The City College of New York
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tDCS at Clinically-Relevant Field Intensity Boosts Motor Learning in Rats

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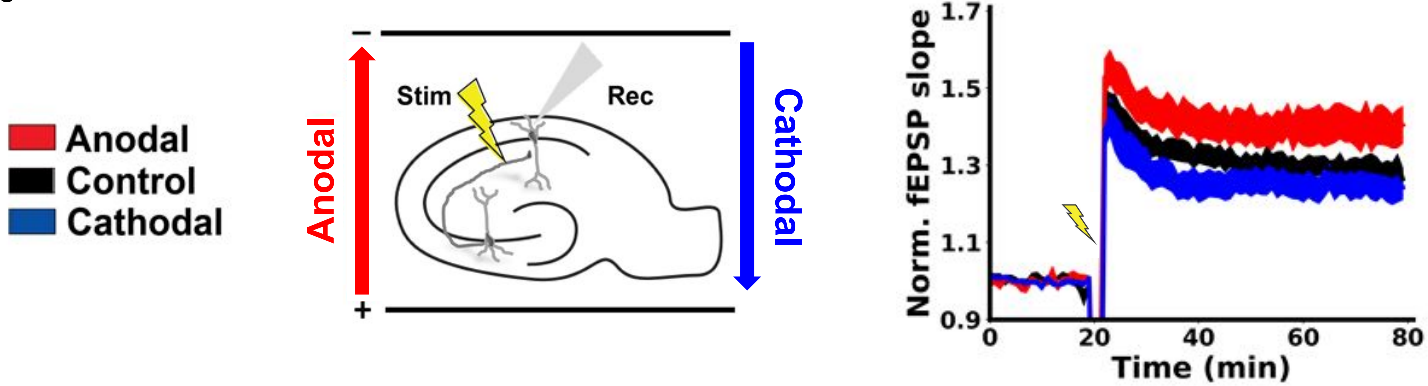
Background

tDCS can change the polarization of the postsynaptic neurons and thereby modulate the brain's endogenous synaptic plasticity and learning.

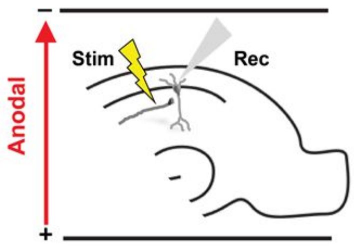
Kronberg et al, Brain Stim 2020

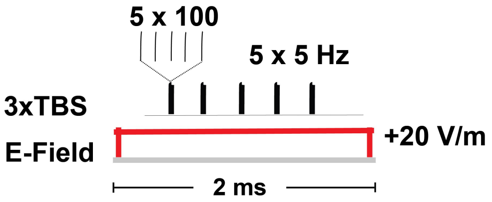


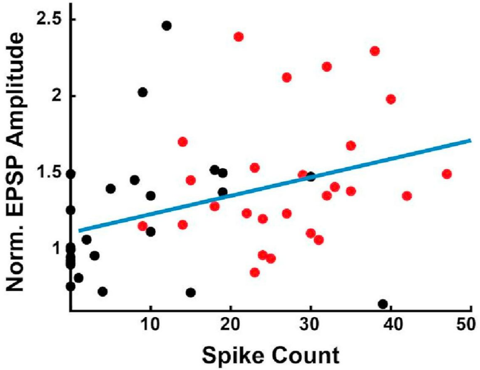
Proposed mechanisms: increase in spiking activity but no direct evidence

