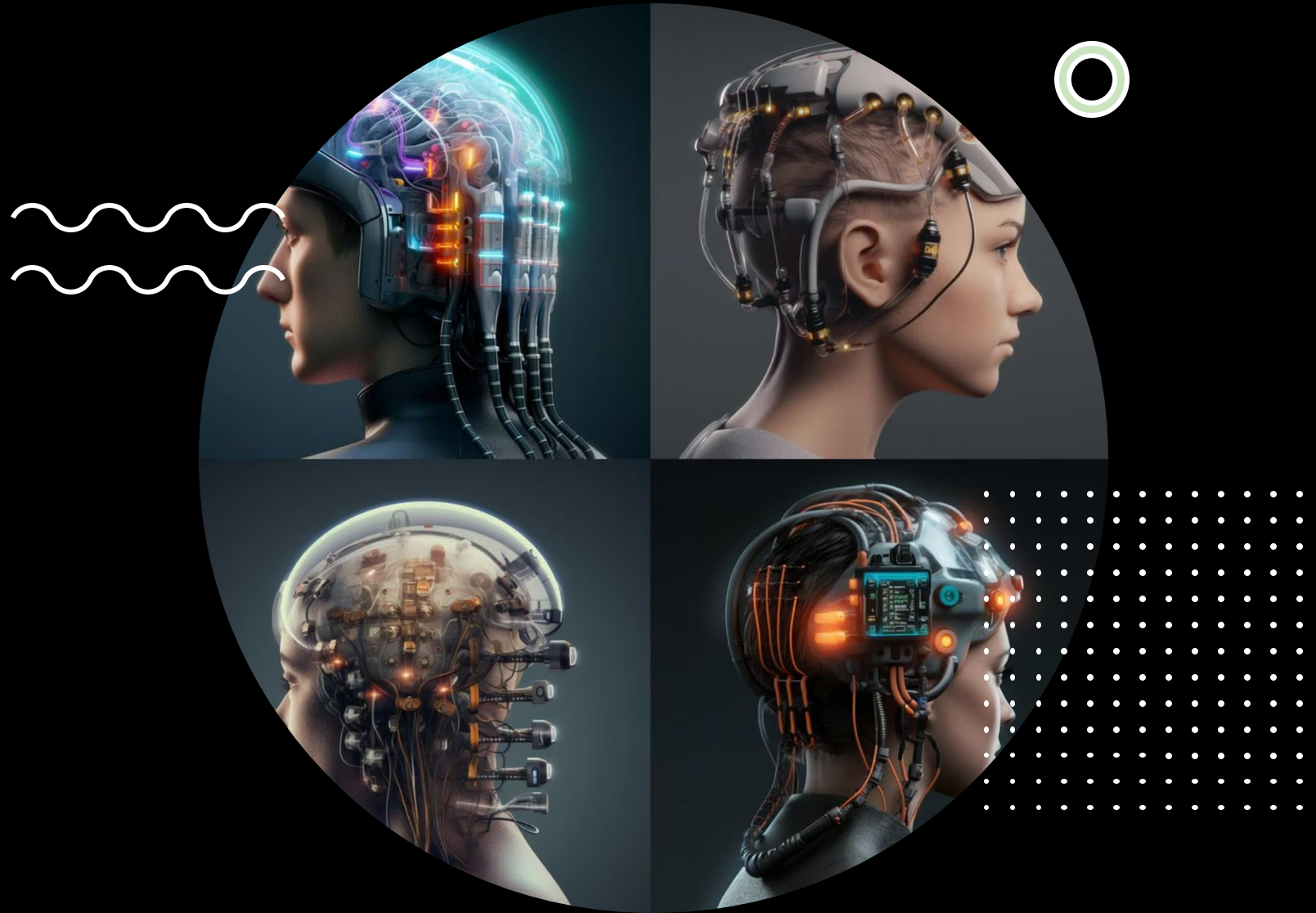


Brain Stimulation

9/17/24



