# USING NON-INVASIVE BRAIN STIMULATION TO MODULATE SUPRASPINAL CIRCUITS AFTER SCI

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# Non-Invasive Brain Stimulation (NIBS)

Two primary classifications of NIBS modalities:

1. Transcranial magnetic stimulation (TMS)

2. Transcranial current stimulation (tCS)

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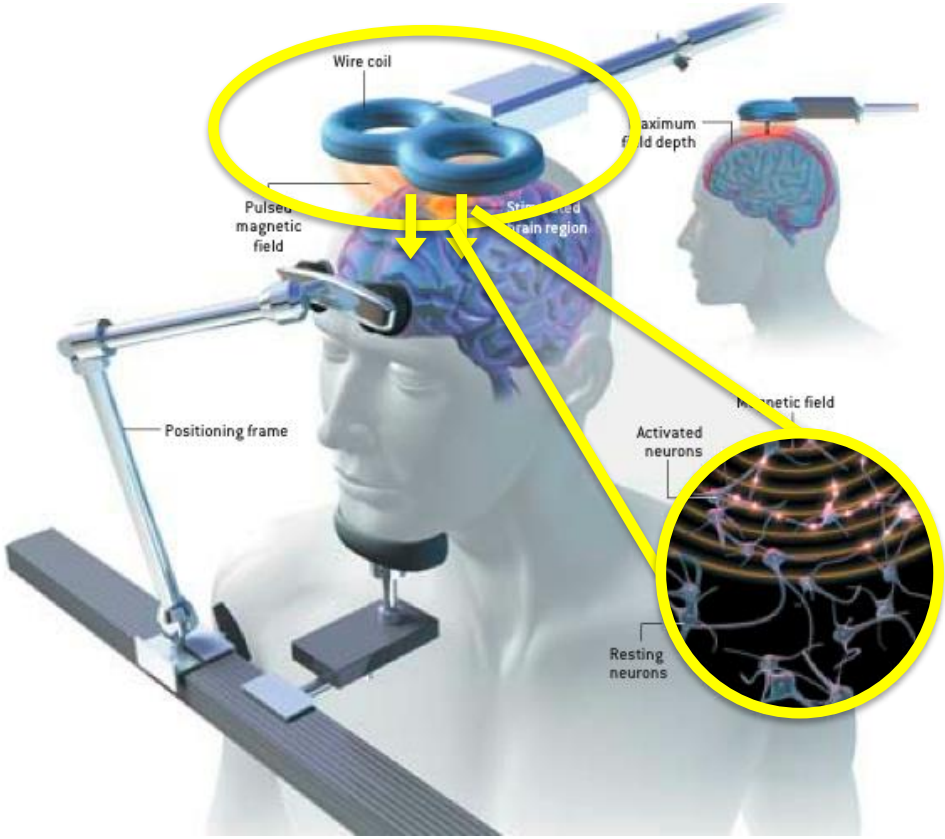
1. Transcranial magnetic stimulation (TMS)
    - Neurophysiology measure: single & paired pulse TMS
    - Neuromodulation tool: repetitive TMS (rTMS), paired associative stimulation (PAS)
2. Transcranial current stimulation (tCS)

# Basic Principles of TMS

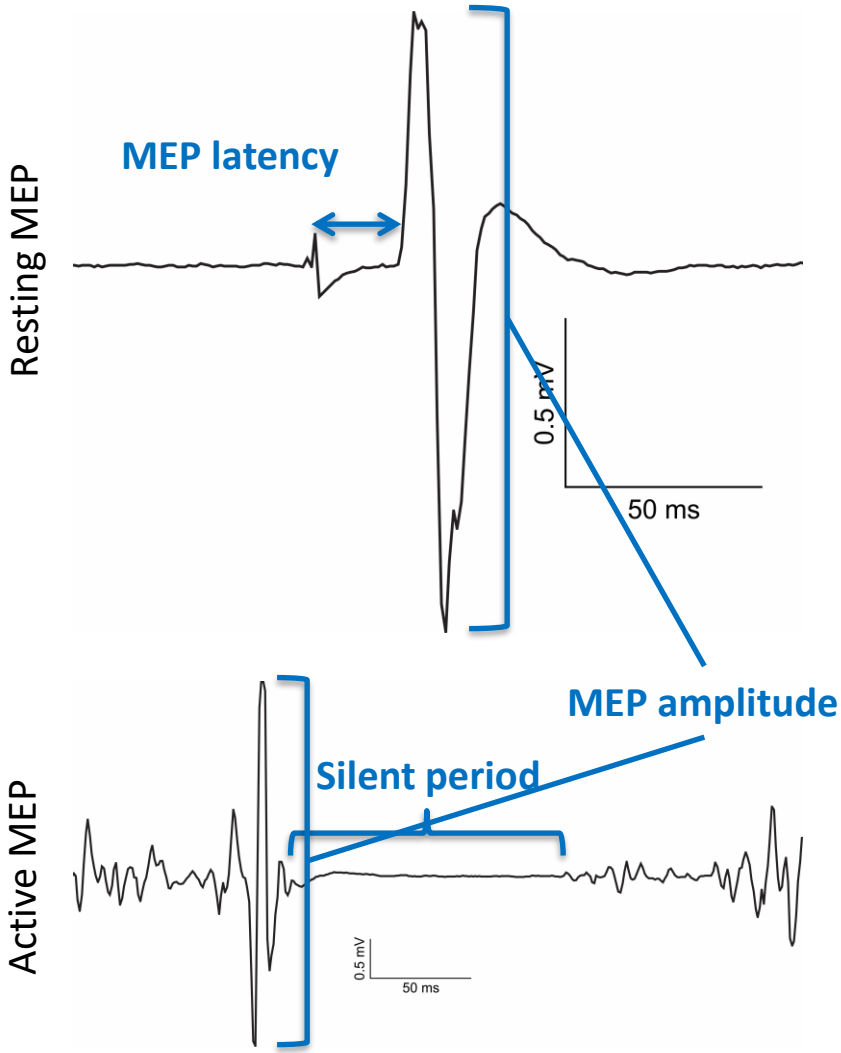
- Electrical current in coil generates magnetic field
- Magnetic field passes through the skull unimpeded
- Alternating magnetic fields induce electrical current in brain




