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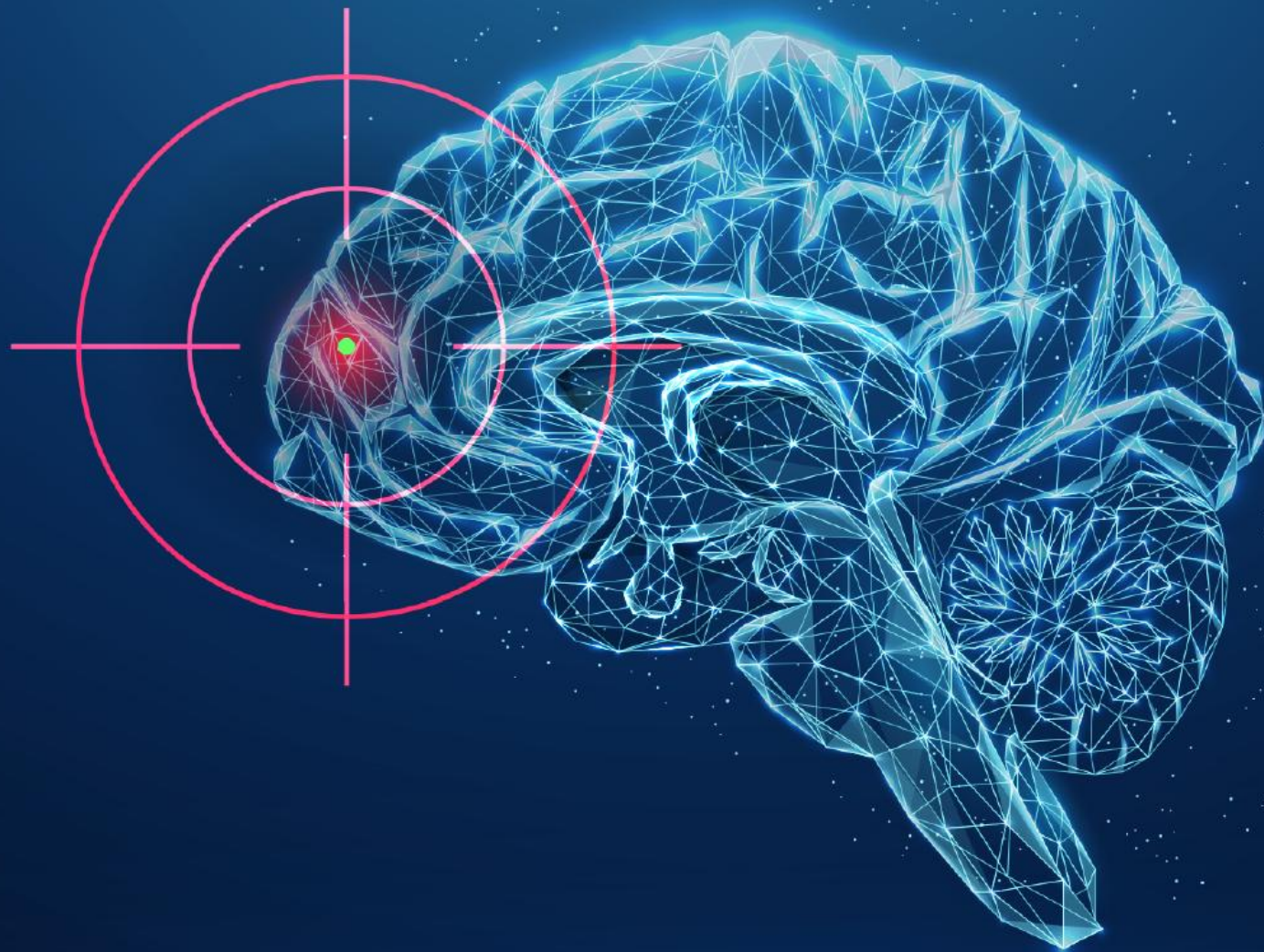
Magnetizing the Mind: Exploring Transcranial Magnetic Stimulation

December 3, 2025

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DISCLAIMERS

Drs. Jennifer Gatchel and Sanjali Kumar have working relationships with McLean Hospital. As such, they have both a financial and an intellectual interest in the webinar content. The purpose of this presentation is to provide a balanced view on the evolving role of TMS in the research and treatment of psychological disorders.

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ATTENDANCE

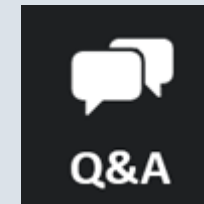
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- A “Certificate of Attendance” will be emailed to live attendees only.
- You must attend for 45 minutes to receive the certificate.

RECORDING

- A recording of this presentation will be emailed to everyone in 2 weeks' time.
- The recording will include the presentation slides.

HAVE A QUESTION?

- You are on mute. Communicate using the **Q&A box** in the webinar screen. Attendees can view and upvote on submitted questions in the Q&A box to help presenters identify popular topics.
- Presentation slides will be posted in the **chat box** of your webinar screen.





