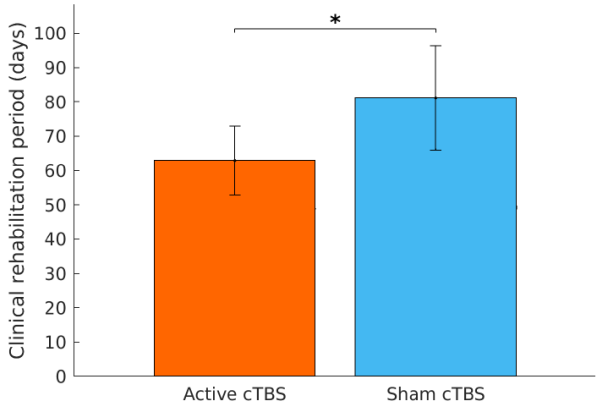


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Transcranial Magnetic Stimulation (TMS)
Stroke

Clinical study

Length of stay

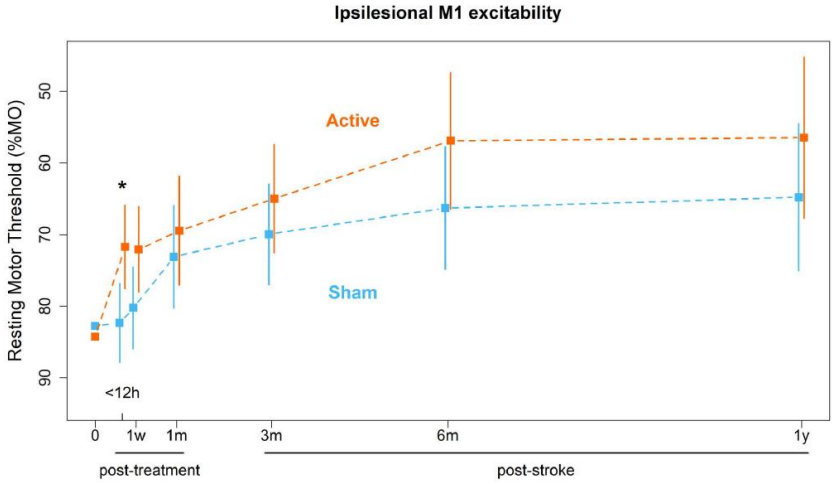


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Transcranial Magnetic Stimulation (TMS)
Stroke

Clinical study

Ipsilesional M1 excitability



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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation



DCRM Dutch Congress of Rehabilitation Medicine

VRA



B-STARS2
Brain STimulation for Arm Recovery after Stroke

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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation





B-STARS2
Brain STimulation for Arm Recovery after Stroke

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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

Neurorehabilitation and Neural Repair
2024, Vol. 38(1) 3–6
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Sage

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]

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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.

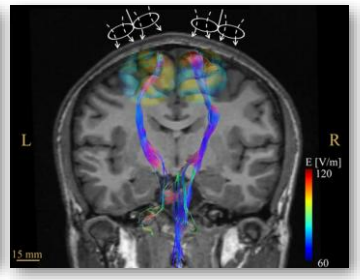
Taskforce topic	Provides consensus recommendations for
SRRR1	
Timeline definitions[3]	Common language and definitions for stroke recovery and rehabilitation field and an agreed vision for accelerating progress in stroke recovery research.
Biomarkers[4]	Biomarkers that were considered ready to be included 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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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Other clinical applications





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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation



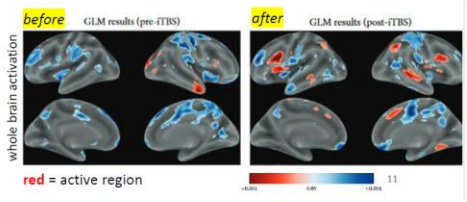
90

Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Other clinical applications

Aphasia: Recommendation
Level B evidence (probable efficacy)

TMS protocol	Inhibitory rTMS
Stimulation site	Inferior frontal gyrus, unaffected site
Clinical stage	chronic stage (> 180 days)
Type of aphasia	Non-fluent aphsia