*George, Sci Am, 2003*

# TMS as Neurophysiology Measure

- Used to assess cortical & spinal circuitry
- Suprathreshold stimulation of the motor cortex elicits muscle response - motor evoked potential (MEP)
- Parameters of interest:
  - MEP amplitude
  - MEP latency
  - Silent period
  - Motor threshold (resting and active)



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Two primary classifications of NIBS modalities:

1. Transcranial magnetic stimulation (TMS)
    - Neurophysiology measure: single & paired pulse TMS
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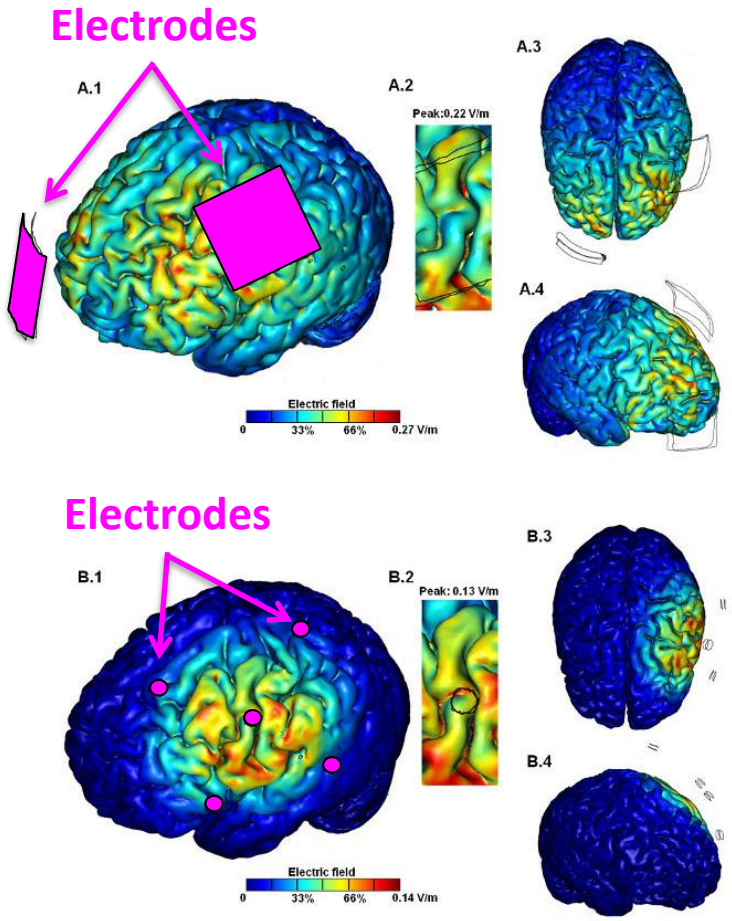
2. Transcranial current stimulation (tCS)
    - direct (tDCS)
    - pulsed (tPCS)
    - alternating (tACS)
    - random noise (tRNS)

# Basic Principles of tCS

- **<u>Subthreshold</u>** stimulation modulating excitability of large brain regions
  - Does not elicit neuronal depolarization
- Mechanism: modulation of neuronal resting excitability
- Two categories:
  - Polarity dependent
    - Excitatory: anodal
    - Inhibitory: cathodal
  - Polarity independent
    - Excitation/inhibition are frequency and intensity dependent




*Adapted from Villamar et al., J Vis Exp, 2013*

# Basic Principles of tCS

**After-Effect Modulation**

**Polarity Dependent**

**Polarity Independent**

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

# Application Basics of tCS

**tDCS Devices**

**tCS Device**
**tDCS, tPCS, tACS, tRNS**

# Application Basics of tCS

- **Stimulation Parameters:**

✓ Current type: DC or AC

✓ Intensity: < 4mA

✓ Frequency: 0- 640Hz

✓ Duration: < 60 min/ day

✓ Ramp up/ down

Antal et al., Clin Neurophysiol, 2017; DaSilva et al., J Vis Exp, 2011; Woods et al., Clin Neurophysiol, 2016

# Application Basics of tCS

- Stimulation Parameters
- **Adverse Effects:**
  - ✓ Itching
  - ✓ Tingling
  - ✓ Headache
  - ✓ Discomfort
  - ✓ Burning Sensations
  - ✓ Skin redness
  - ✓ Mild fatigue
  - ✓ Skin burns


Antal et al., Clin Neurophysiol, 2017; DaSilva et al., J Vis Exp, 2011; Woods et al., Clin Neurophysiol, 2016