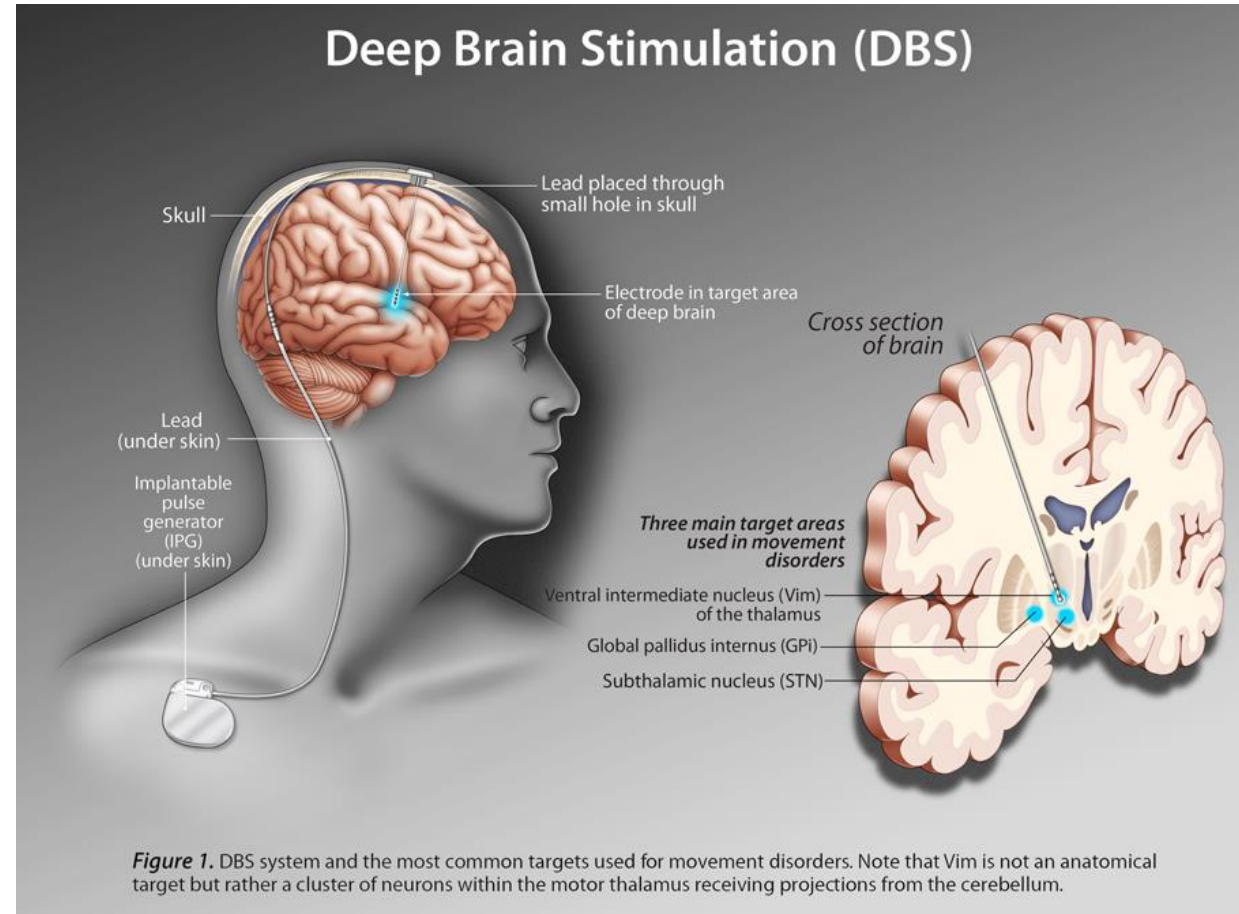
What is brain stimulation?