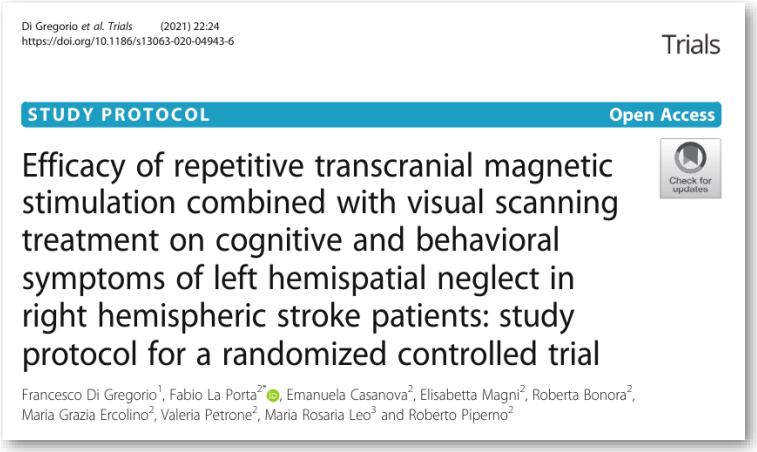


Griffis JC, 2016, Neural plasticity

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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Other clinical applications



Di Gregorio *et al. Trials* (2021) 22:24
https://doi.org/10.1186/s13063-020-04943-6

Trials

STUDY PROTOCOL Open Access

Efficacy of repetitive transcranial magnetic stimulation combined with visual scanning treatment on cognitive and behavioral symptoms of left hemispatial neglect in right hemispheric stroke patients: study protocol for a randomized controlled trial

Francesco Di Gregorio[1], Fabio La Porta[2*], Emanuela Casanova[2], Elisabetta Magni[2], Roberta Bonora[2], Maria Grazia Ercolino[2], Valeria Petrone[2], Maria Rosaria Leo[3] and Roberto Piperno[2]

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Non-Invasive Brain Stimulation



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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

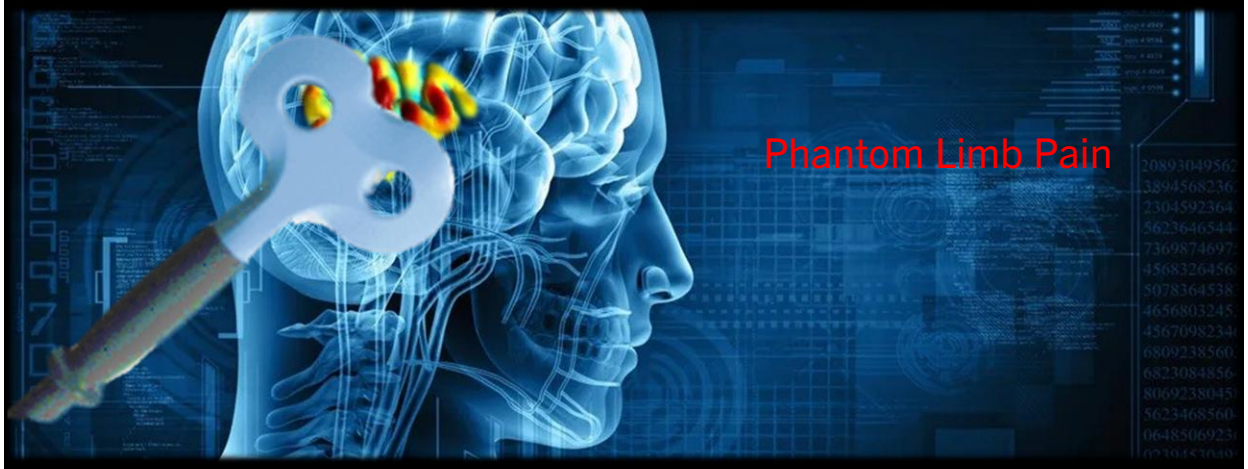
Other clinical applications

neuropathic pain: Recommendation
Level A evidence (definite efficacy)

TMS protocol	activating HF-rTMS
Stimulation site	Motor cortex (M1) contralateral to pain side

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Non-Invasive Brain Stimulation



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REVALIDATIE ziekenhuis

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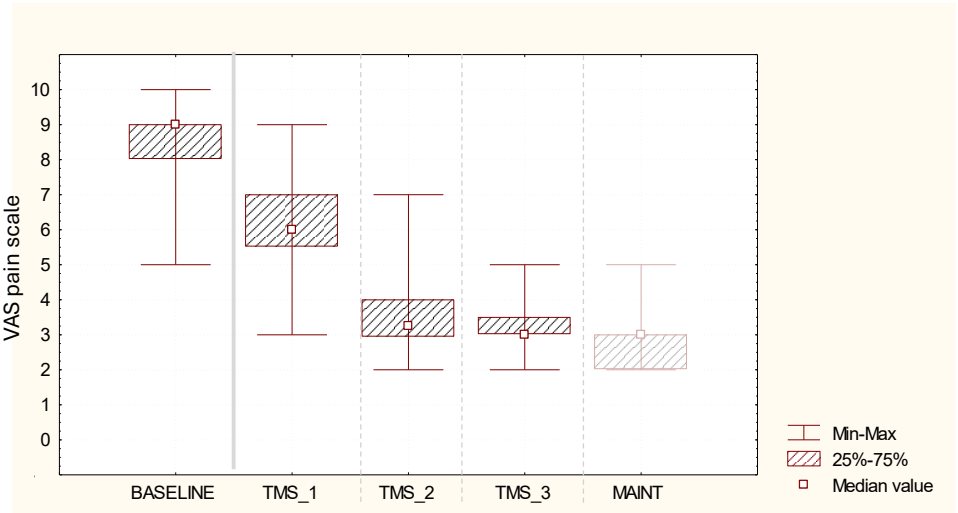
Visual analogue scale (VAS) score