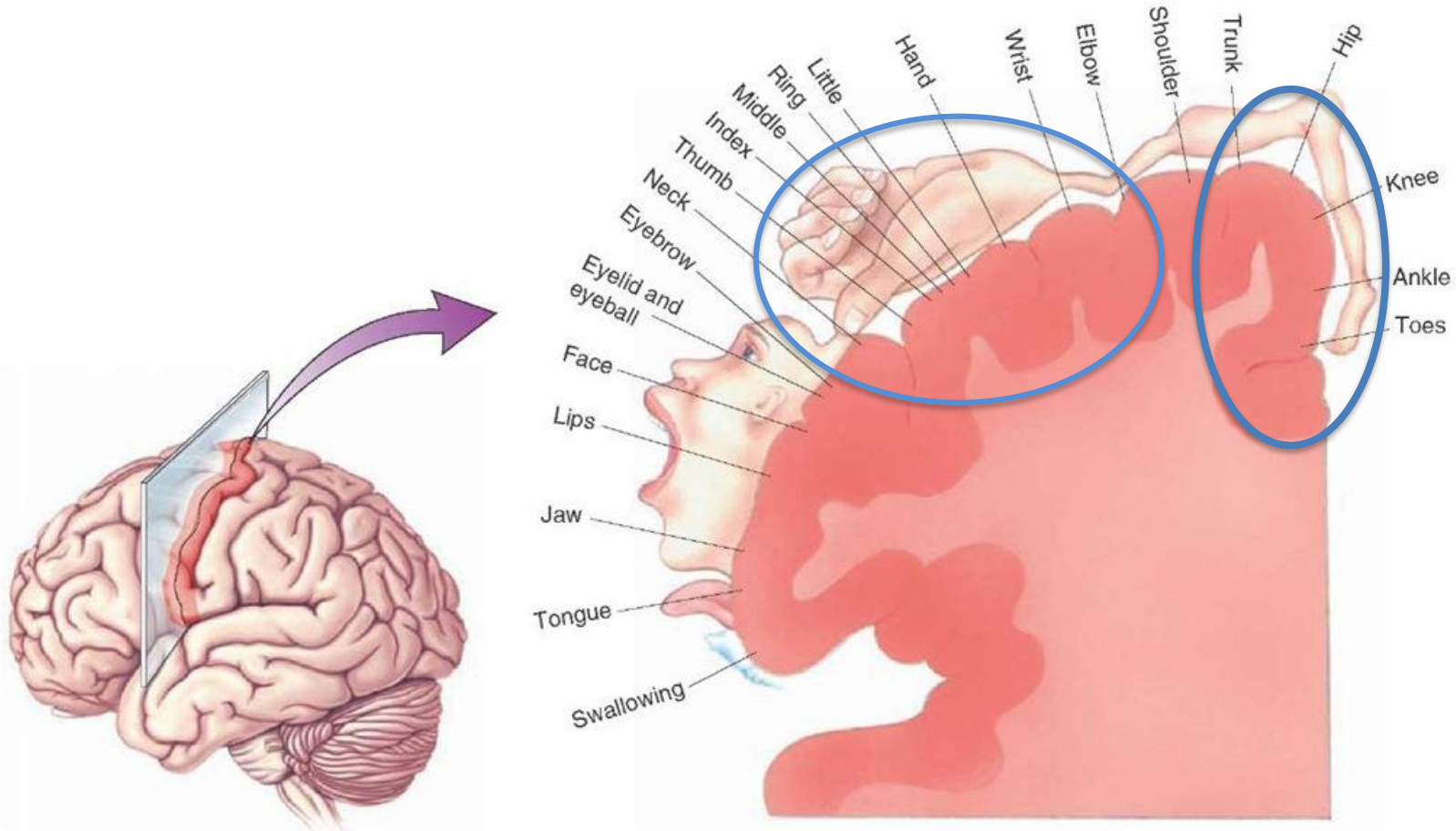
# Application Basics of tCS

- Stimulation Parameters
- Adverse Effects
- **Contraindications:**
  - ✓ Implanted metallic device in the head
  - ✓ Uncontrolled seizures
  - ✓ Severe headache history
  - ✓ Scalp Lesions
  - ✓ Pregnancy
  - ✓ Pacemaker

Antal et al., Clin Neurophysiol, 2017; DaSilva et al., J Vis Exp, 2011; Woods et al., Clin Neurophysiol, 2016