- Technological approach to **neuromodulation** – alteration of brain activity
- Can be **invasive** or **non-invasive**
- Effects are **temporary**, though they may have long-lasting impact
- Can be used for clinical treatment or neuroenhancement, most techniques seem to enhance neuroplasticity
- Can be very precise, effective, and safe in certain scenarios
- But it is still an emerging space with lots of unknowns

Type	Invasiveness	Spatial Resolution	Depth	Mechanism
Deep brain stimulation (DBS)	Invasive	High	Deep, can be anywhere surgery will reach	Electrical impulses via implanted electrodes to modulate neural circuits
Transcranial Electrical Stimulation (TES)	Non-invasive	Low	Shallow, 1-2 cm	Weak electrical current to the scalp to alter neuronal excitability
Transcranial Magnetic Stimulation (TMS)	Non-invasive	Moderate	Loses accuracy as it goes deeper, 1-3 cm	Pulsed magnetic fields to induce electrical currents in target area
Transcranial Ultrasound (TUS)	Non-invasive	High	Deep, up to 6 cm or more	Focused ultrasound waves to modulate neural activity in target area
Photobiomodulation (PBM)	Non-invasive	Low	Shallow, 1-2 cm	Infrared light to stimulate cellular processes and enhance brain metabolism

Deep Brain Stimulation (DBS)

- Surgically-implanted electrode to modulate neural activity with electrical stimulation
- Pulse generator creates different stimulation parameters – needs to be regularly tuned and adjusted
- Useful for Parkinson's, essential tremor, dystonia, epilepsy
- Believed to work by disrupting abnormal electrical activity in neural circuits



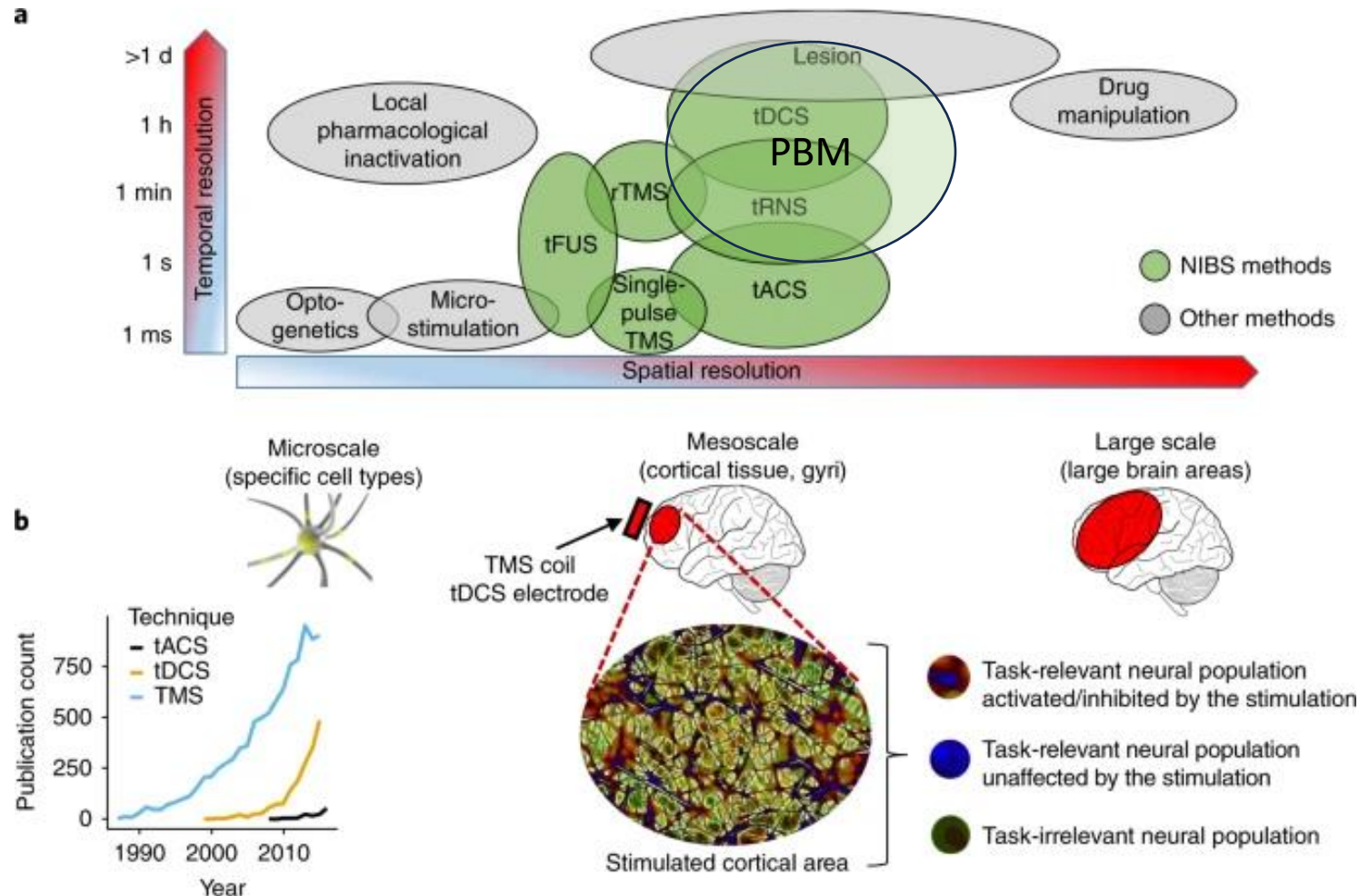
Non-invasive brain stimulation (NIBS)


