Motor learning with tDCS in Rats

Forouzan Farahani[1], Preston Williams[2], Mihály Vöröslakos[3], Niranjan Kahdka, Marom Bikson[1], John Martin[2], Lucas Parra[1]

[1]Dep. of Biomedical Engineering, City Colllege of New York, NY;
[2]Dep. of Molecular, Cellular and Biomedical Sciences, CUNY School of Medicine, New York, NY;
[3]Neuroscience Institute, Langone Medical Center, New York University, New York, NY

Introduction

One promising application of tDCS is to modulate motor excitability and motor learning [1]. Human and animal studies have demonstrated that anodal tDCS increases motor evoked potential (MEP). However, it is not clear that changes in TMS-evoked MEP have any actual relevance to normal behavior. Functional and structural changes in the primary motor cortex (M1) have been associated with motor skill learning. Therefore, tDCS human and animal studies have targeted this region to modulate motor learning.

From in vitro experimnts, we know concurrent DCS with synpatic plasticity induction will result a boost in long-term pontiation (LTP)[2,3]. We showed that andaol DCS depolazires soma of the postsynaptic neurons and will increase the somatic spiking. We also know that pairing concurrent DCS with multiple synpatic plasticity inductions (space learning) has an accumulative effect on LTP [4].

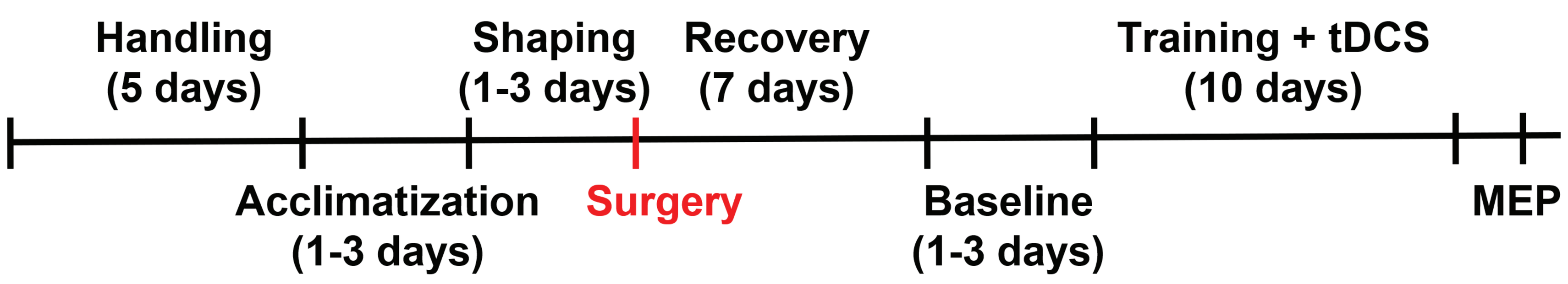
In addition, training enhanes learnining via synaptic plasticty. Inspired by in vitro experiments, here we addresssed whether concurrent anodal tDCS with training will enhance performance accross several training days.

