



Comparing the Neuro-modulatory Effects of High-Definition Transcranial Electrical Stimulation Waveforms in Chronic Stroke Patients

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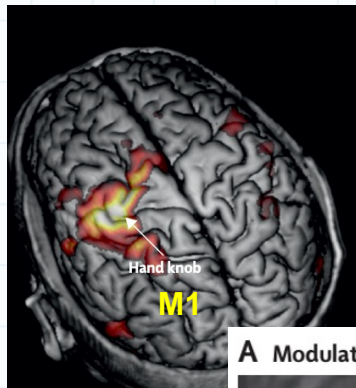


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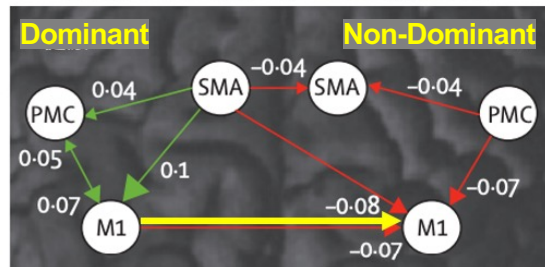
BACKGROUND & OBJECTIVE

Inter-Hemispheric Inhibition (IHI)

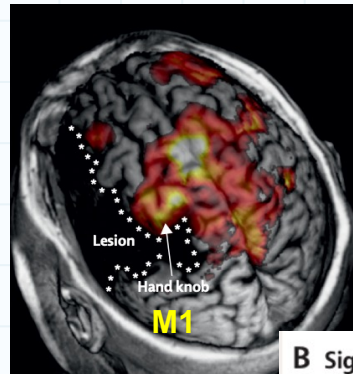
Healthy Participants



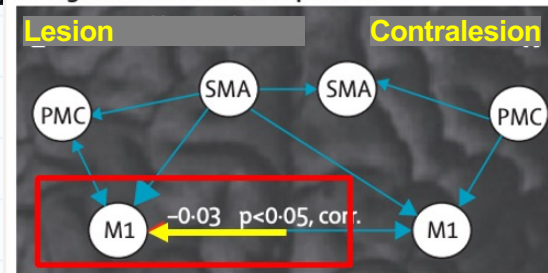
A Modulations of coupling in healthy controls



Stroke Patients



B Significant difference in patients



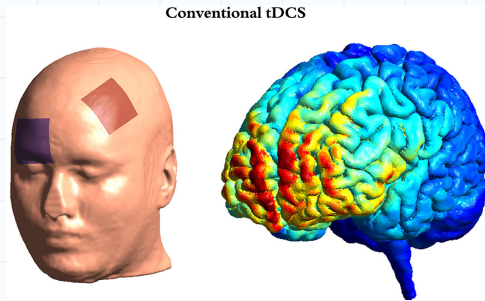
→ Positive coupling
 → Negative coupling
 → No significant difference with healthy controls

High-Definition Transcranial Electrical Stimulation (HD-tES)

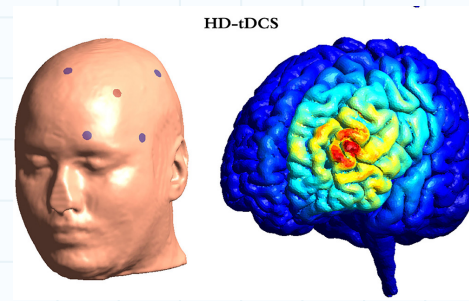
✓ Conventional tDCS has been shown to effectively modulate cortical excitability

Elsner, B., et al., (2020)

Conventional tDCS
(25-35cm²)