Magnetism
(TMS)


Sound (TUS)

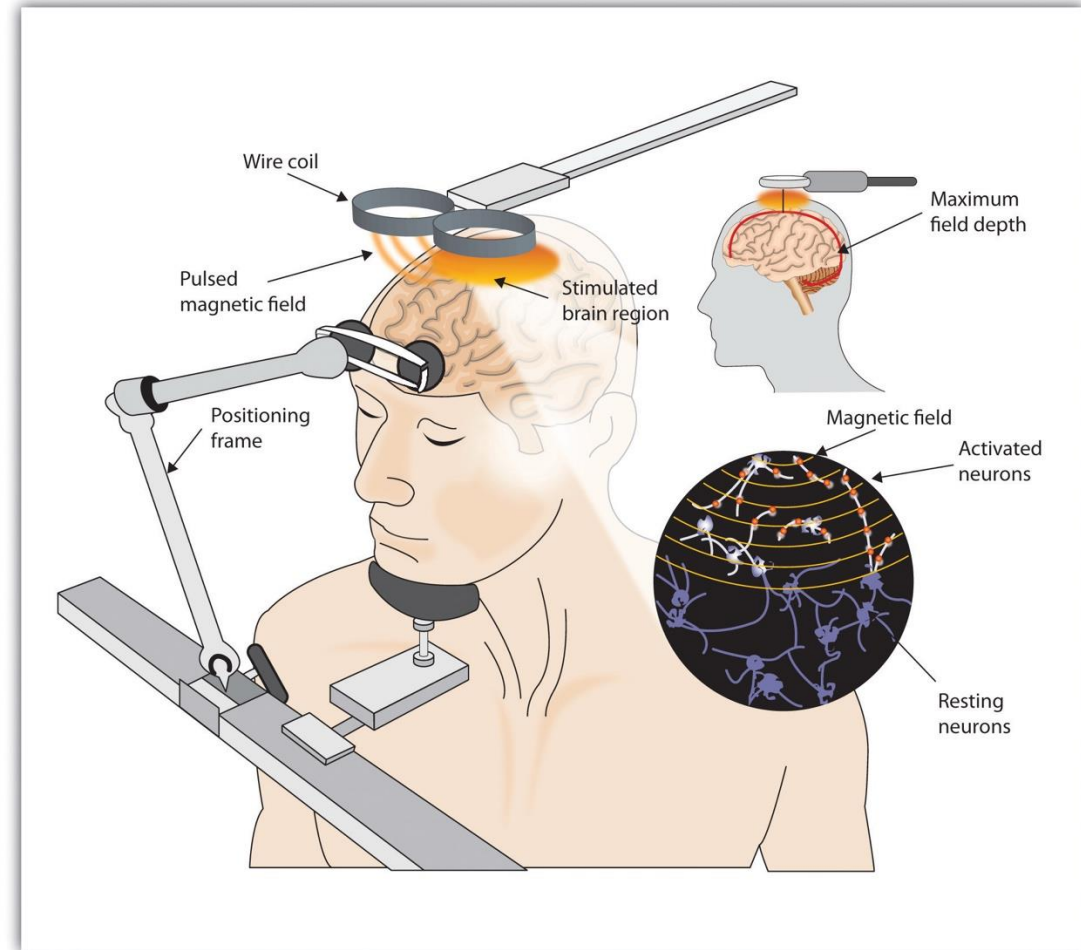

Electricity (TES)


Light (PBM)



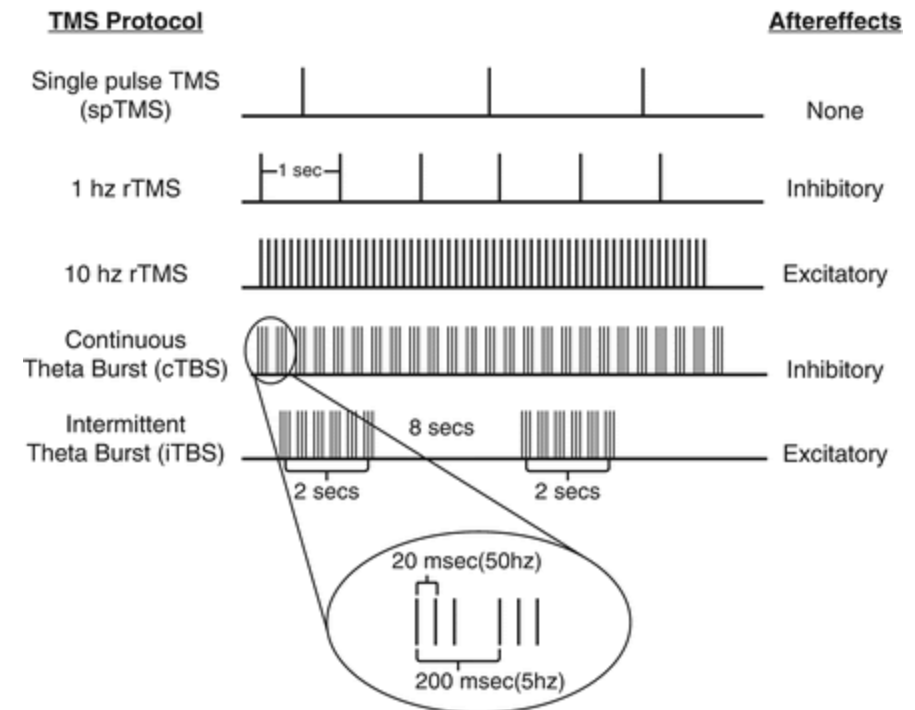
Transcranial Magnetic Stimulation (TMS)

- Magnetic pulses stimulate or inhibit neuronal activity by altering electrical signaling
- High spatial accuracy on the cortex
- Most common brain stimulation technique, only NIBS currently approved for clinical use (treatment-resistant depression)
- **Motor threshold:** field intensity is calibrated to the strength it takes to cause a thumb twitch by stimulating motor cortex
- Typical treatments: 20-40 minutes, 5x/week for 4-6 weeks
- Effects are brief, but repeated applications can be long-lasting



