Conférence scientifique

Jeudi 12 juin 2025 de 12 h 00 à 13 h 00

Jason Neva, Ph. D.

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Université de Montréal – CRIUGM

Understanding and Enhancing the Neural Mechanisms Supporting Motor Learning: Applications to Motor Rehabilitation

CRIR
Centre de recherche interdisciplinaire en réadaptation du Montréal métropolitain

IURDPM
Institut universitaire sur la réadaptation en déficience physique de Montréal

Centre intégré universitaire de santé et de services sociaux du Centre-Sud-de-l'Île-de-Montréal
Québec

Harnessing Neuroplasticity to Enhance Motor Learning: *Applications in Rehabilitation*

Jason Neva, PhD

Associate Professor

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Faculté de médecine
Université de Montréal et du monde.

Centre de recherche iugm
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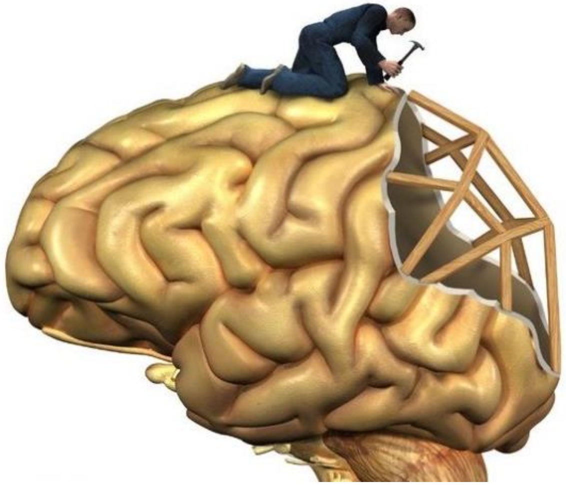
ELPN lab

Effort Learning Performance Neuroplasticity

Neuroplasticity mechanisms supporting motor learning



Motor skill learning
(healthy people)

Neuroplasticity
The ability of the brain to form and reorganize itself

Re-learning function
(e.g. after stroke)

My Lab & Research Streams

ELPN lab

Fundamental

Applied

1 **Motor Learning & Motor Control**

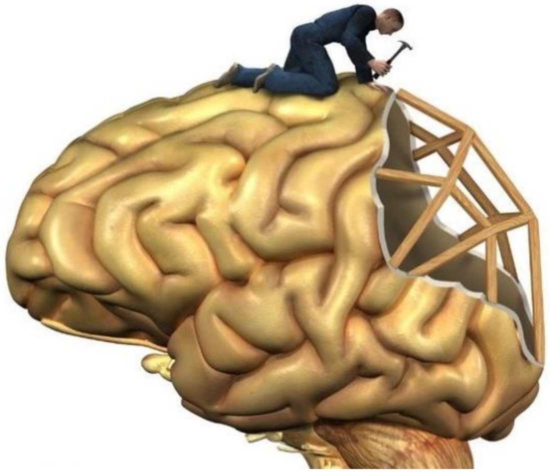
2 **Acute Exercise, rTMS**

3 **Aging, Parkinson's Disease & Stroke**

Transcranial Magnetic Stimulation (TMS):
to *measure* and *modulate* brain excitability

Adjunct Interventions: Boosting Brain & Behavior

Aerobic exercise



↑ neuroplasticity

Repetitive TMS (rTMS)

