Clinically Accessible Brain Stimulation for Improving Function after Spinal Cord Injury

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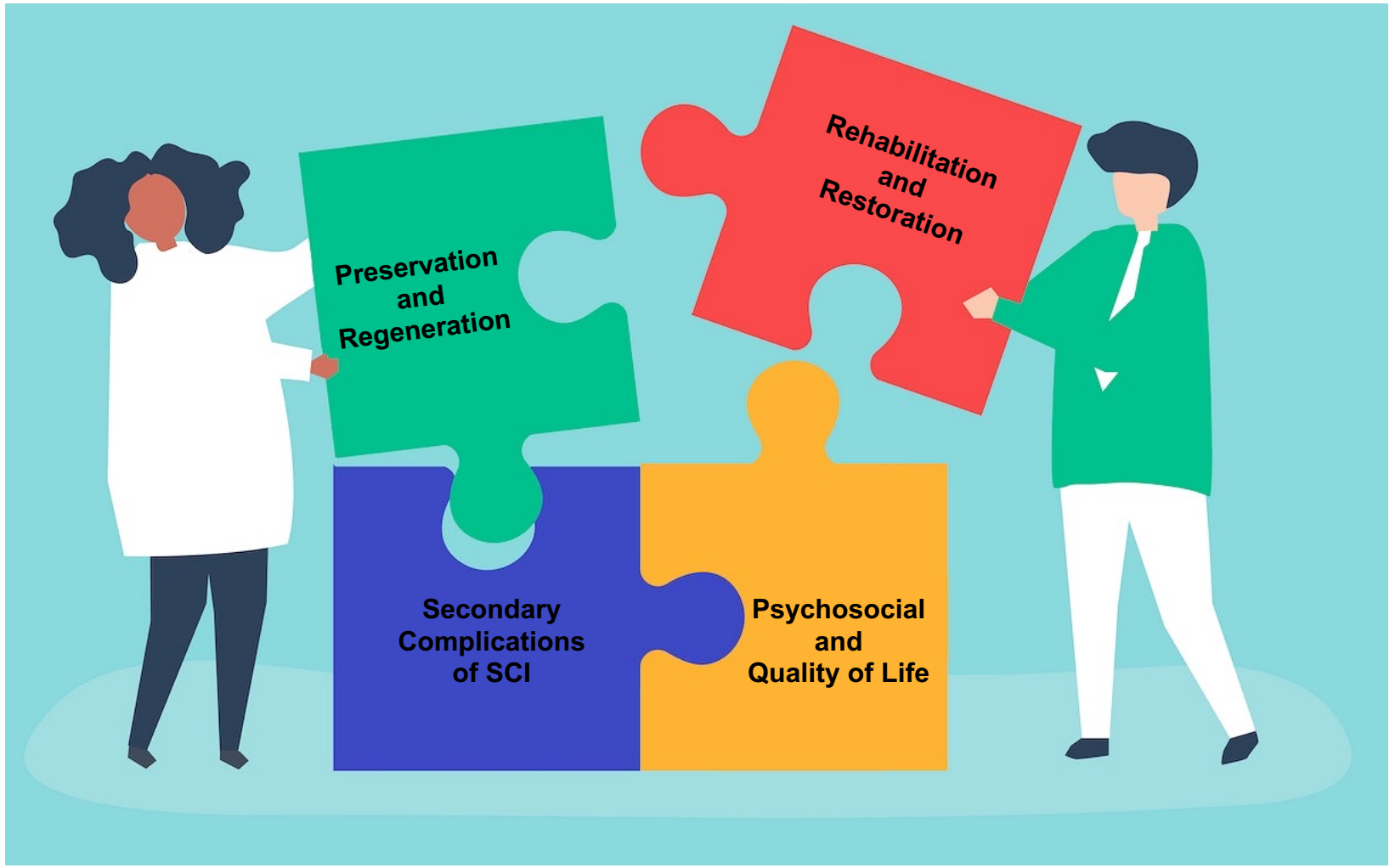

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SCI Research Laboratory At Shepherd

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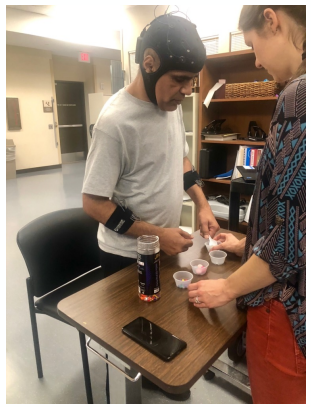

Research

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Why Brain Stimulation?

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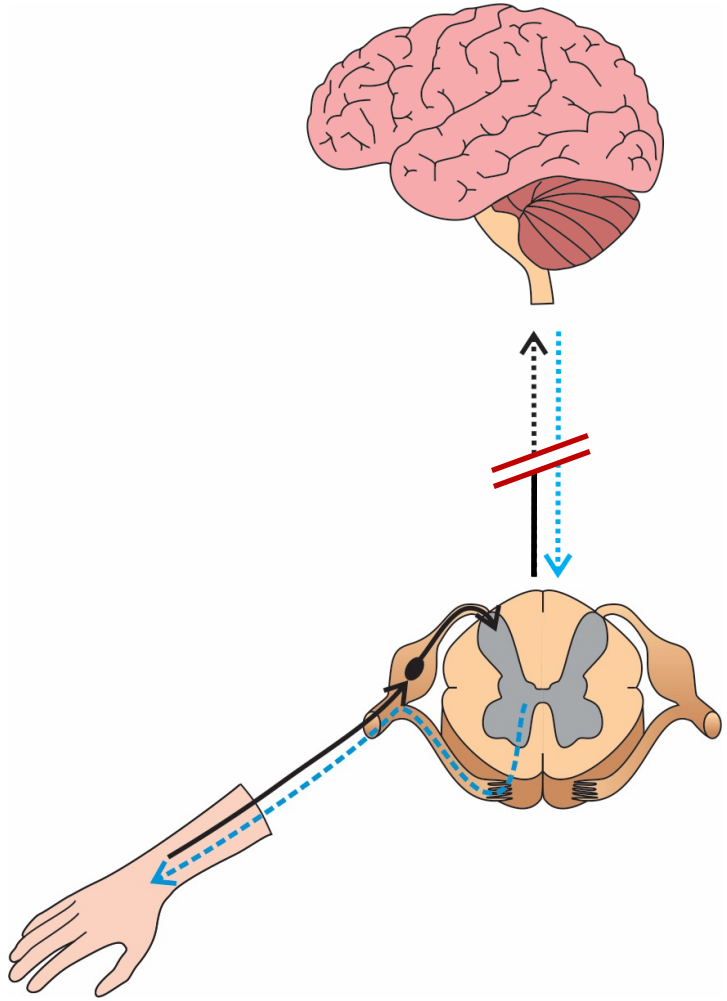
Why brain stimulation?

After SCI, damage to the spinal cord in the **primary** source of impairment



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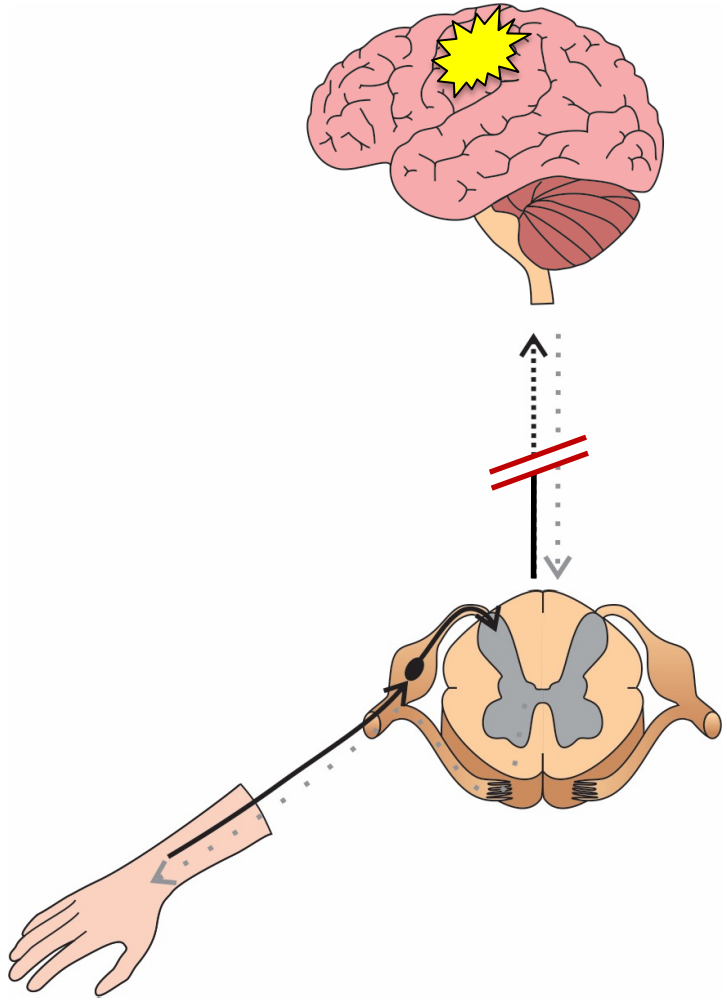
Why brain stimulation?