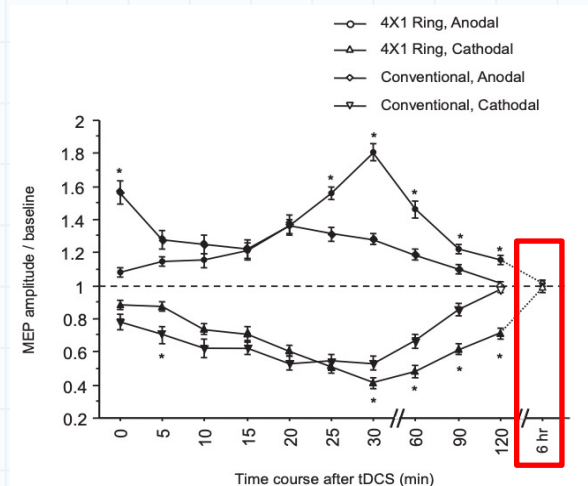


4x1 HD-montage
(1.13 cm²)



- Diffuse current spread
- Limited spatial focality
- Poor targeting specificity

- Higher spatial resolution
- More precise current targeting
- More **stable and consistent neuromodulatory effects**



Kuo, H. I., et al. (2013)

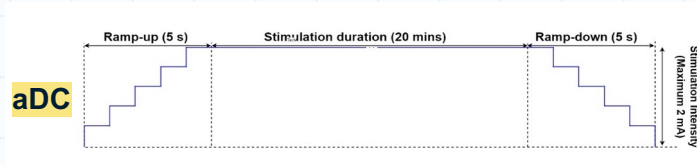
HD-tES Waveform Types



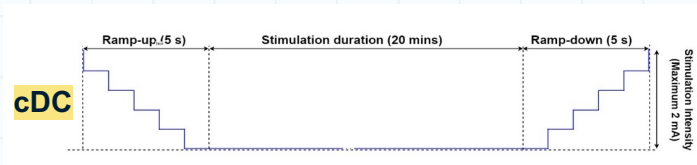
Conventional Direct Current (DC)

*subthreshold modulation of neuronal membrane potential

Anodal direct current (aDC)



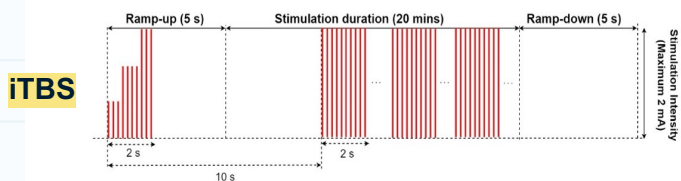
Cathodal direct current (cDC)



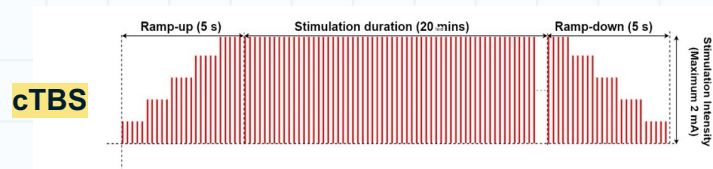
Theta Burst Stimulation (TBS)

*originally developed for rTMS, to mimic endogenous neural rhythms
*comprises 3 pulses at 50 Hz, repeated at 200 ms in a continuous pattern

Intermittent theta burst stimulation (iTBS)



Continuous theta burst stimulation (cTBS)