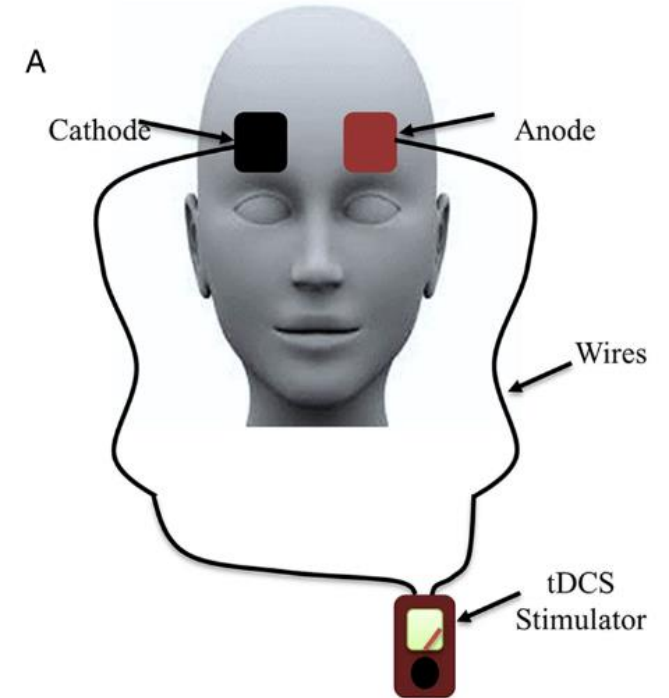
Types of TMS

- **Repetitive TMS (rTMS)**: repeated pulses over a session to produce longer lasting effects
- **Theta Burst TMS (TBS)**: pulse at theta frequency (5 Hz), mimics natural theta rhythms, induces synaptic plasticity
- **Intermittent TBS (iTBS)**: high-frequency stimulation (usually 50 Hz) at 5 Hz intervals, with breaks between bursts. Has **excitatory** effect
 - Target left dorsolateral prefrontal cortex (mood regulation, cognitive control) for depression or cognitive enhancement
- **Continuous TBS (cTBS)**: continuous pattern of high-frequency bursts at 5 Hz with no breaks. Has **inhibitory** effect
 - Target right dorsolateral prefrontal cortex (overactive in emotional regulation, fear response) for anxiety



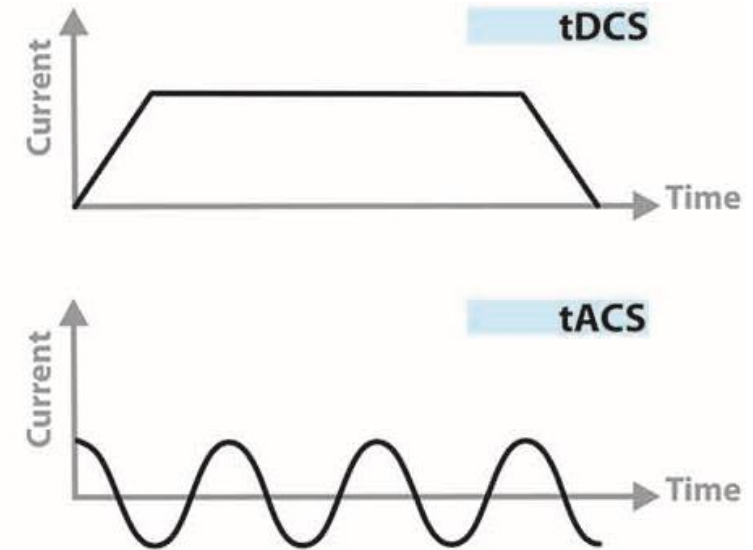
Transcranial Electrical Stimulation (TES)

- Pass electric current through electrodes placed on the scalp. Most (90+%) of the electric current will pass over the skin, but some will penetrate the brain and affect neuronal firing.
 - **Anode** location loses negative charge, causing increase in excitability (depolarization)
 - **Cathode** location gains negative charge, causing reduction in excitability (hyperpolarization)
- Location of anode/cathode affects what areas of the brain you are going to alter
- Effects can last for minutes to hours
- May induce heightened plasticity