Dr. Jennifer R. Gatchel



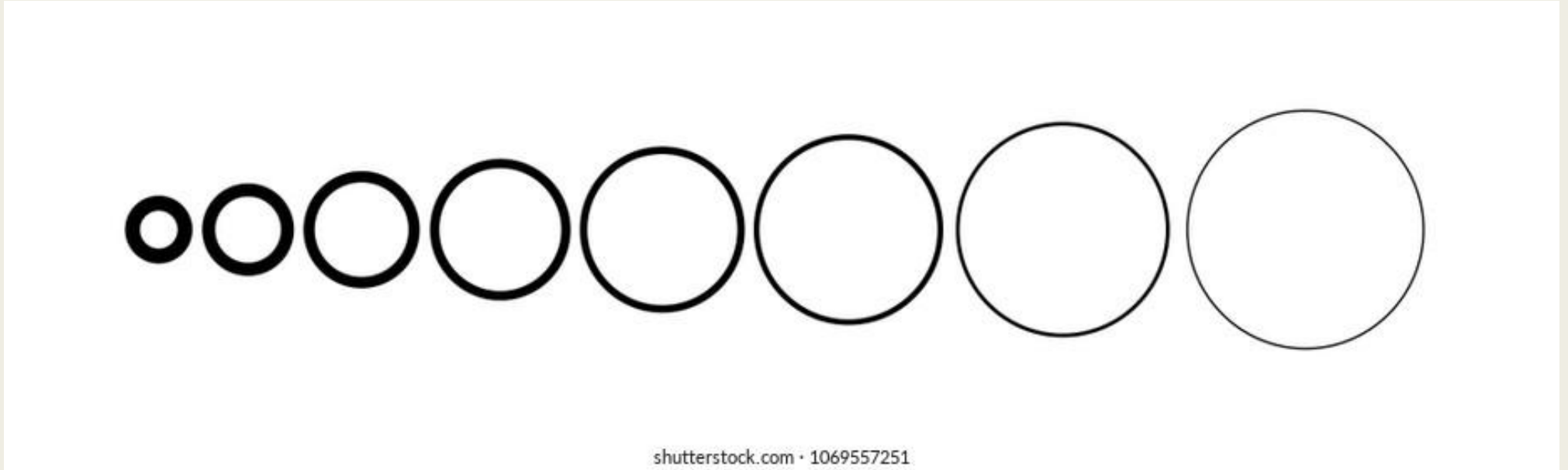
Dr. Sanjali Kumar

PRESENTERS

- Jennifer R. Gatchel, MD, PhD
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 - *Instructor of Psychiatry, Harvard Medical School*

Objectives

- Participants will gain a working knowledge of the mechanisms of action for TMS, indications and contraindications for TMS, efficacy of TMS, and the safety profile of TMS.
- Participants will demonstrate the ability to describe how TMS can be used in special populations and methods that can be used to personalize and optimize TMS treatment.
- Participants will be able to understand and discuss the future direction that TMS treatment might take.



**PROGRESSION FOR THE TALK:
START SMALL AND THEN ZOOM OUT TO BECOME LESS FOCAL, BUT
DEEPER (NOT UNLIKE MAGNETIC FIELDS THEMSELVES...)**

Progression for the Talk

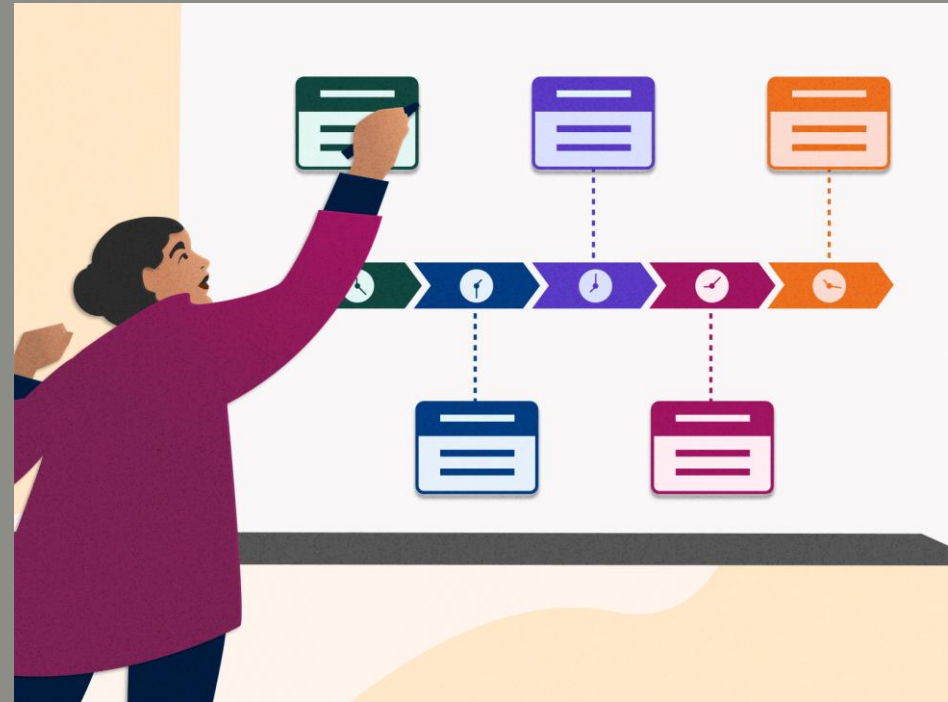
Small: history; distilled physics; MOA; indications; contraindications; efficacy; adverse events

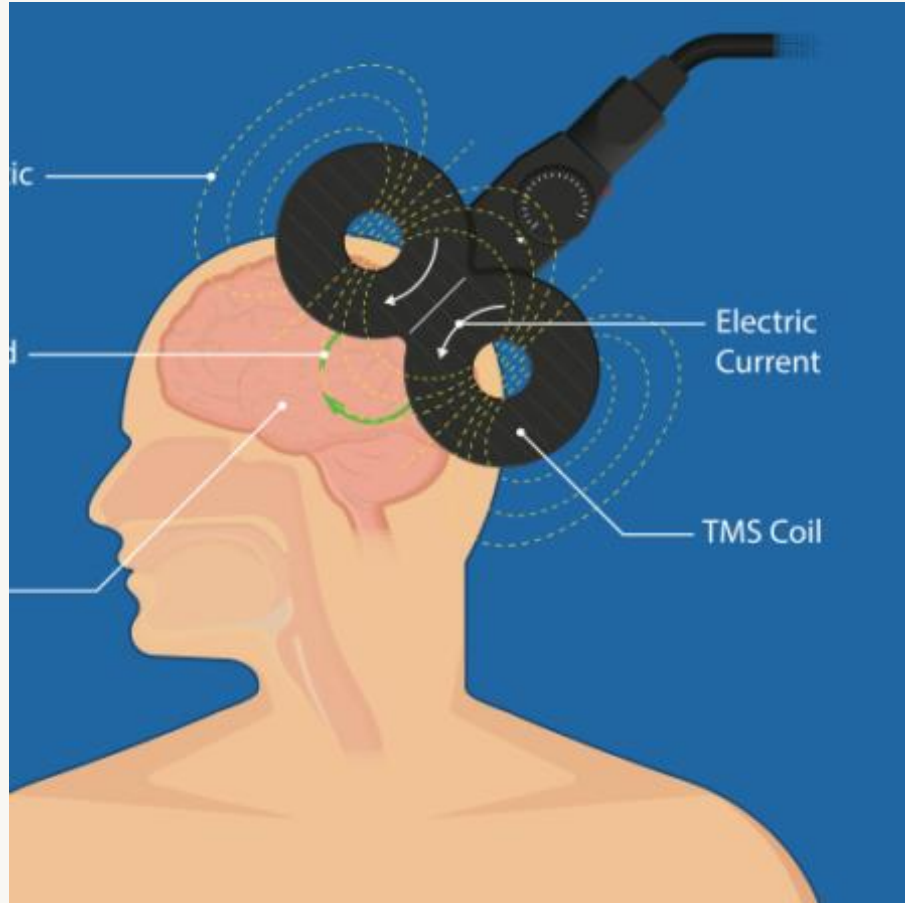
Getting bigger: administering the treatment; special populations; optimizing response