Effects of DCS on synaptic plasticity is mediated by modulating somatic spiking

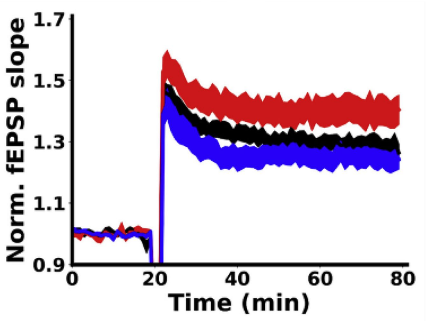
Whole-cell patch clamp recording



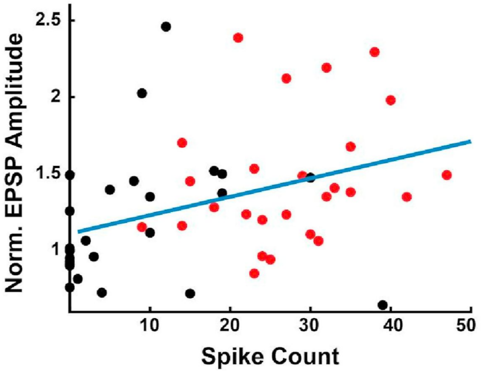




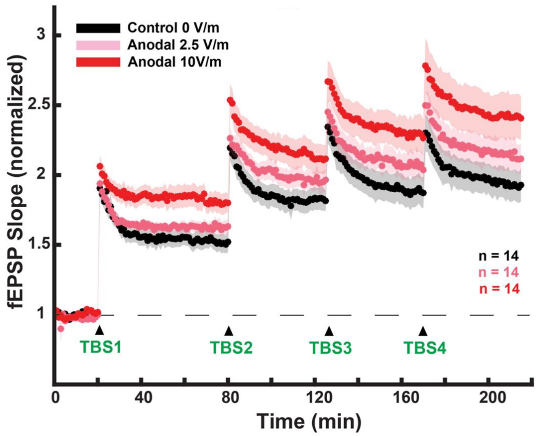
Summary of in vitro



Kronberg et al, Brain Stim 2020



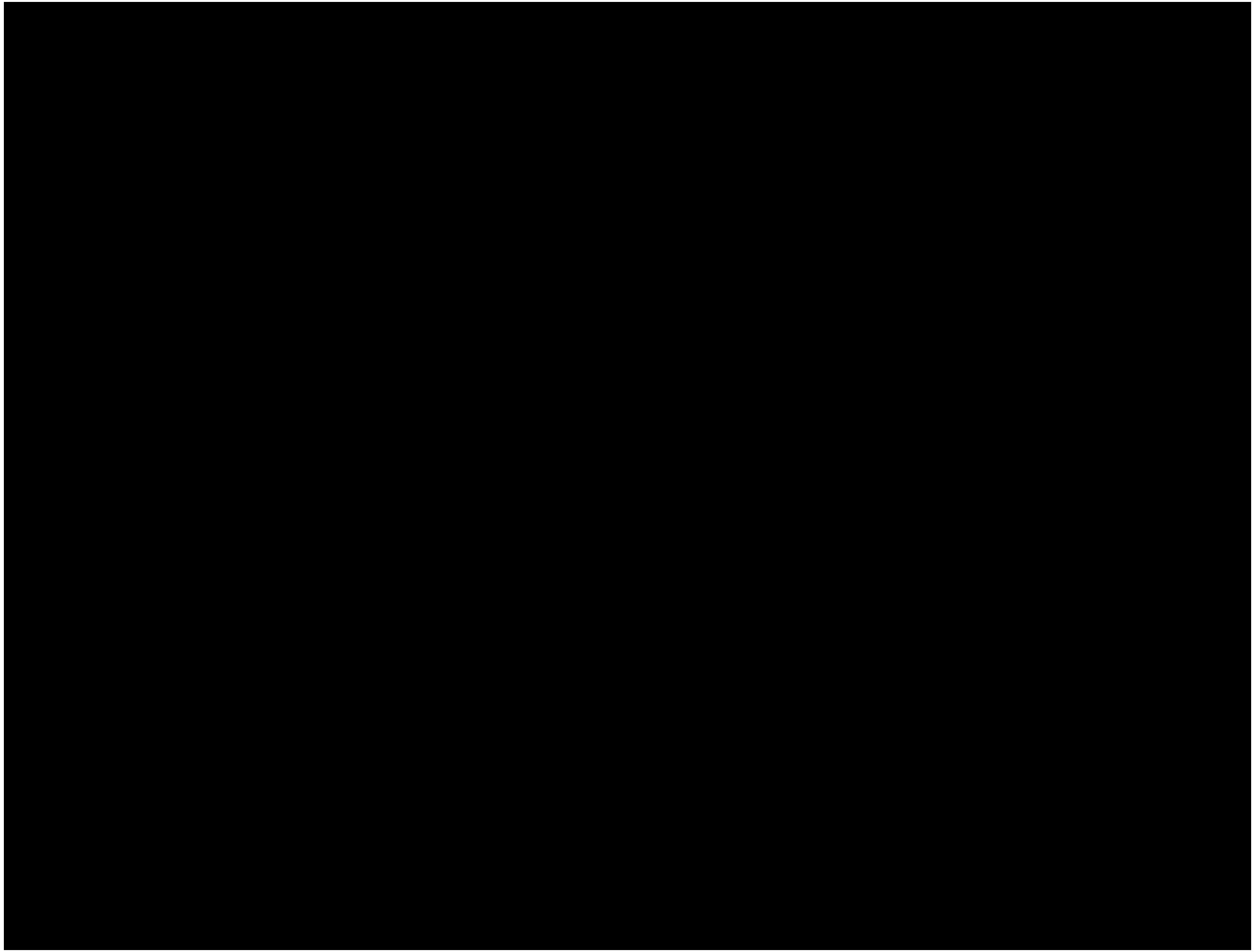
Farahani et al, Brain Stim 2021



Sharma et al, Brain Stim 2022

Behavior

2x speed



Anodal tDCS boost motor skill learning

Hypothesis:

concurrent tDCS + days of training

↓

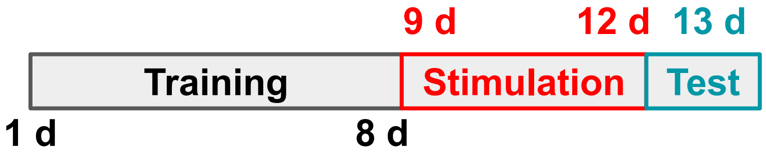
Synaptic plasticity ↑

↓

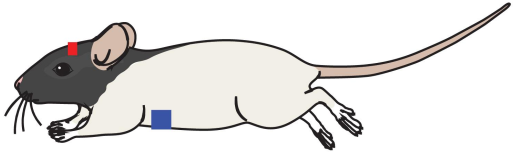
Enhanced learning performance in rats ↑

Experimental design: tDCS

- Previous study (Barbati et al, 2020):
  - Approx E > 15 V/m

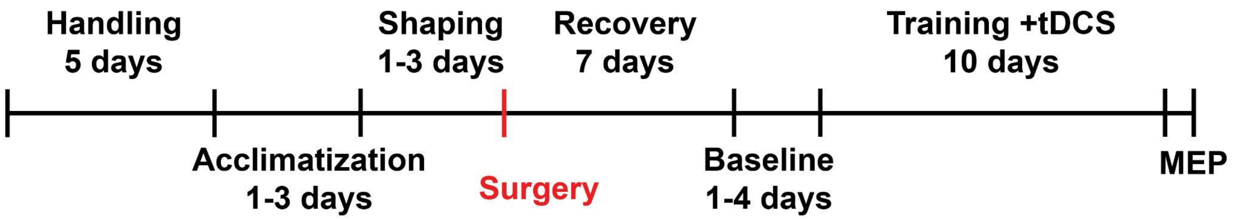


- Present work:
  - E = 2 V/m



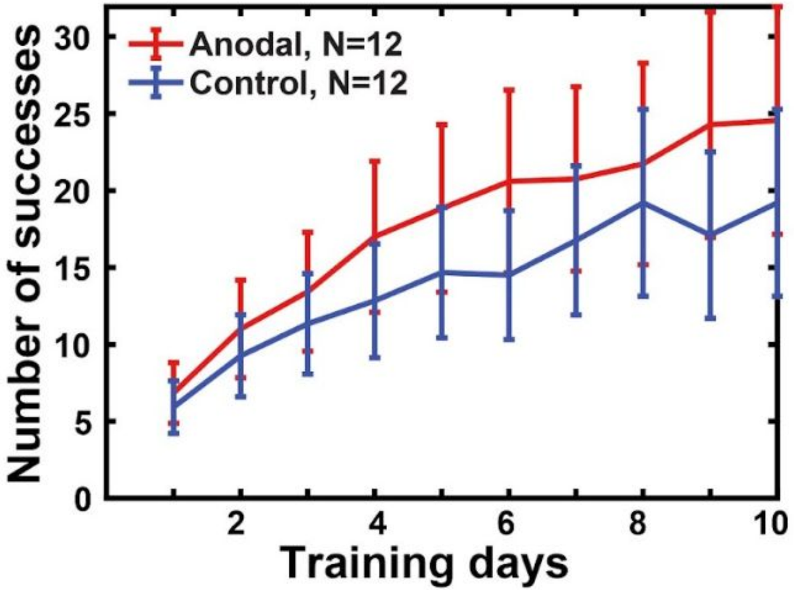
- Human experiments
  - E = 0.5 V/m

TImeline of the experiments



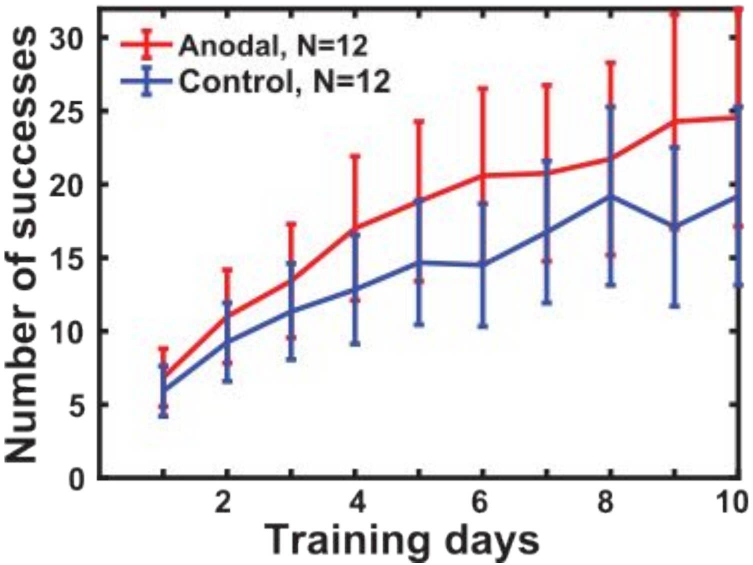
An interaction between days of training with stimulation condition

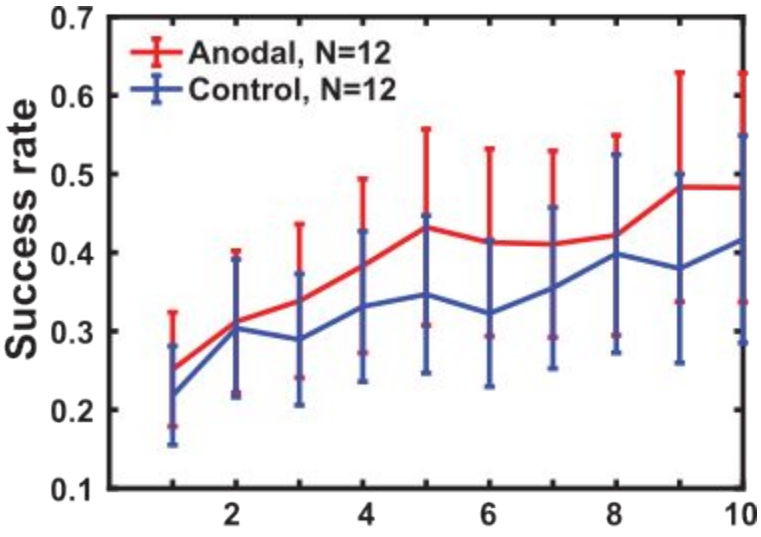
Using a linear mixed effect model: p=0.008