Maladaptive cortical plasticity also occurs after SCI: cortical reorganization & reduced cortical excitability

Further reduction in the amount of information transmitted through the ***descending*** spinal cord circuitry

Additional impairments in volitional muscle activation



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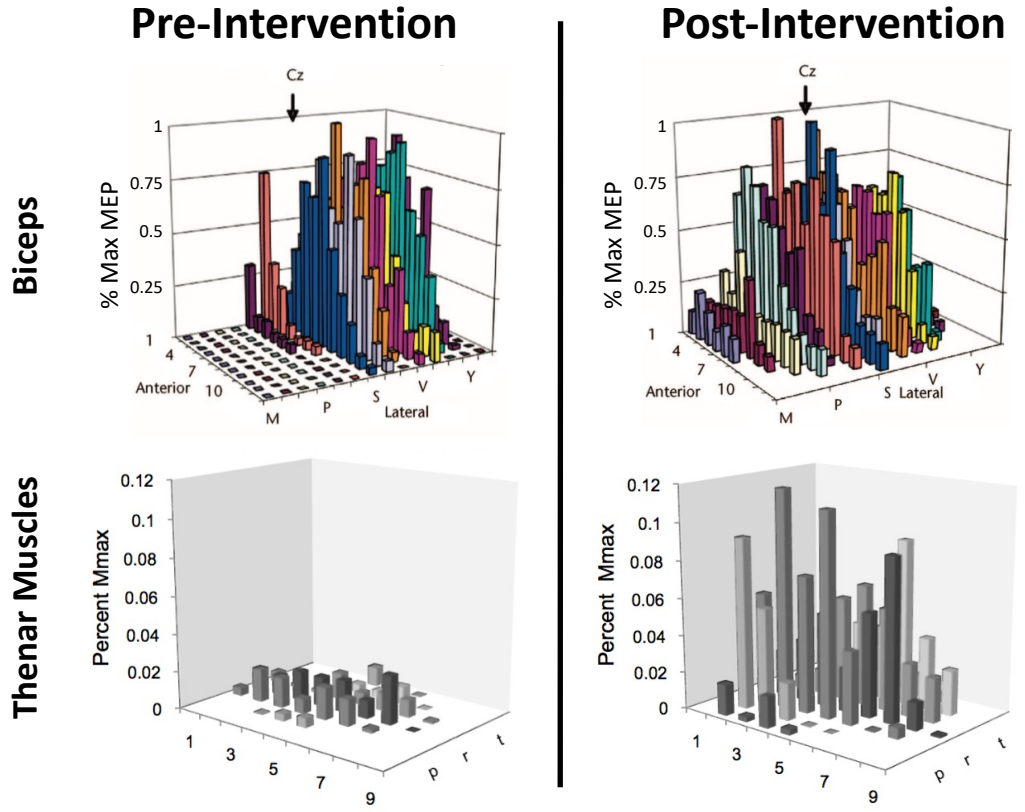
Why brain stimulation?

Maladaptive cortical plasticity can be reversed with combined training and stimulation



Hoffman & Field-Fote: Phys Ther, 2007 (top), Top Spinal Cord Rehabil, 2013 (bottom)

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Why brain stimulation?

Peripheral stimulation ***indirectly*** modulates brain excitability

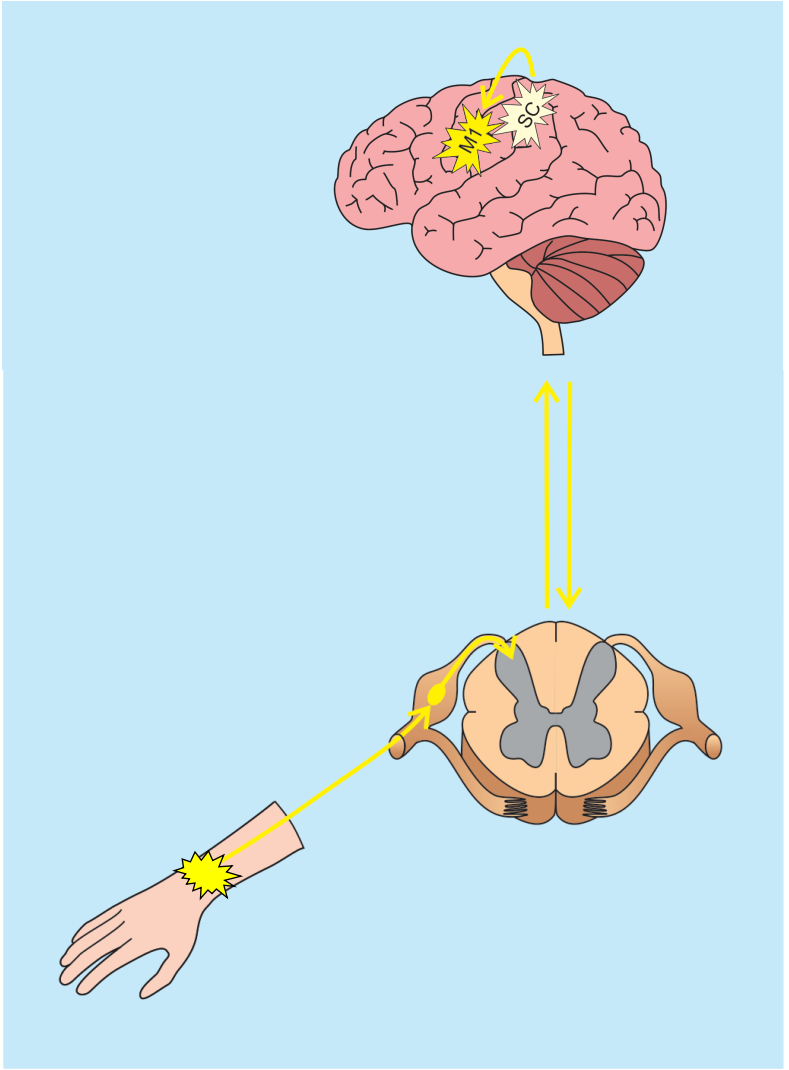
Electrical stimulation increases brain activity in the sensory cortex (SC) by sending signals through ***ascending*** spinal cord circuitry

⬇

Sensory cortex (SC) activation enhances activity in the motor cortex (M1)

⬇

Motor cortex (M1) activation increases descending corticospinal drive through the spinal cord



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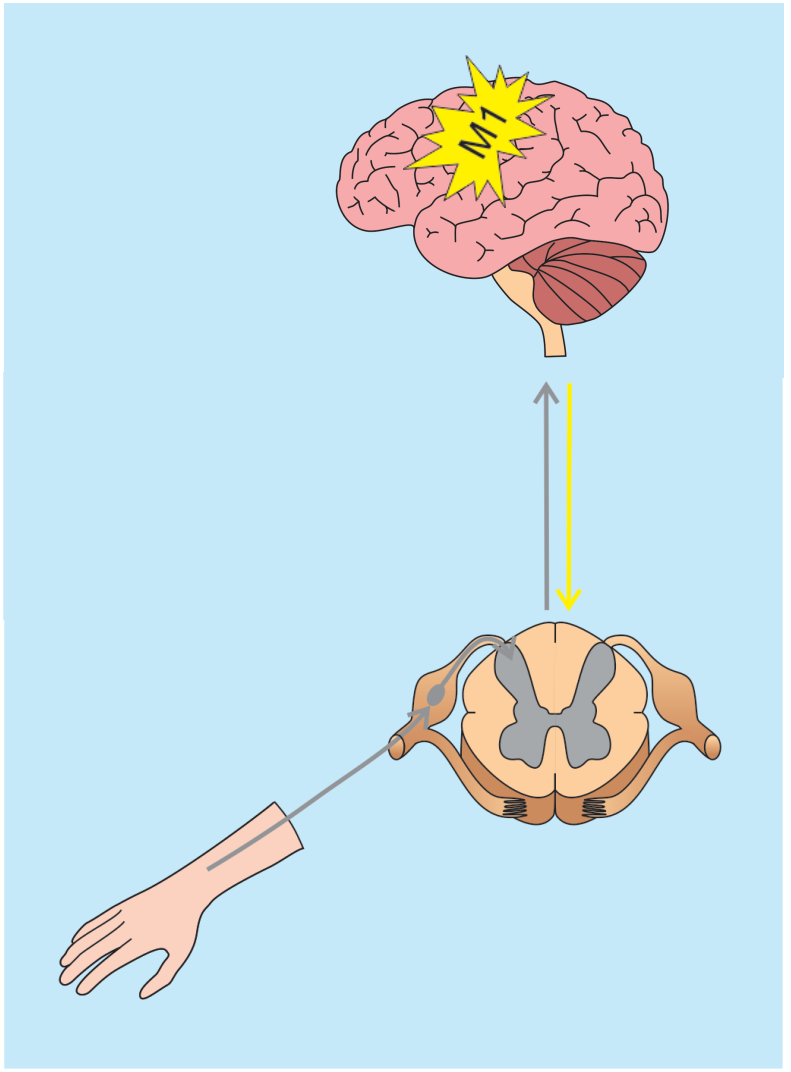
Why brain stimulation?