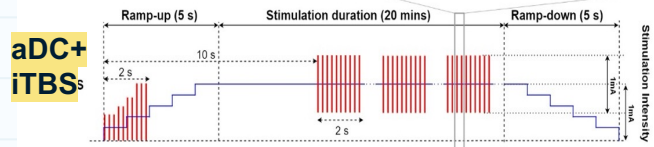


HD-tES Waveform Types

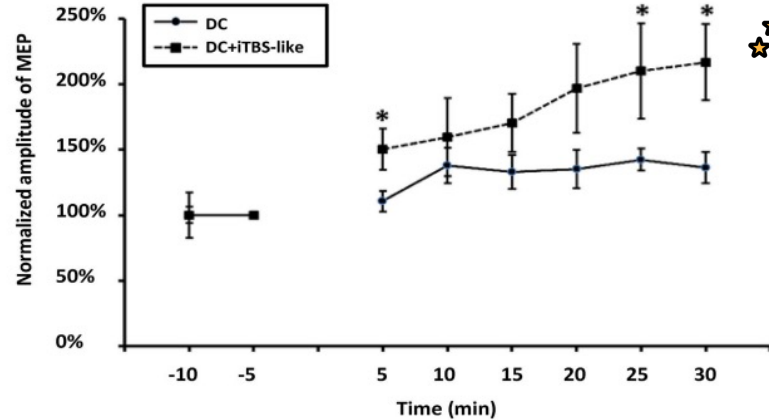
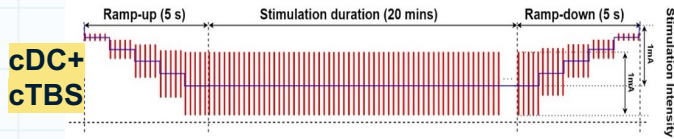
Combined Waveform (DC-TBS)

* Subthreshold membrane polarization + Activity-dependent plasticity

Anodal DC-TBS current (aDC+iTBS)



Cathodal DC-TBS current (cDC+cTBS)



○ Stability and consistency of excitability modulation
○ Prolonged after-effects

Study Limitations and Objectives

- Lack of systematic waveform comparisons
- Limited evidence on combined protocols (aDC + iTBS, cDC + cTBS)



1. Systematically compare the modulatory effects across all waveforms
2. Investigate cortical responses to different waveforms in stroke patients
3. Assess feasibility and clinical applicability in stroke patients