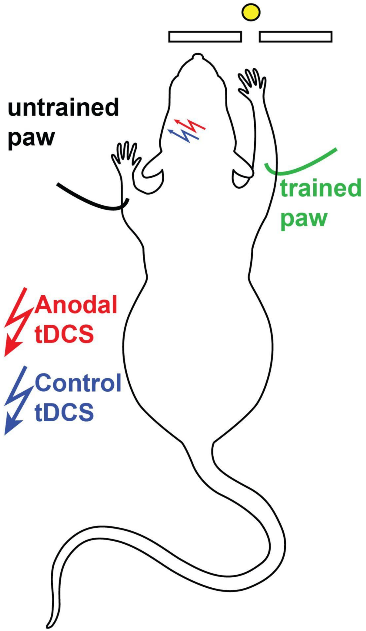
An interaction between days of training with stimulation condition

A linear mixed effect model finds an interaction between days with stimulation condition:

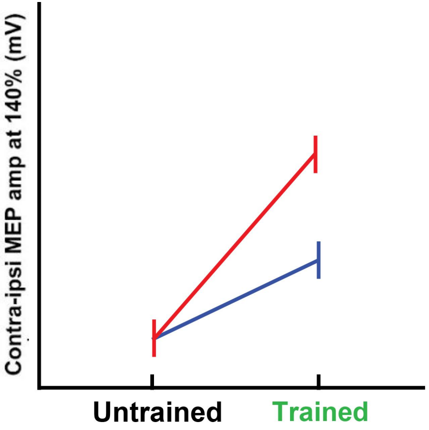




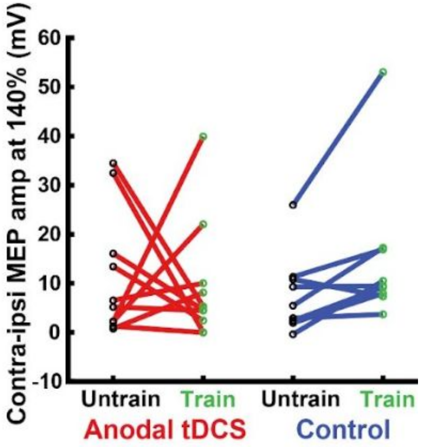
Motor Evoked Potential (MEP)



Prediction

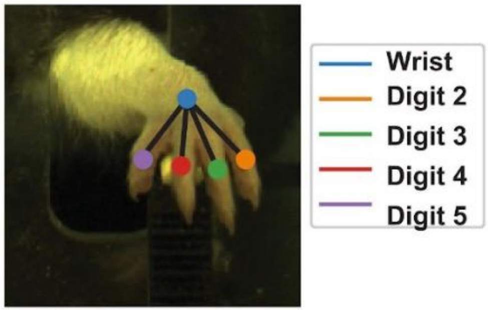


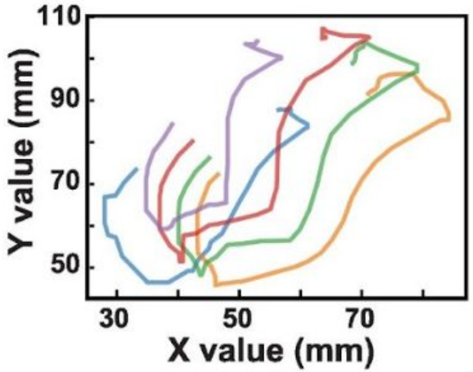
Our results

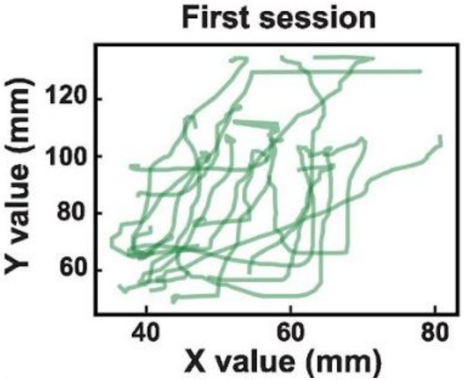


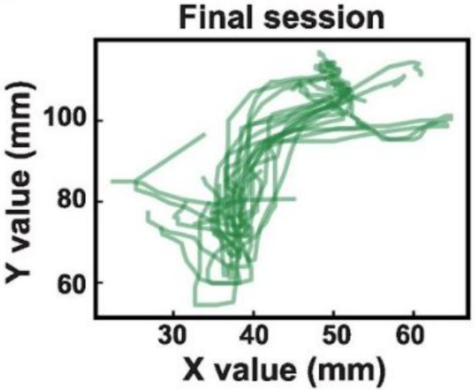
N = 10 N =9

Does behavior become more stereotypical?

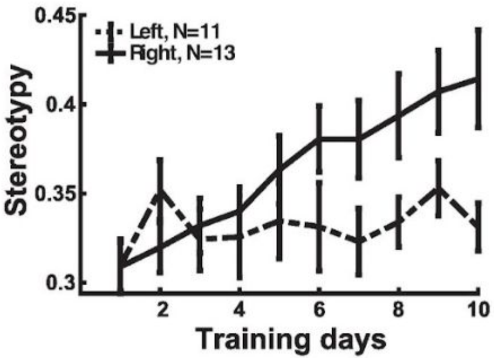




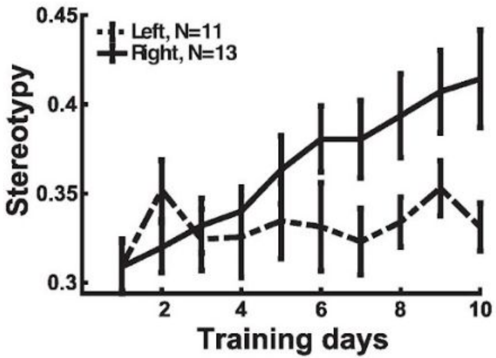


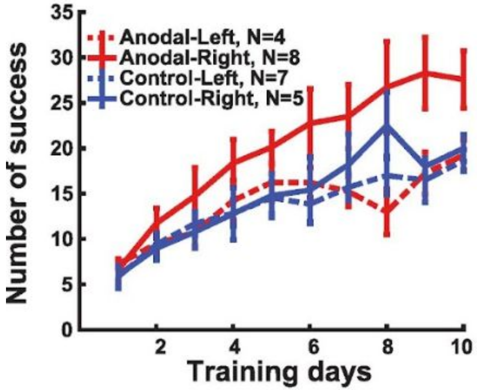


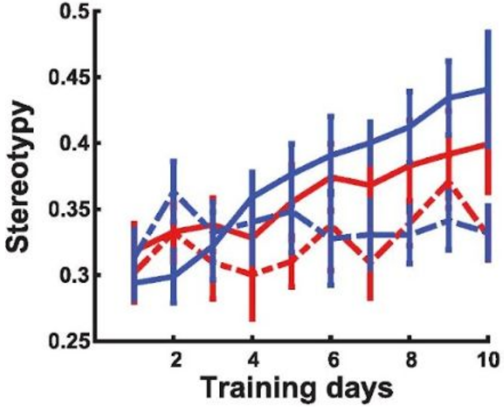
Does behavior become more stereotypical?