Non-invasive brain stimulation allows us to excite the brain ***directly***



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Intro to tES

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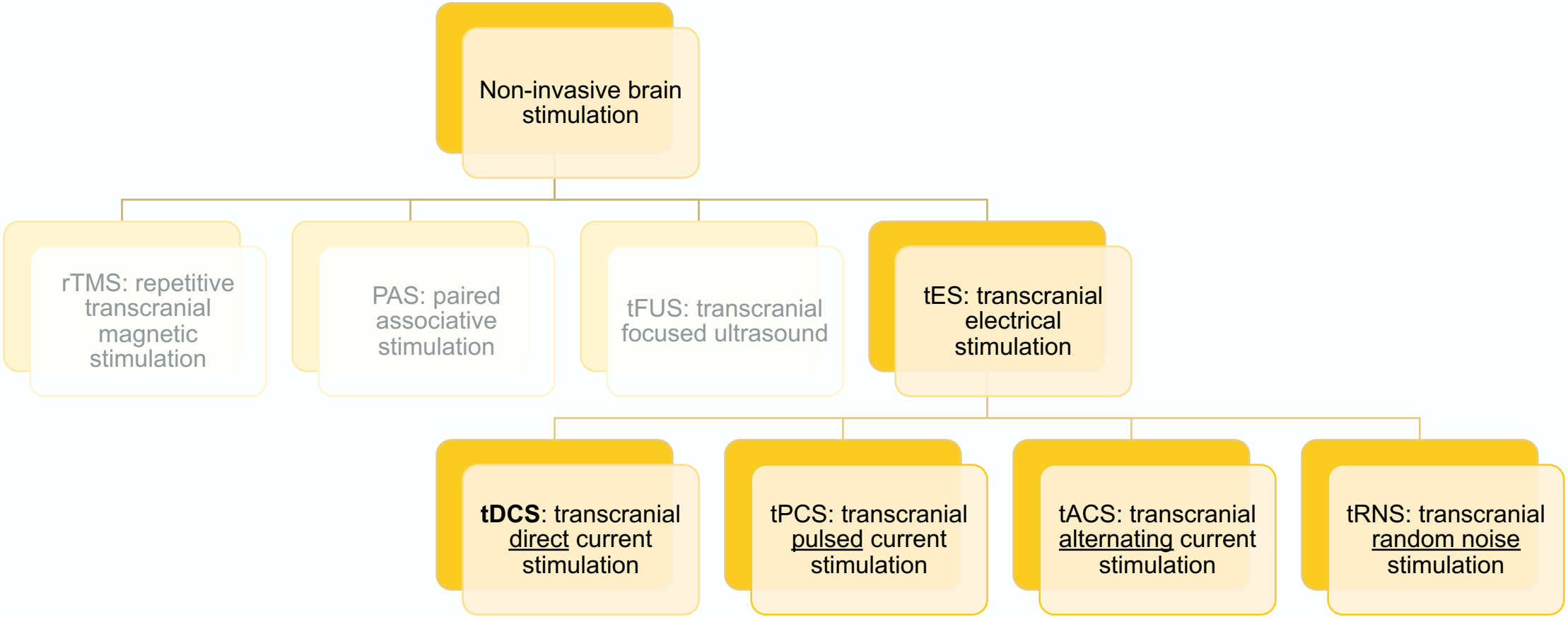
Transcranial electrical stimulation (tES)



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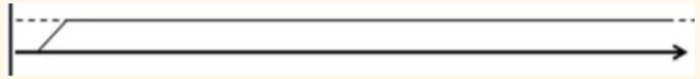
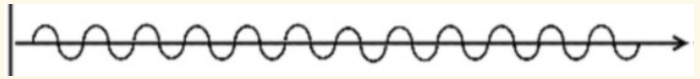
Types of tES

tES type	Type of current applied
Direct: **tDCS**	
Pulsed: **tPCS**	
Alternating: **tACS**	
Random Noise: **tRNS**	

Waveforms adapted from: Jaberzadeh & Zoghi, Basic Clin Neurosci, 2013; Jaberzadeh et al., PLOS One, 2015

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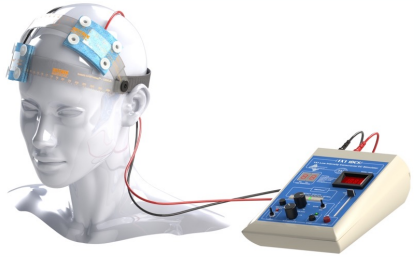
tES Accessibility

Cost	✓Less expensive
Application	✓Non-invasive ✓Minimal training ✓Short setup ✓Allows for movement
Portability	✓ Small ✓ Transportable



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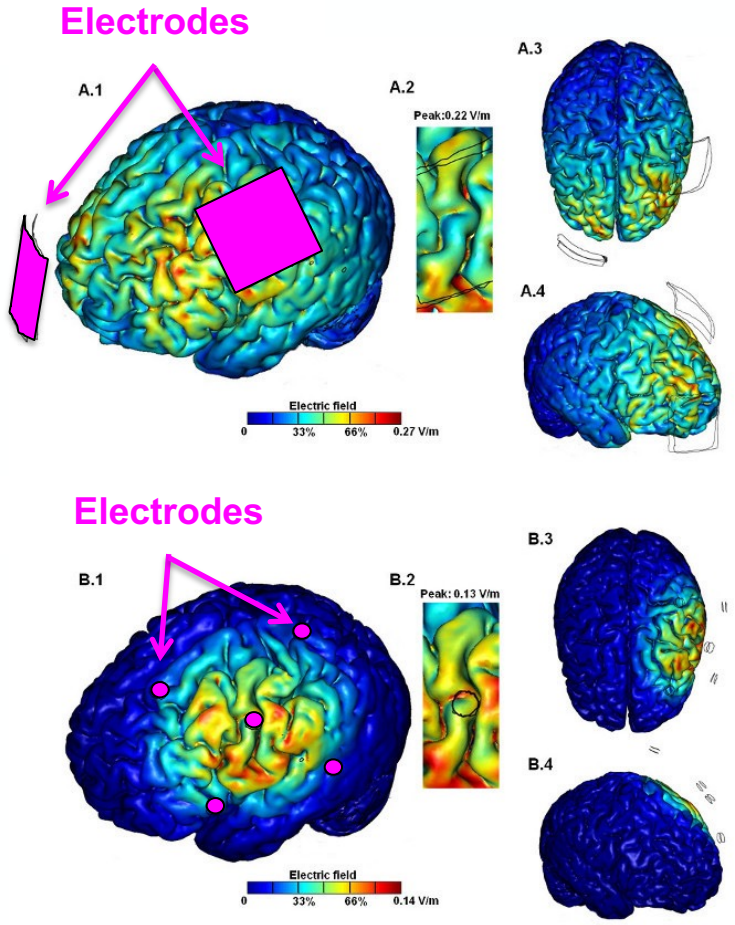
How Does tES work?

- Subthreshold stimulation
  - does not cause firing of brain cells
  - modulates excitability of the brain
- Used to improve function of muscles with some remaining connections
  - the amount of remaining connections needed for tES to be effective is currently unknown



Villamar et al., JOVE, 2013

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How Does tES work?

Increased brain excitability

⬇

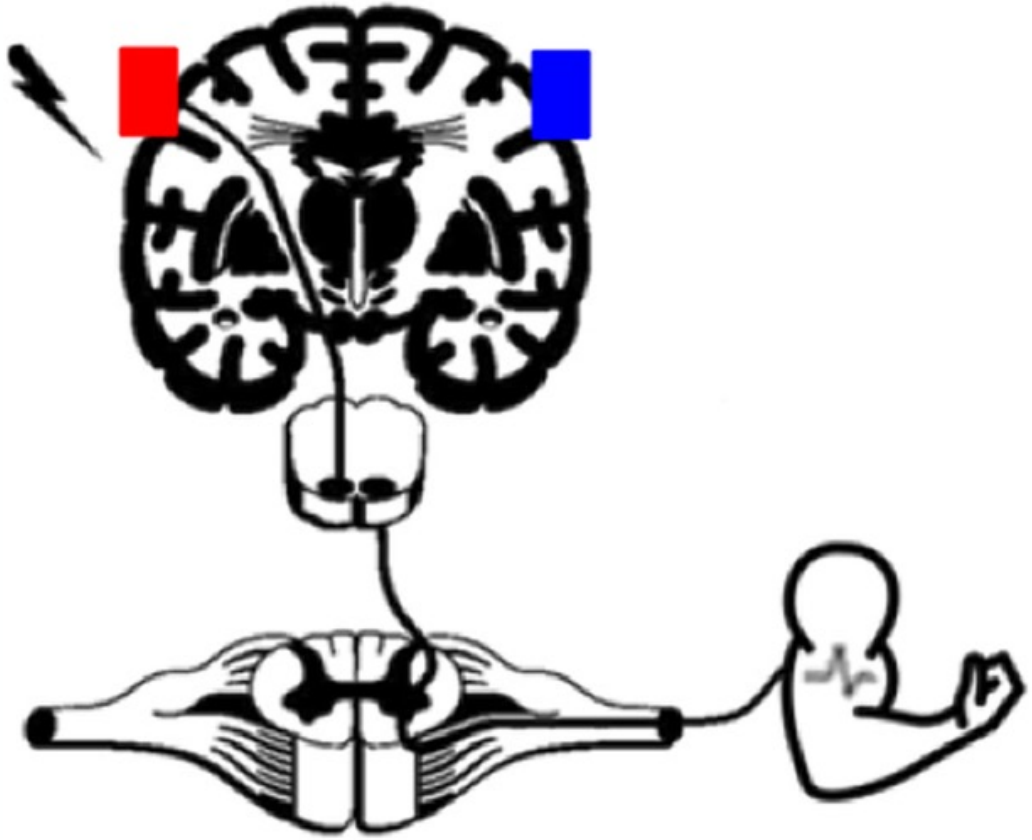
Improved volitional activation of brain circuits