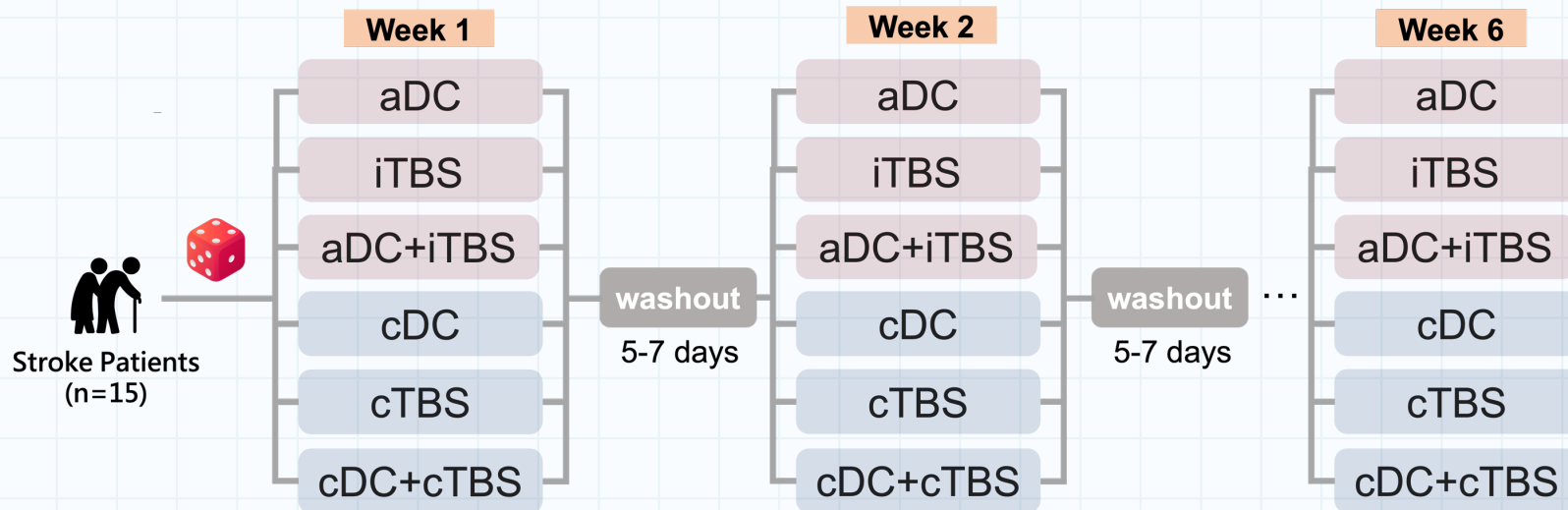


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METHODS

Study Design

Triple-blind, randomized controlled trial



counter balance design



Eligibility Criteria



Inclusion Criteria

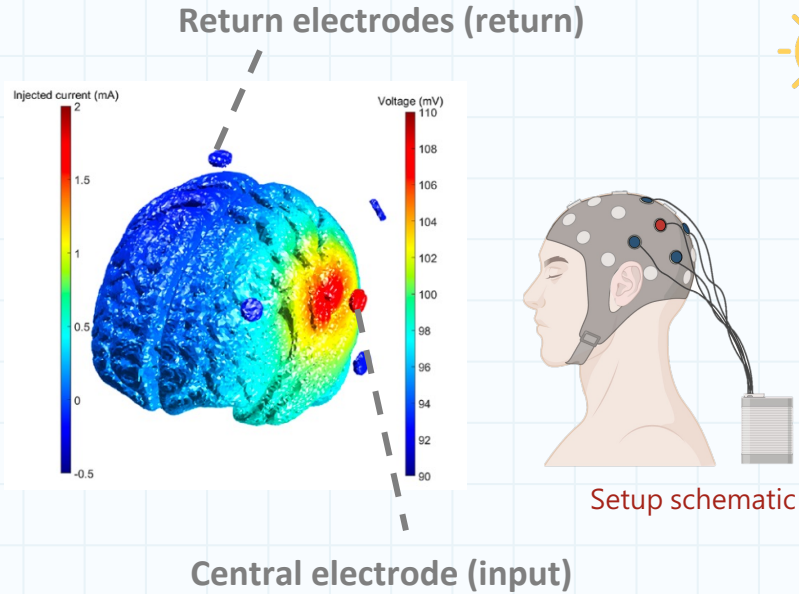
- Age \geq 20 years
- Diagnosis of ischemic or hemorrhagic stroke
- Time since stroke \geq **6 months**
- Unilateral hemiparesis
- Upper extremity **Brunnstrom stage III–V**
- Modified Ashworth Scale(MAS) \leq 3



Exclusion Criteria

- **Contraindications to electrical stimulation (e.g., seizure, atrial fibrillation)**
- Scalp skin conditions (e.g., hypersensitivity, contact dermatitis, allodynia, allergic pain)
- Severe cognitive or psychiatric disorders
- History of alcohol or substance abuse
- Contracture, rigidity, inflammation, or heterotopic ossification of the affected upper limb
- Use of medications affecting the CNS or potentially altering seizure threshold
- Rheumatic diseases (e.g., systemic lupus erythematosus, RA, ankylosing spondylitis)