Biggest: experimental/what's to come

History/Timeline

- 1985: Invention of modern TMS by Anthony Barker in England
- 2008: FDA Approval for treatment resistant unipolar major depression in adults
- 2013: When major insurance companies started covering TMS





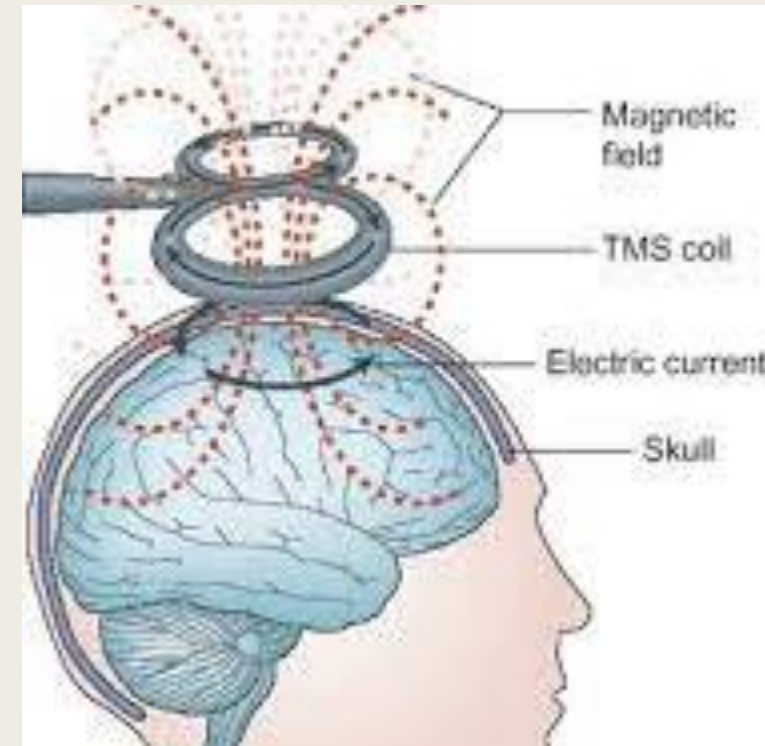
Distilled Physics

- Electrical current is passed through a metal coil



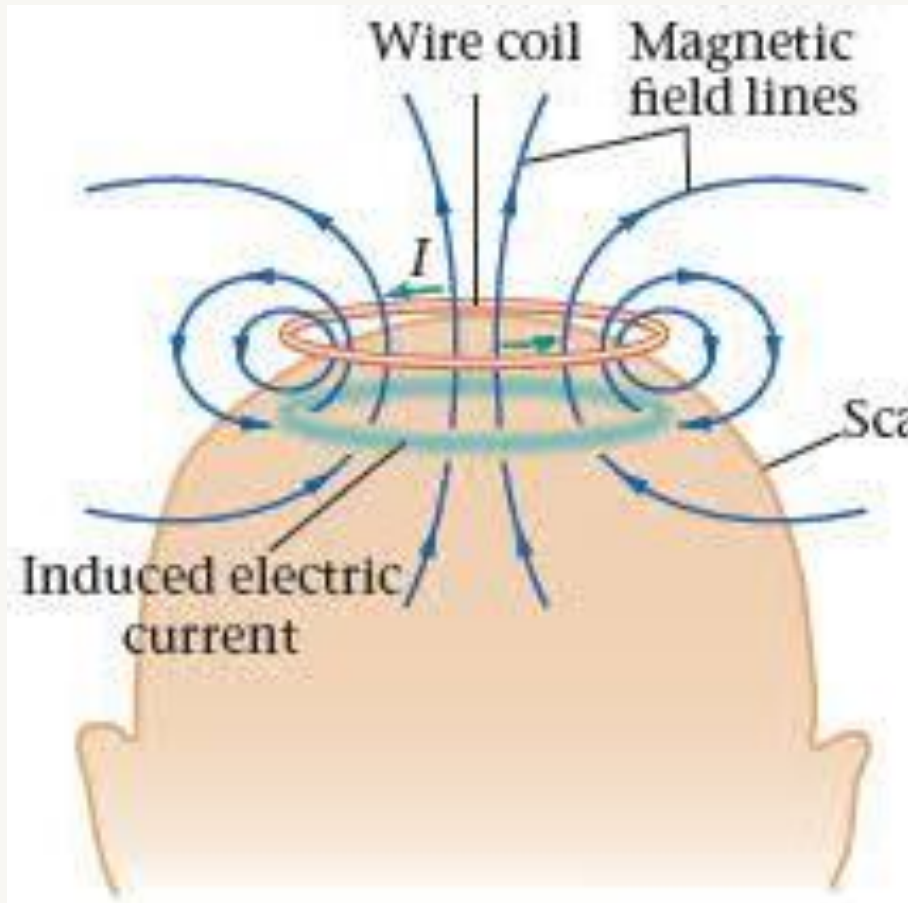
Distilled Physics

- This electrical current passing through the coil creates rapidly alternating magnetic fields



Allan C et al. 2012; Image from:

<https://www.sciencedirect.com/science/article/abs/pii/B978012382235200010X>



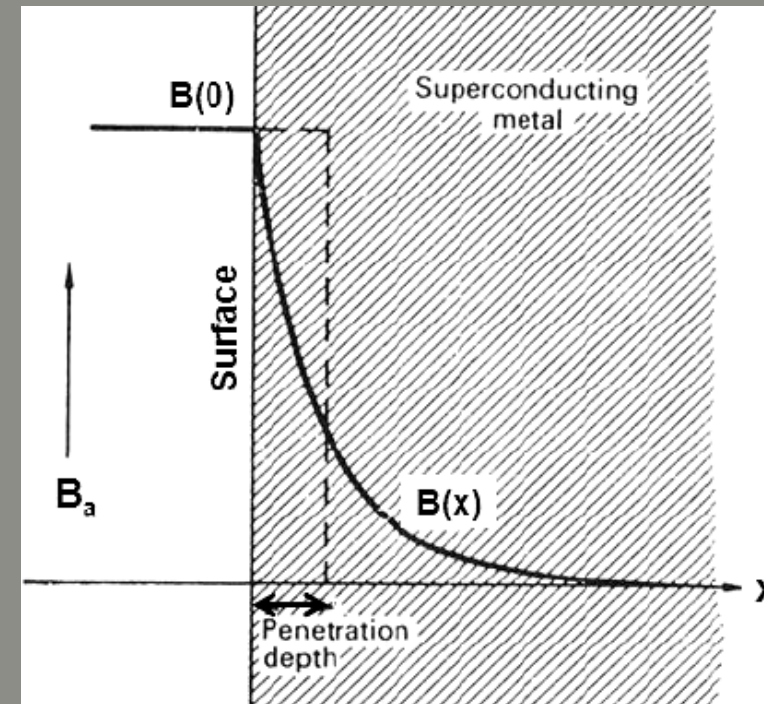
Distilled Physics

- The rate of change of the magnetic field is what induces electric currents that then depolarize neurons in a focal area of the cortex



Distilled Physics

- The strength of the magnetic field decreases exponentially, the further it gets from the coil. This is not because it is being attenuated by the tissue - it actually travels virtually unimpeded. This is just inherently how magnetic fields work.
- Therefore, the electrical currents that were induced by the magnetic field, also decrease the deeper they get into the tissue

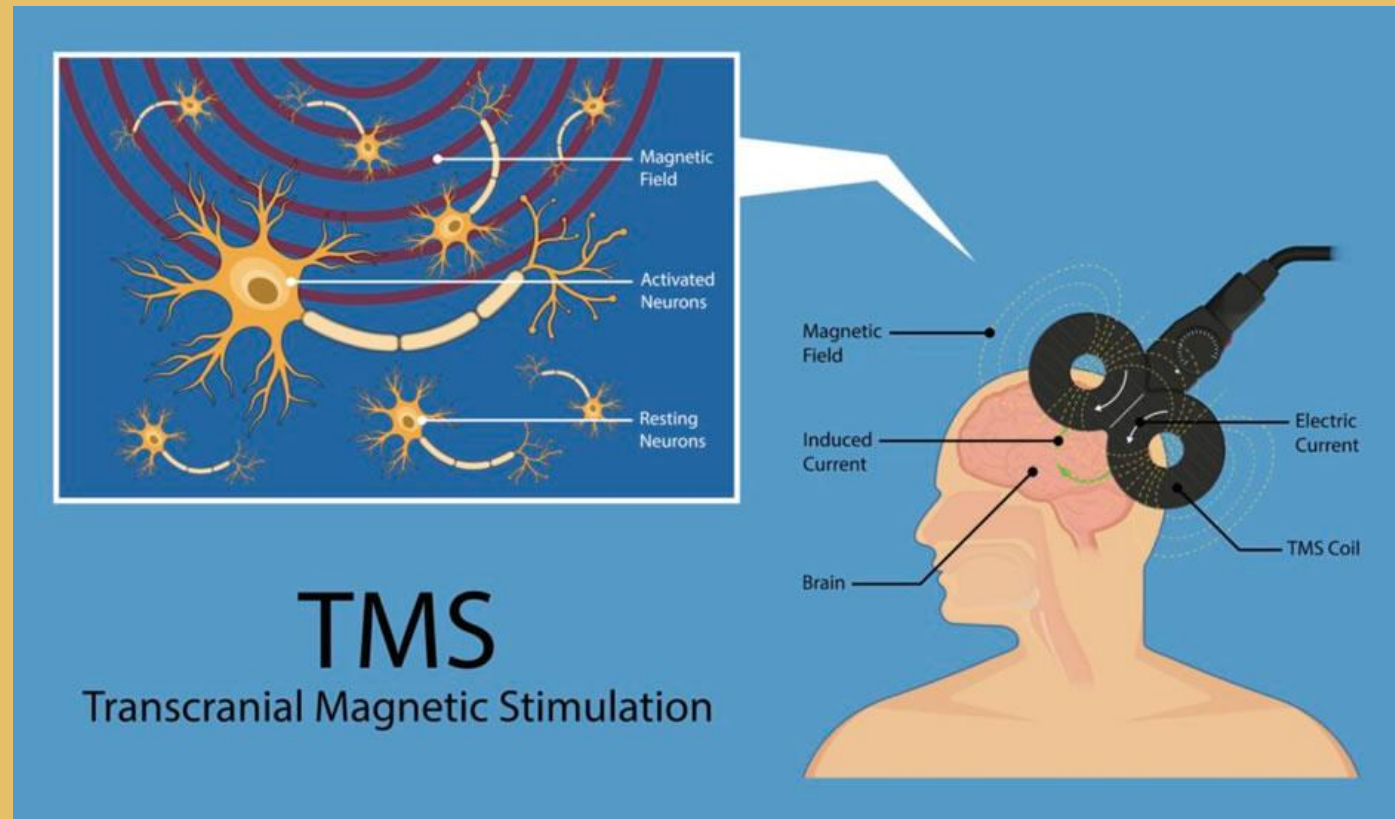


Distilled Physics

- So, if the magnetic field strength decreases exponentially, with downstream effects of the induced electrical field and tissue stimulation also decreasing, how can we affect deeper regions of the brain distal to the location immediately underneath the coil? Via neuronal circuits