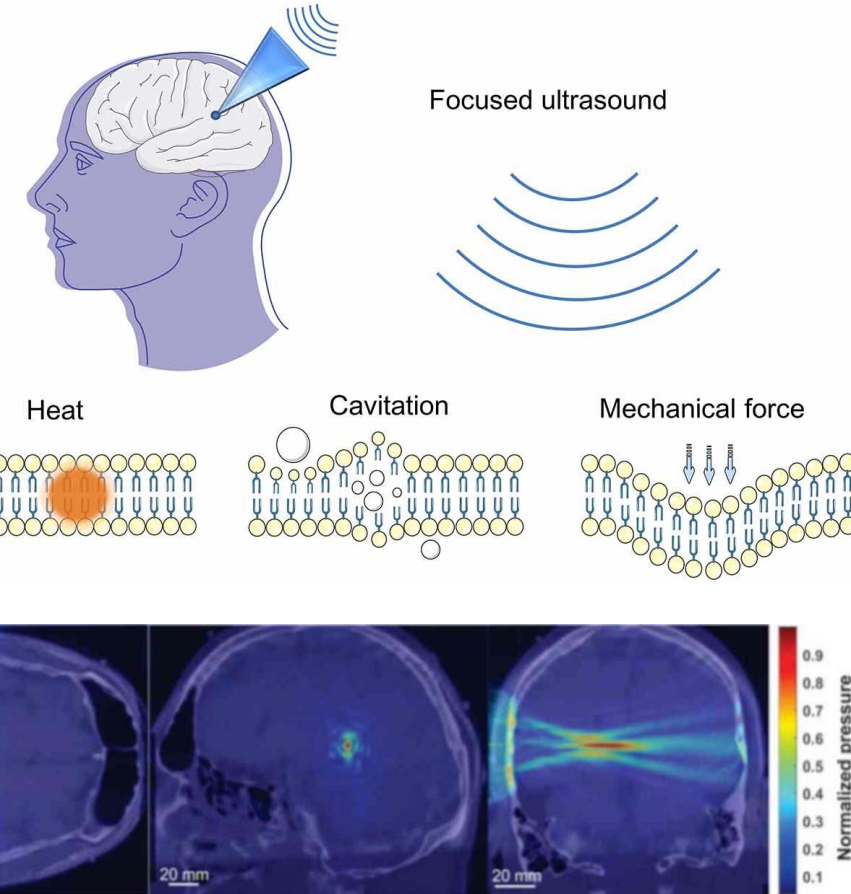
Types of TES

- **Transcranial direct current stimulation (tDCS):** continuous direct current is passed
 - Can enhance plasticity, modulate neurotransmitters
 - Can improve cognitive functioning
- **Transcranial alternating current stimulation (tACS):** alternating current is delivered, at any frequency you want to use
 - Designed to modulate ongoing brain oscillations through entrainment
 - Can help with essential tremor, Parkinson's, schizophrenia, OCD, enhanced learning