# Application Basics of tCS:

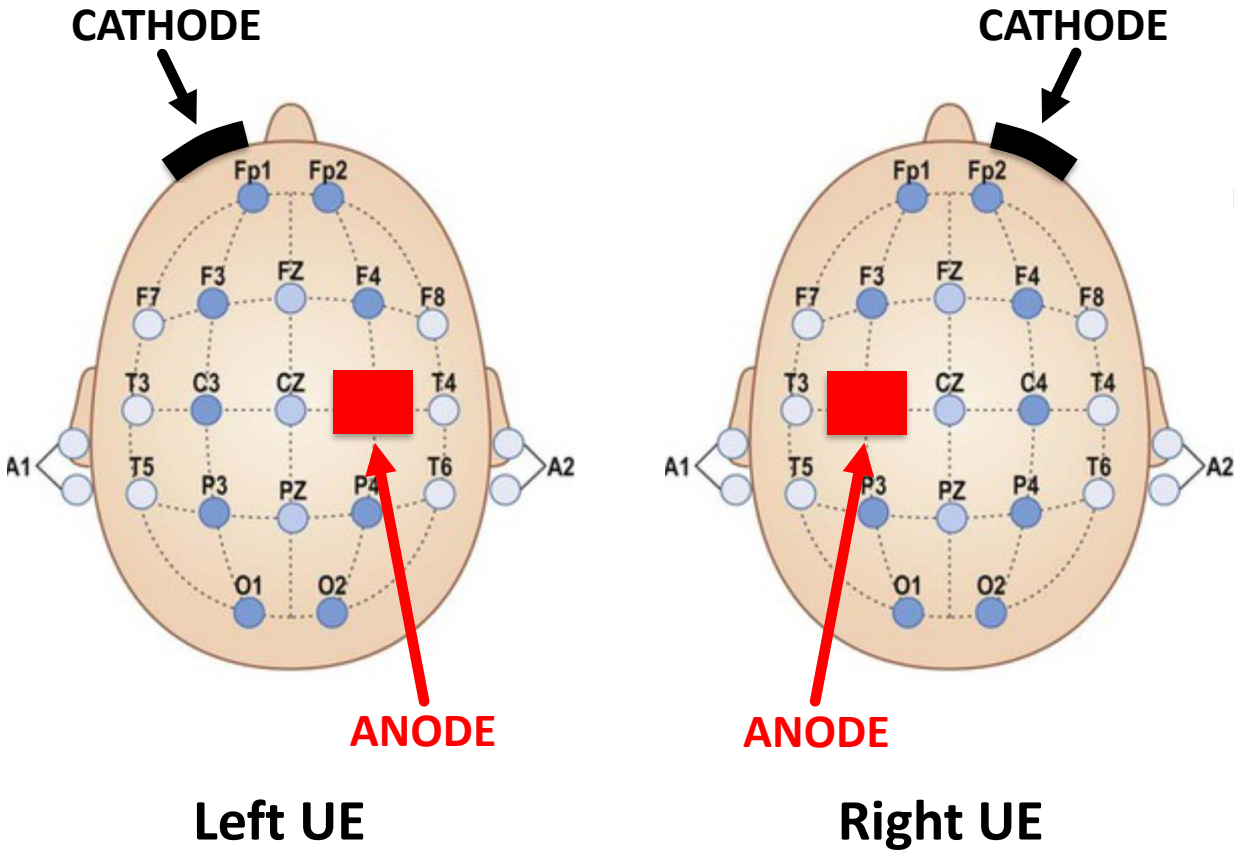
## *Using Montages to Direct Effects*




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

# Application Basics of TCS:

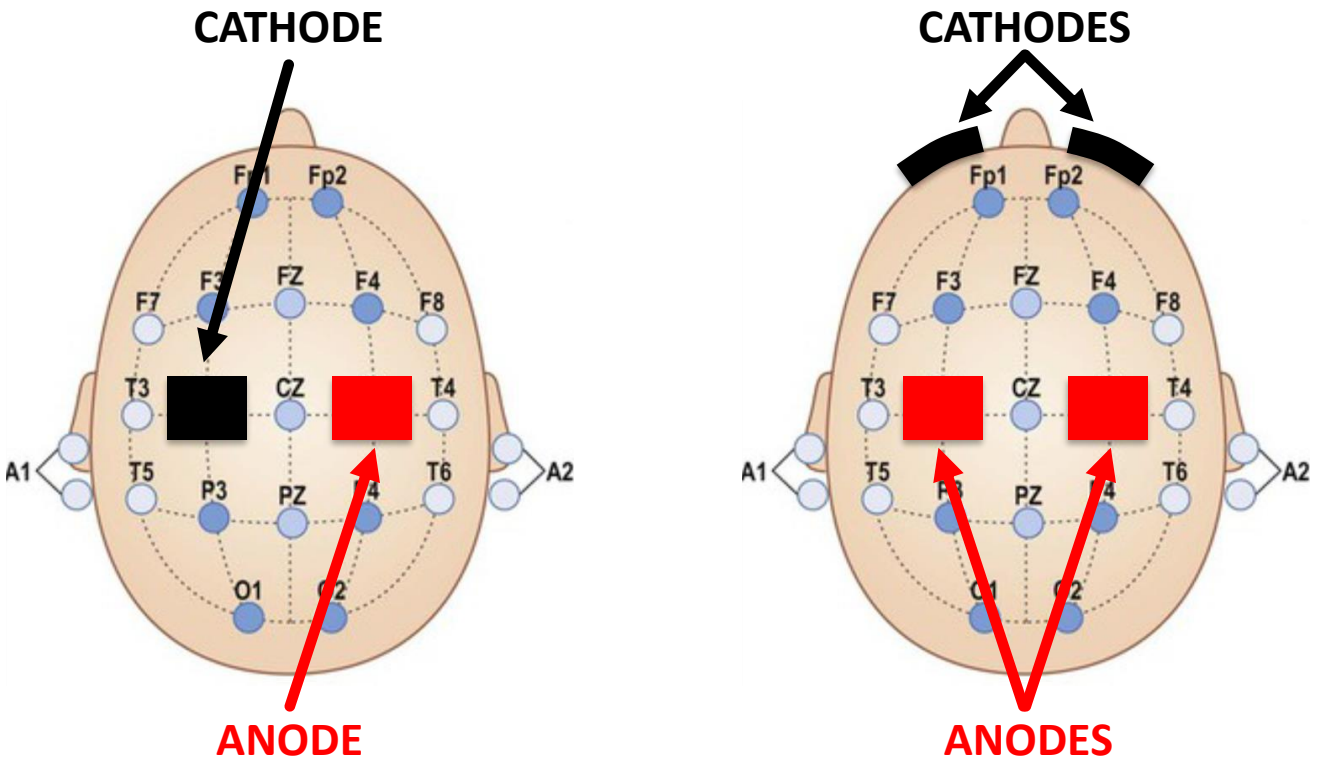
## *Montages for **Upper** Extremity Neuromodulation*