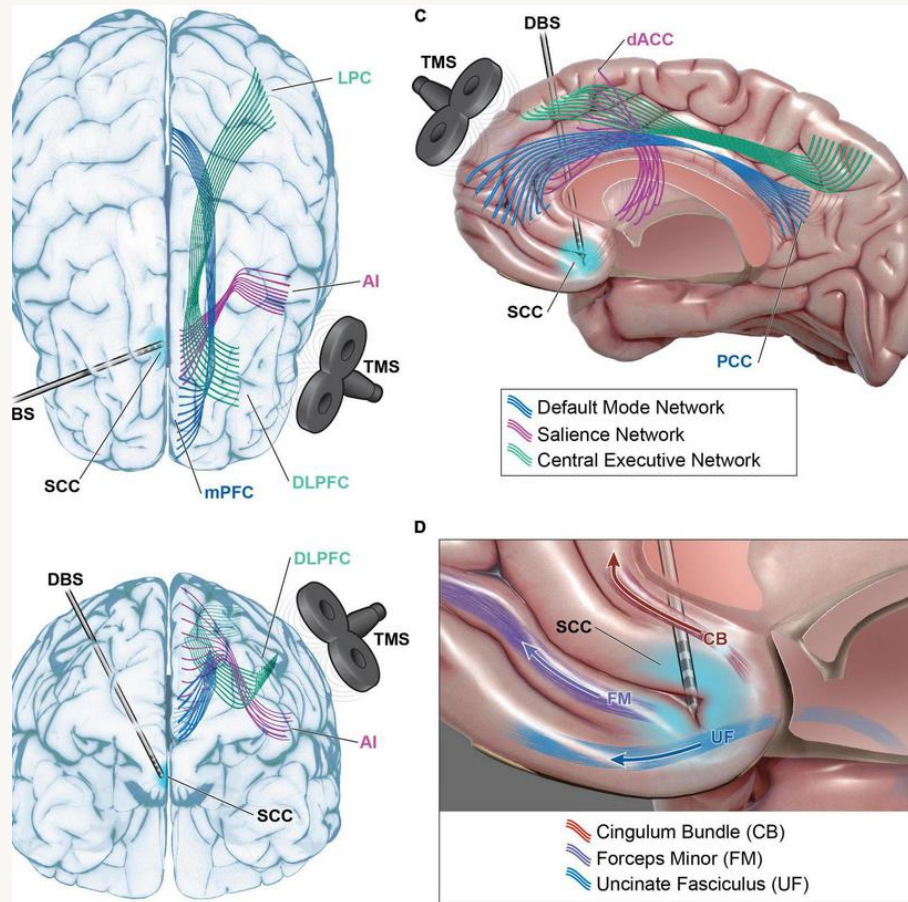
Distilled Physics

- To summarize: electrical current in coil -> rapidly alternating magnetic field -> induced electrical current -> depolarize neurons
- Neurotransmitters and chemicals in the synapse convey electrical signals from neuron to neuron
- Fiber tracts make connections all over the brain
- We have found that many circuits in the brain are affected by depression, and many of these circuits can be accessed via dorsolateral prefrontal cortex with TMS



MOA

- Several very credible hypotheses, supported by research



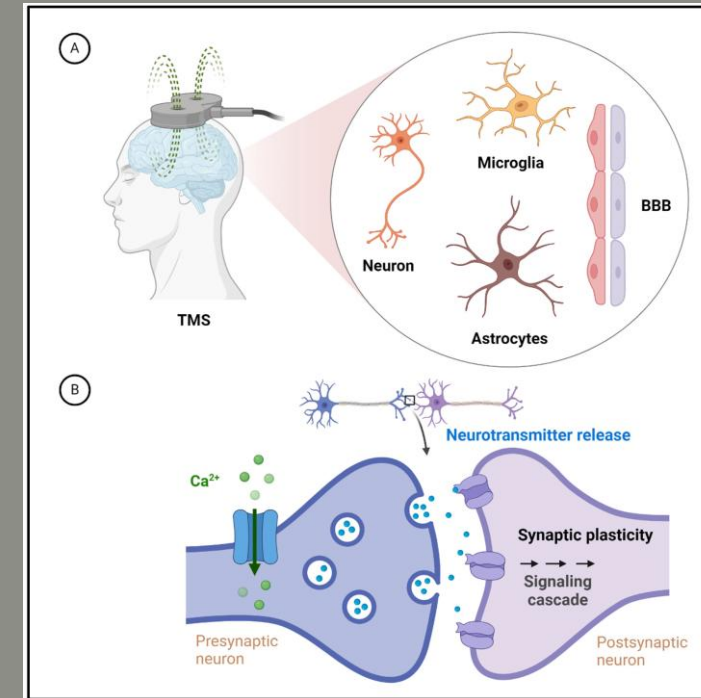
MOA

- Brain circuits: as discussed before, stimulating a cortical region can affect parts of the brain much further away via neuronal circuits. Example: stimulation of left DLPFC may decrease functional connectivity between the default mode network (DMN) and the anterior cingulate cortex (ACC). If pt's baseline connectivity between ACC and DMN was higher, they are more likely to respond to TMS therapy



MOA

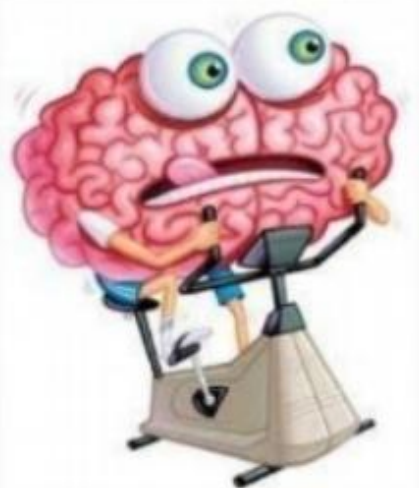
1. Neuroplasticity: functional changes (ex: long term potentiation, long term depression, synaptic strengthening) -> structural changes (sprouting/pruning, more neuronal synapses, receptors, dendritic spine growth/density, etc) -> result that are more likely to endure over time



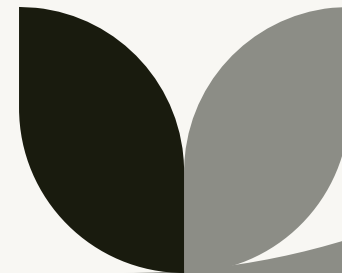
MOA

Actions of BDNF

- Sustains the viability of neurons (neuroprotection)
- Increases dendritic arborization and the number of synapses.
- BDNF gene is suppressed by stress (via cortisol).
- Decreased BDNF levels lead to neuronal atrophy and neuronal death.
- BDNF levels are low in depression, but increase with antidepressant treatment.
- Exercise increases BDNF levels.