McGill Pain Questionnaire-Dutch Language Version

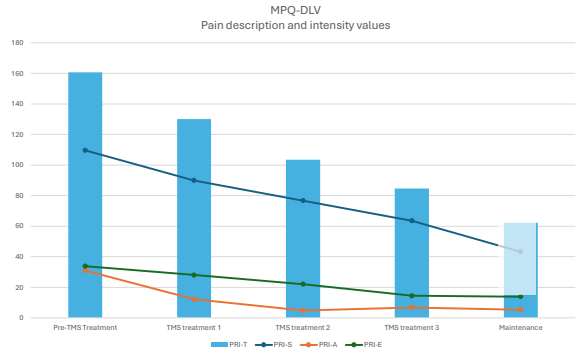
Patient-reported remote clinical monitoring of visual analogue scale (VAS) score



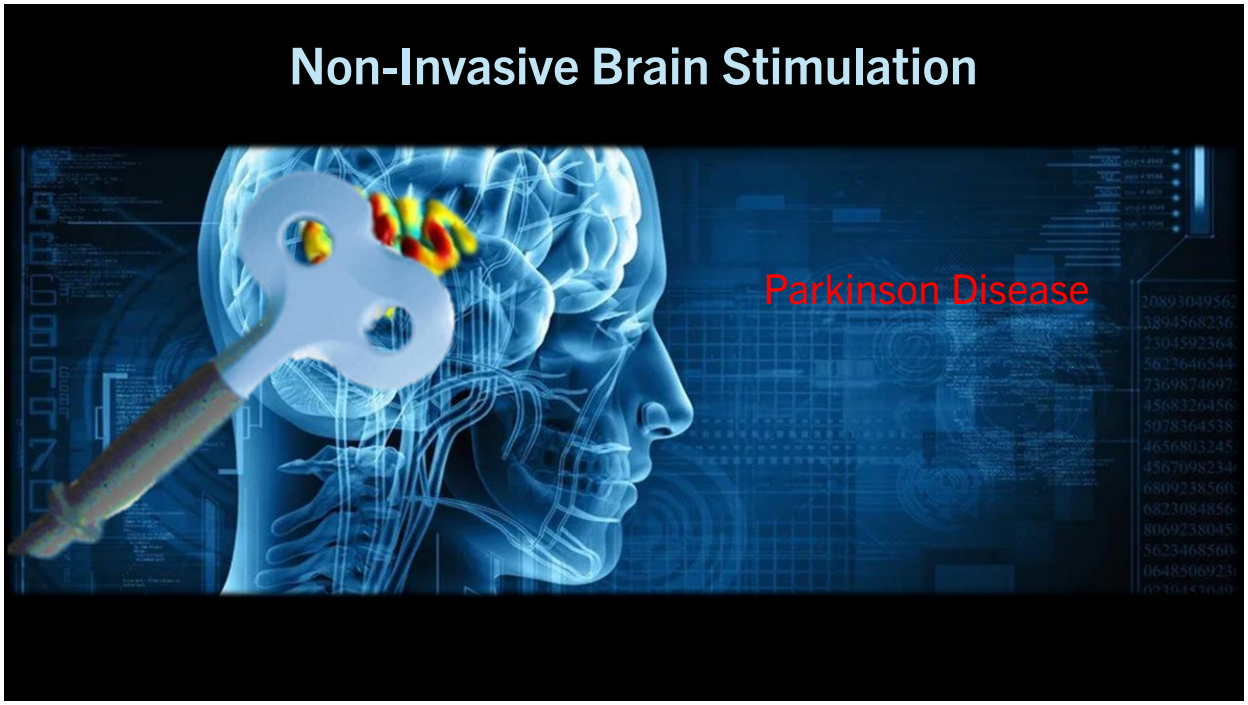
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98