↑ motor (re)-learning

1

Aerobic Exercise:
↑ *Motor Learning*
↑ *Neuroplasticity*

2

TMS:
Measure & Modulate the Brain

3

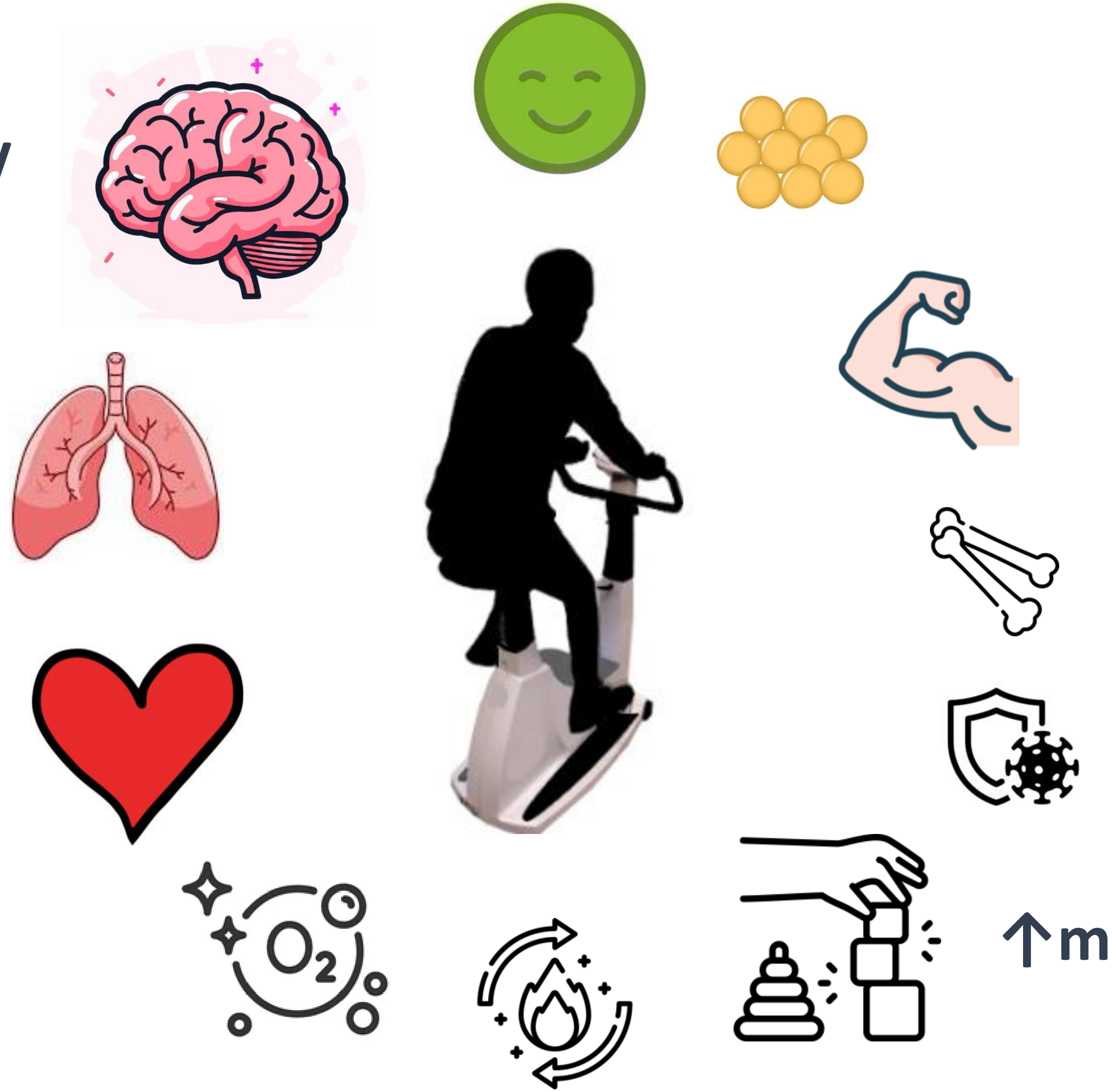
Clinical Application & Future Work

1

Aerobic Exercise:
↑ *Motor Learning*

Aerobic Exercise: Boosting Brain & Behavior

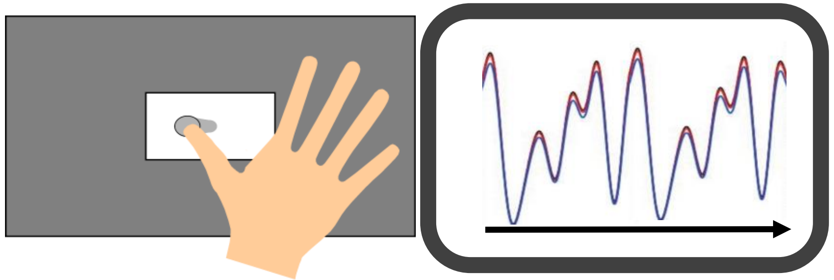
↑neuroplasticity

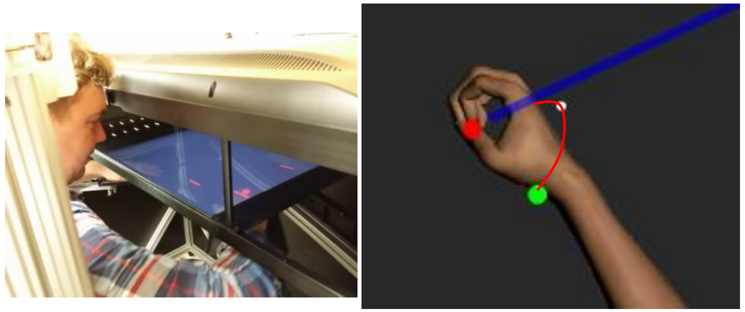


↑motor learning

Exercise enhances motor learning

Acute bout
lower limb cycling exercise
~20 min – moderate-vigorous





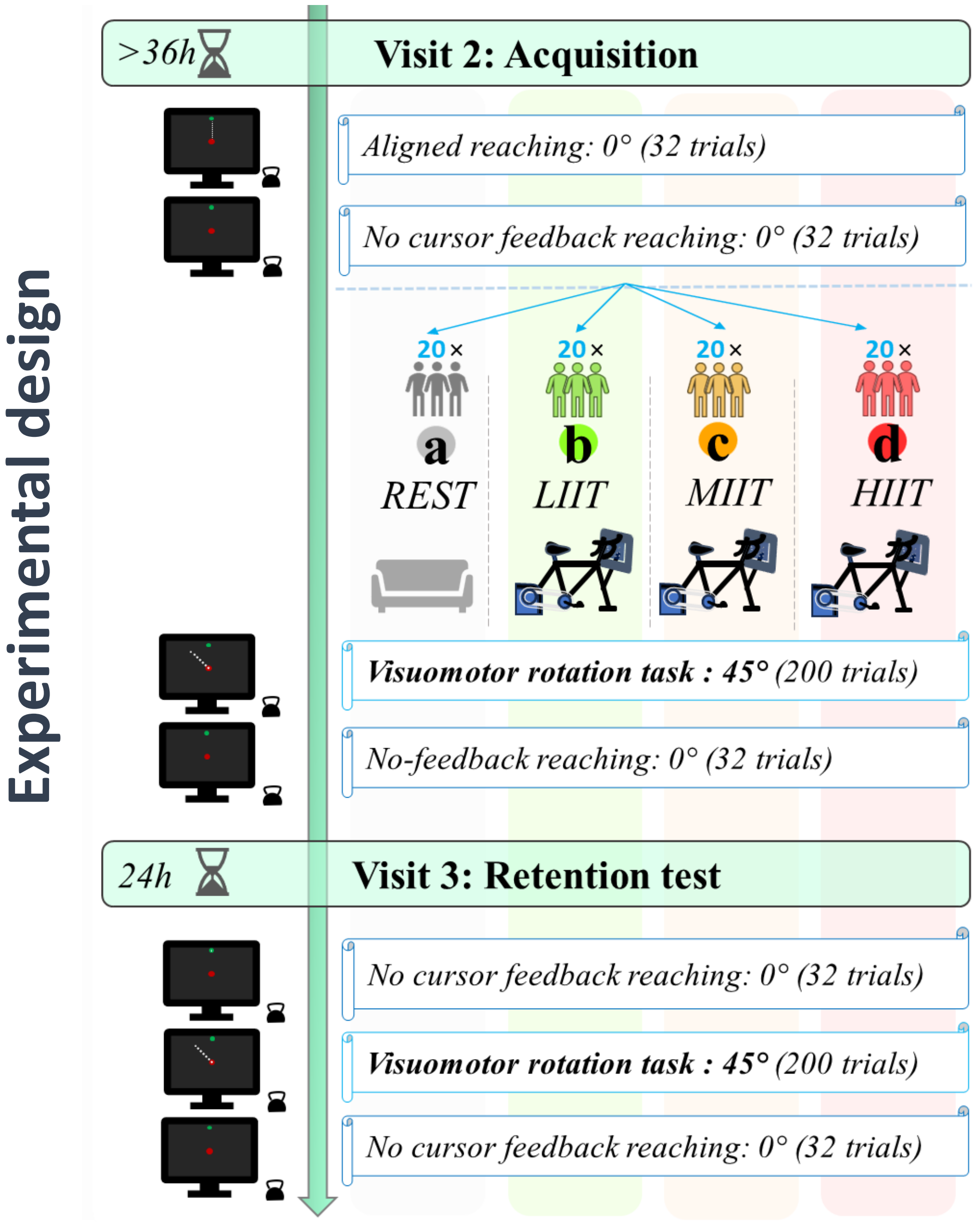
Skilled motor practice
with the *upper limb*

Unanswered questions:

- Exercise <u>intensity??</u>
- Exercise <u>type??</u>

Roig et al., 2012 *PLOS One*
Neva et al., 2019 *Exp Brain Res*
Wanner et al., 2020 *Neurosci Biobehav Rev*
Neva, 2025 Encyclopedia of the Human Brain, 2nd Ed
Youssef et al., 2025 *(in prep)*

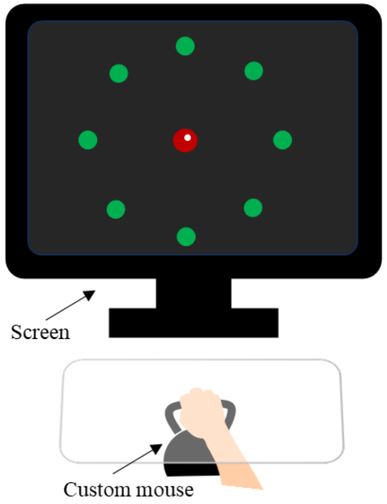
Is there a dose-response effect of acute exercise intensity?



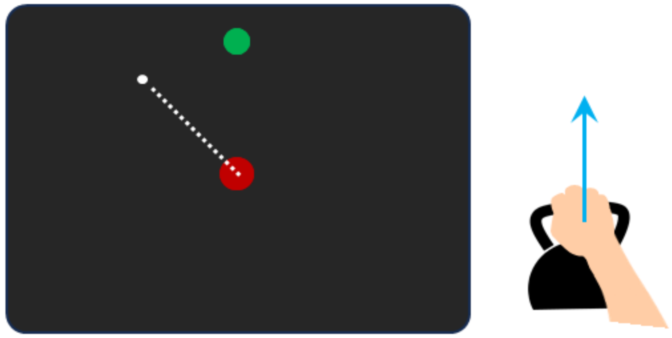
Nesrine Harroum, PhD candidate

N = 80; young adults, between-subjects design

LIIT: Light-intensity interval training
MIIT: Moderate-intensity interval training
HIIT: High-intensity interval training
REST: seated rest



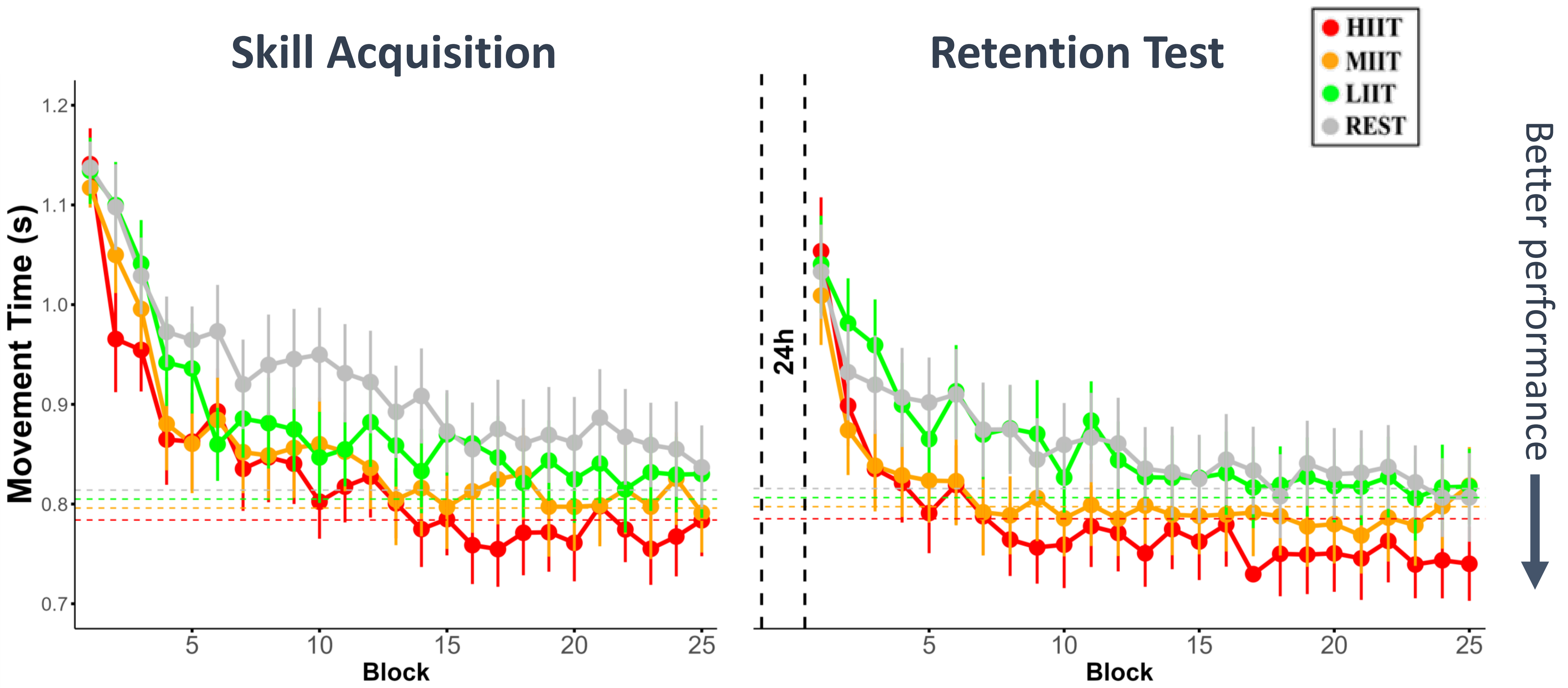
Visuomotor rotation task : 45°



*Cursor feedback is rotated **systematically** by 45° about the starting target.*