Experiment Design



Enhance excitability of lesion hemisphere

Excitatory waveforms → ipsilesional M1

aDC, iTBS, aDC+iTBS

Inhibitory waveforms → contralesional M1

cDC, cTBS, cDC+cTBS

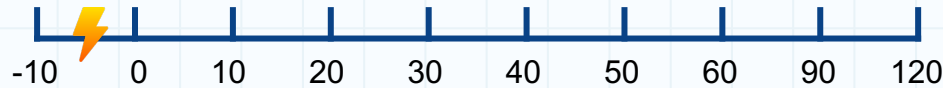
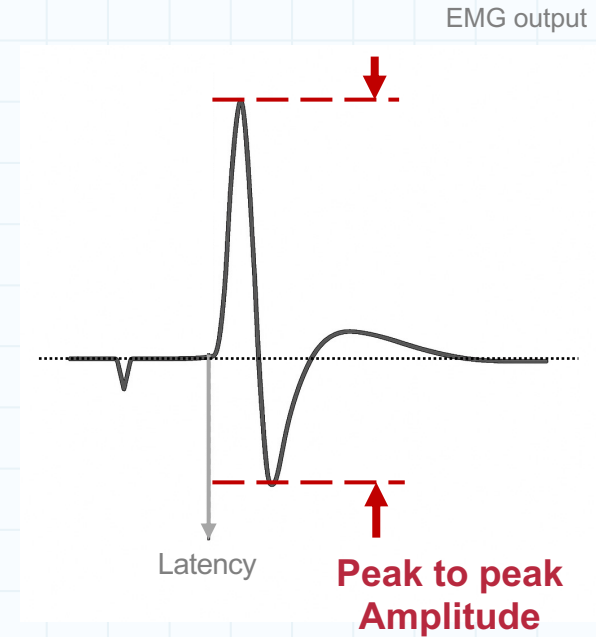
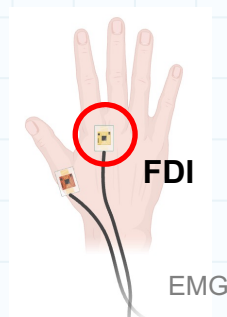
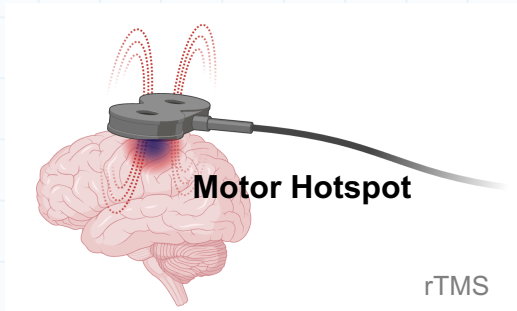
*M1: Primary motor cortex



Neurophysiological Outcomes

Motor evoked potentials (MEPs)

- Equipment: TMS and EMG
- Stimulation Intensity: 120% of resting motor threshold (rMT)



2mA HD-tES, 10min

Data Analysis

SPSS 29.0

$$\Delta MEP = \frac{MEP_{Time} - MEP_{Baseline}}{MEP_{Baseline}}$$

Relative Change

- Changes were normalized to session-specific baseline MEPs to control for individual variability and allow for comparison of cortical responses over time.

Note: Non-evoked MEPs (0 μ V) were replaced with 20 μ V to enable calculation of the relative change





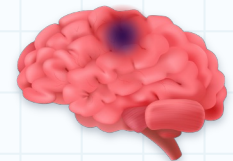
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RESULTS