MPQ-DLV
Pain description and intensity values
180
160
140
120
100
80
60
40
20
0
Pre-TMS Treatment
TMS treatment 1
TMS treatment 2
TMS treatment 3
Maintenance
PRI-T
PRI-S
PRI-A
PRI-E

99

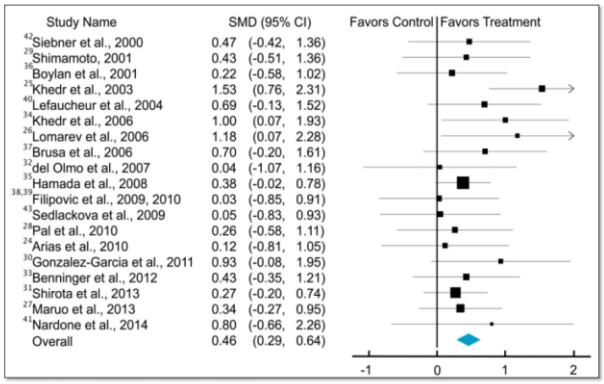

Non-Invasive Brain Stimulation
Parkinson Disease

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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Other clinical applications

rTMS: **Parkinson's disease**



Chou YH et al., 2015, JAMA Neurol



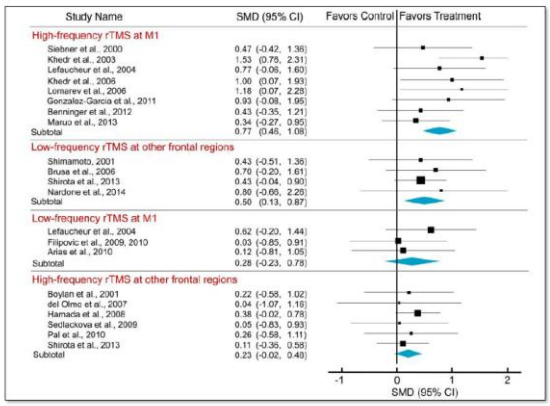
rTMS improves motor symptoms