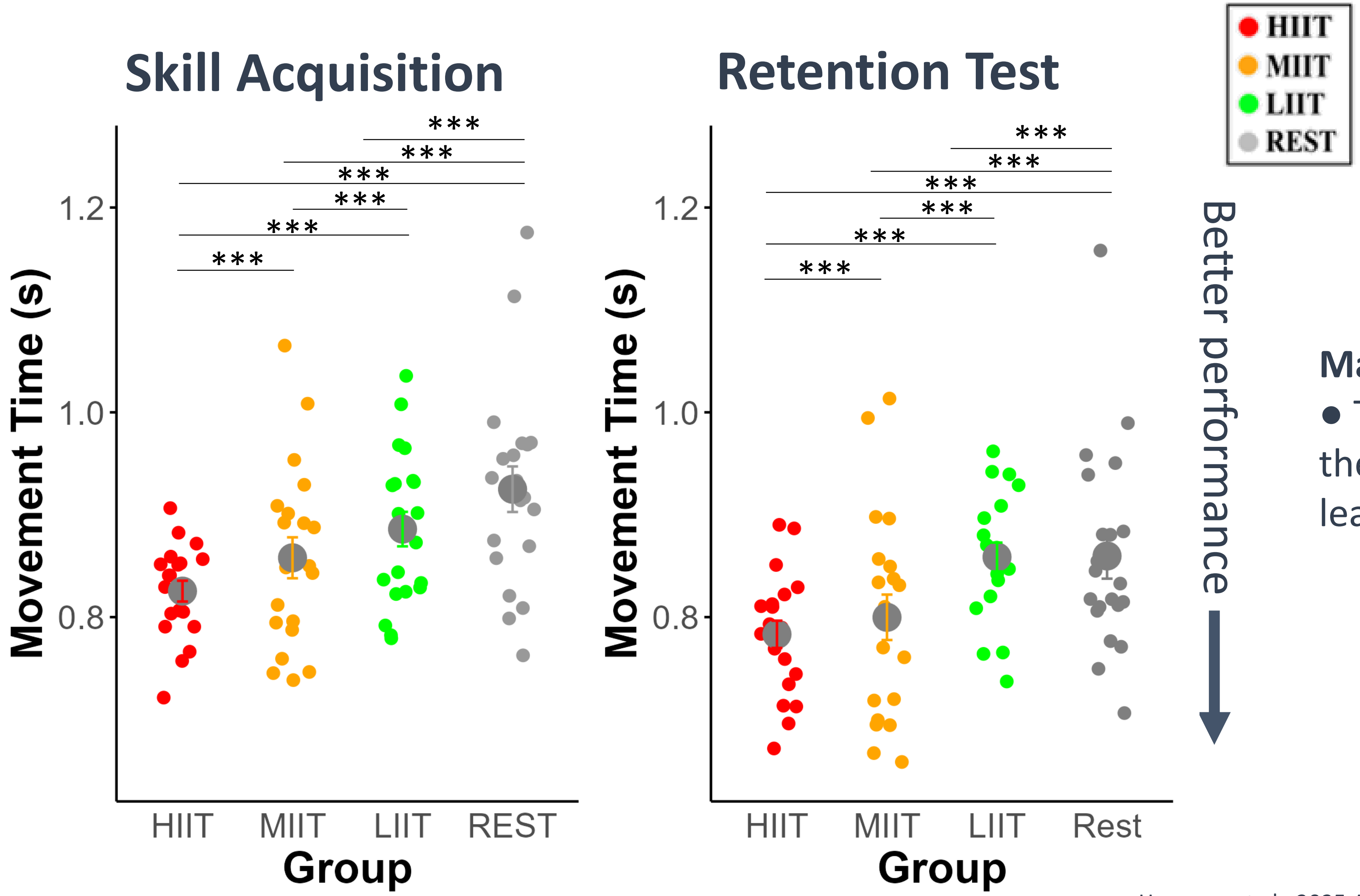
Harroum et al., 2025 *J Sport Health Sci (submitted)*

There is a dose-response effect of acute exercise intensity!



Harroum et al., 2025 *J Sport Health Sci (submitted)*

There is a dose-response effect of acute exercise <u>intensity!</u>

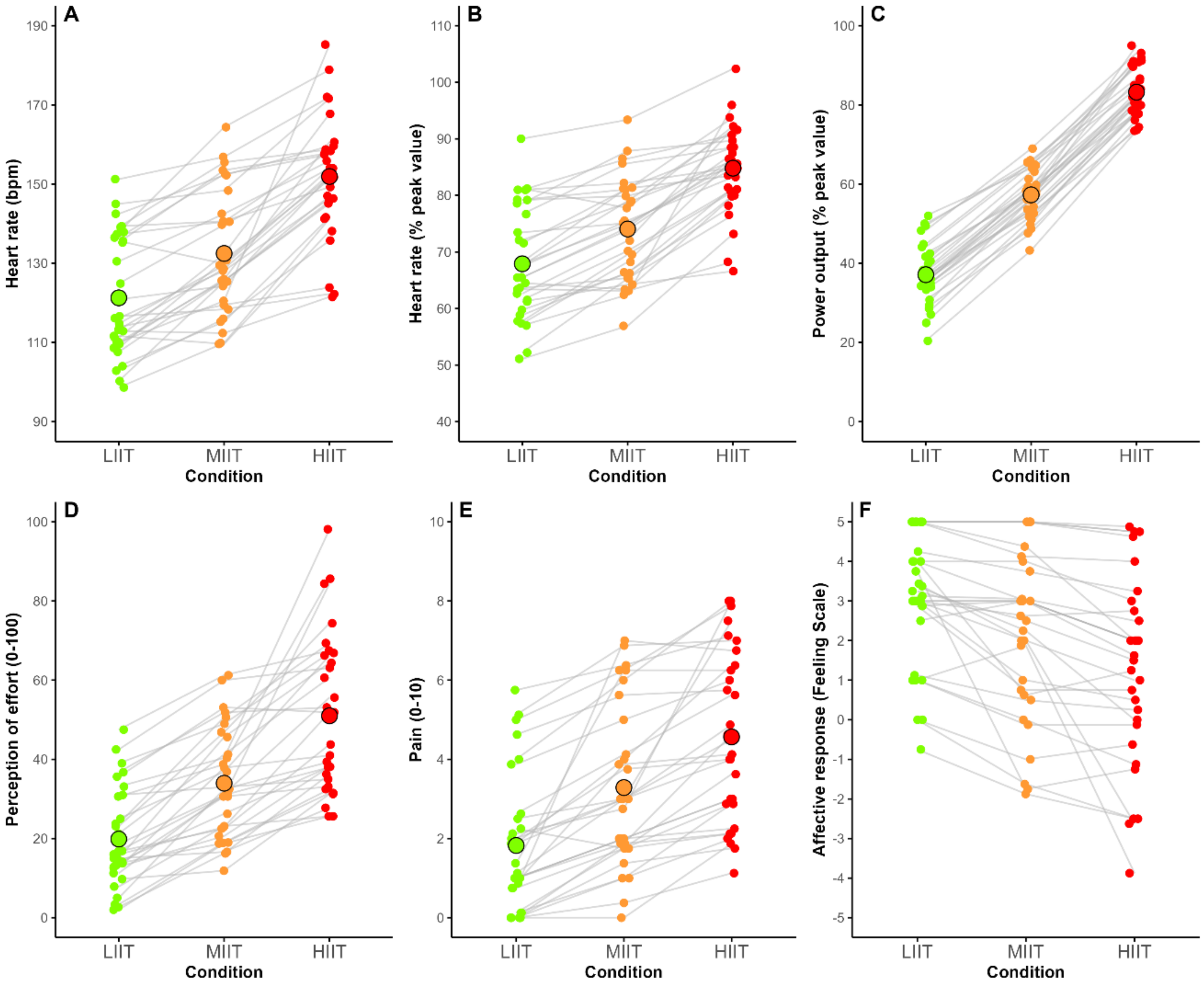


Main result(s):

- The greater the intensity, the greater the motor learning enhancement

Harroum et al., 2025 *J Sport Health Sci (submitted)*

Dose-response effect of intensity on psycho-physiological measures



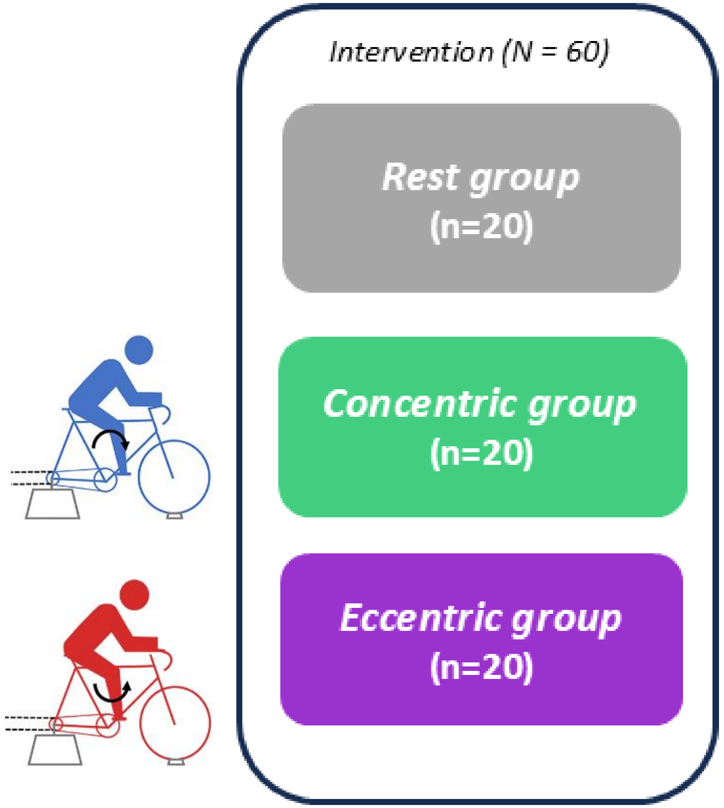
With ↑ exercise intensity there is:

- ↑ **perception of effort**
- ↑ **muscle pain**
- ↑ ***negative* affect**

Is there an effect of acute exercise <u>type?</u>

Layale Youssef, PhD student

Youssef et al., 2025
J Sport Health Sci (under review)