⬇

Enhanced descending drive through the remaining connections in the spinal cord

⬇

Overall goal: Improved muscle activity & function



Morya et al., J Neuroeng Rehabil, 2019

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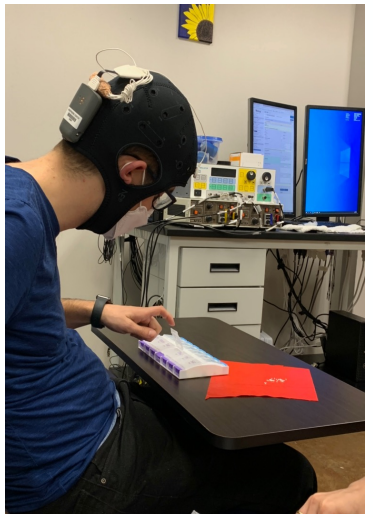
How Does tES work?

- **Functional targeting** is key for tES efficacy:
  - tES efficacy is enhanced when the brain regions being targeted are active
  - Therefore, tES should be applied in combination with task-specific training



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tES Safety

Overall, tES modalities are very safe with similar side effects to other types of electrical stimulation

Most common:

- Skin redness
- Itching
- Tingling
- Headache
- Burning sensation
- Discomfort

Least common:

- Phosphenes
- Fatigue
- Nausea
- Insomnia
- Skin lesions/burns

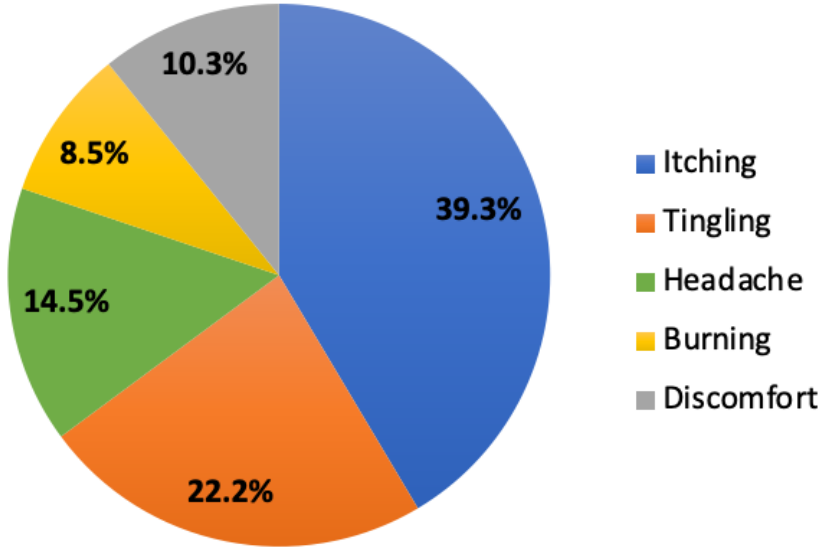

Chart created from Brunoni et al., Int J Neuropsychopharmacol, 2011

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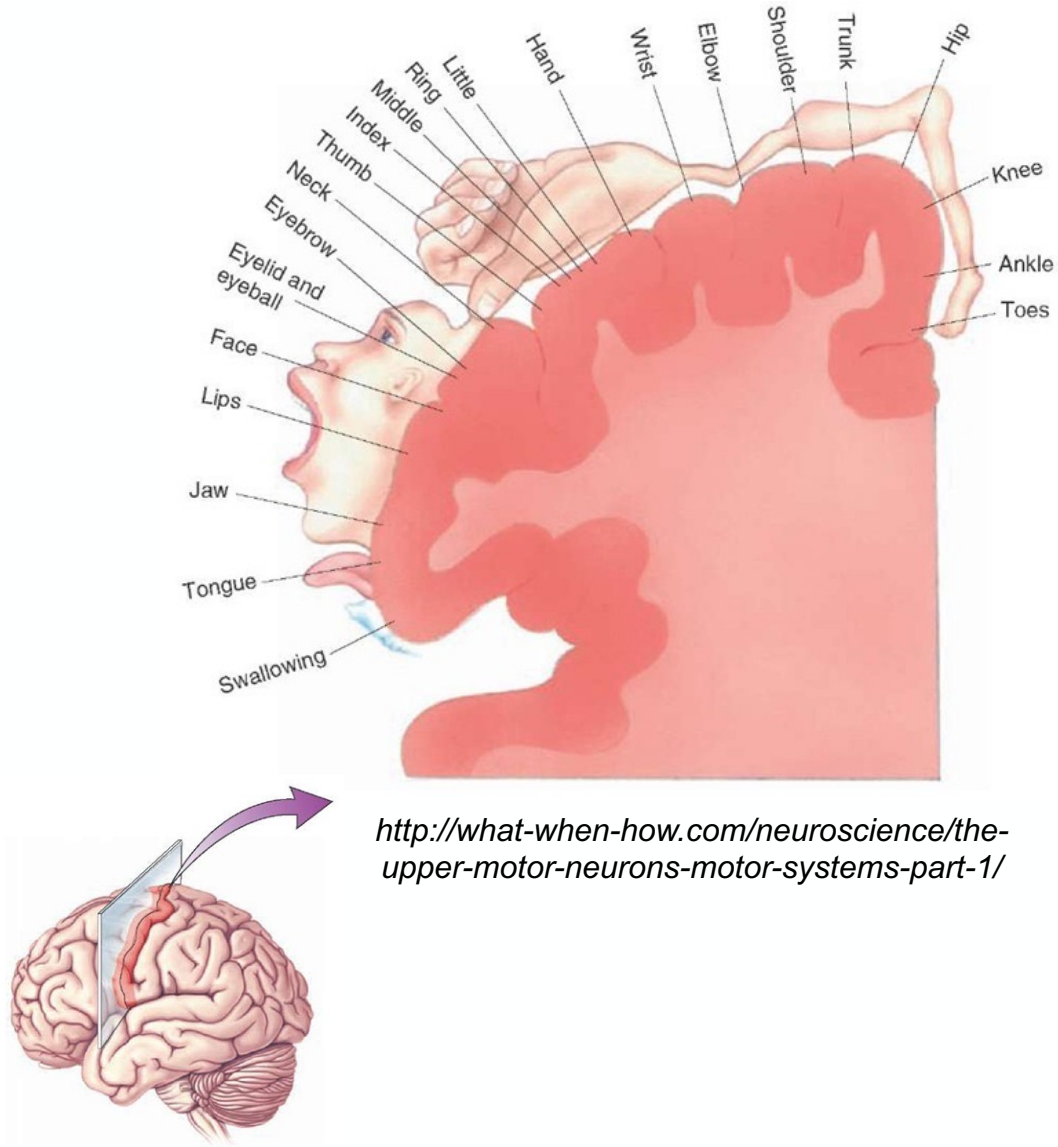
tES Application

- Setup
  - Applied via electrodes placed inside of saline-soaked sponges
  - Electrodes attached to head via straps/cap
  - Electrode placement determined by the area of the brain that you want to target



http://what-when-how.com/neuroscience/the-upper-motor-neurons-motor-systems-part-1/