*Adapted from www.clinicalgate.com/epilepsy-8*

# Application Basics of TCS:

## *Montages for **Upper** Extremity Neuromodulation*

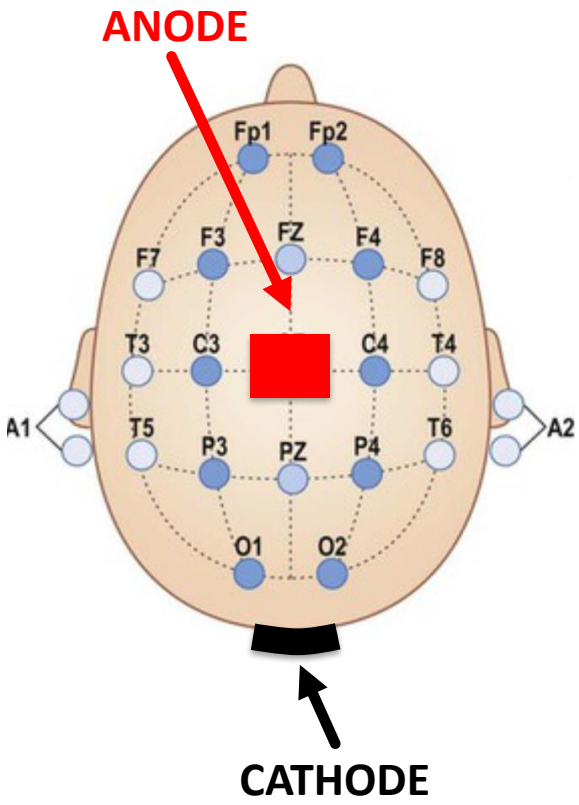



**Both UEs**

*Adapted from www.clinicalgate.com/epilepsy-8*

# Application Basics of TCS:

## *Montage for **Lower** Extremity Neuromodualtion*




*Adapted from www.clinicalgate.com/epilepsy-8*

# Advantages of tCS

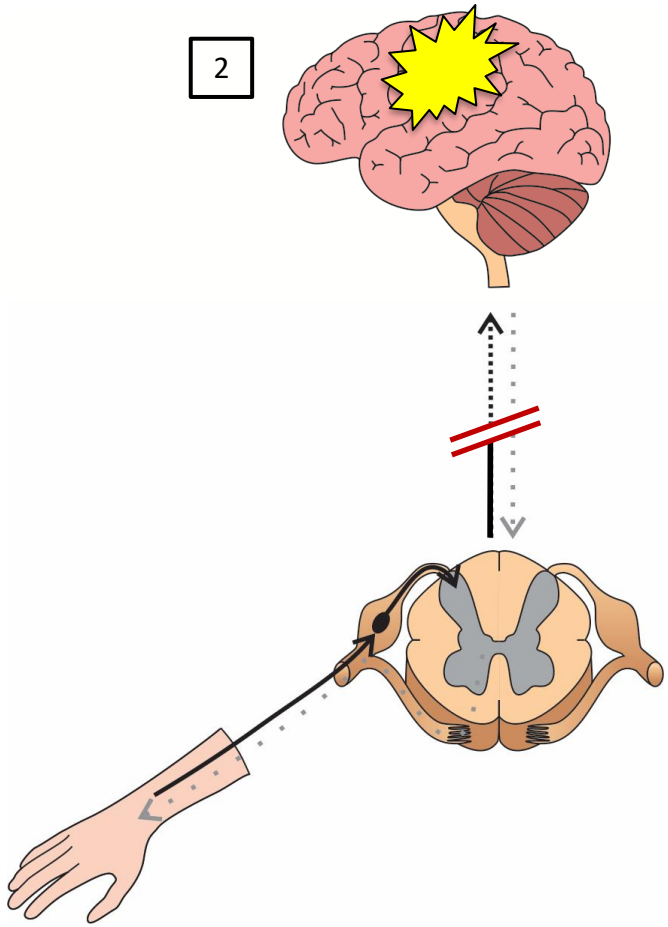
| | tCS |
|---|---|
| Focality | • Broad stimulation area |
| Cost | ✓ **More affordable** |
| Portability | ✓ **Small footprint, easy to transport** |
| Ease of Use | ✓ **Easily applied** |
| Application | ✓**Participant can move during stimulation** |