Behavior becomes more stereotypical for right-pawed rats.







Conclusion:

Weak electric field and motor skill learning:

Concurrent tDCS interacts with days of training in behavioral outcome.

Concurrent tDCS with training in MEP amplitude interacts but in the opposite direction.

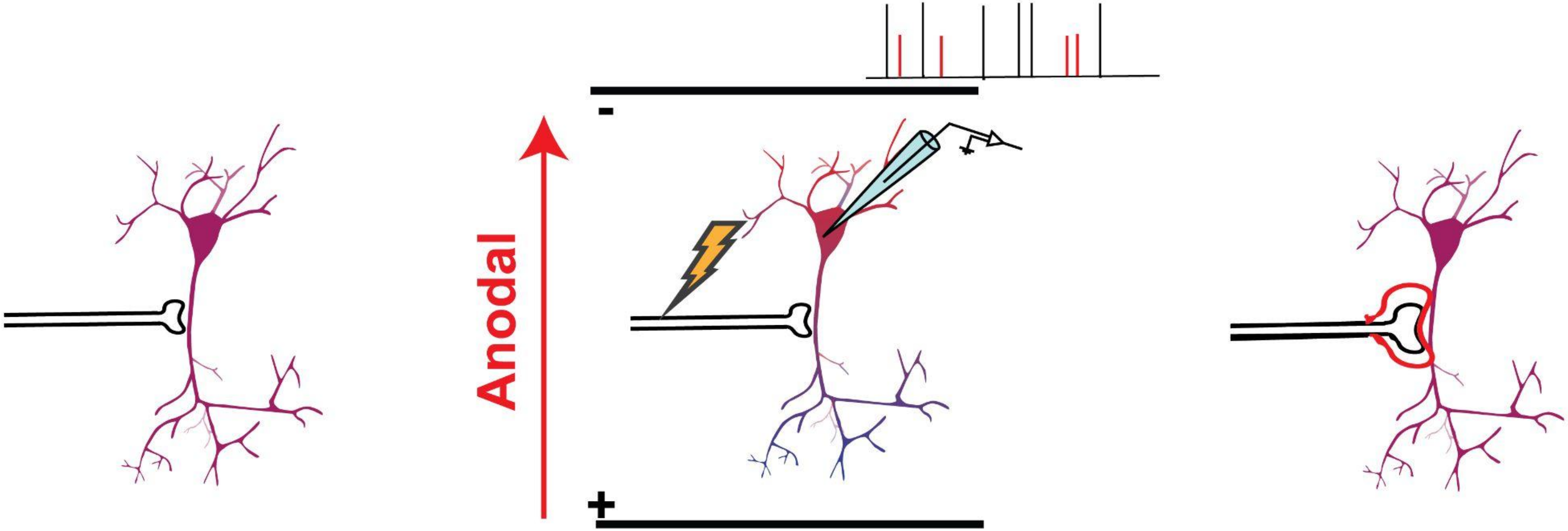
Possible explanation:

They do not have the same mechanistic substrate:
corticocortical vs. corticospinal connections

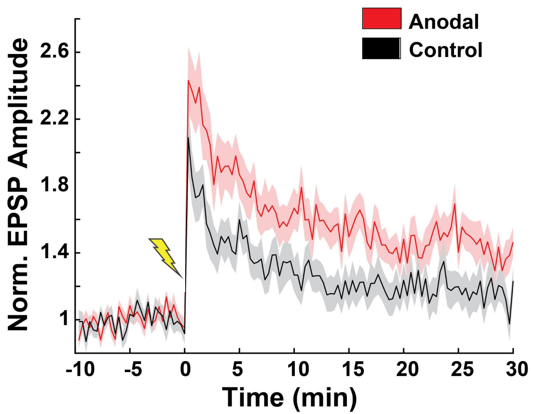
Underlying mechanism

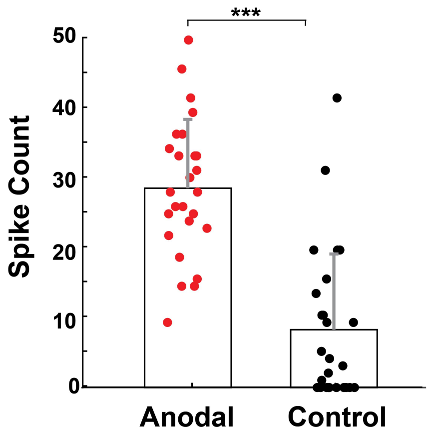
- ❑ **Higher firing rate ➡ stronger potentiation**

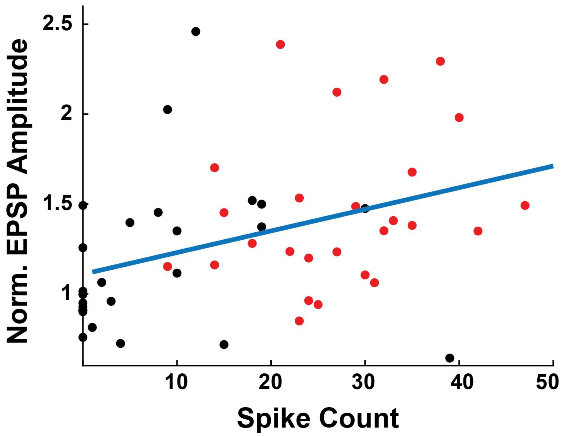
  Sjöström et al, 1993, Science



Results:







N = 26

N = 26

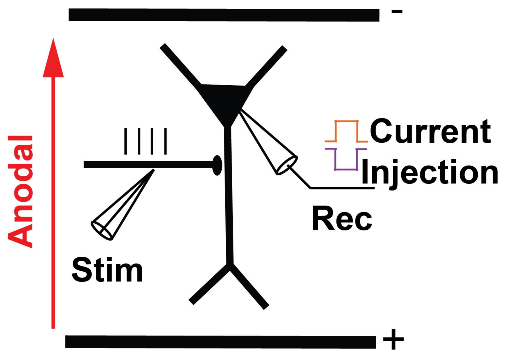
***p < 0.001

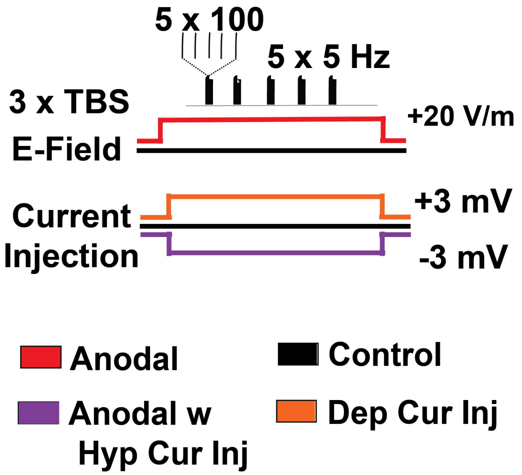
r=0.38

Controlled intervention to establish causality

Emulate: injecting a positive current to depolarize the soma

Abolish: DCS while injecting a negative current

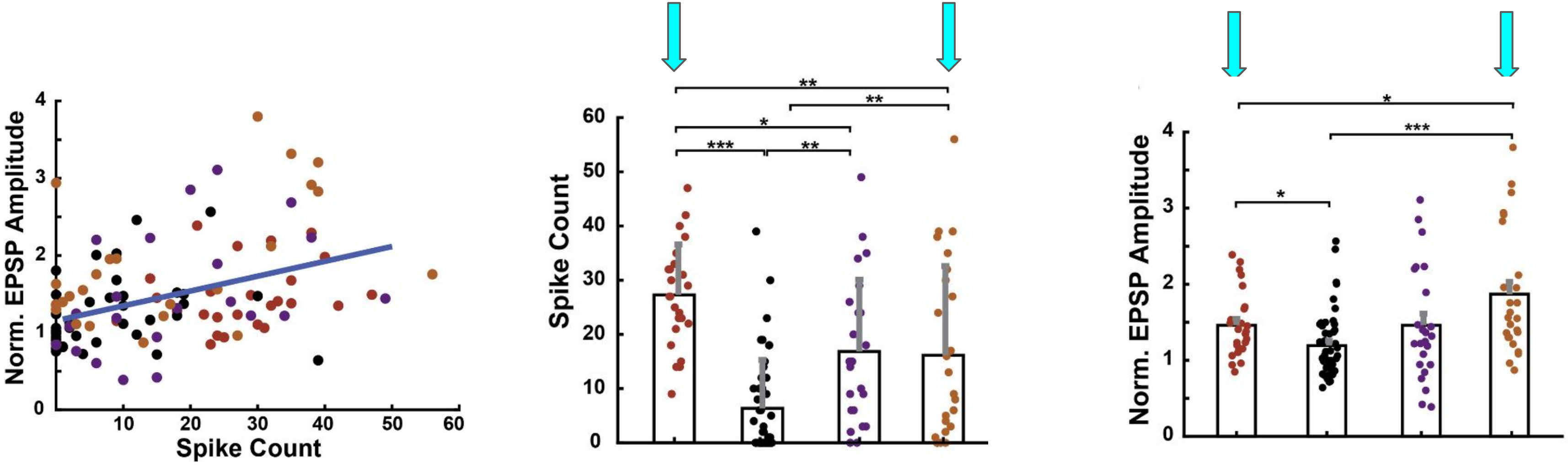




Earlier studies: 0.15 mv per 1V/m electric field

Radman et al. 2009 Brain Stim.; Berzhanskaya et al 2013 J. Comput Neurosci.

Results:

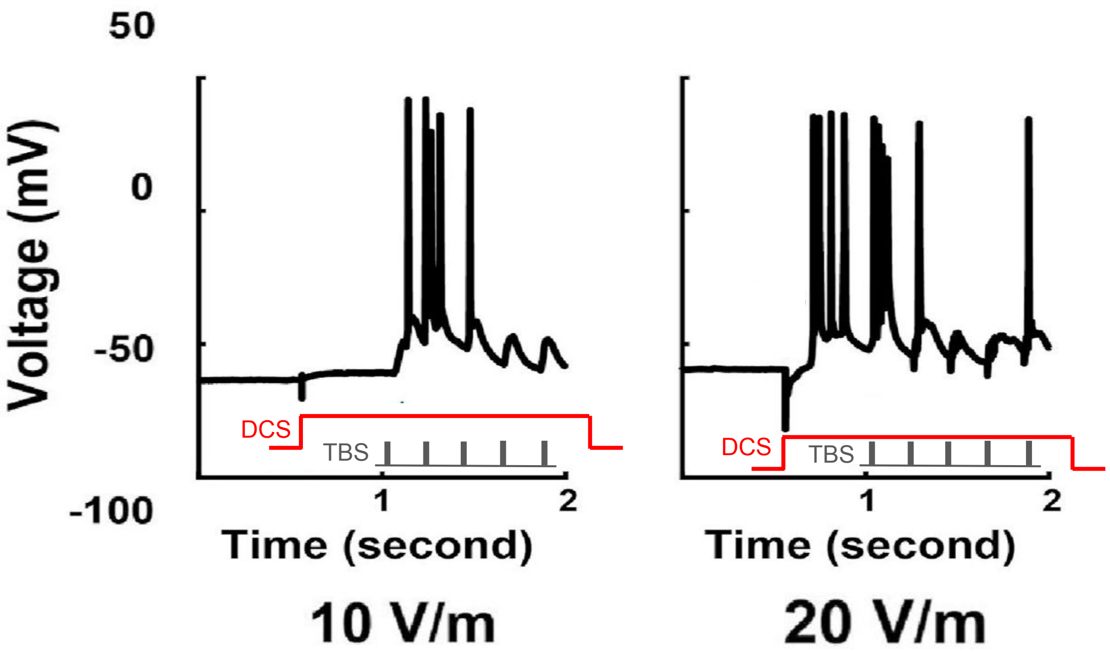


r=0.42

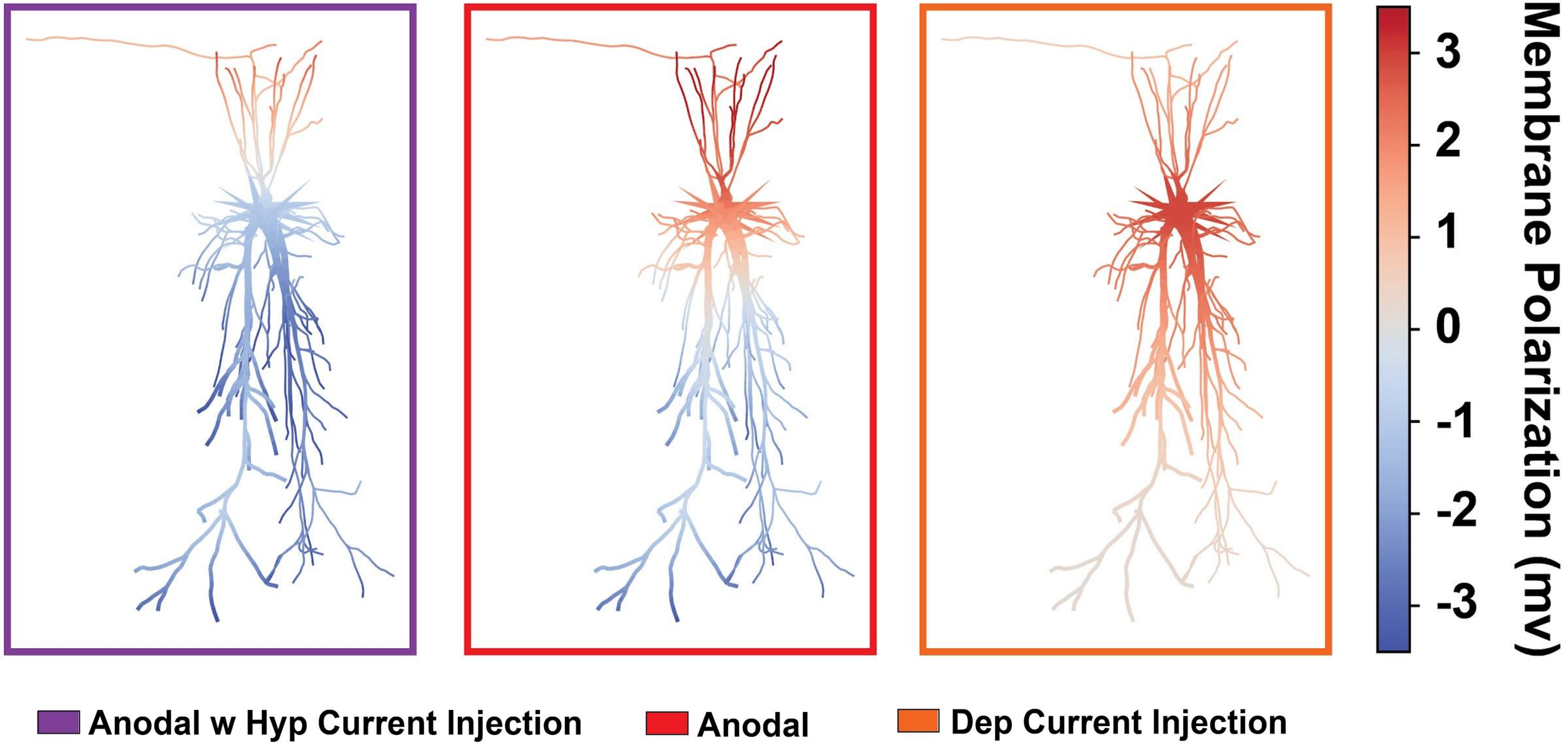
N = 48, N = 26, N =24, N =25

Anodal
Control
Anodal w Hyp Current Injection
Dep Current Injection

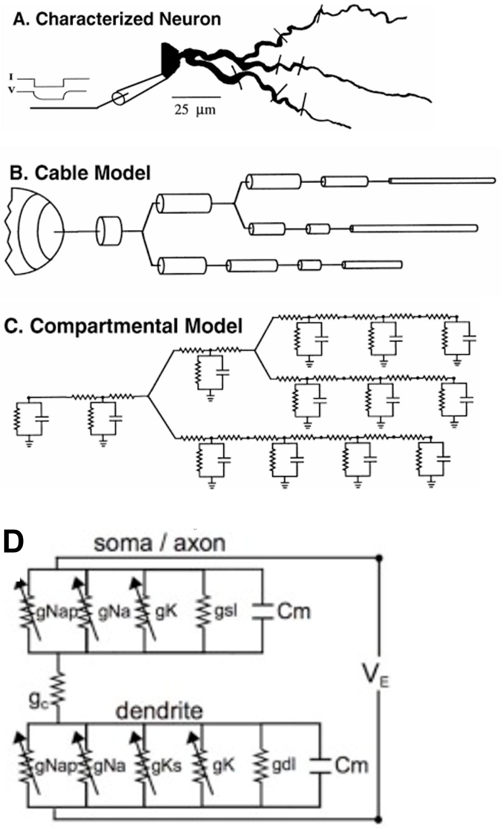
DCS evoked network activity



Computational modeling



Computational modeling



•Voltage dynamics (Berzhanskaya et al 2013 J. Comput Neurosci.)

•Membrane polarization and acute effects (Radman et al. 2009 Brain Stim.; Bikson et al.2004 J. Physiol.)

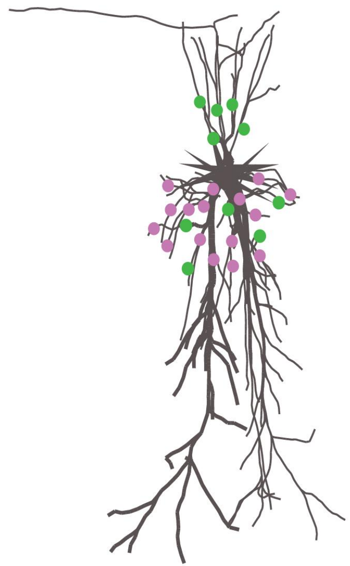
•Synaptic plasticity (Clopath et al. 2010 Nat. Neurosci.): **M1**

•M1 + Poisson Spike trains: **M2**

To include DCS-induced network activity

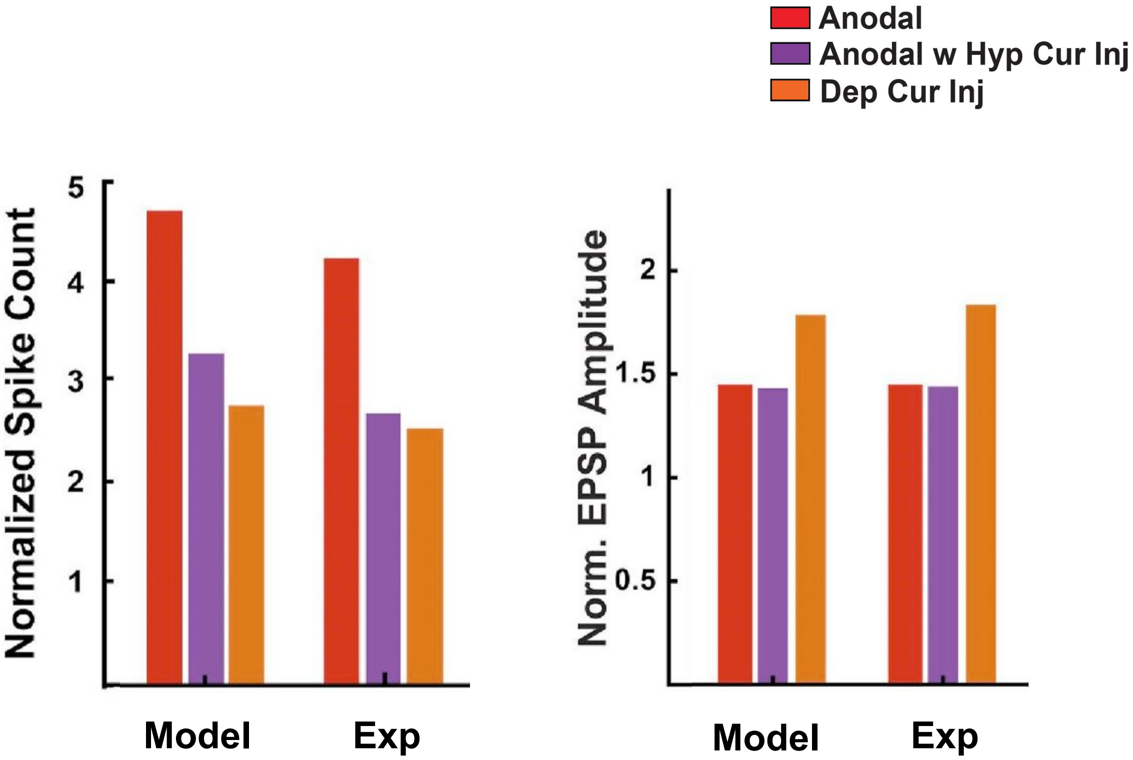
•M2 + homeostatic mechanism(Delattre et al, 2015, Front Cell Neurosci): **M3**