101

Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

Other clinical applications

rTMS: **Parkinson's disease**



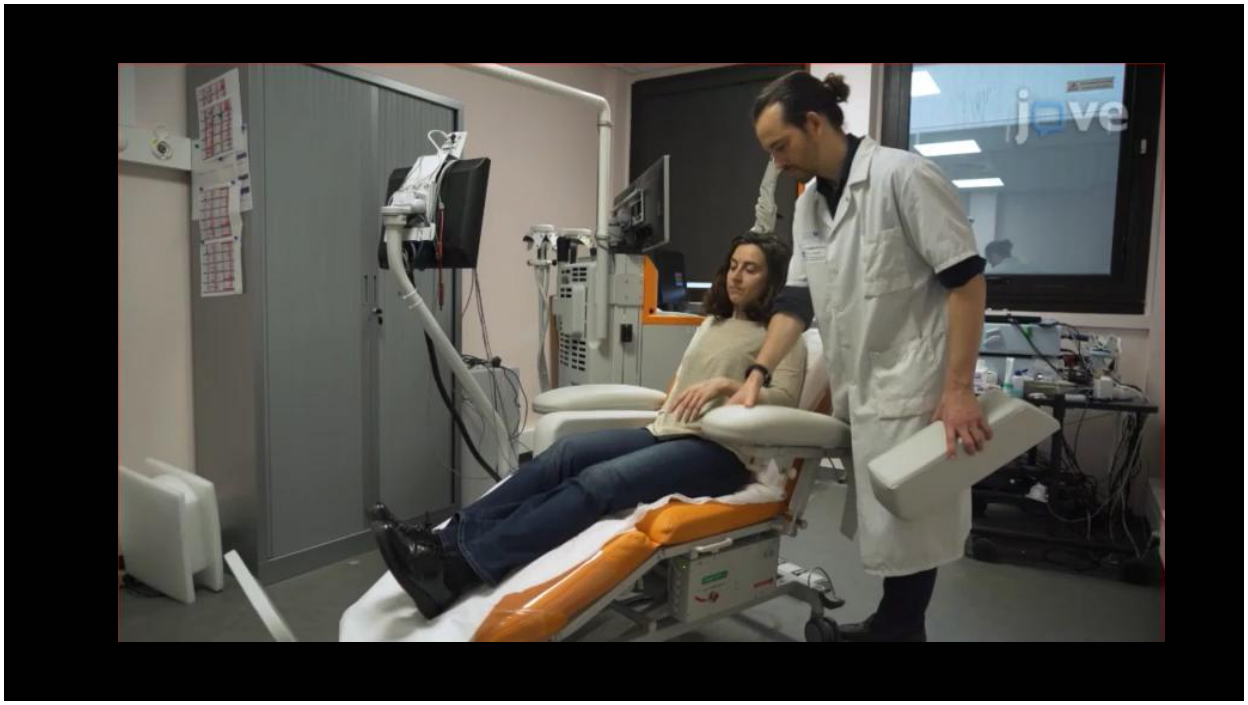
Chou YH et al., 2015, JAMA Neurol

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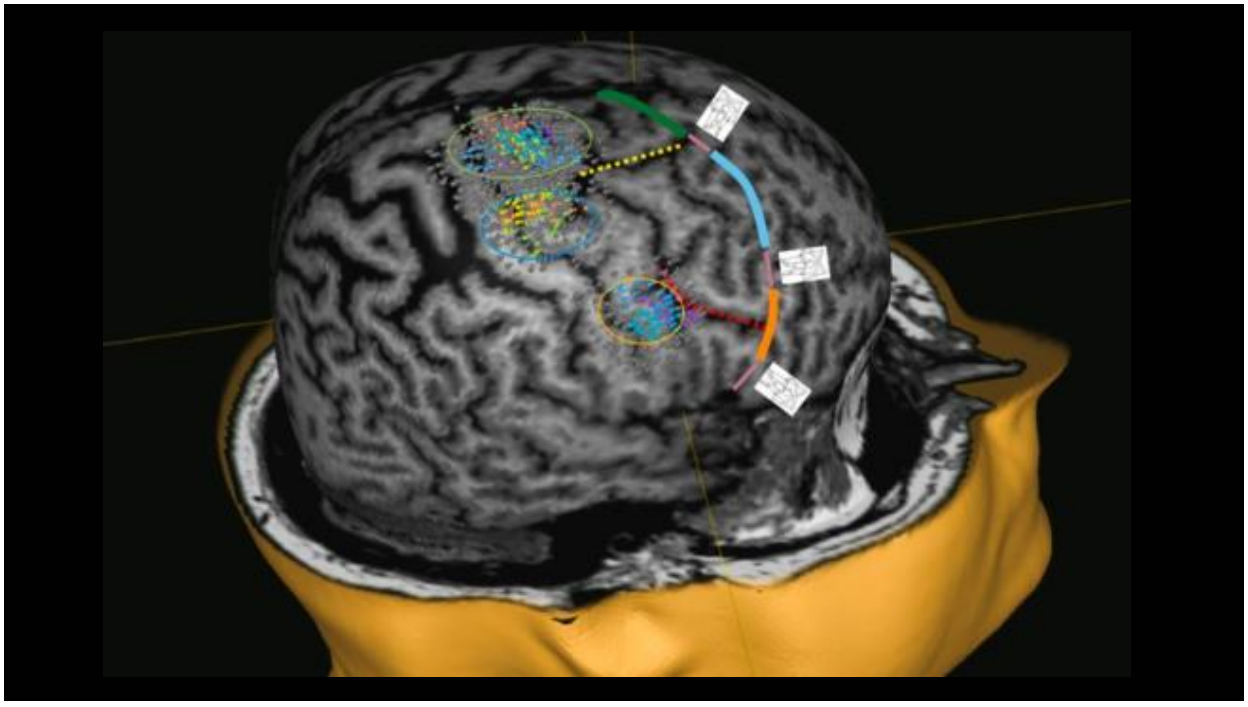


High frequency superior to low frequency

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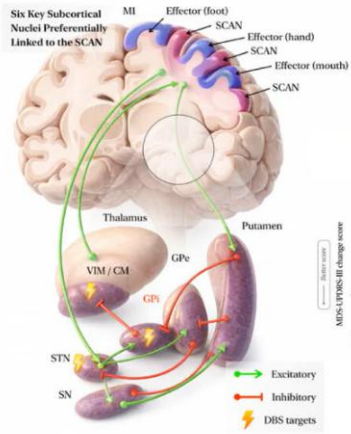


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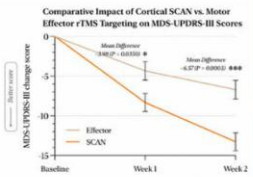