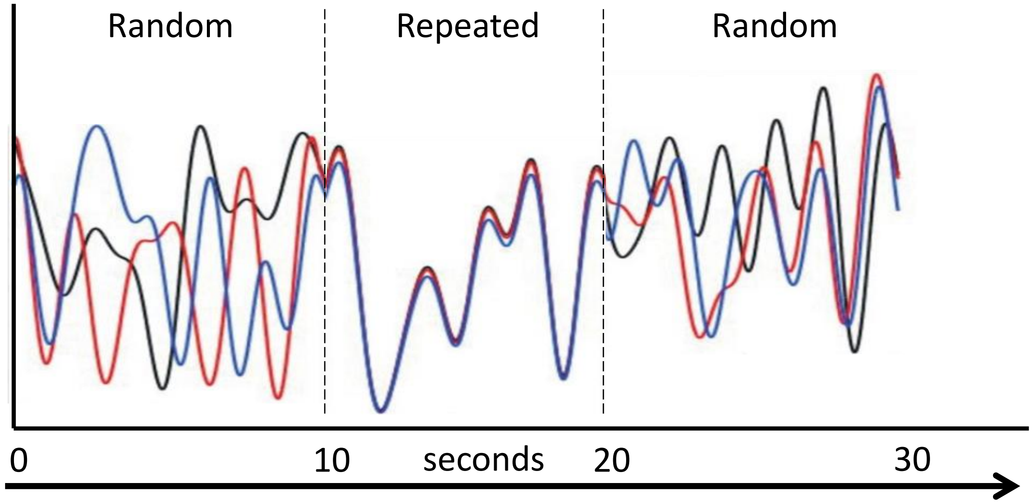


CTT: Continuous tracking task

→ CTT Practice
8 Blocks (80 trials)

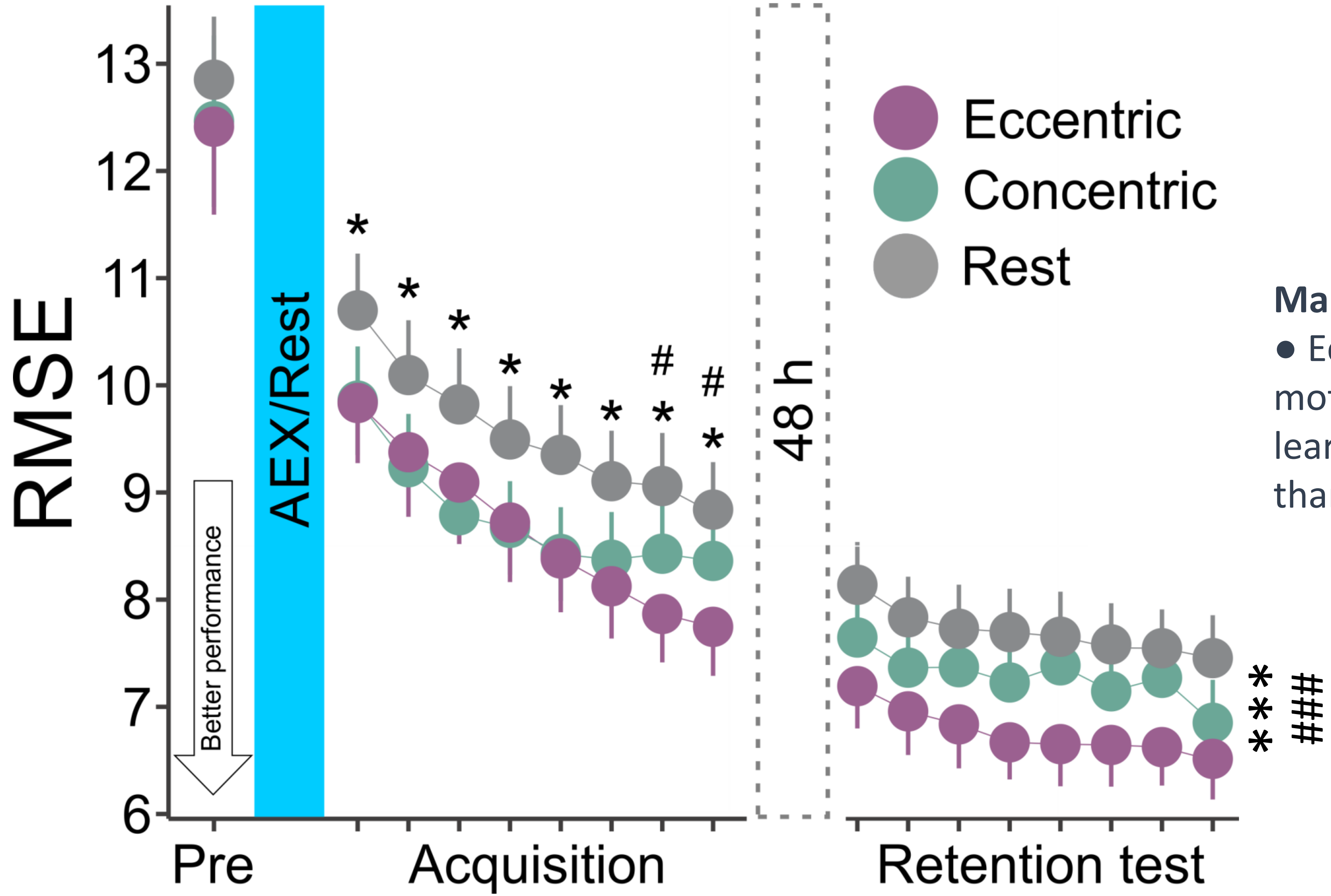
48 h →

CTT Retention
8 Blocks (80 trials)



There is an effect of acute exercise type!

Youssef et al., 2025
J Sport Health Sci (under review)

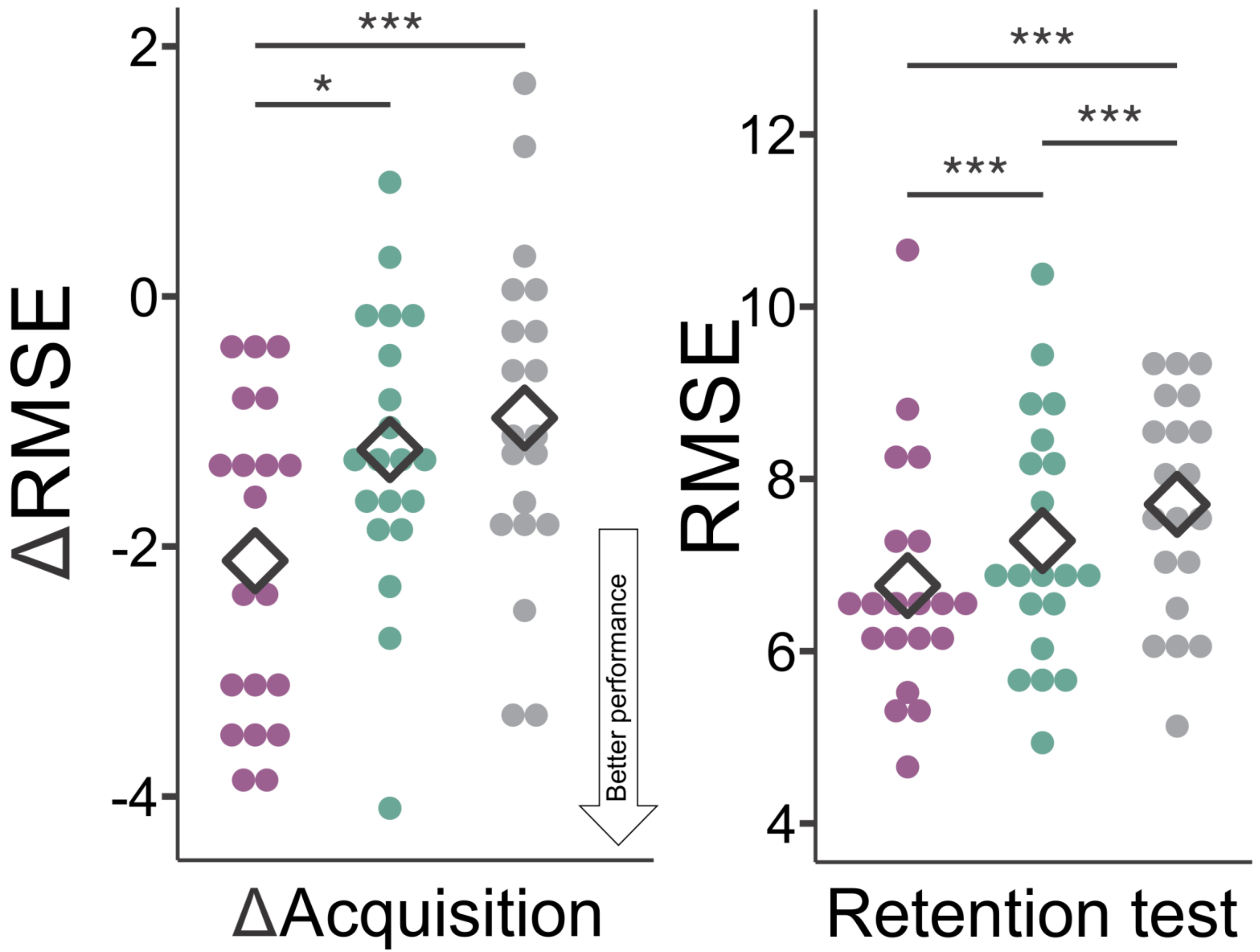


Main result(s):

- Eccentric exercise enhances motor skill acquisition and learning to a greater extent than concentric exercise

There is an effect of acute exercise type!