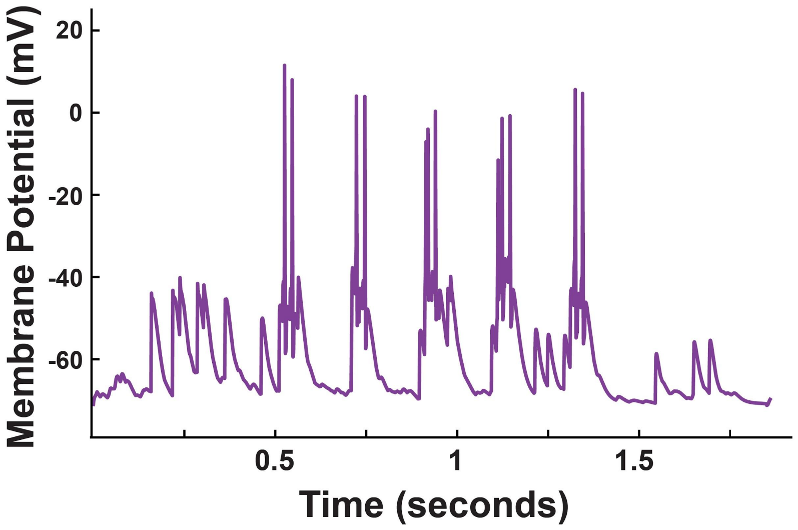
Computational modeling



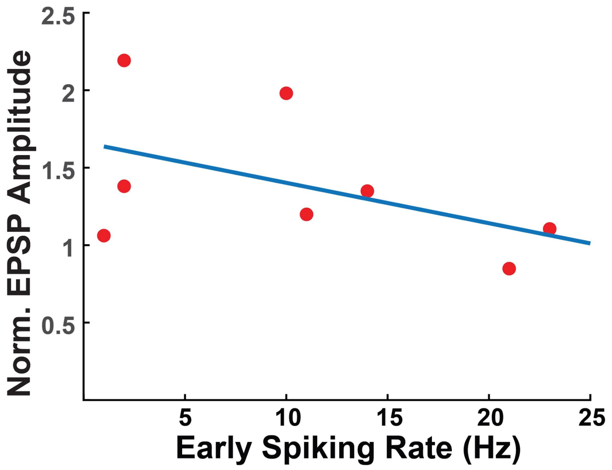
Synapses stimulated by TBS

Synapses stimulated by spontaneous network activity due to DCS





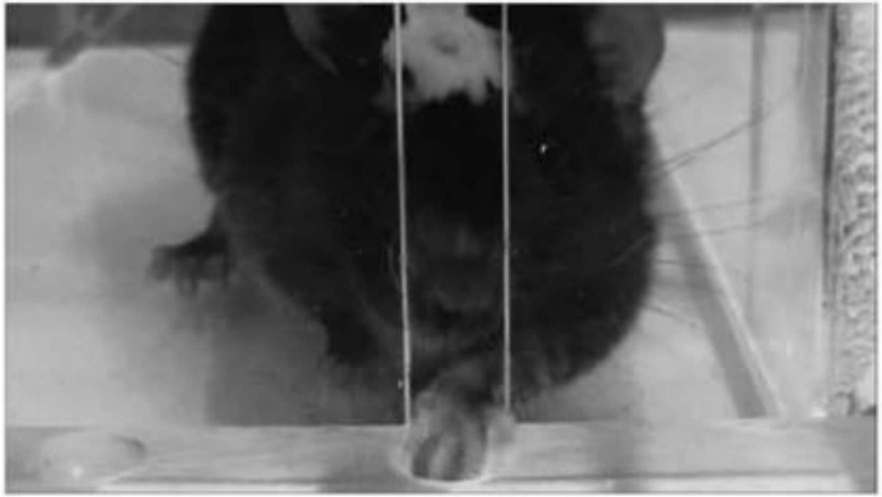
Membrane Potential (mV)
20
0
-20
-40
-60
0.5
1
1.5
Time (seconds)

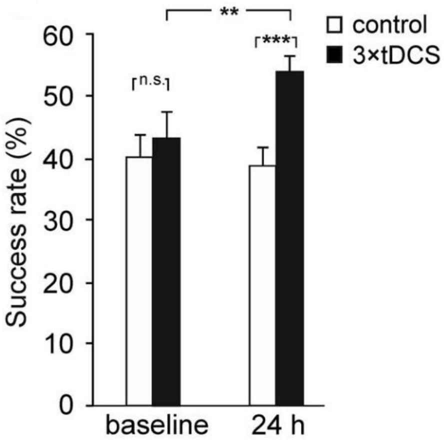


Norm. EPSP Amplitude
2.5
2
1.5
1
0.5
5
10
15
20
25
Early Spiking Rate (Hz)