# Non-Invasive Brain Stimulation in Persons with SCI

# Maladaptive Cortical Plasticity Post-SCI:

## Reduced Motor Evoked Potential (MEP) Amplitude

1. Disruption of communication within the spinal cord
2. Decrease in cortical excitability



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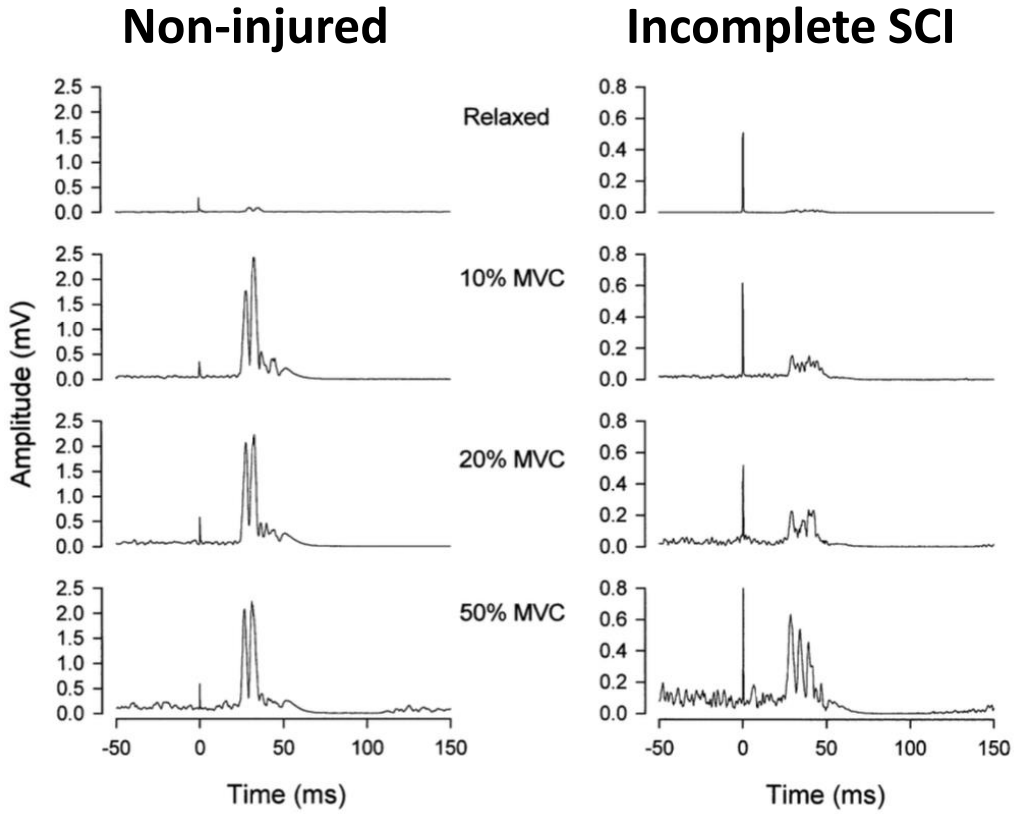
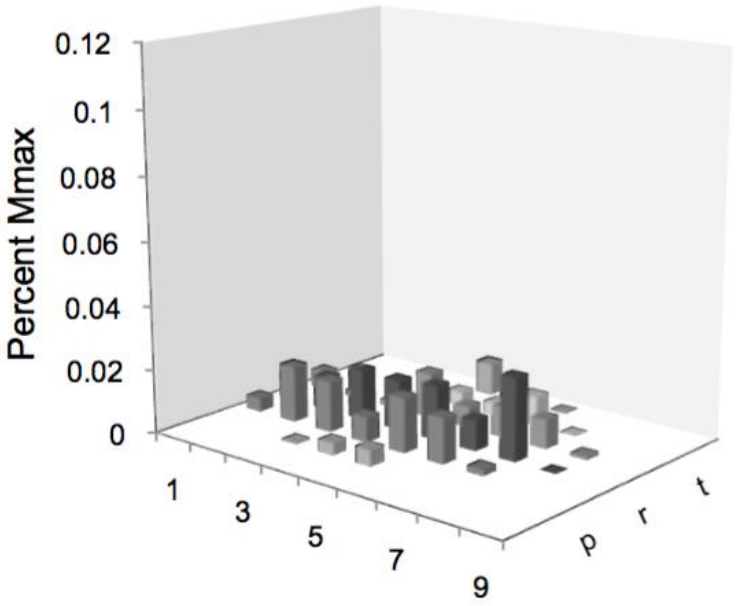


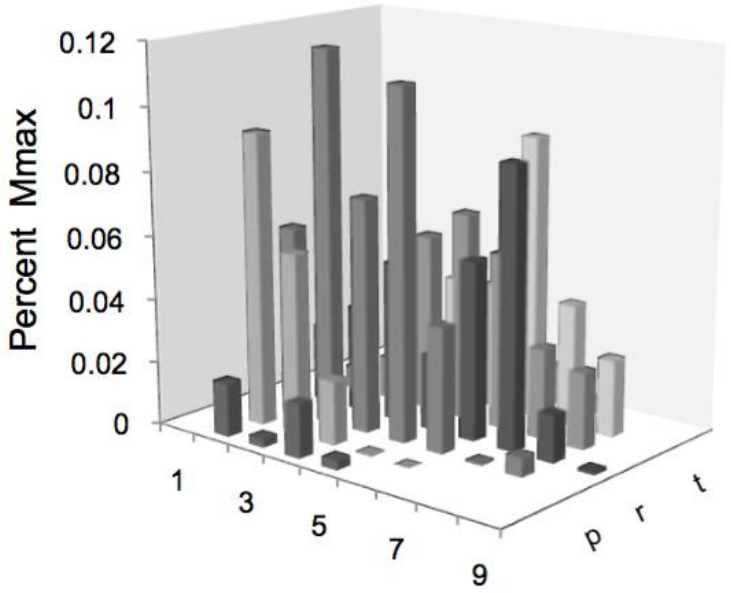

*Davey et al., Exp Brain Res,1999*

# Reversing Maladaptive Cortical Plasticity of Thenar Muscles in Persons with SCI

**Pre-Intervention**




**Post-Intervention**




*Hoffman & Field-Fote, Top Spinal Cord Rehabil, 2013*

# NIBS Studies in SCI Research: Recruitment Completed

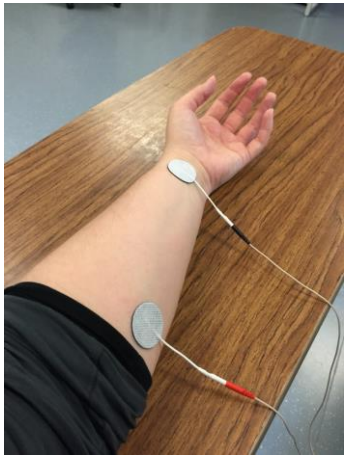
# Conditioning Neural Circuits to Improve Upper Extremity Function