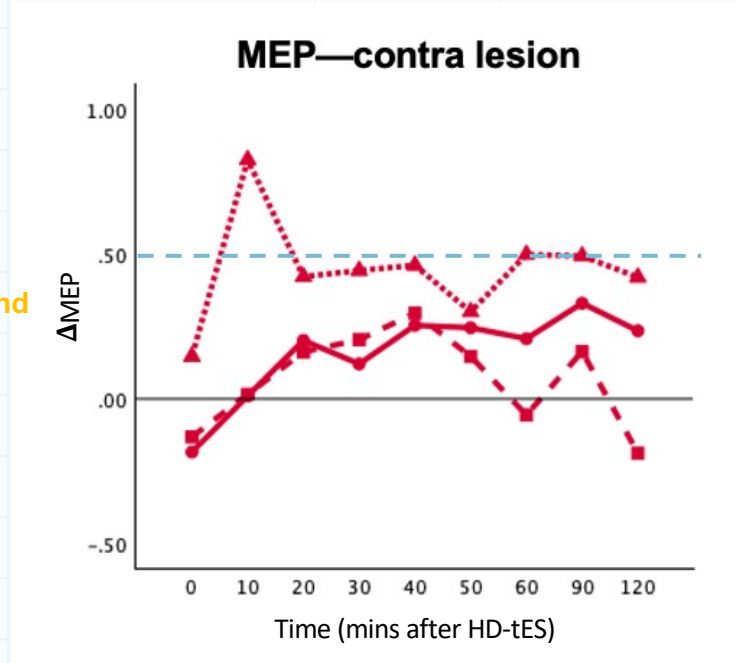
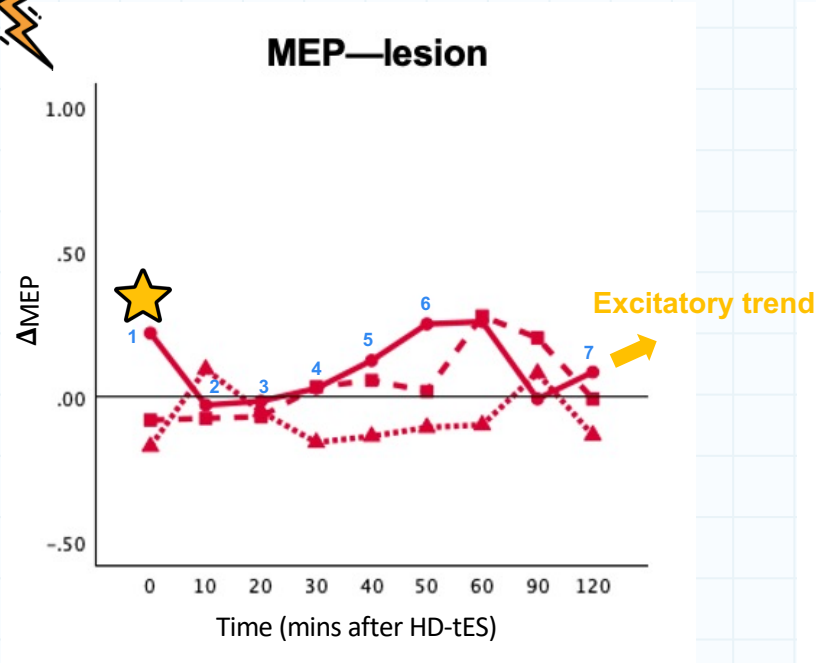
Demographic characteristics

Table 1. Baseline characteristics of the participants

| | Chronic Stroke Patients (n=15) |
|--|---------------------------------------|
| Age (years, mean±SD) | 60.47 ± 10.82 |
| Sex, n (%) | |
| Male | 9 (60.0%) |
| Female | 6 (40.0%) |
| Time since stroke onset (months, mean±SD) | 32.60 ± 37.73 |
| Stroke type, n (%) | |
| Ischemic | 7 (46.7%) |
| Hemorrhagic | 8 (53.3%) |
| Lesioned hemisphere side, n (%) | |
| Left | 7 (46.7%) |
| Right | 8 (53.3%) |
| Brunnstrom stage | |
| Proximal | 4.30 ± 0.75 |
| Distal | 4.13 ± 0.77 |
| Education level, n (%) | |
| ≤ High school | 6 (40.0%) |
| College or above | 9 (60.0%) |