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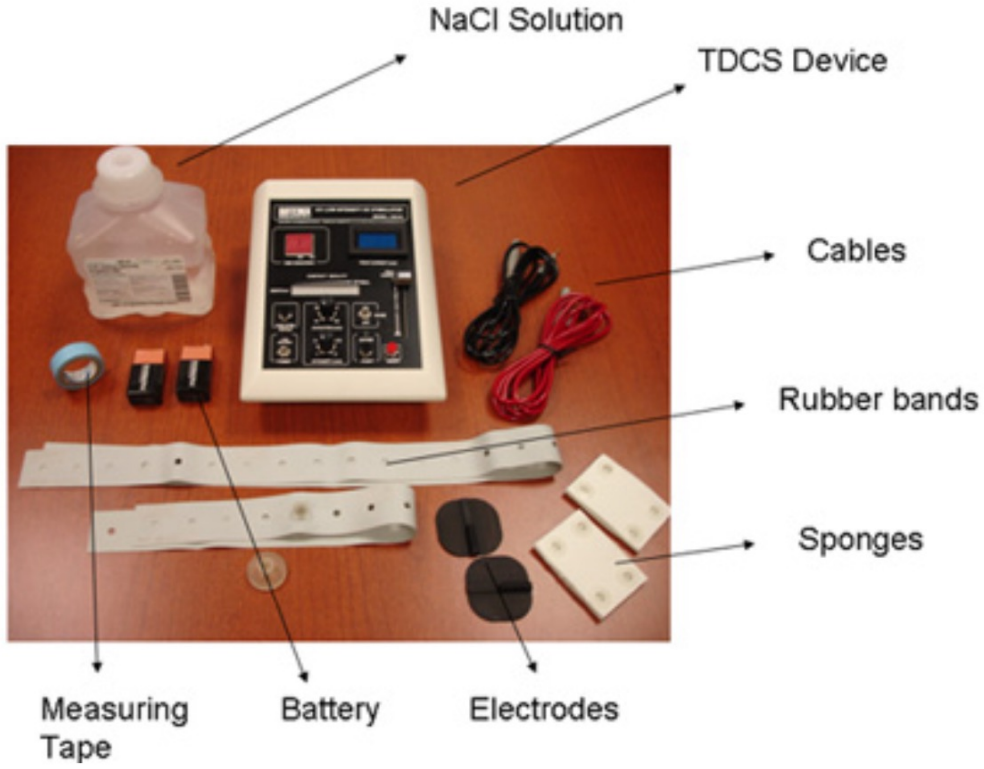
tES Application

- Setup
  - Applied via electrodes placed inside of saline-soaked sponges
  - Electrodes attached to head via straps/cap
  - Electrode placement determined by the area of the brain that you want to target
- Intensity: 1-2 mA
- Duration: 20-30 minutes
- tES after-effects last for up to 90 minutes



DaSilva et al., JOVE, 2011

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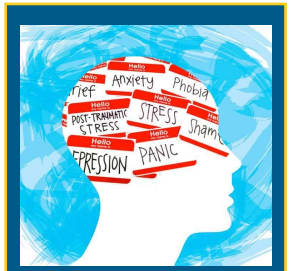
tES Application

Learning & Memory

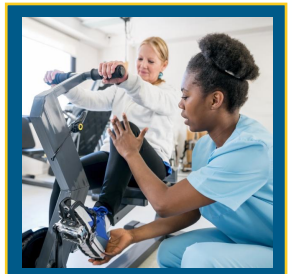
Speech/Language Disorders

Exercise Performance

Pain



Mental Health Disorders



Neuro-rehabilitation

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tES for Neurorehabilitation

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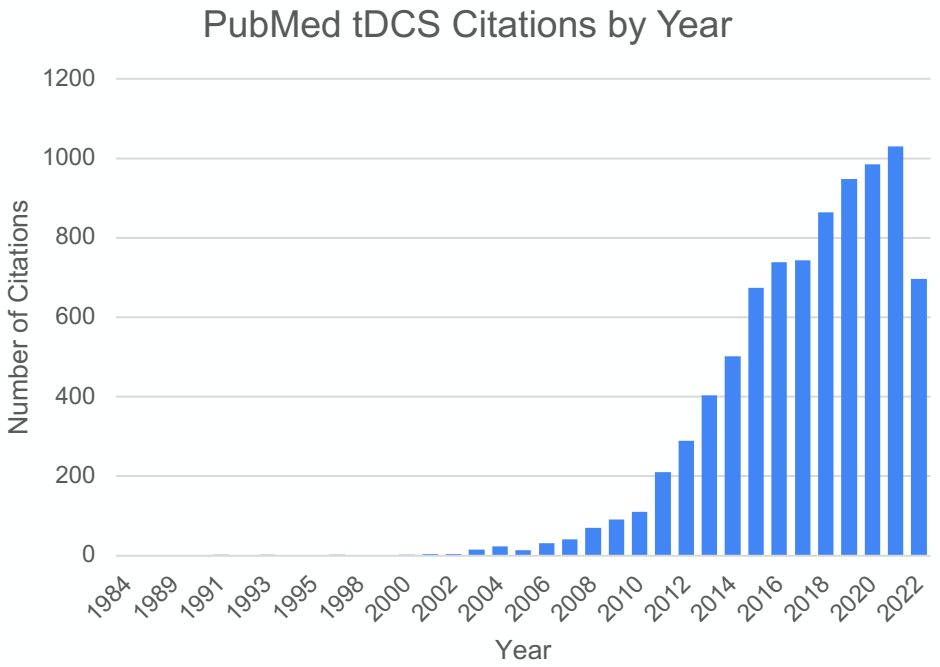
tES as a Neurorehabilitation Tool

- **tDCS** is the most common type of tES
- Majority of research has been performed among individuals with stroke
- Research investigating the use of tDCS in other neurologic disorders, including SCI, is growing
- Evidence for the use of tDCS as a neurorehabilitation tool is mixed
  - Some studies have shown that tDCS is effective while others have not



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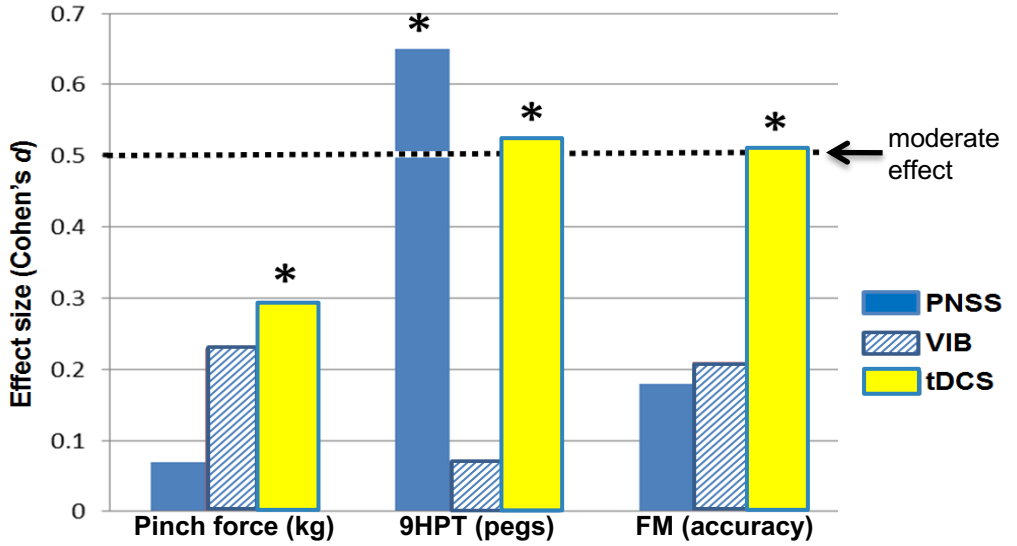
tES Effects among PwSCI

- Participants:
  - Individuals with chronic (> 1 year) cervical SCI
  - Visible twitch of thumb muscle on one hand
- Randomized crossover: 1 session for each type of intervention tested
- 30-minutes of stimulation combined with arm and hand training



Gomes-Osman & Field-Fote, Clin Rehabil, 2014

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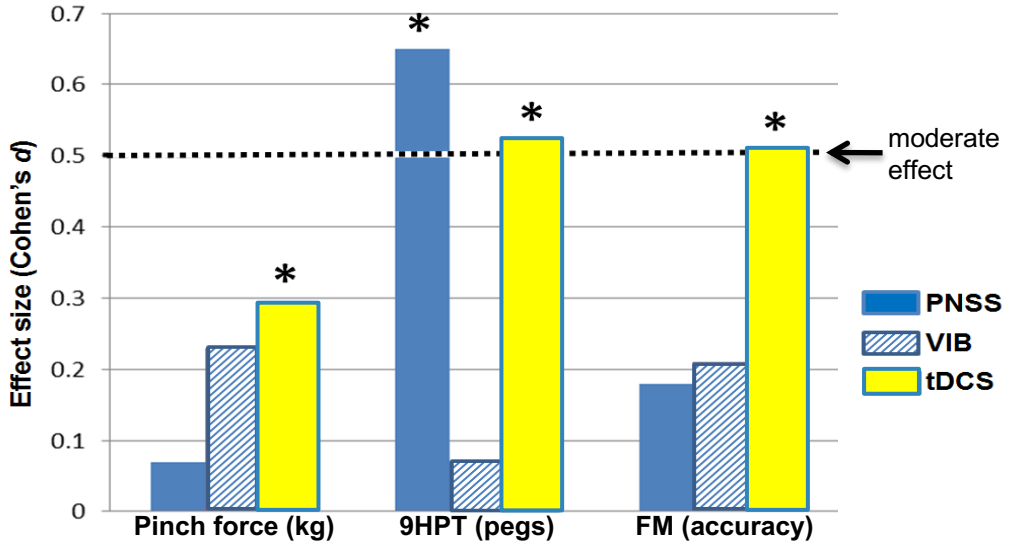
tES Effects among PwSCI

- tDCS + training led to significant improvements in three outcomes:
  - Key pinch strength (pinch force)
  - Peg test performance (9HPT)
  - Fine motor tracking accuracy (FM)
- Improvements in peg test performance and fine motor tracking accuracy with tDCS met the criteria for a moderate effect
  - Research suggests that effect sizes may be more important than p-values (significance) for assessing clinical meaningfulness