Purpose:

- To examine how well people with tetraplegia are able to use their arms and hands after receiving fine motor training (FMT) combined with stimulation to increase brain excitability either directly or indirectly

Direct brain stimulation: Transcranial direct current stimulation

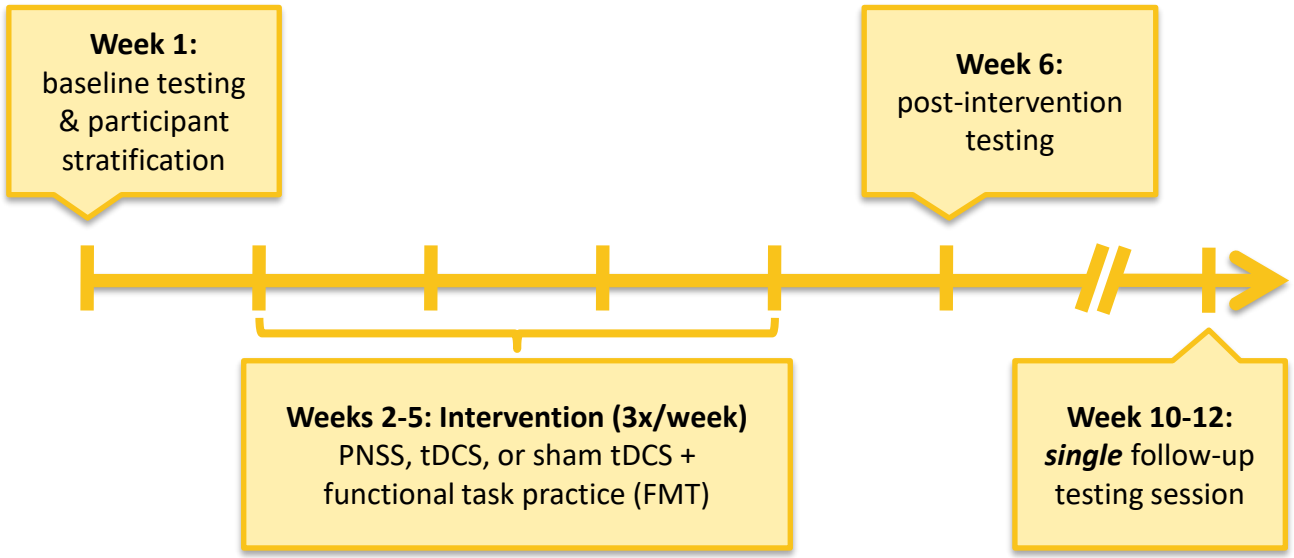
Indirect brain stimulation: Peripheral nerve somatosensory stimulation



# Conditioning Neural Circuits to Improve Upper Extremity Function

## Design

- Randomized controlled trial: each participant is randomly assigned to one of three groups: tDCS + FMT, PNSS + FMT, or sham tDCS + FMT



# Conditioning Neural Circuits to Improve Upper Extremity Function

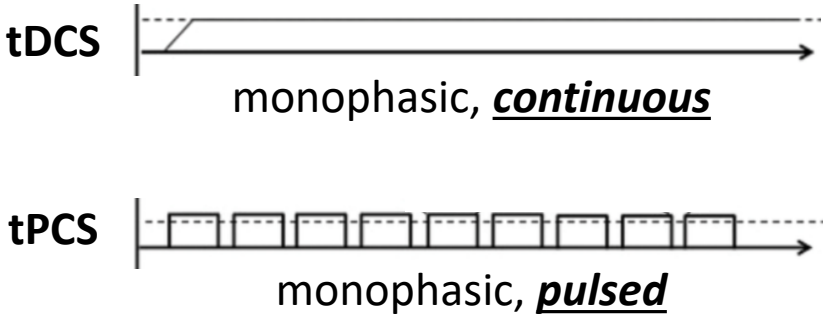
Outcome Measures:

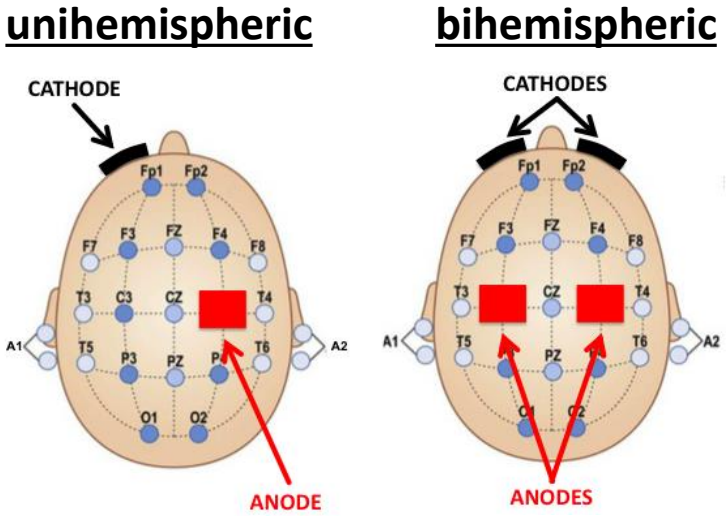
- UE motor impairment and function
- UE strength and sensation
- Participant perception of function/participation
- Participant perception of quality of life
- Corticospinal excitability
- Spinal reflex excitability

# Enhancing Corticospinal Excitability to Improve Functional Recovery

Purpose:

- To compare four different stimulation conditions for increasing brain excitability to determine which is best for helping people with tetraplegia improve their ability to use their arms and hands