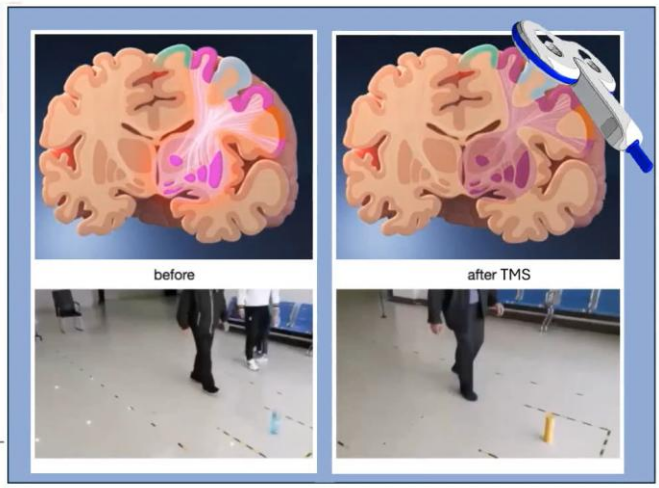
104

Somato-Cognitive Action Network (SCAN) Connectivity as a Clinical Target in Parkinson's Disease





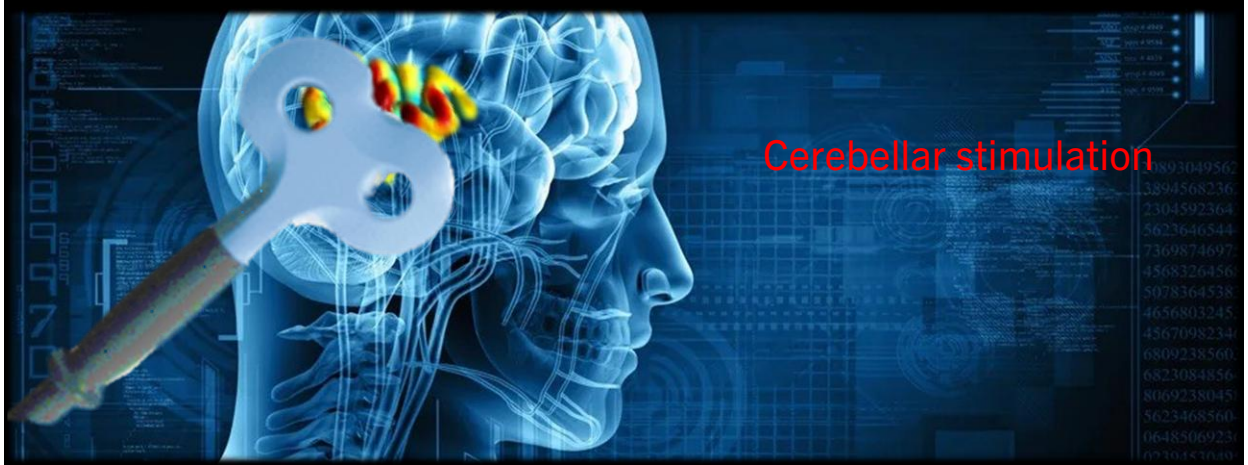




Ren, J., Zhang, W., Dahmani, L. et al. Parkinson's disease as a somato-cognitive action network disorder. *Nature* (2026). https://doi.org/10.1038/s41586-025-10059-1

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Non-Invasive Brain Stimulation



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Transcranial Magnetic Stimulation (TMS)
in neurorehabilitation

rTMS and cerebellar ataxia

Table 1. Studies assessing the effects of repetitive transcranial magnetic stimulation (rTMS) in patients with cerebellar ataxia.

	Study	Patients	Sham	Blinding	Stimulation	Protocol
1999	[54]	4	No	Not reported	Inion and cerebellar hemispheres	30 pulses (100% MSO) at 0.17 Hz every day for 21 days
2002	[55]	74	Yes	Patients and examiners	Inion and cerebellar hemispheres	30 pulses (100% MSO) at 0.17 Hz every day for 21 days
2006	[56]	20	No	Yes	Inion and cerebellar hemispheres	30 pulses (100% MSO) at 0.2 Hz every day for 8 weeks
2013	[60]	1	No	Not reported	Inion and cerebellar hemispheres	30 pulses (100% MSO) at 0.17 Hz every day for 21 days
2019	[61]	1	Yes	Not reported	Inion and cerebellar hemispheres	500 pulses (90% RMT) at 5 Hz for 10 s with a 50 s interval, every day for 2 days/week for 4 months
2018	[62]	1	Yes	Not reported	Motor cortices and cerebellar hemispheres	40 pulses (100% RMT) over Cz at 0.2 Hz + 20 pulses (50% RMT) over inion at 0.5 Hz every day for 4 weeks
2019	[63]	1	No	Not reported	Inion	1500 pulses (100% MSO) at 10 Hz for 1 s with a 10 s interval, every day for 4 weeks
2019	[64]	20	Yes	Yes	Inion and cerebellar hemispheres	30 pulses (100% MSO) at 0.17 Hz every day for 21 days

MSO: maximum stimulator output; RMT: resting motor threshold.