Gomes-Osman & Field-Fote, Clin Rehabil, 2014

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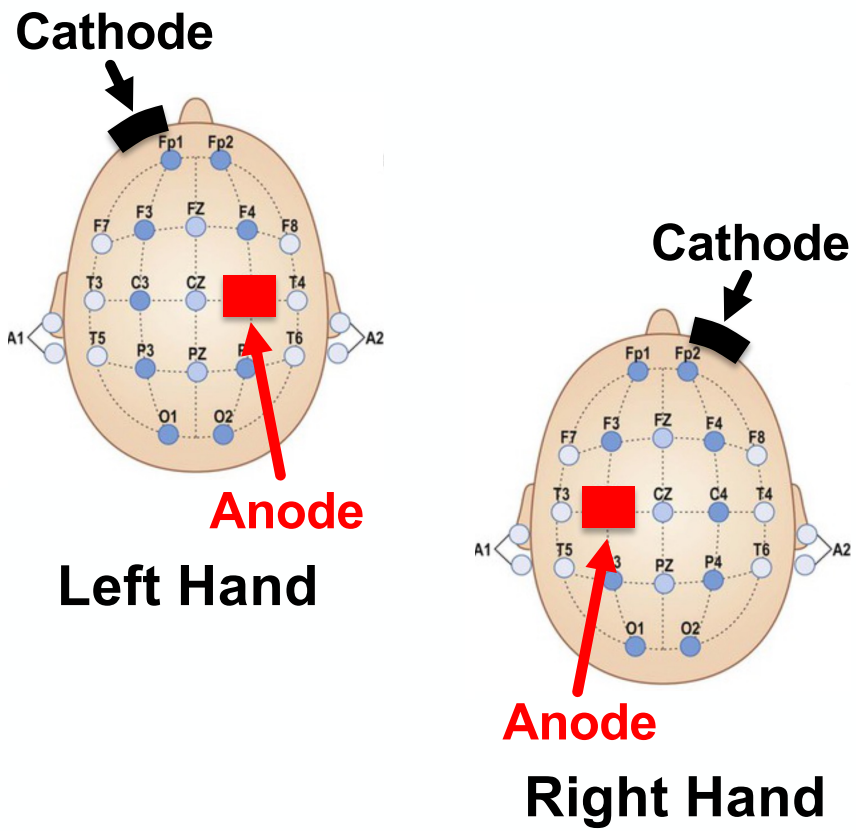
tES Effects among PwSCI

While these results are encouraging, stimulation was only designed to target one hand

Unihemispheric



Adapted from www.clinicalgate.com/epilepsy-8

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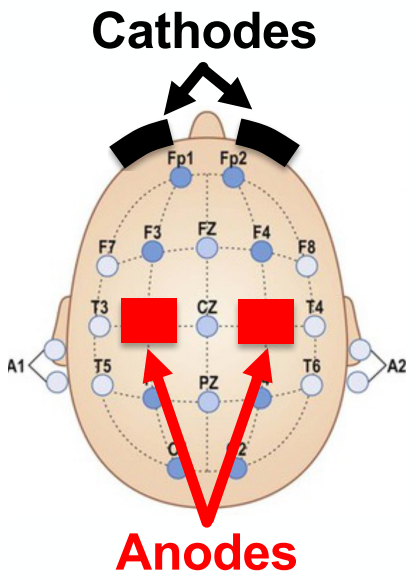
tES Effects among PwSCI

While these results are encouraging, stimulation was only designed to target one hand

Because hand impairments following cervical SCI are often bilateral, excitatory stimulation targeting both hands may be of value

Bihemispheric



Adapted from www.clinicalgate.com/epilepsy-8

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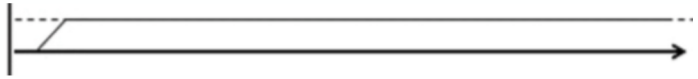
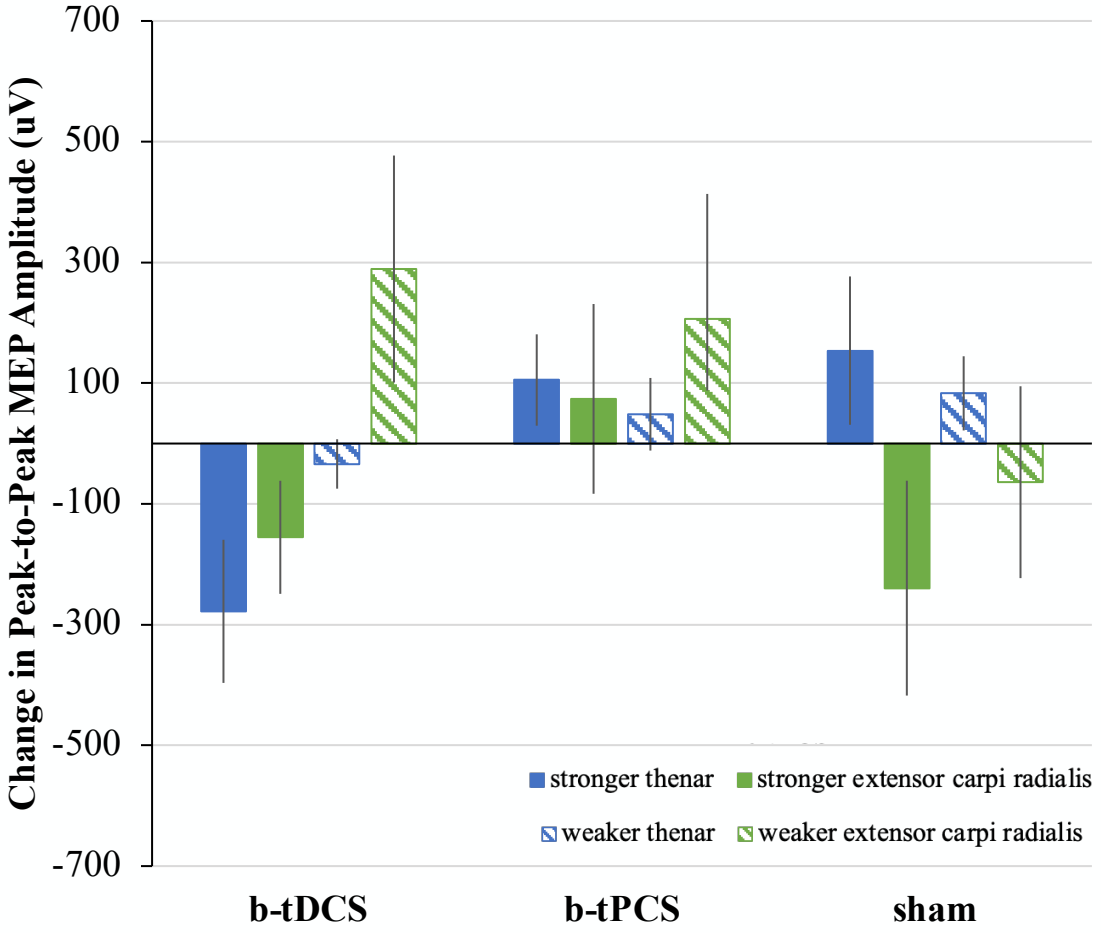
tES Effects among PwSCI

- Participants:
  - Individuals with cervical SCI (> 3 months)
  - Visible twitch of one muscle in each hand
- Randomized crossover: 1 session for each type of tES tested
  - b-tDCS 
  - b-tPCS 
  - sham
- 20-minutes of stimulation combined with arm and hand training