tDCS and motor skill learning

- tDCS experiment in mice

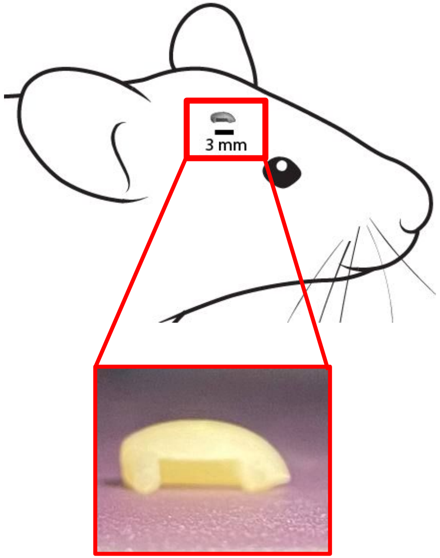




Barbati et al, Cereb Cortex 2020

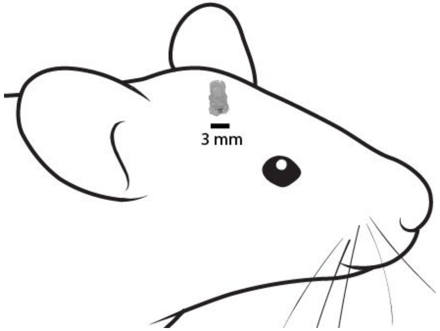
Technical development

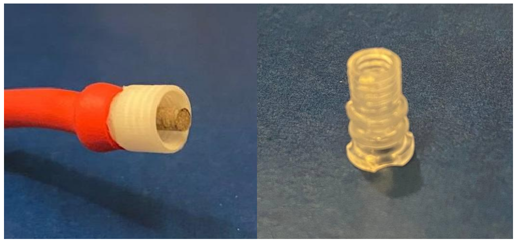
PI Plate, 2x2 mm^2



- Not stable current over 10 sessions

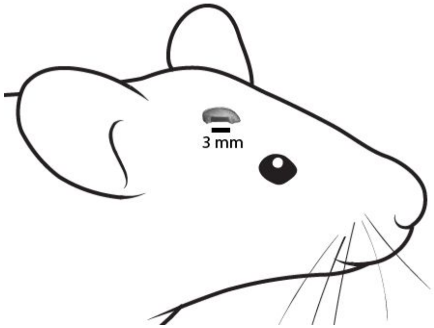
Ag/AgCl, Cylinder



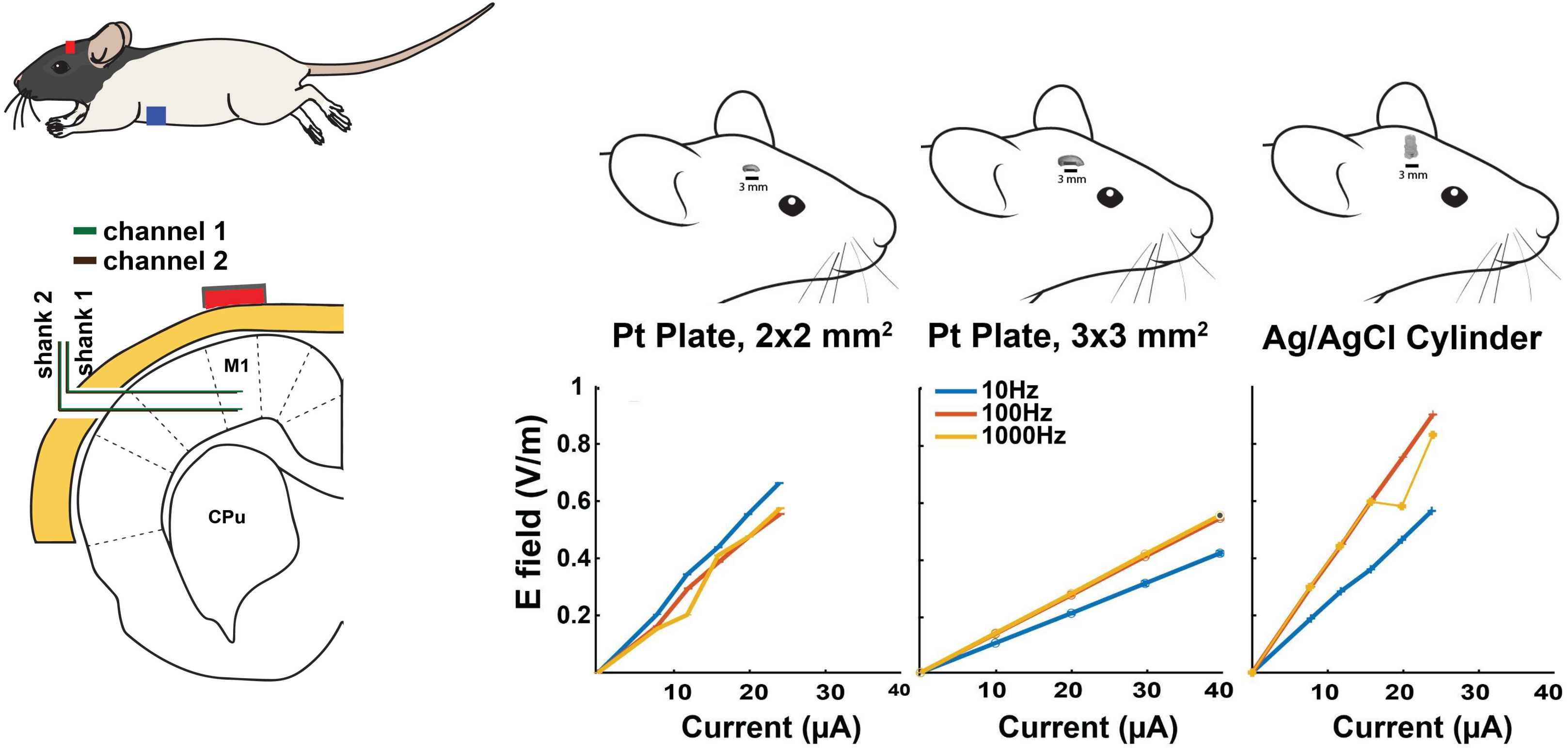


- Gel residual and infection
- Ag/AgCl electrode break

PI Plate, 3x3 mm^2

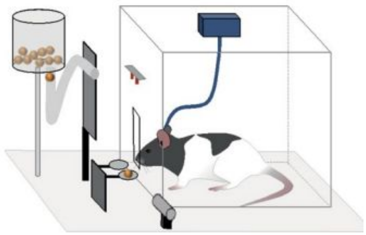


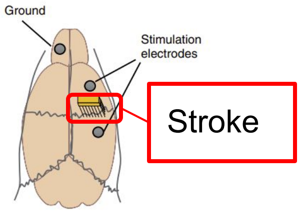
Measuring electric field

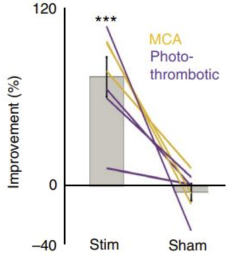


tDCS and motor skill learning

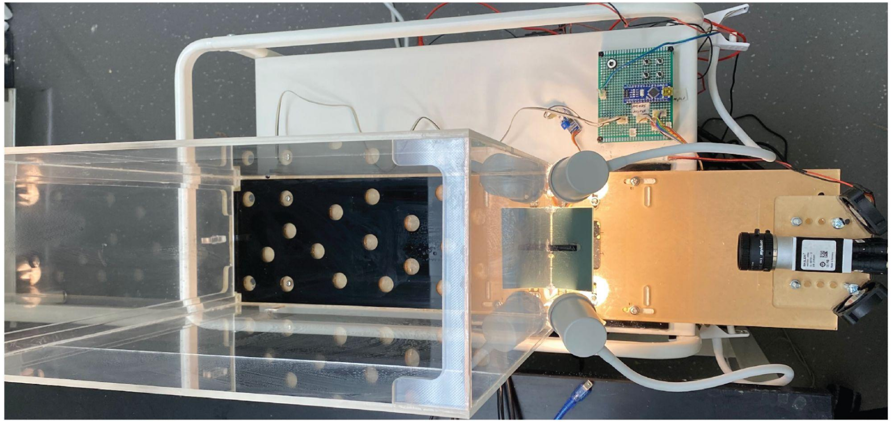
- ❑ tDCS experiment in rats

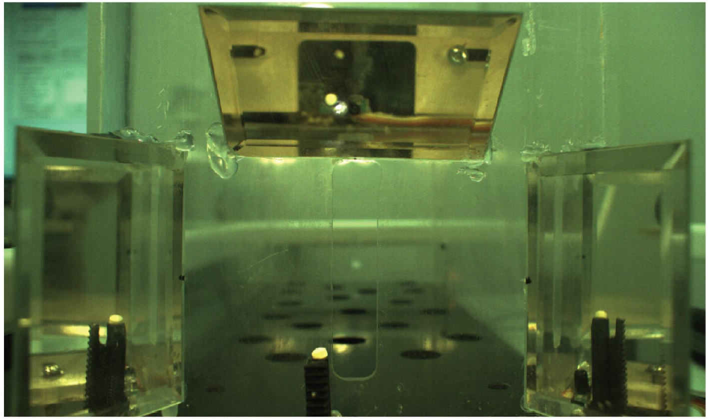




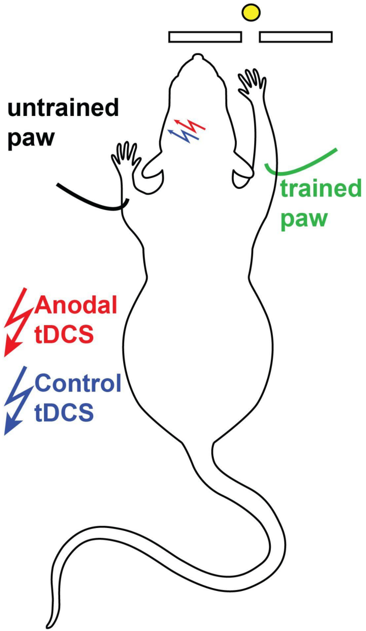


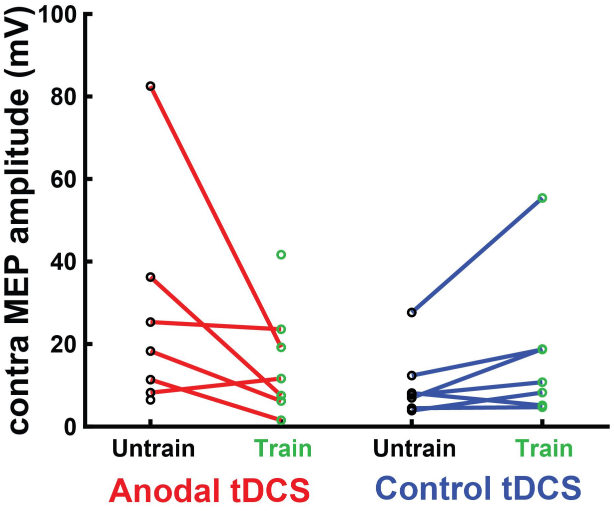
Behavioral chamber





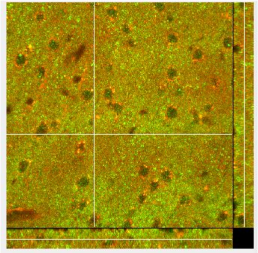
Motor Evoked Potential (MEP)





Future work:

Immunohistochemistry of synaptic marker



Studying the effect of tDCS on MEP amplitude after several days of stimulation only

Retrograde labelling of neurons

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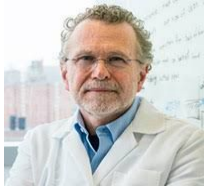



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