Method

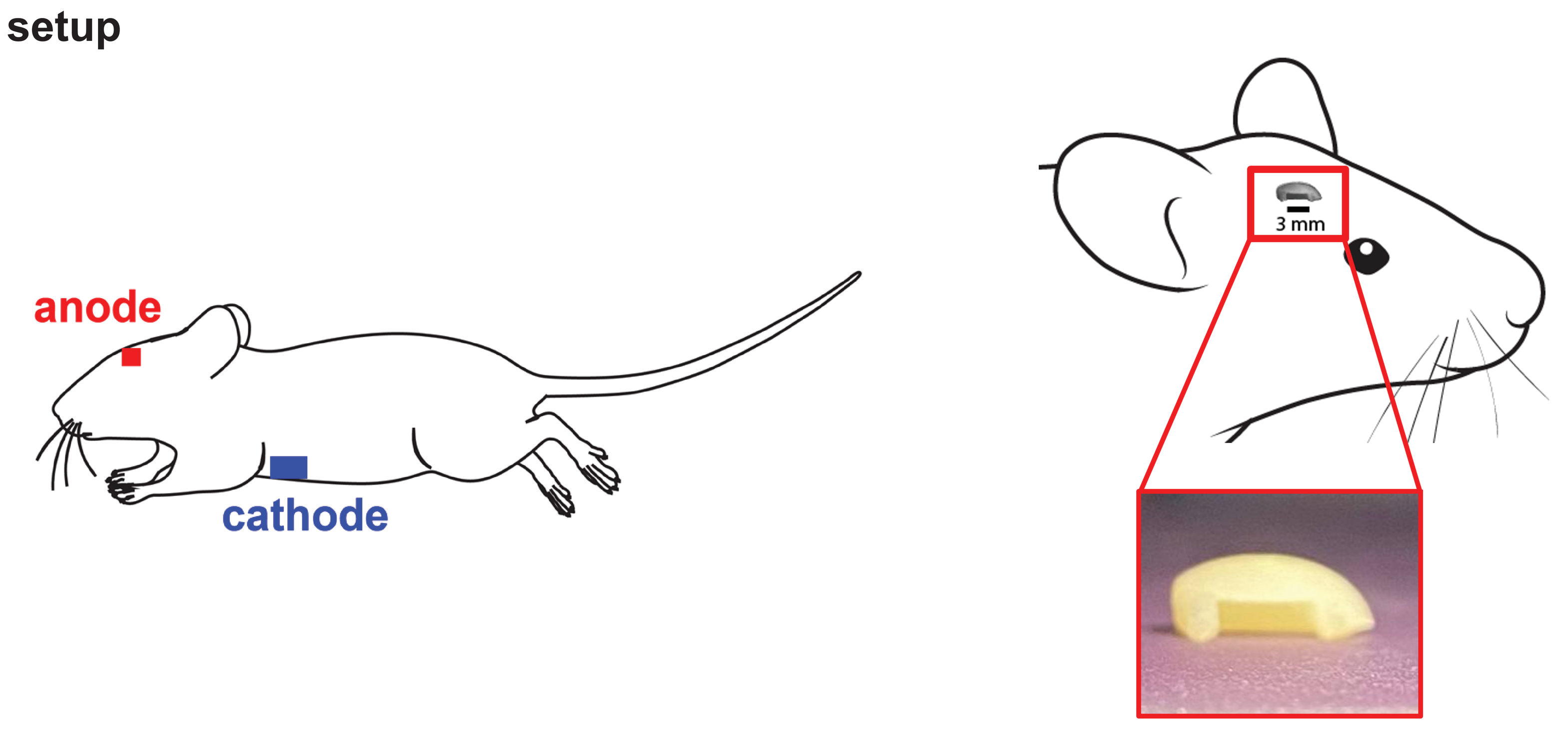
Here we tested for the first time tDCS concurrently with a behavioral learning task in rodents. The pellet-reaching task we use here in rats is a classic model of motor learning involving synaptic changes in motor cortex. We developed a new electrode montage that trades off intensity with electro-chemical stability over 10 training sessions, while maintaining animal safety and mobility. We measured field intensity intracranially and built a computational model to match our electrode montage. Animals were trained for 20 min with concurrent tDCS over 10 daily sessions. MEP were measured with direct cortical microstimulation in a terminal experiment under anesthesia.