Iddings et al., in preparation

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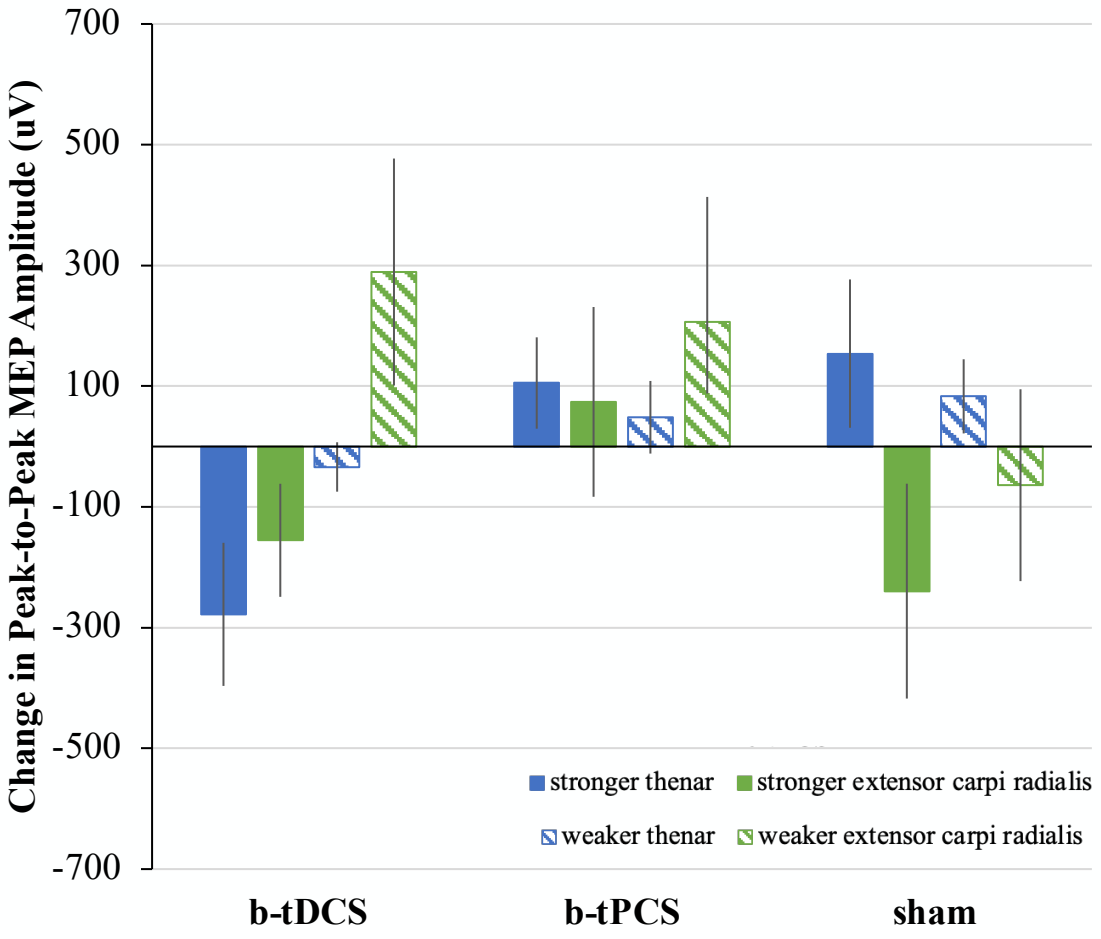
tES Effects among PwSCI

Bihemispheric, excitatory tPCS (b-tPCS) increased descending corticospinal excitability in arm (extensor carpi radialis) and hand (thenar) muscles of both stronger and weaker arms



Iddings et al., in preparation

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tES Effects among PwSCI

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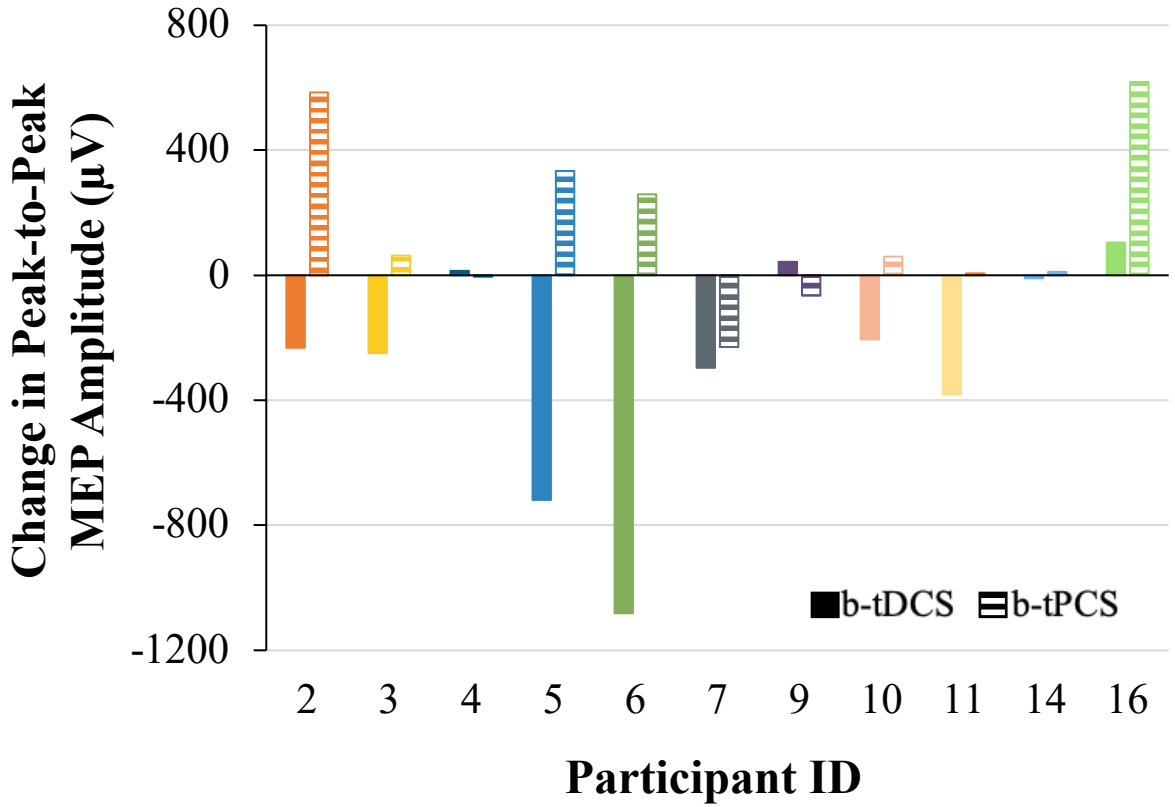

Iddings et al., in preparation

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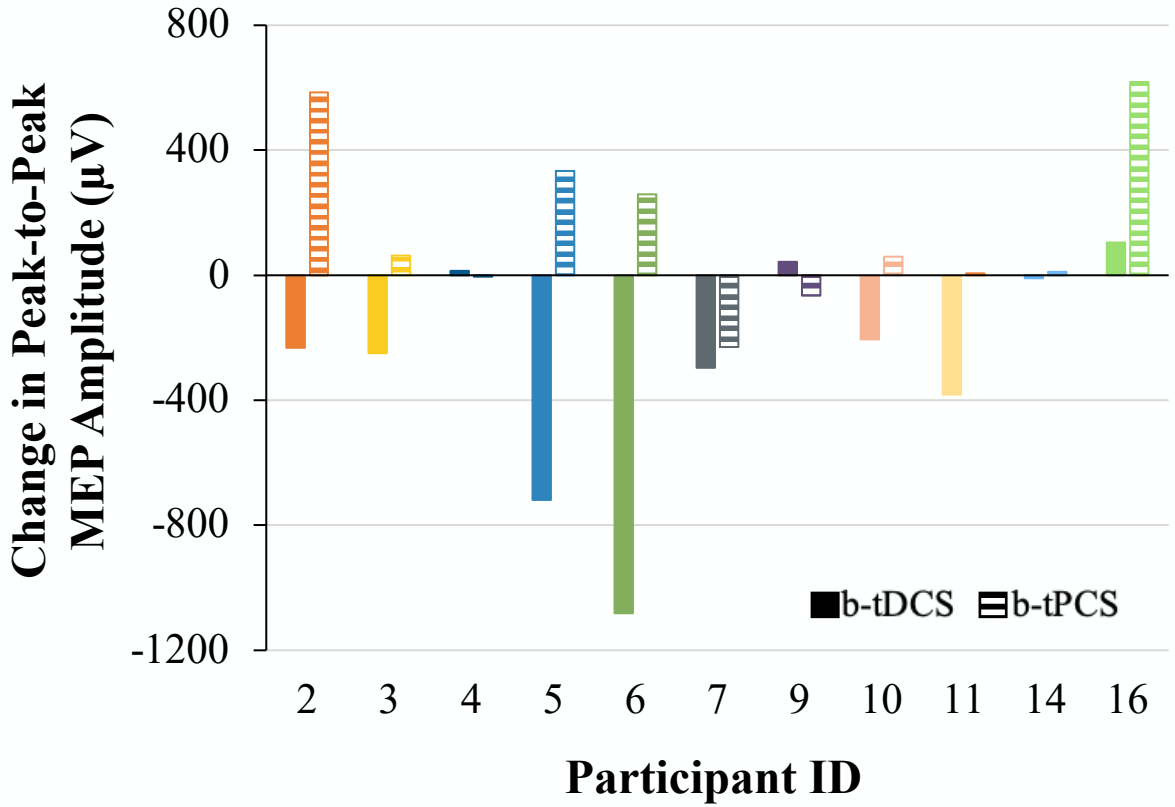
tES Effects among PwSCI

Responsiveness to different types of tES varied between participants

Additional research is needed to determine:

1. The people who respond best to stimulation
2. What conditions lead to the best responses



Iddings et al., in preparation

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tES Research Moving Forward

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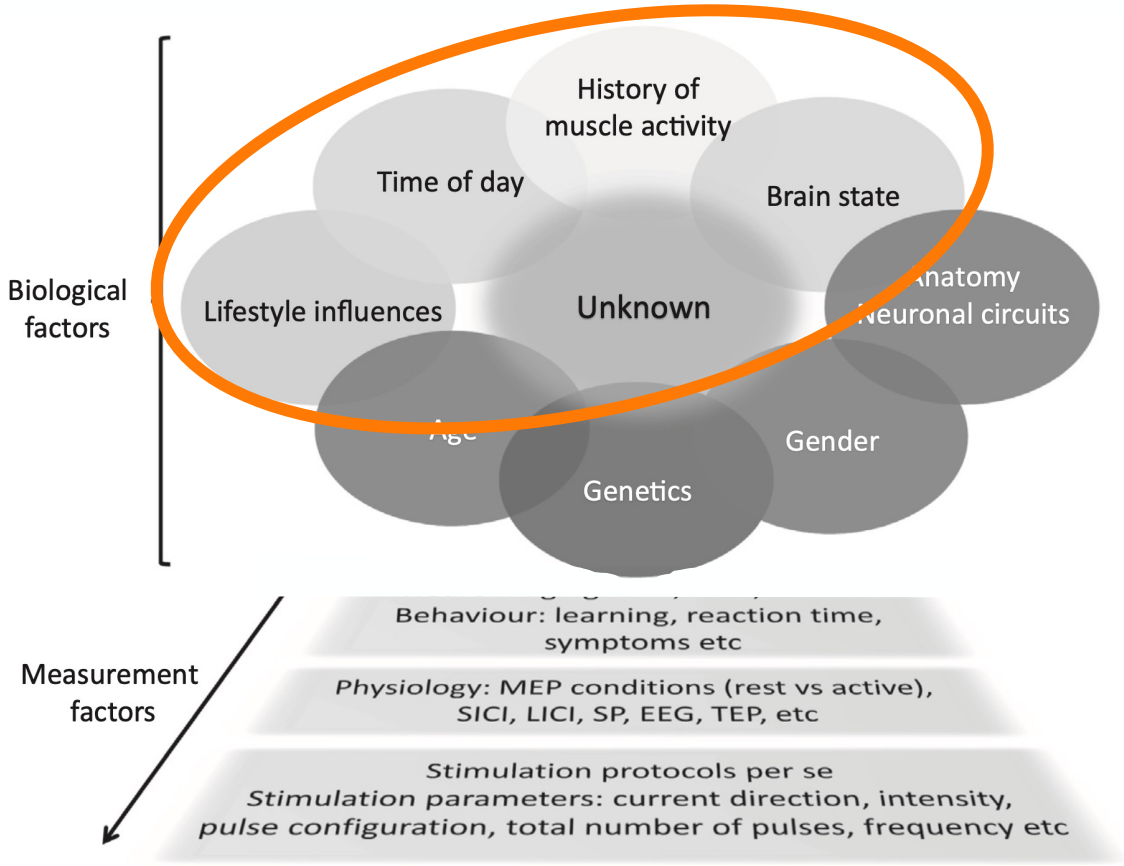
Moving Forward: Addressing Variability

Inter-individual variability



Huang et al., Clin Neurophysiol, 2017

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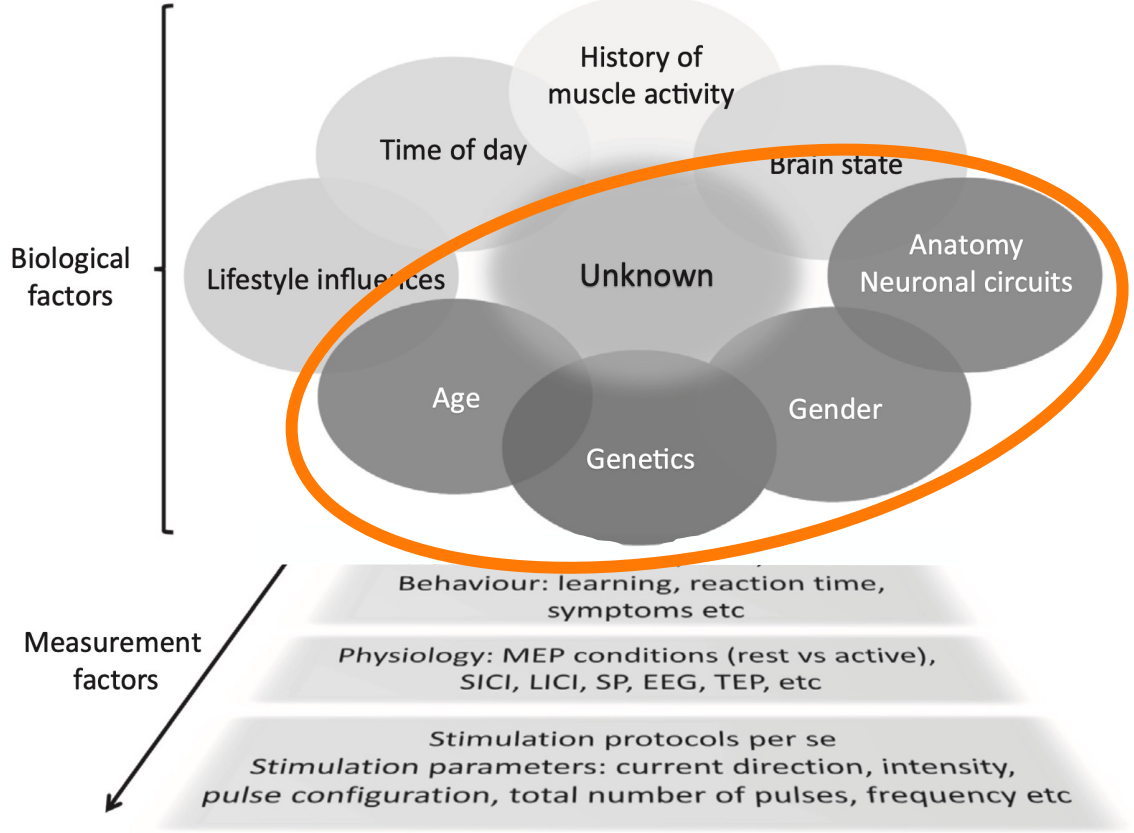
Moving Forward: Addressing Variability

Inter-individual variability

Intra-individual variability



Huang et al., Clin Neurophysiol, 2017

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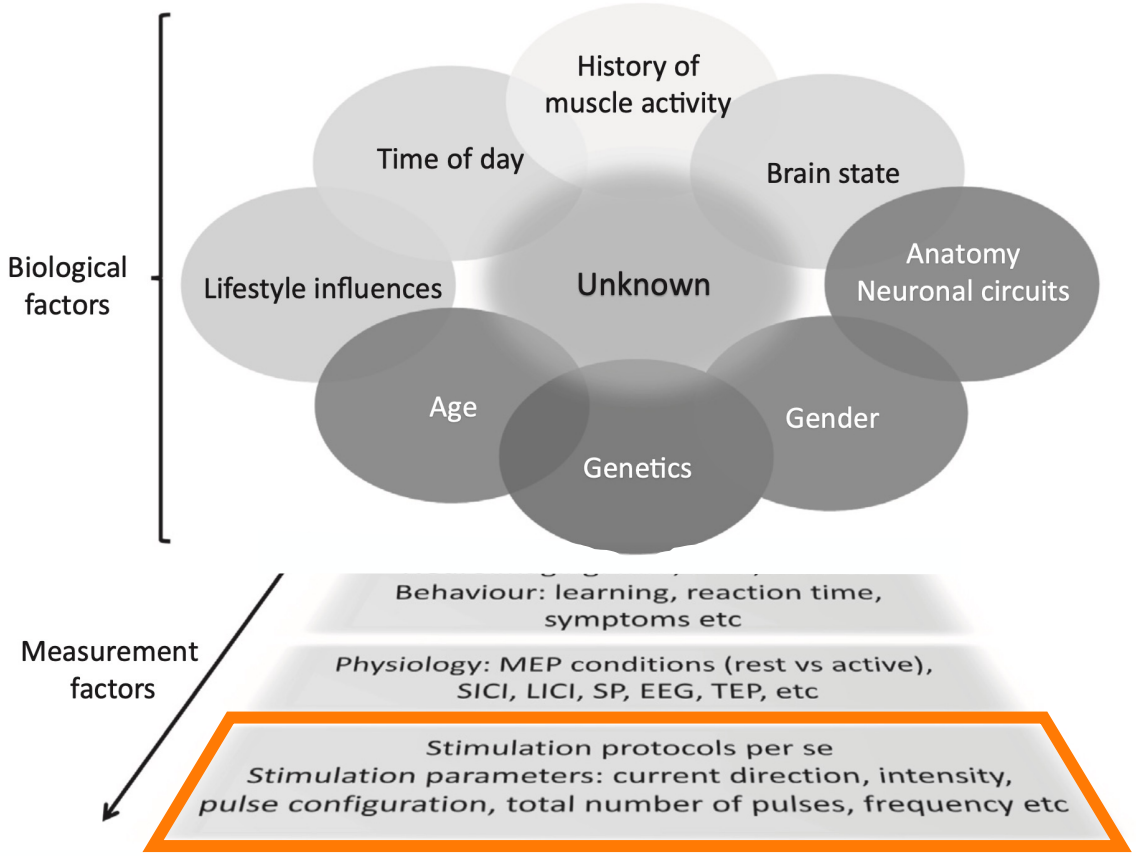
Moving Forward: Addressing Variability

Stimulation parameters can also contribute to variability between different studies



Huang et al., Clin Neurophysiol, 2017

Moving Forward: Where Do We Go From Here?

- Biomarker identification
- tES Dosing
  - Type of stimulation
  - Location of stimulation
  - Intensity of stimulation
  - Number of sessions

Famm, Nature, 2013

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Acknowledgments

Thank you to our **Research Participants**
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NIDILRR
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