Youssef et al., 2025
J Sport Health Sci (under review)



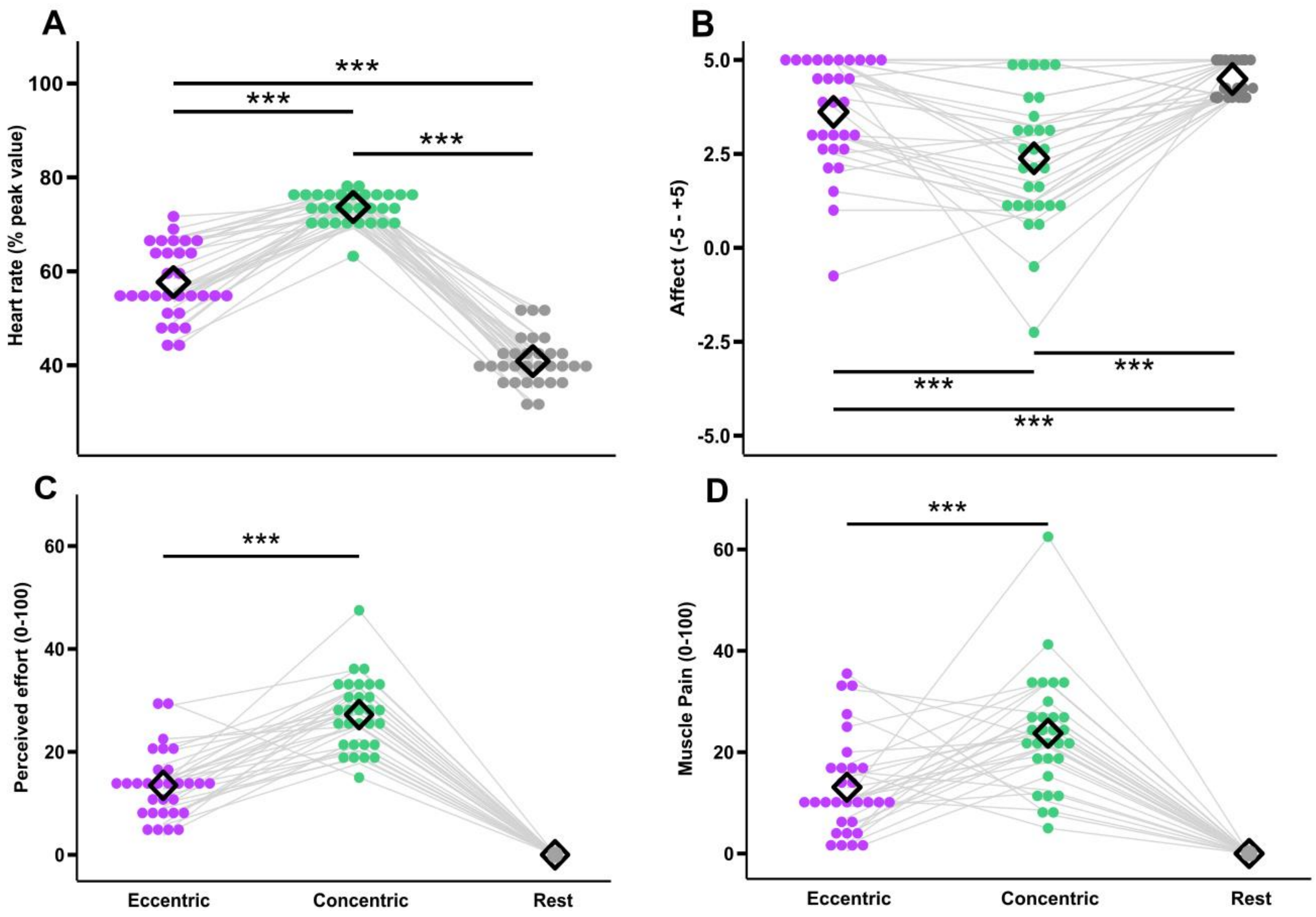
Main result(s):

● Eccentric exercise enhances motor skill acquisition and learning to a greater extent than concentric exercise

The effect of exercise type on psycho-physiological measures

Eccentric vs concentric exercise:
- ↓ heart rate response
- ↑ *positive* affect
- ↓ perception of effort
- ↓ muscle pain *during* exercise

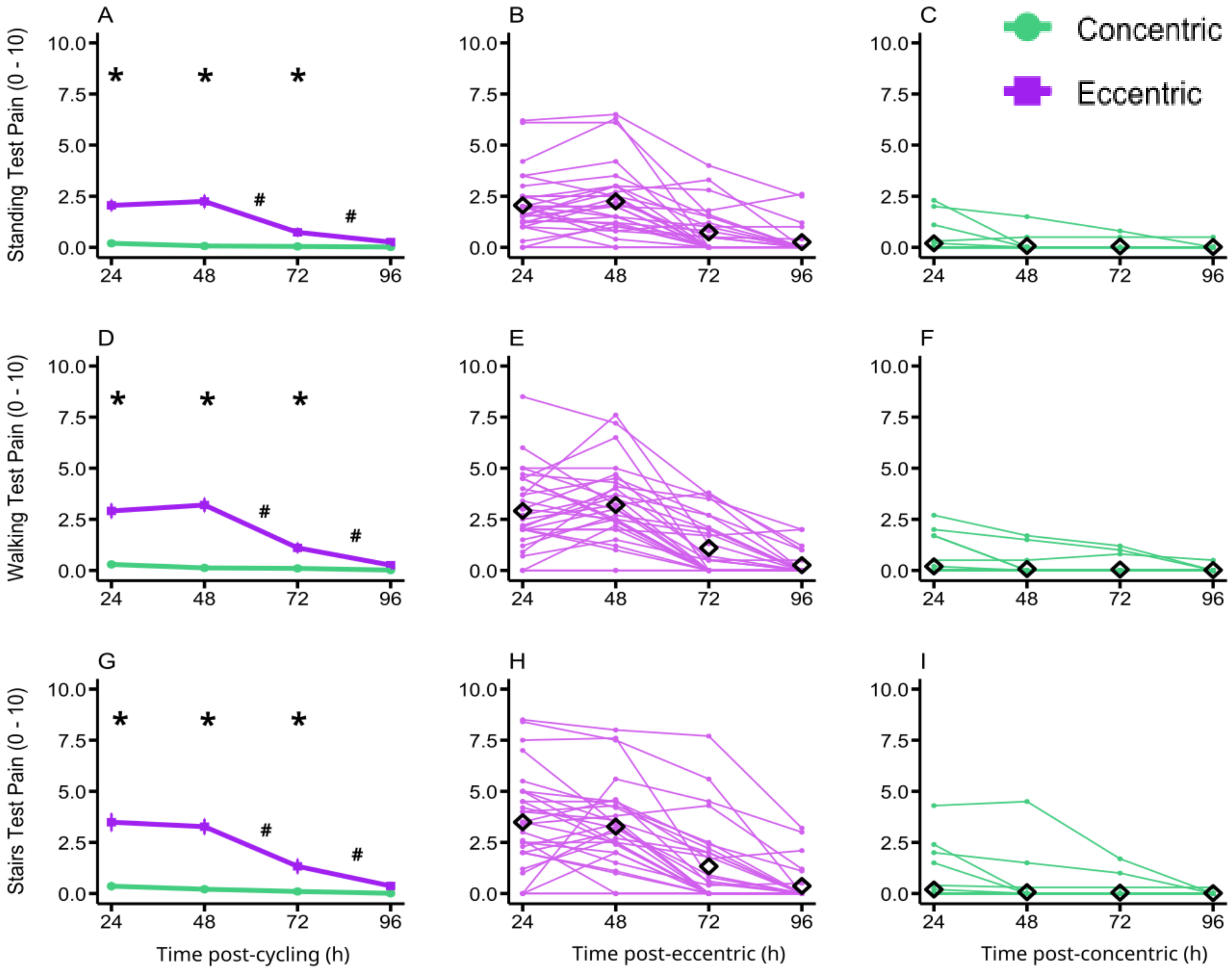
However……



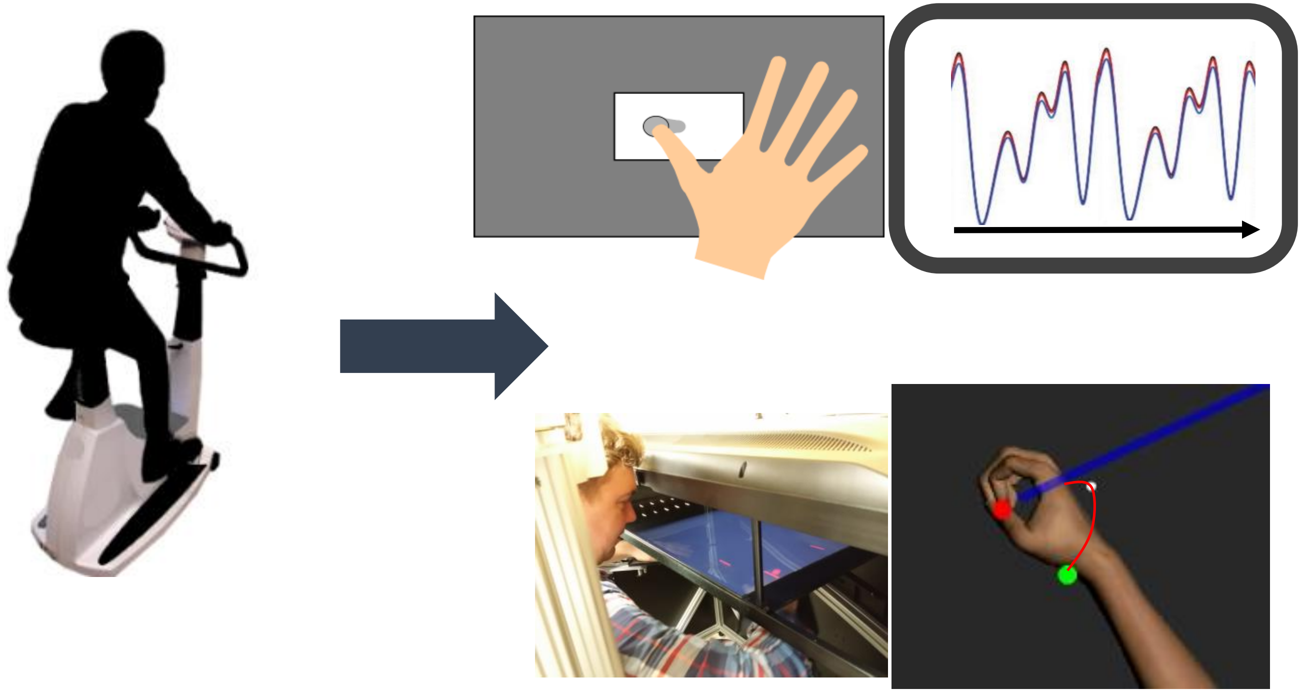
The effect of exercise <u>type</u> on *long-term muscle pain*