Behavioral setup

Expermental fimeline

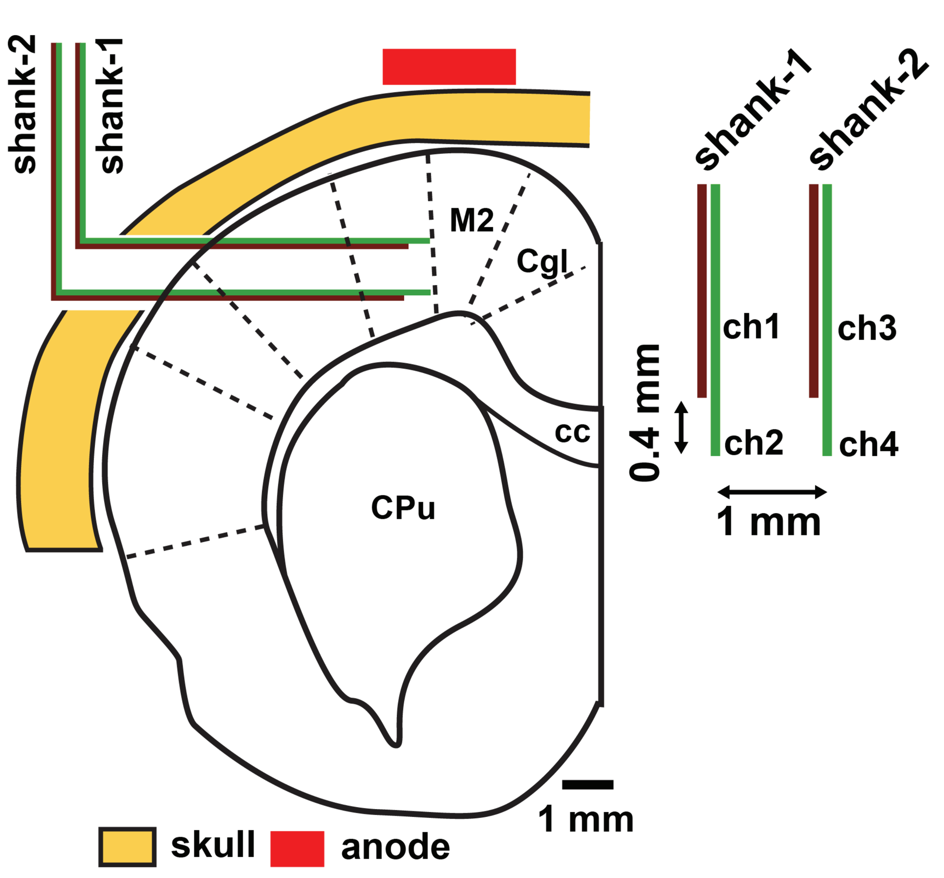


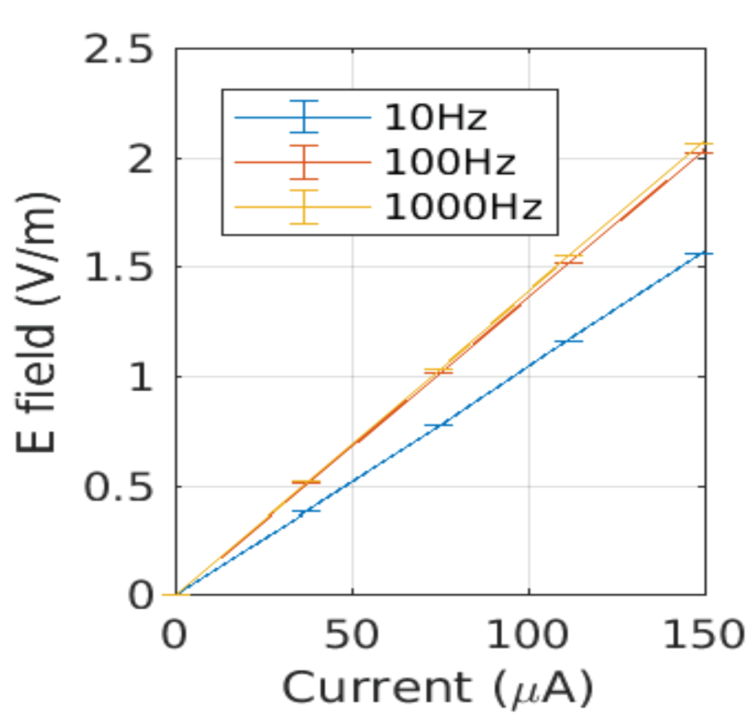
tDCS setup



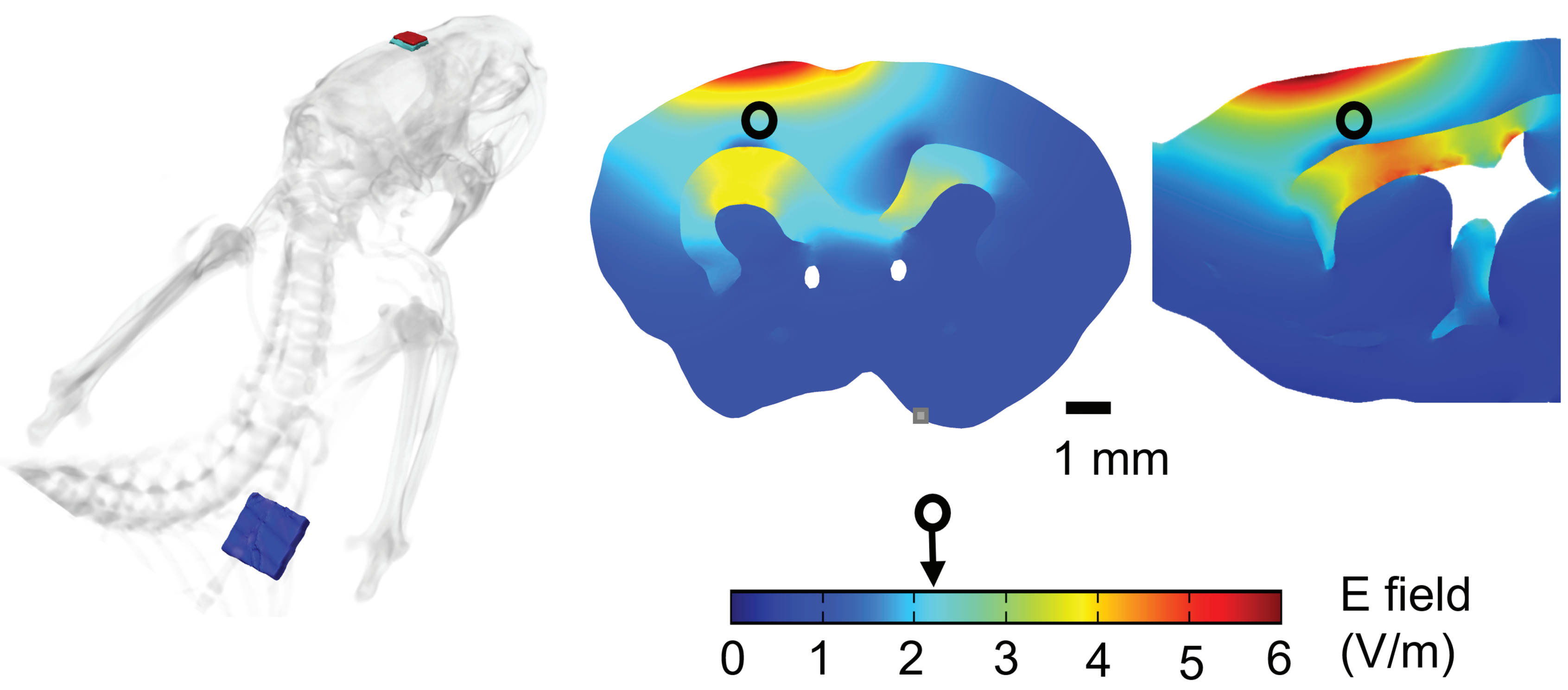
Results

Electric field measurement



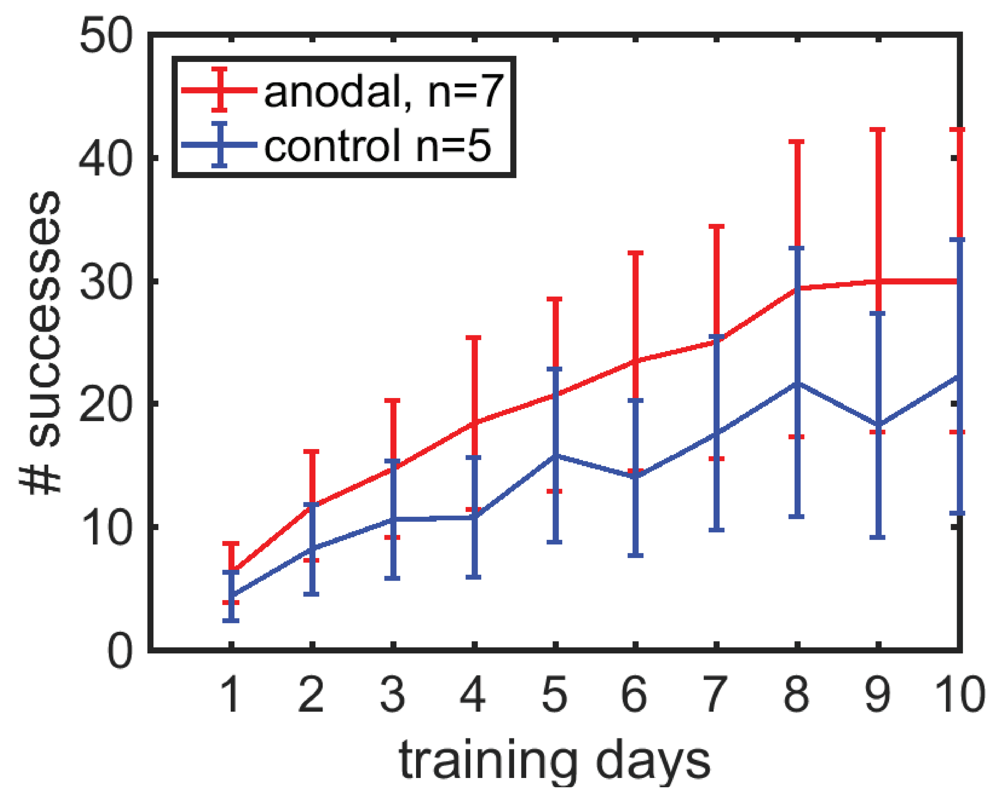


Computational modeling of electric field



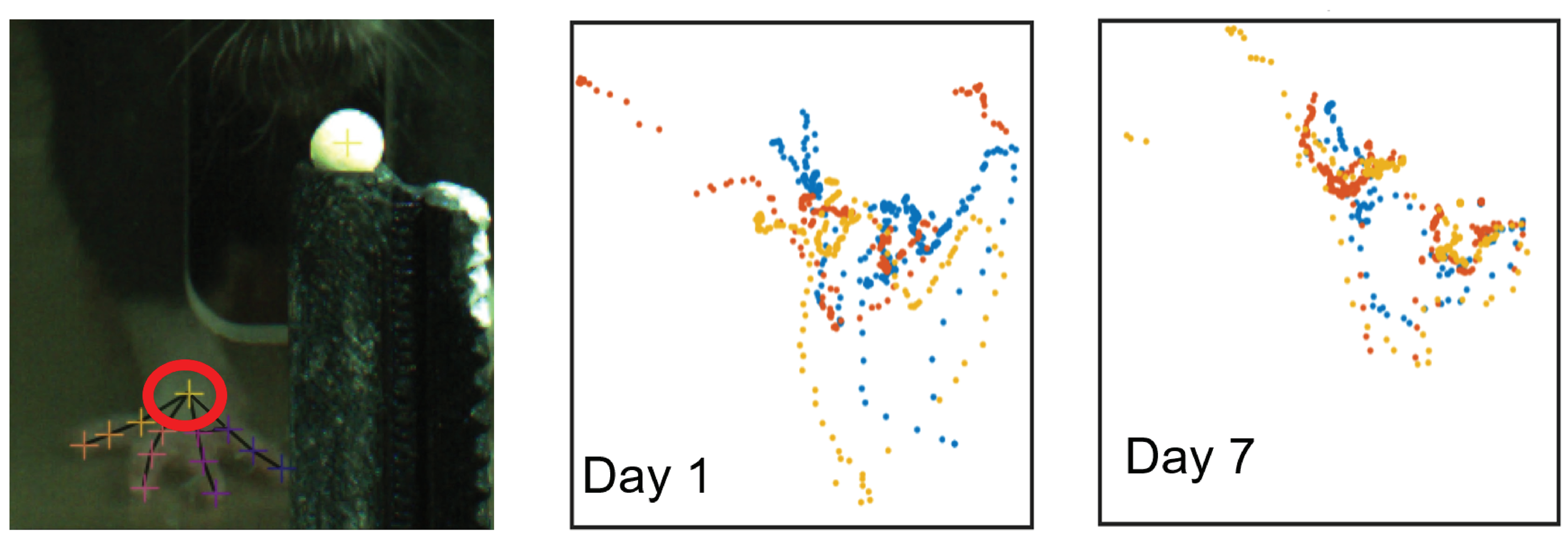