Non-Invasive Cerebellar Stimulation in Neurodegenerative Ataxia: A Literature Review

Int. J. Mol. Sci. **2020**, *21*(6), 1948

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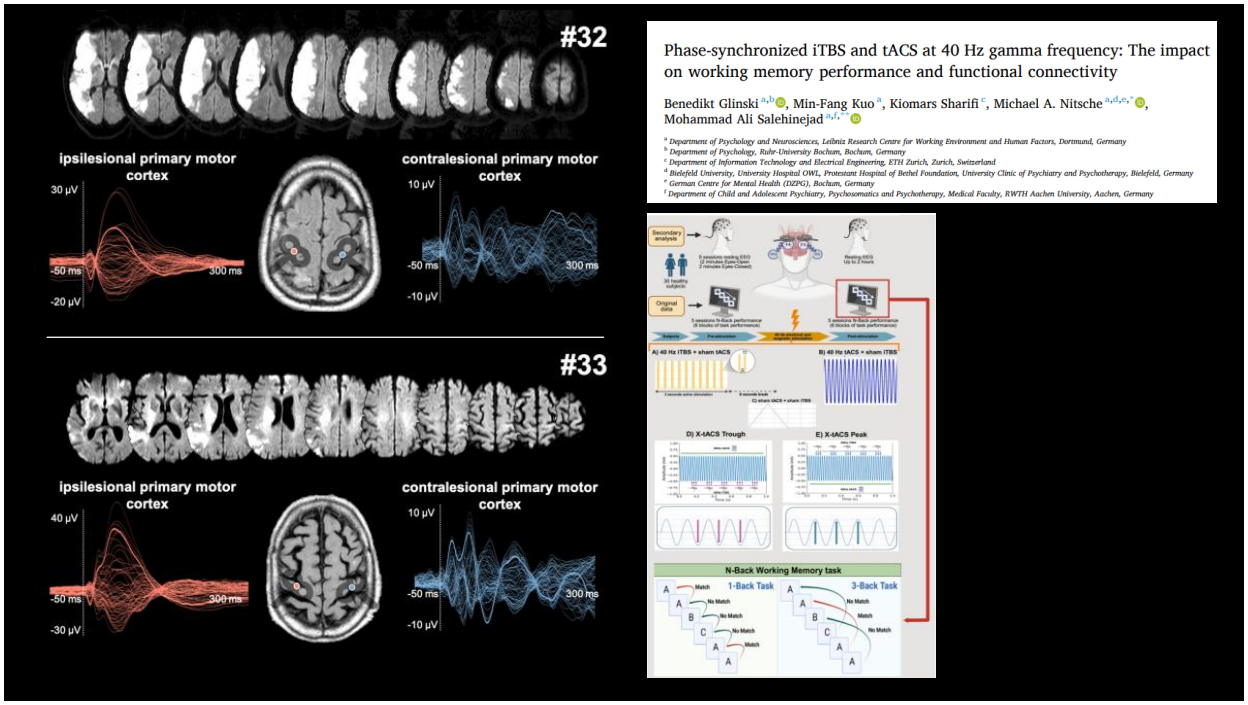


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Non-Invasive Neuromodulation



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Phase-synchronized iTBS and tACS at 40 Hz gamma frequency: The impact on working memory performance and functional connectivity

Benedikt Glinski [a,b], Min-Fang Kuo [a], Kiomars Sharifi [c], Michael A. Nitsche [a,d,e,*], Mohammad Ali Salehinejad [a,f,**]

[a] Department of Psychology and Neurosciences, Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany
[b] Department of Psychology, Ruhr-University Bochum, Bochum, Germany
[c] Department of Information Technology and Electrical Engineering, ETH Zurich, Zurich, Switzerland
[d] Bielefeld University, University Hospital OWL, Protestant Hospital of Bethel Foundation, University Clinic of Psychiatry and Psychotherapy, Bielefeld, Germany
[e] German Centre for Mental Health (DZPG), Bochum, Germany
[f] Department of Child and Adolescent Psychiatry, Psychosomatics and Psychotherapy, Medical Faculty, RWTH Aachen University, Aachen, Germany

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Non-Invasive Neuromodulation

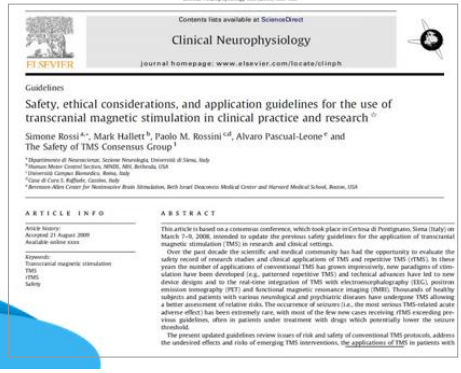


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Transcranial Magnetic Stimulation (TMS)
Safety