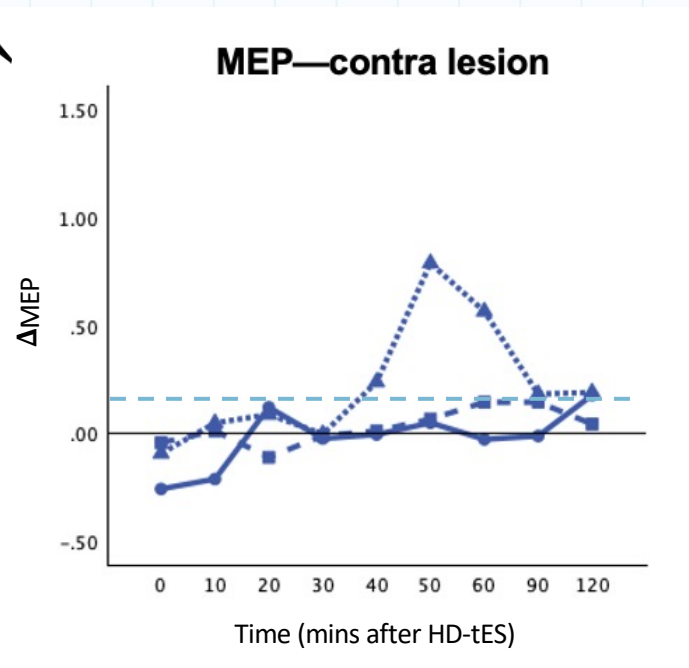
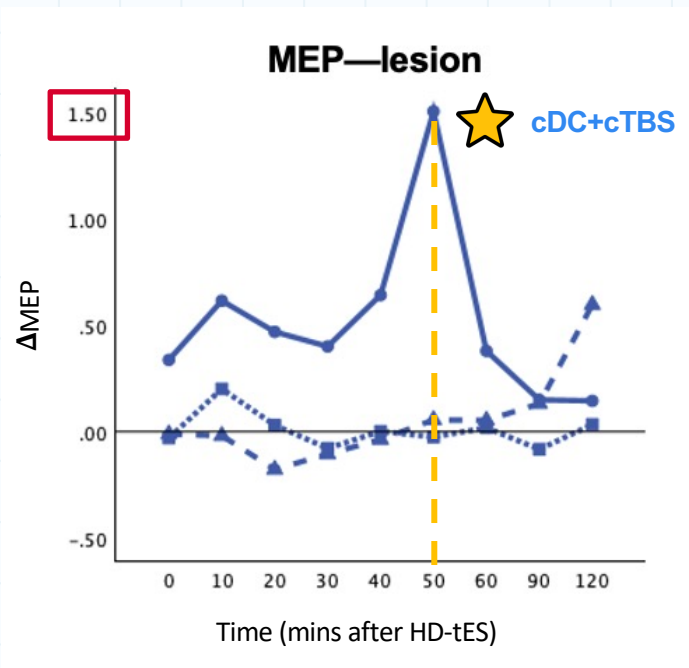
Excitatory Waveforms