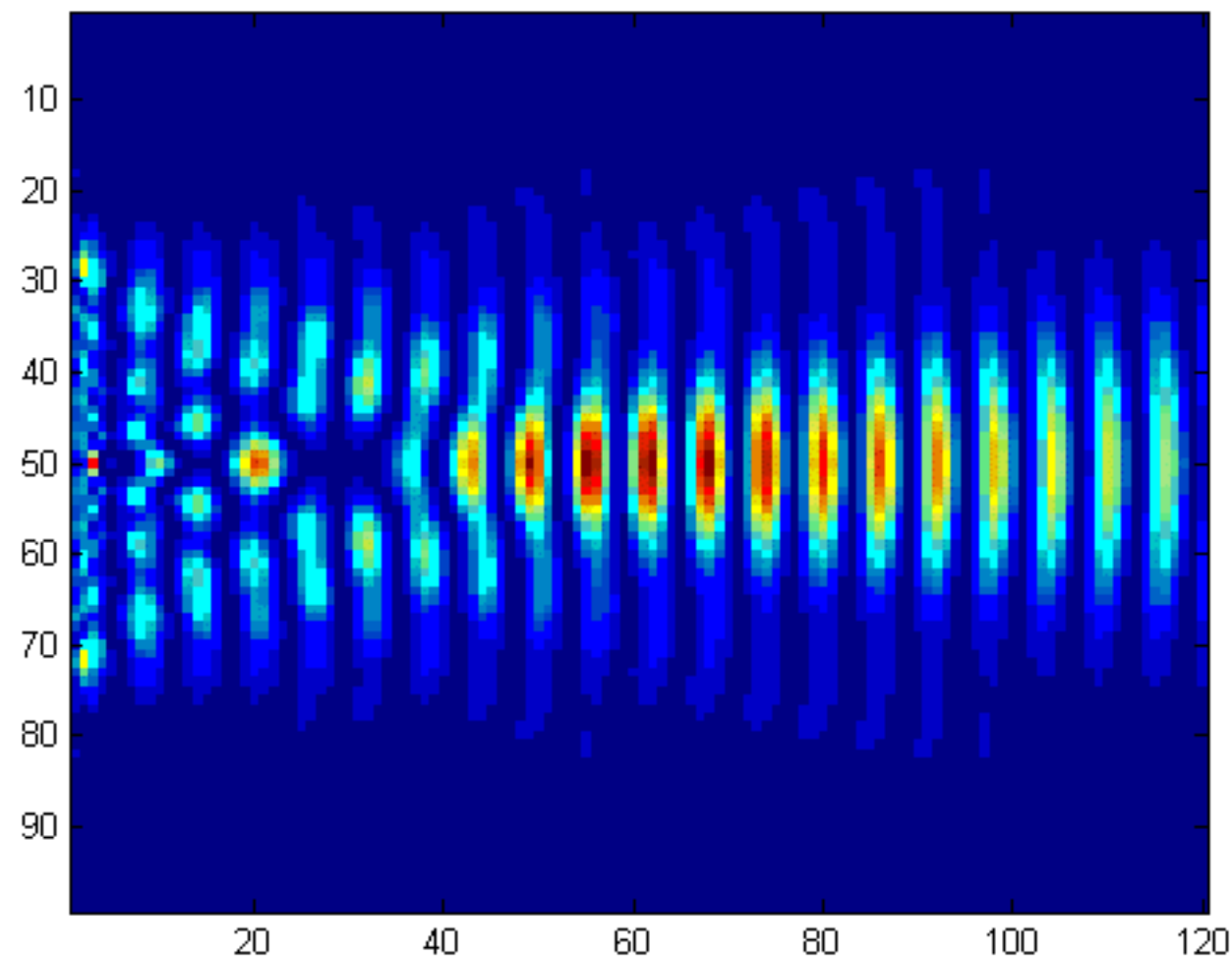


Transcranial Focused Ultrasound (tFUS)

- Uses focused ultrasound waves to modulate brain activity at precise targets
- Works through a variety of possible mechanisms – heat, mechanical, resonance effects
 - Field is still developing on what types of acoustic waves work best
- Only NIBS technique that can target **subcortically**, with high precision
- Induces heightened neuroplasticity
- Effects can last minutes to hours or more



Transcranial Focused Ultrasound (tFUS)



Brain Photobiomodulation (PBM)

- Uses infrared light to stimulate brain activity and cellular processes
- Feeds energy to the cellular pathway that produces ATP, giving the cell more energy to do whatever it was already trying to do
- Can enhance cognitive functioning, healing from injury, slow neurodegeneration, reduce inflammation and oxidative stress
- Pulsing at different frequencies may induce different types of effects
- Infrared light therapy works in all areas of the body, not just the brain!