Behavioral results

A linear mixed effect model: an interaction between days with stimulation condition with an effect size of Cohen's f=0.67

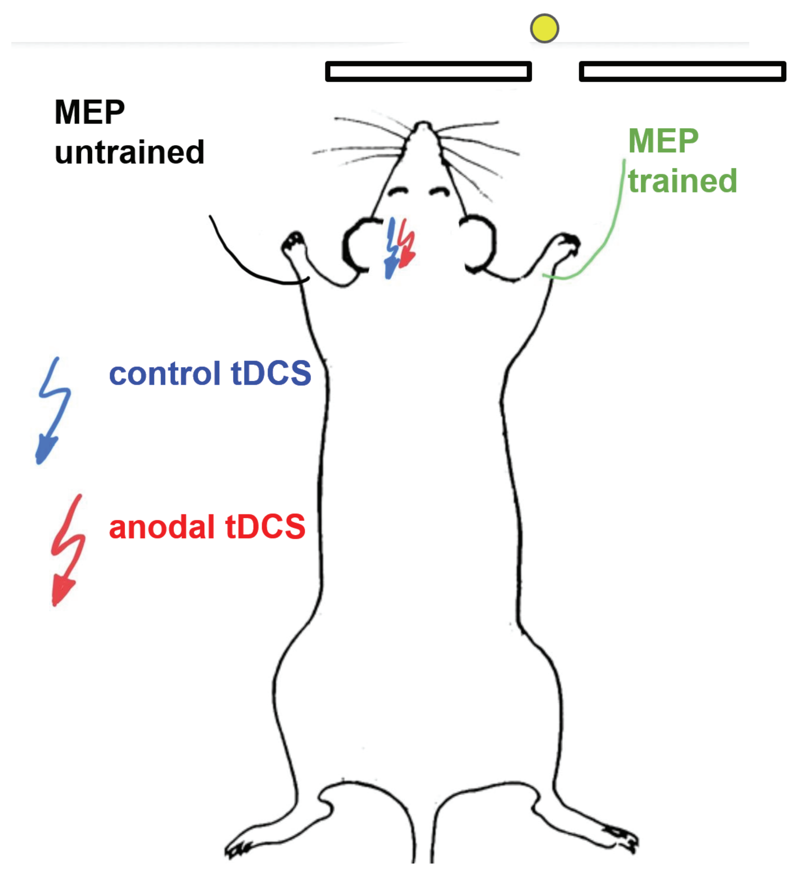


Future work

Kinematic of movement



Motor evoked potential (MEP)



Conclusion

- Bridging the gap between in-vitro and human experiments
- Concurrent tDCS with training across several days of training
- Accumulative effect of tDCS

References:

1) Hsu, Gavin, et al. "Robust enhancement of motor sequence learning with 4mA transcranial electric stimulation." bioRxiv (2022).

2) Kronberg, Greg, et al. "Direct current stimulation boosts hebbian plasticity in vitro." Brain stimulation 13.2 (2020): 287-301.

3) Farahani, Forouzan, et al. "Effects of direct current stimulation on synaptic plasticity in a single neuron." Brain Stimulation 14.3 (2021): 588-597.

4) Sharma, Mahima, et al. "Weak DCS causes a relatively strong cumulative boost of synaptic plasticity with spaced learning." Brain Stimulation 15.1 (2022): 57-62.