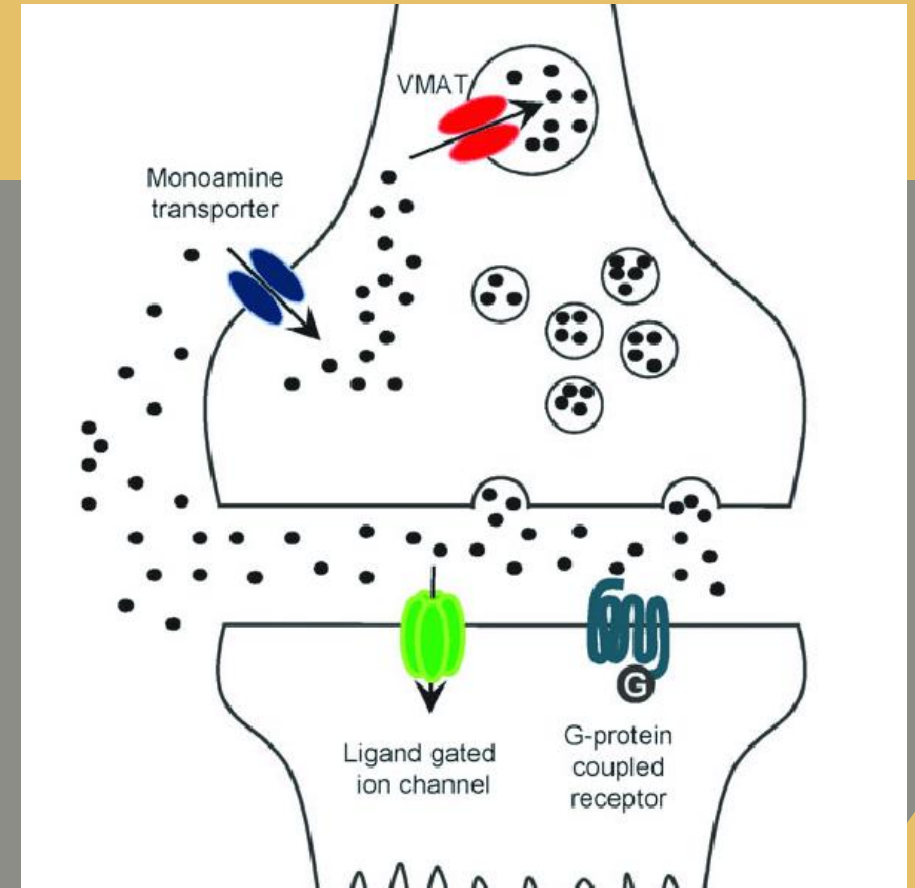


Increased expression of Brain Derived Neurotrophic Factor (BDNF). Implicated in neuronal growth, survival, plasticity. Pts with MDD have been shown to have low serum BDNF concentrations, which has normalized with antidepressant therapy, including TMS



MOA

Molecular affects: increased monoamine turnover, changes in GABA, glutamate, normalization of HPA axis



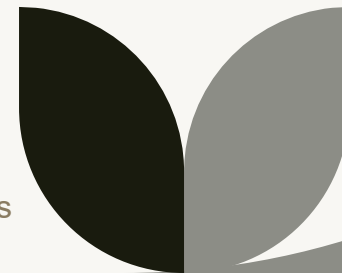
George MS et al. 2011; Image from: https://www.researchgate.net/figure/A-Schematic-representation-of-a-simplified-monoaminergic-synapse-Monoamine-transmitters_fig9_26321511

MOA

Increased regional cerebral blood flow



Shinba T et al. 2018; Image from:
<https://www.renalandurologynews.com/news/hemodialysis-induces-decline-in-cerebral-blood-flow-in-elderly/>



Indications

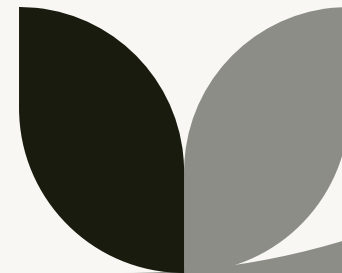
TRD unipolar depression. Mostly dependent on insurance definition of what is “treatment resistant”: most common: 4 or more antidepressants, across 2 different med classes, with at least 2 augmenting agents

Indications

March 2024: adolescents 15-21



<https://ir.neuronetics.com/news-releases/news-release-details/neurostarr-advanced-therapy-receives-fda-clearance-first-line>; Image from:
<https://psychiatryresource.com/articles/tms-for-adolescent-depression>



Indications

- FDA cleared: migraine; OCD (2018; 2020; 2022): medial prefrontal cortex and anterior cingulate cortex – with concurrent med therapy and symptom provocations prior to treatments; smoking cessation (2020) short term; comorbid anxiety symptoms in adult pts with MDD (2021)

Contraindications/Safety Profile

- 13 item clinician-administered questionnaire:
 - *1. Do you have epilepsy or have you ever had a convulsion or a seizure?*
 - *Have you ever had a fainting spell or syncope? If yes, please describe on which occasion(s)?*
 - *Have you ever had a head trauma that was diagnosed as a concussion or was associated with LOC?*
 - *Do you have any hearing problems or ringing in your ears?*
 - *Do you have cochlear implants?*
 - *Are you pregnant or is there any chance that you might be?*
 - *Do you have metal in the brain, skull, or elsewhere in your body (splinters, fragments, clips, etc)? If so, specify the type of metal.*
 - *Do you have an implanted neurotransmitter (DBS, epidural/subdural, VNS)?*
 - *Do you have a cardiac pacemaker or intracardiac lines?*
 - *Do you have a medication infusion device?*
 - *Are you taking any medications? (please list)*
 - *Did you ever undergo TMS in the past? If so, were there any problems?*
 - *Did you ever undergo MRI in the past? If so, were there any problems?*