Expert Guidelines TMS 2021

2009



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]

ARTICLE INFO

ABSTRACT



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,z], 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,z], Abraham Zangen [an], Ulf Ziemann [ao], Mark Hallett [ap,z,*],

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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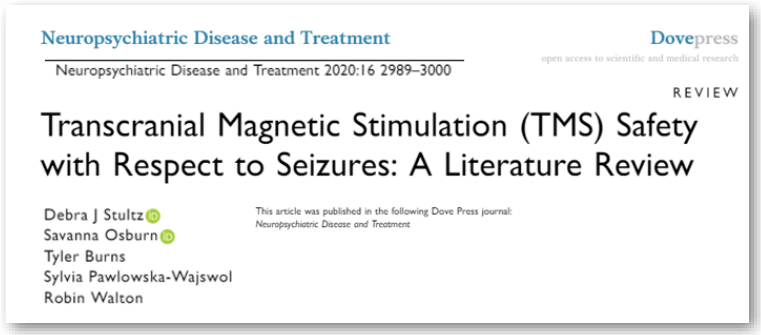
Transcranial Magnetic Stimulation (TMS)
Safety

Contraindications

1. **The only absolute contraindication** 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. **All the rest contraindications are relative** 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

Dovepress
open access to scientific and medical research

Neuropsychiatric Disease and Treatment 2020:16 2989–3000

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

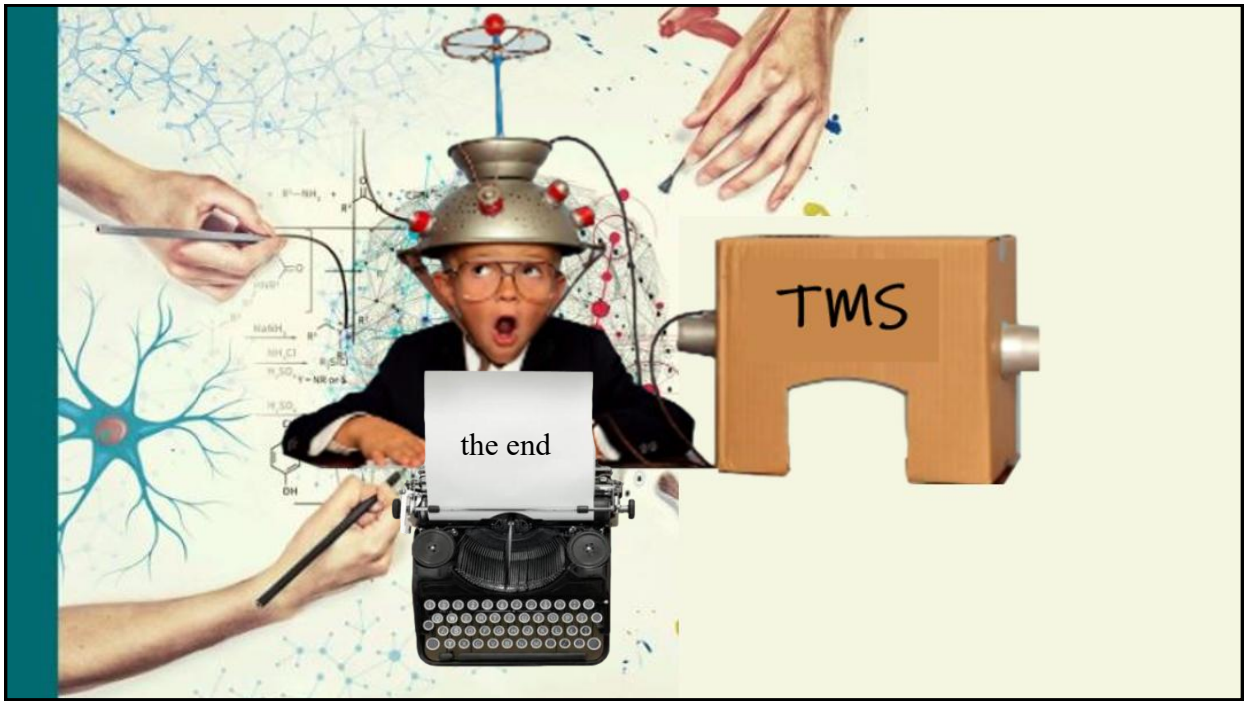
De Hoogstraat Revalidatie | UMC Utrecht



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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