●—● aDC+iTBS ■- - iTBS ▲... aDC



Inhibitory Waveforms

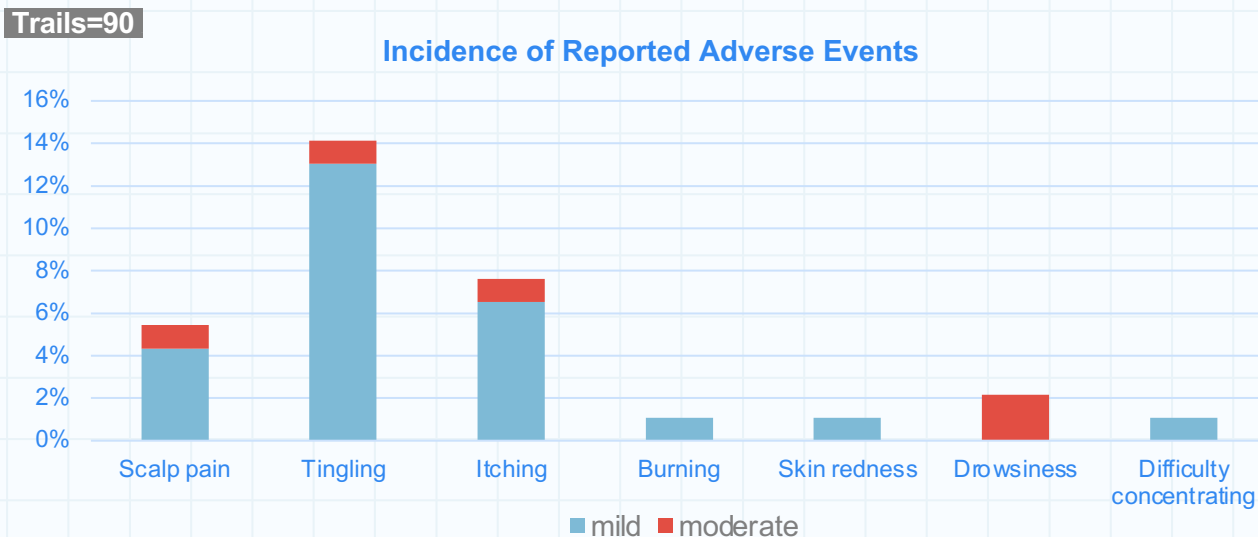


- - \blacktriangle - - cDC - - \blacksquare - - cTBS - - \bullet - - cDC+cTBS



Safety Monitoring

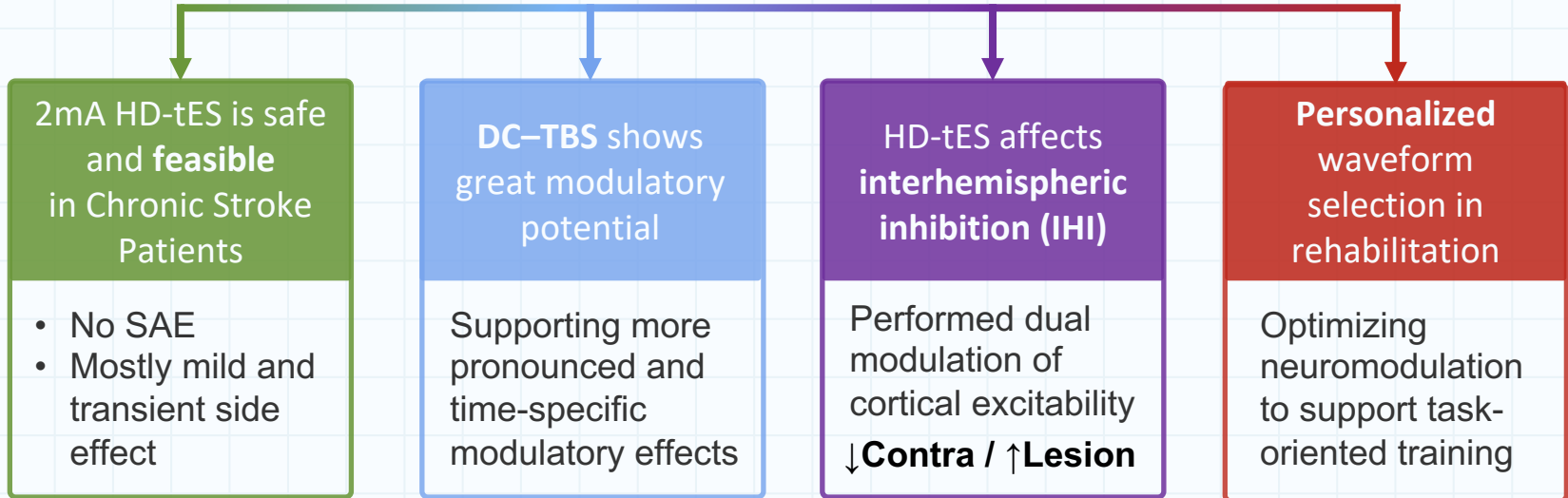
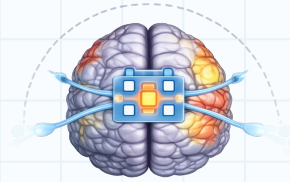
- Adverse events assessed after each session using a questionnaire, rated on a 4-point scale (none, mild, moderate, severe)



- ✓ All reported adverse events were transient and resolved following stimulation
- ✓ No serious adverse event (SAE) were report



Take Home Message



Highlighting the importance of individualized neuromodulation strategies in rehabilitation

Thanks for Listening

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