Contraindications/Safety Profile



The only absolute contraindication to TMS is non-removable metallic objects in or around the head (within 30cm of treatment coil): excludes most dental/orthodontic work (generally nonferromagnetic)

Contraindications/Safety Profile

- Not “absolute” contraindications, but definitely should be handled with extreme caution:
 - *Implanted electrodes/stimulators (deep brain stimulation)*
 - *Aneurysm clips/coils (plastic would be safe)*
 - *Cochlear implants*
 - *Intracranial stents*
 - *Bullet or other metal fragments*
 - *Vagus nerve stimulator (TMS is not positioned near the stimulator apparatus. Best to consult with VNS experts.)*

Contraindications/Safety Profile



Even if a device is greater than 30cm away, be cautious if it is affected by physiological cues such as: pacemaker, ICD, insulin pump, spinal cord stimulator, inspire (sleep apnea implanted device). Can it be turned off?



Tattoos/permanent makeup: if metallic ink was used, could heat up



Piercings: if precious metal or ceramic, don't need to be removed



TMS and botox for migraines: wait 24hrs before doing TMS, as to not disturb injection site/binding of toxins



In general, just bc it is MRI safe, don't automatically assume that it is safe for TMS. The intensity of TMS treatment is strong enough to cause nerves to fire, which isn't the case for MRI's

Contraindications/Safety Profile

Personal/family hx of seizures: extra caution, take other risk factors into context. Make sure benefits outweigh risks



TBI: increases seizure risk. Should be cleared by a neurologist



TMS and ketamine: recommend to do TMS prior to ketamine (lowers seizure threshold)



THC: no safety concerns, but heavy use may decrease effectiveness of TMS (agonist of cannabinoid receptor: may affect neuroplasticity effects)



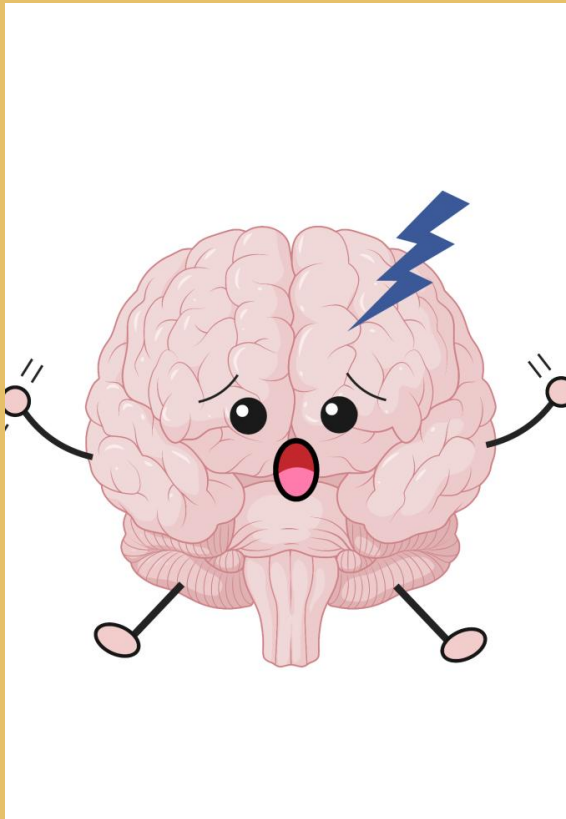
Medications that lower seizure threshold: generally safe due to low seizure risk from TMS, but should be taken in context with other risk factors such as alcohol use, sleep deprivation, etc)

Contraindications/Safety Profile



- Psychotic features; hypomanic/manic sx's: generally better served with other treatment modalities, like ECT. Generally not covered by insurance companies
- Important insurance company caveat: even if not overtly medically unsafe, may be an exclusionary criteria for insurance

Safety and Adverse Events



- Most significant: seizure risk.
 - *TMS seizure risk: 0.1% (1:1000 pts treated)*
 - *Pt with known epilepsy receiving TMS: 0.2%*
 - *Wellbutrin: up to 0.4%*
 - *Celexa: 0.3%*
 - *Prozac 0.2%*
 - *Effexor 0.1%*
 - *General population: 0.5-1%*

Safety and Adverse Events

- Seizures will only happen while pt is in the chair, not when pt is driving home, etc. Generally staff member is with pt throughout the treatment. If seizure does occur, it is self limited (doesn't increase chances for developing epilepsy). No injuries requiring treatment or episodes of status epilepticus have occurred with TMS (per literature)

Safety and Adverse Events

- Factors that increase seizure risk: hx of epilepsy, TBI, other neurological d/o's, seizure threshold lowering medications, alcohol/benzo w/d, sleep deprivation, ED, excessive caffeine

Safety and Adverse Events

What can you do?: monitor carefully before and during tx, check MT's regularly and with med/sleep/substance use changes. Refrain from tx if concerned

Safety and Adverse Events

If seizure does occur: terminate tx -> assess airway breathing and circulation -> after convulsions end, turn pt onto their side to help clear airway and prevent aspiration -> call emergency services -> carefully document event and behaviors before, during, and after seizure



Safety and Adverse Events

- Most common side effects: facial muscle twitching, scalp pain: slightly change position of coil; HA, eye/jaw/tooth pain, choking/aspiration: use mouthguard, no food/loose mouthpieces, OTC analgesic pre-tx, transient effects on hearing: ear plugs for pt and staff

Safety and Adverse Events

- If you start to see signs of mania/hypomania developing, stop TMS, re-assess, gather collateral, consider alternate treatments like ECT

Treatment Itself

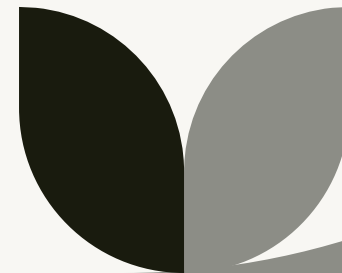
- Pre-treatment assessment (addressing indications, risk factors, and safety profile mentioned above)
- Treatment team: Prescriber: psychiatrist or other qualified clinician oversees treatment, prescribes TMS, and completes the initial mapping (specifics on this are currently fluid). Generally should be immediately available during tx. Actual treatment is generally done by nurse/tech