Eccentric vs concentric exercise:

- ↑ **muscle pain *after* exercise**
  - 24h, 48h & 72h post
  - peak at ~48h post



Exercise enhances motor learning



***Answered* questions:**

- Exercise intensity??
  - ↑ intensity, ↑ learning
- Exercise type??
  - Eccentric ↑ more than concentric (traditional)

Important considerations:

- psycho-physiological responses

Roig et al., 2012 *PLOS One*
Neva et al., 2019 *Exp Brain Res*
Wanner et al., 2020 *Neurosci Biobehav Rev*
Neva, 2025 Encyclopedia of the Human Brain, 2nd Ed
Youssef et al., 2025 *(in prep)*

Youssef et al., 2025 *J Sport Health Sci (under review)*
Harroum et al., 2025 *J Sport Health Sci (submitted)*

1

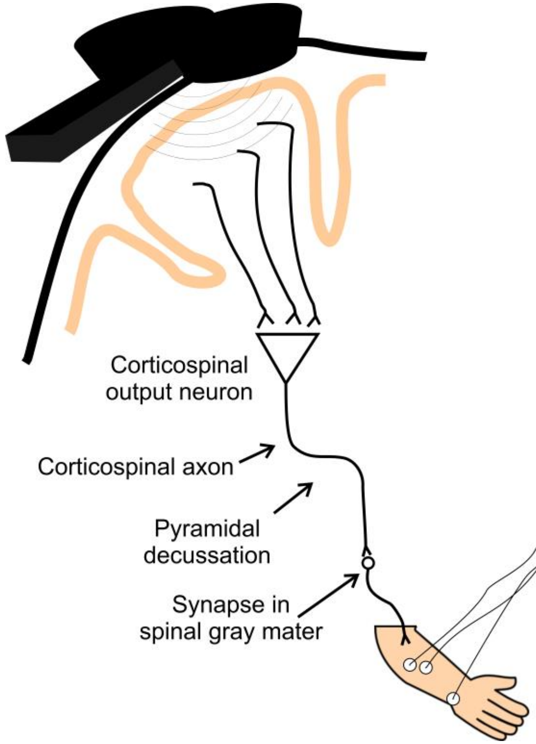
Aerobic Exercise:

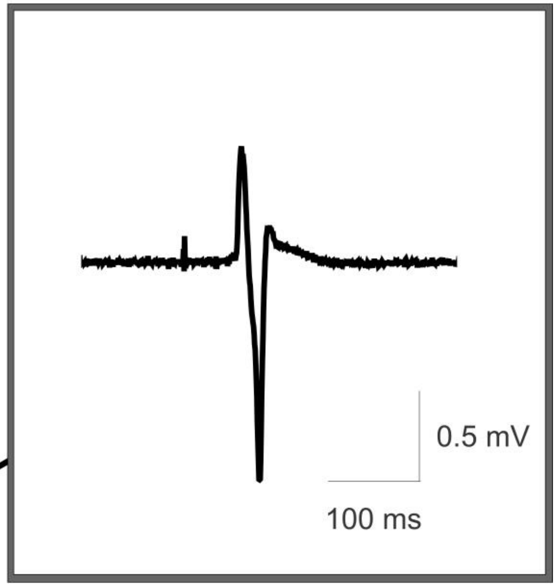
↑ *Motor Learning*

↑ *Neuroplasticity*

Measuring neuroplasticity mechanisms

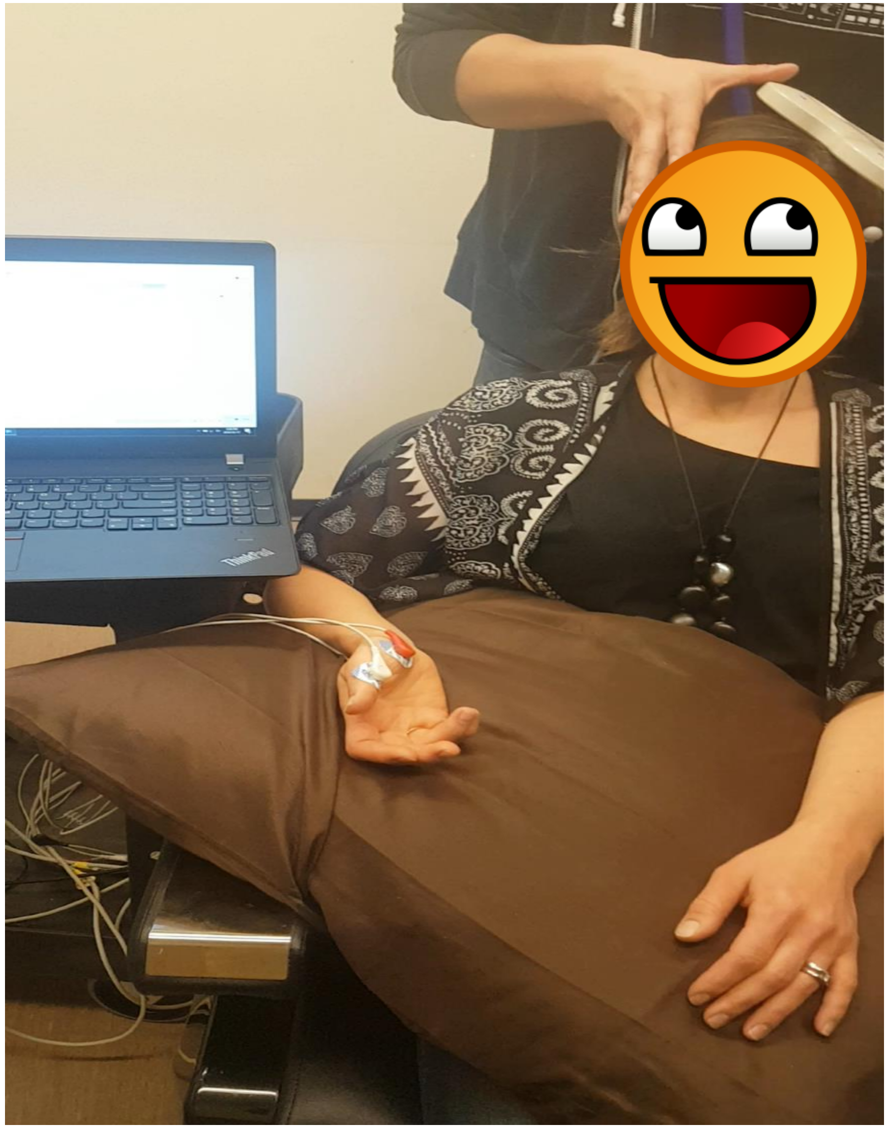
Transcranial magnetic stimulation (TMS)





Motor evoked potential (MEP)

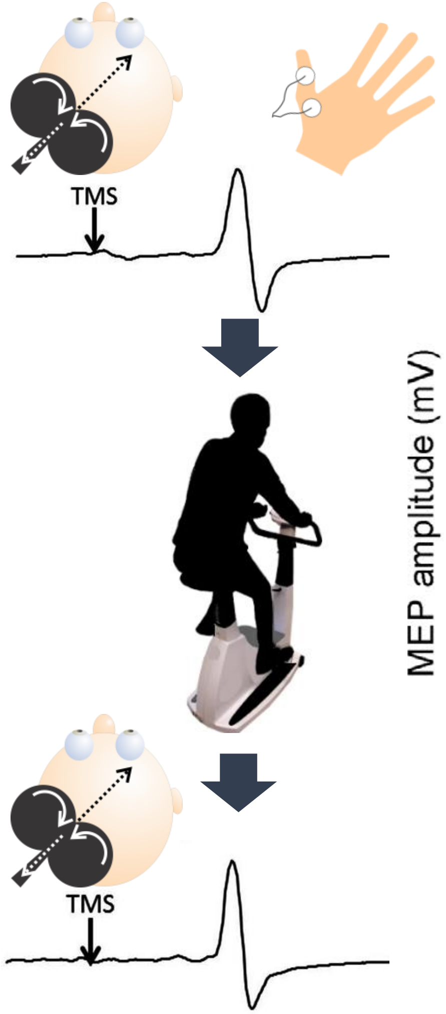
Surface electromyography (EMG)