# Enhancing Corticospinal Excitability to Improve Functional Recovery

## Design:

- Randomized crossover trial
- Each subject participates in a single session of each stimulation type

## Outcome Measures:

- Motor Control – timed tapping task
- Dexterity – nine hole peg test (9HPT)
- Strength – key pinch force
- Corticospinal excitability – motor evoked potentials

# NIBS Studies in SCI Research: Current & Upcoming

# Random Noise to Enhance Corticomotor Drive for Improved Hand Function

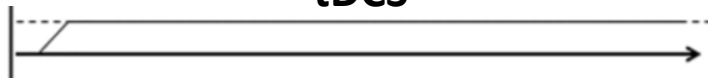
Purpose:

- To compare the effects on cortical excitability, motor and sensory function of 3-day combined tRNS + fine motor training protocol to tDCS + fine motor training and to sham-stimulation + fine motor training protocols in individuals with tetraplegia.

**tRNS**

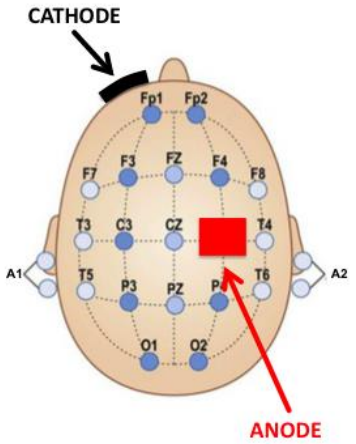
biphasic, random

**tDCS**



monophasic, ***continuous***

**unihemispheric**



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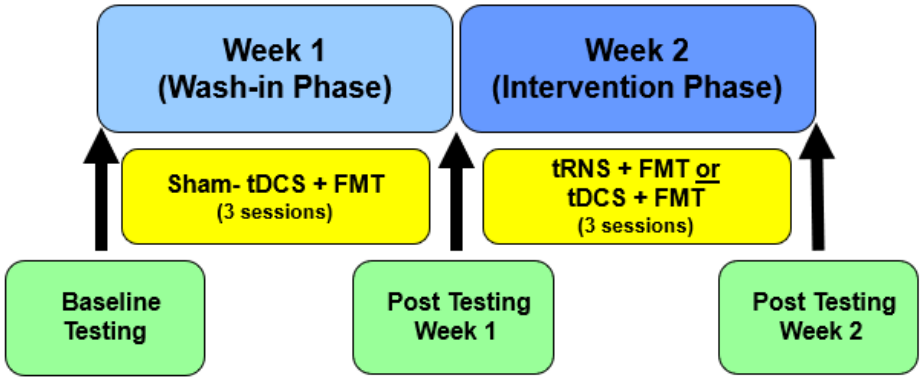



Outcome Measures:

Cortical Excitability- Motor Evoked Potentials

Unimanual Function- Grasp and Release Test

Bimanual Function- CAHAI_9

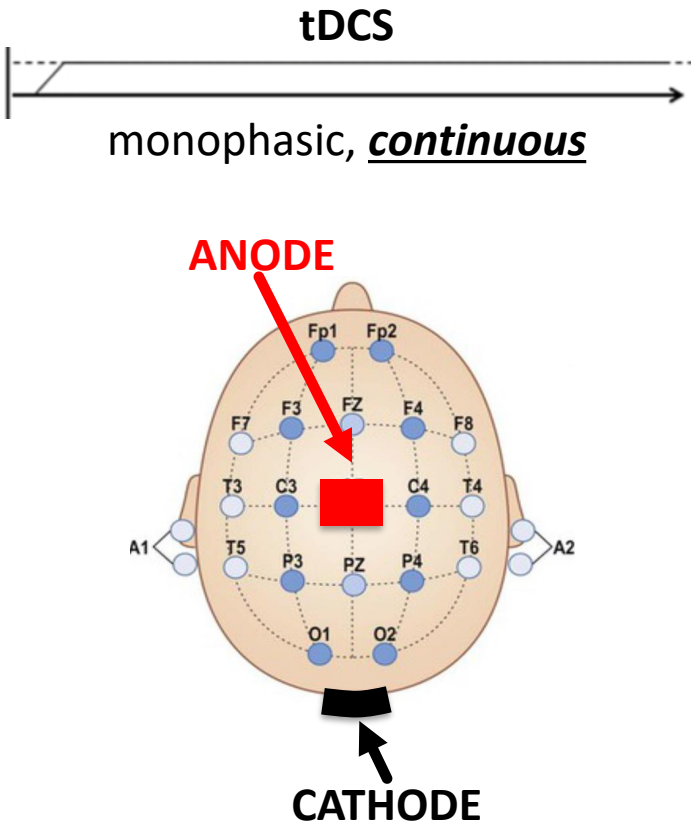
Sensory Function- Sensation subtest of GRASSP &
revised Nottingham Sensory Assessment

Strength- Pinch and Grasp strength

# Enhancing Corticospinal Activation for Improved Walking Function

Purpose:

- Determine if moderate-intensity, circuit training can improve walking-related outcomes
- Determine if the addition of non-invasive brain stimulation will result in greater improvements in function compared to circuit training alone



# Enhancing Corticospinal Activation for Improved Walking Function

## Design:

- Randomized controlled trial
- Each participant is randomly assigned to one of two groups: tDCS + training OR sham tDCS + training

## Outcome Measures:

- Walking Function
- LE strength
- Balance
- Spasticity
- Functional Strength

**CIRCUIT TRAINING**


***Note:*** *Task modification and balance support provided as needed*

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# Questions?