Image from: <https://gspatients.com/how-to-establish-strong-doctor-patient-relationships/>

Treatment Itself

- Outpatient procedure. Pt can drive themselves to and from the procedure. Depending on the machine/protocol, typical daily appt generally lasts for about 20-40min. Most common protocol calls for daily treatments (Mon-Fri) for 30 treatments, and 6 treatments of a taper
- Collect surveys throughout the tx course



Treatment Itself

- Standard Techniques
 - *Surface cortical stimulation (high and low frequency): most commonly used*
 - *Deep stimulation: theoretically affects cortical structures, along with deeper parts of the brain*
 - *Theta burst stimulation: intended to mimic endogenous theta rhythms. Takes 3-10min instead of the conventional 30-40min*

Treatment Itself

- Parameters:
 - *Frequency (# of magnetic pulses per second: in Hz)*
 - High/fast: greater than 1 pulse/sec (usually 10-20); left DLPFC; excitatory
 - Low/slow: less than or equal to 1 pulse/sec; right DLPFC; inhibitory (indications: high risk for seizure, poor tolerability, anxious features)
 - *Intensity: % of resting MT (established during first mapping appt). Stimulate the motor cortex to find the minimum amount of energy required to evoke motor response (usually contralateral small hand muscles). Movement is assessed visually or with EMG. Intensity is usually 100-120% of MT*
- Parameters
 - *Train duration ("on" time, ex: 4sec)*
 - *Intertrain interval: down time in between successive trains (ex: 26sec)*
 - *Number of trains*
 - *Usually, studies report total number of pulses delivered (ex: 3000)*
 - *Stimulation site*
 - Also part of mapping session. Different methods for finding location to tx (often the DLPFC): 5.5-7cm anterior vs Beam F3 method vs neuronavigation guided by MRI

Treatment Itself



- Most common protocol for unipolar MDD: frequency: 10hz; 3000 total pulses; intensity: 100-120%MT for 4-6wks. Variations of the protocol are being developed, and vary based on machine used and target pathology
- There is continued research on the benefit of maintenance tx

Efficacy

- About 50-60% of people with TRD experience a clinically significant response with TMS. About 1/3 of these individuals experience full remission of their symptoms

Efficacy



- Studies have shown that the benefits are stable 4wks after treatment, and can last up to one year
 - *A meta analysis of 732 patients who responded to acute TMS treatment were tracked. The proportion of initial responders who sustained response were:*
 - 3mo: 67%
 - 6mo: 53%
 - 12mo: 46%



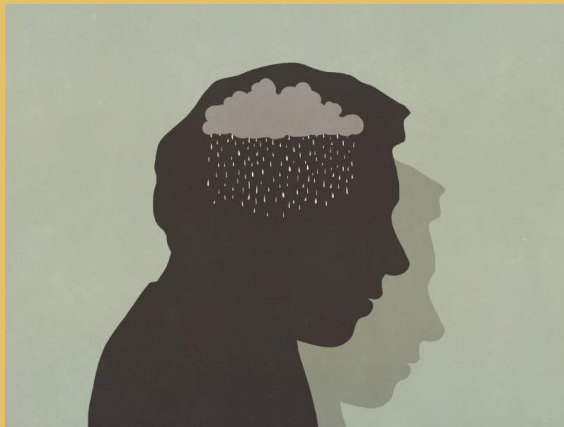
Special Populations

- Geriatric Population
 - *Can be helpful if intensity (ex: high frequency, deep TMS, etc) of treatment is sufficient, given inherent prefrontal atrophy*



Special Populations

- Post Stroke Depression
 - *Helpful as an adjunct treatment with general care (medications, therapy, etc). Shown to improve depression, ADL's, neurological function*



Shen X et al. 2017; Image from:
<https://www.heart.org/en/news/2023/02/20/understanding-the-stroke-depression-link-and-what-survivors-and-families-can-do>

Special Populations



- Pediatrics
 - *New FDA clearance as first line add-on treatment for adolescents (15-21yo)*
 - *Neurostar data showed that in real-world data analysis of 1,169 pts, 78% experienced clinical significant improvement*
 - *Important to consider: no increase in suicide, no neg neurocog effects, no structural brain changes: pt 110*
 - *Growing field and increasingly important, given increase in affected children and adolescents since the pandemic*

Special Populations



- Pregnancy and postpartum depression
 - *Generally found to be safe for the fetus, given that the magnetic field rapidly drops off. So far, no poor reported outcomes to fetuses born to mothers who were treated with TMS*
 - *Check MT's more often (~weekly), monitor for hypotension*

Optimizing Response



- Psychotherapy? Captive audience 5 days per week for 6 weeks
 - *CBT, talk, watch videos, set goals (regular accountability inherently baked in)*
 - *Several studies have shown that TMS helps with cognition, working memory, processing speed, etc. So could it have a synergistic effect?*

Optimizing Response

- What if my patient isn't getting better?
 - Keep treating. Sometimes people just need more pulses
 - *How many sessions/pulses are optimal? Maintenance vs extending? Stay tuned. We do know that the more residuals symptoms that exist, the higher the chance for relapse*
 - Understand more nuance about the symptoms that aren't being addressed. Pathology priority?
 - Recheck MT
 - Switch protocols (high frequency vs low frequency; left sided vs right sided)

Optimizing Response

- *What if TMS didn't work?*
 - Good quality psych care: safety assessment, manage emotional lability, rally support system, consider other treatment modalities (ex: ECT)

Experimental/What's To Come?

- No good evidence yet, but it's being worked on: bipolar depression, GAD, insomnia, PTSD, OUD, AUD, schizophrenia (AH and neg symptoms), ADHD, chronic pain, tinnitus, tourettes, alzheimers
- Experimental techniques:
 - *Accelerated TMS (ex: SAINT protocol: theta burst/10 treatments per day/FMRI guided; 19/22 pts met remission (1 dropped out))*
 - *High Dose (more pulses)*
 - *Bilateral TMS*



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AUDIENCE Q&A

FINAL THOUGHTS

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- Take our survey immediately after the webinar has concluded.

THANK YOU!

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