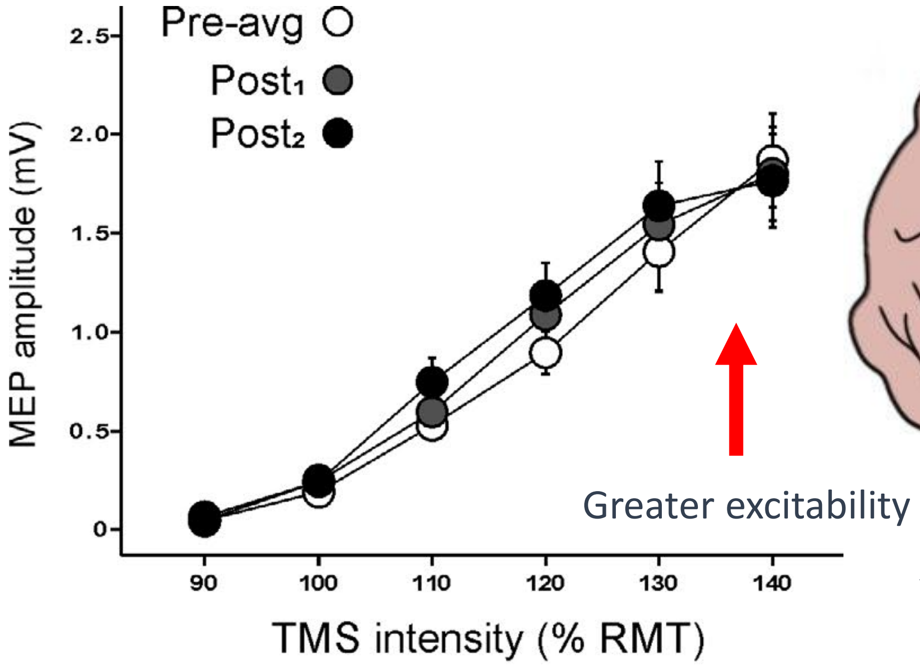


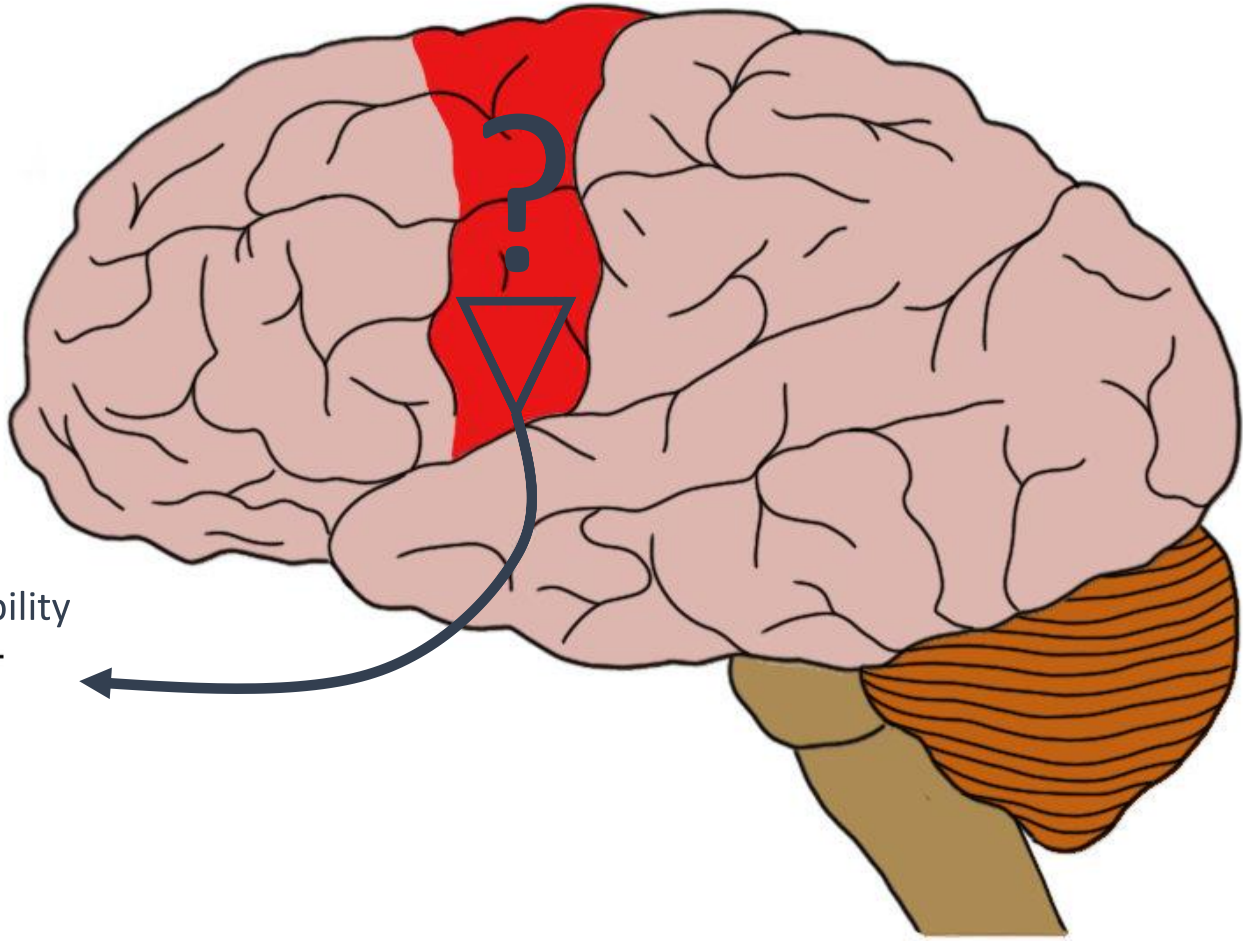
- TMS assesses brain excitability
- Biomarker of ***neuroplasticity***

Chen et al., 2008 *Clin Neurophysiol*; Neva et al., 2020 *Wiley Enc Health Psych*

Corticospinal excitability does ***not*** change

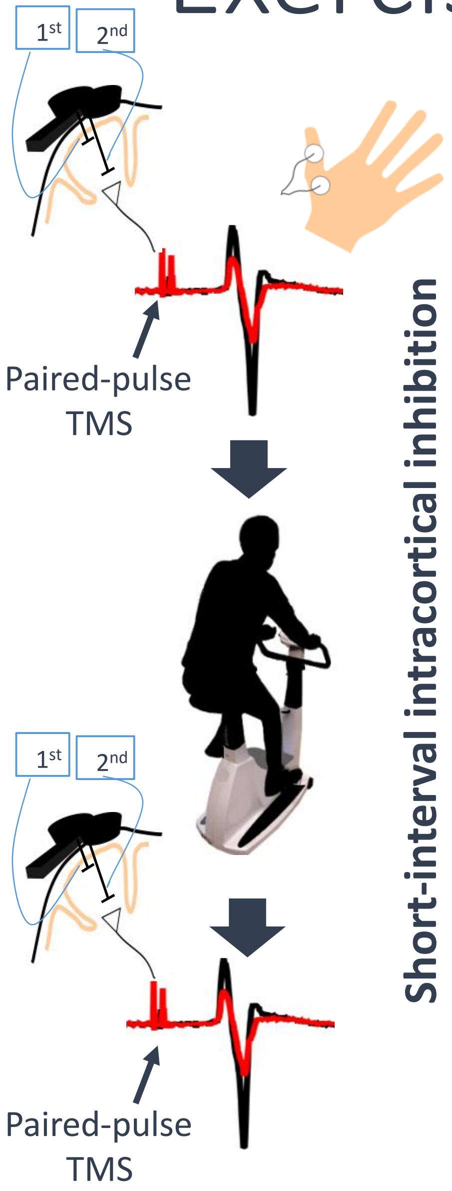


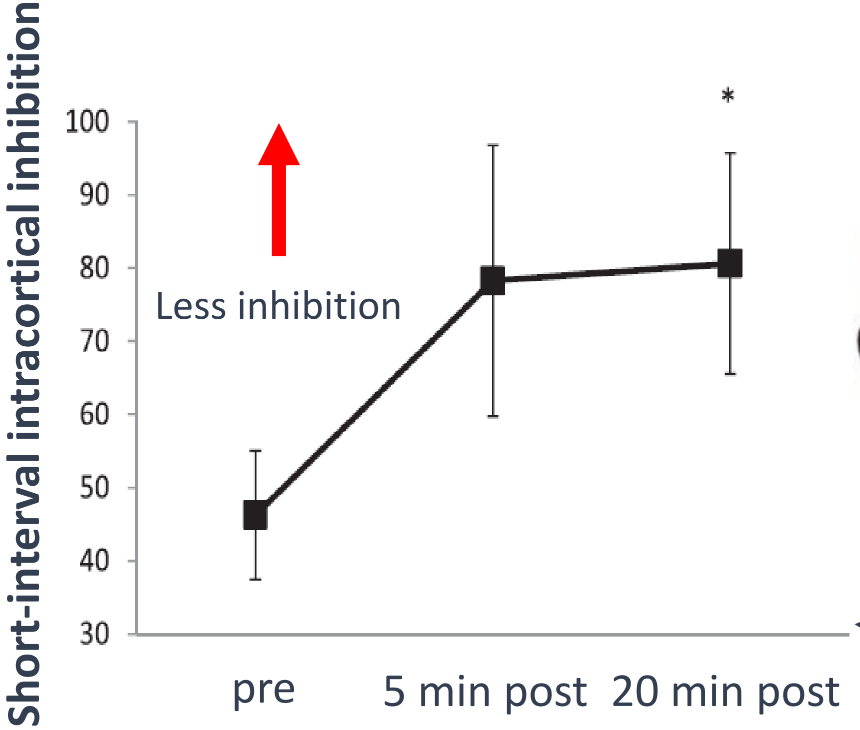


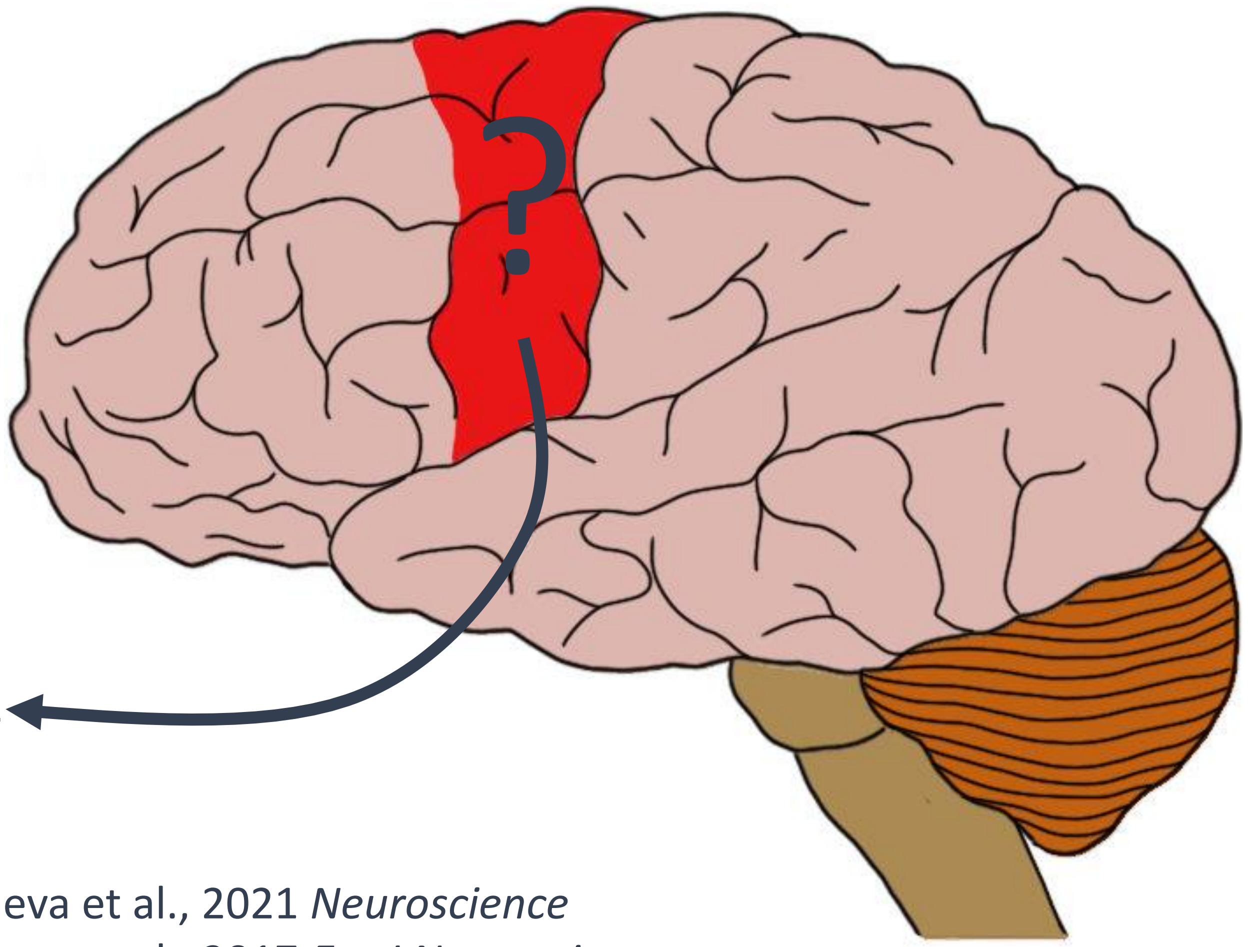


Neva et al., 2020, 2017 *Eur J Neurosci*

Exercise decreases motor cortex inhibition





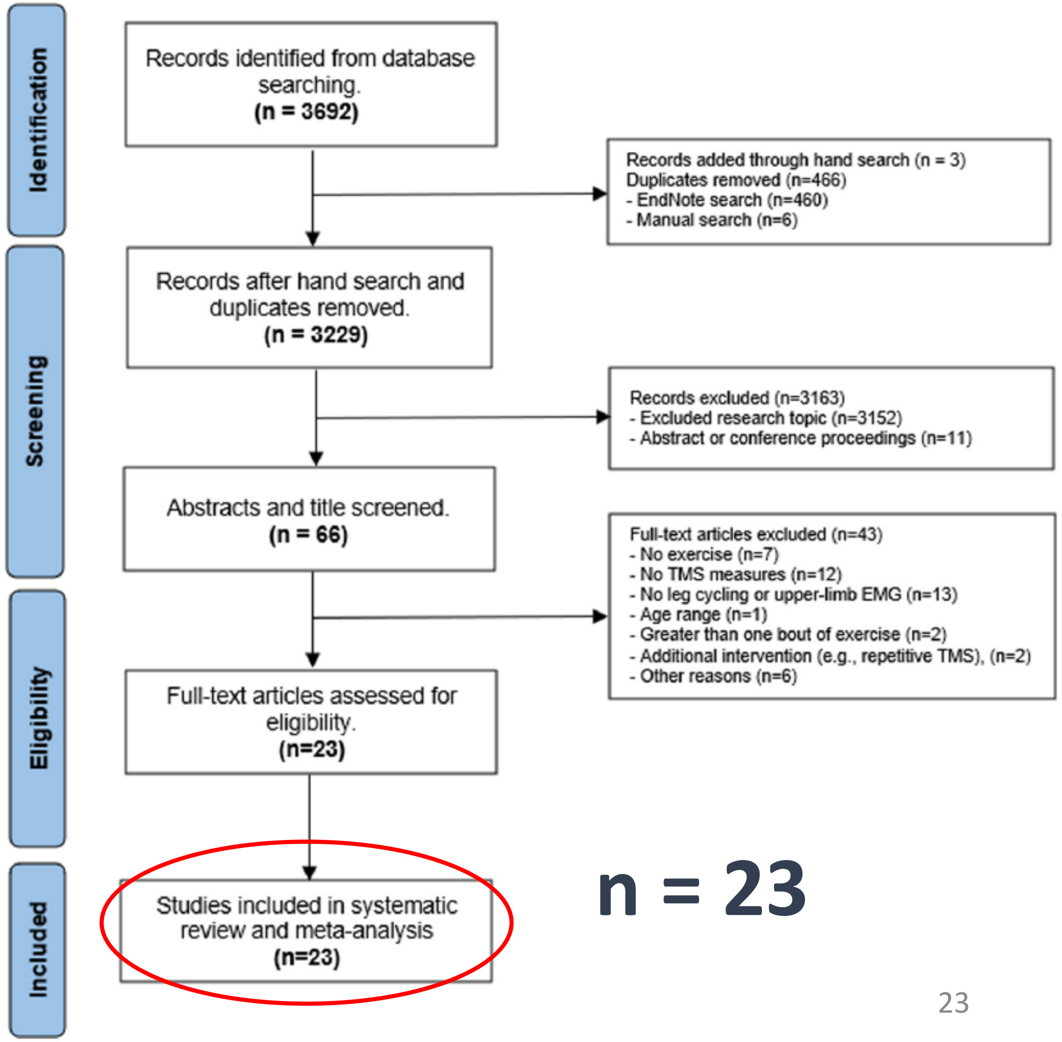


Neva et al., 2021 *Neuroscience*
Neva et al., 2017 *Eur J Neurosci*
Singh, Duncan, Neva et al., 2014 *BMC Sport Sci*

Exercise-induced neuroplasticity (TMS): A meta-analysis

Layale Youssef, PhD candidate

1. What **TMS measure** is most **consistently** impacted by acute exercise?
2. What is the effect of **exercise intensity?**

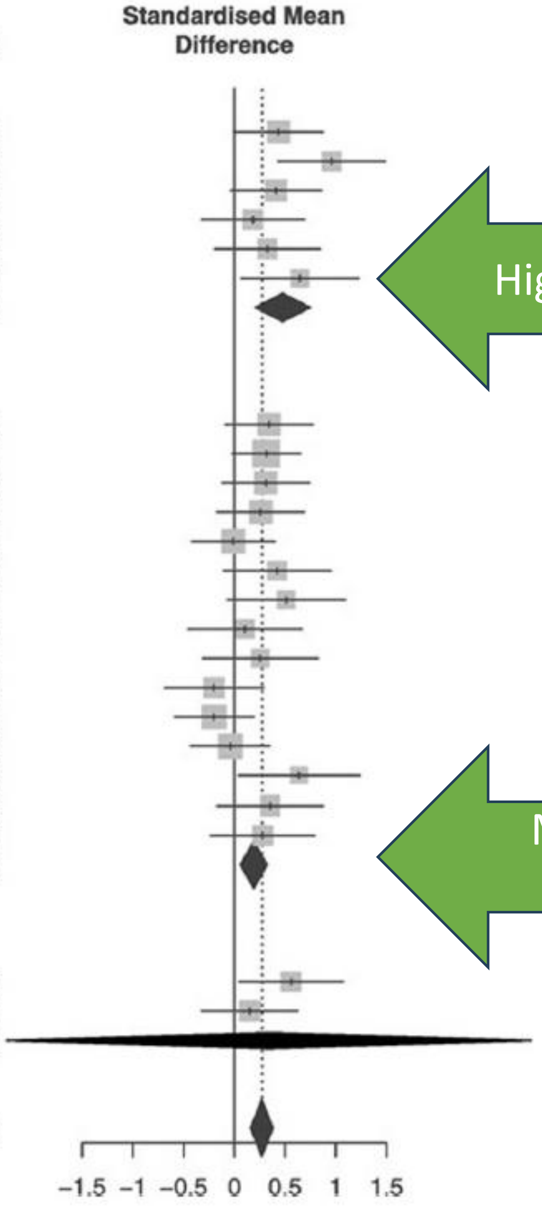


n = 23

Youssef et al., 2024 *Neurosci Biobehav Rev*

↓ SICI (cortical inhibition) after exercise

Study	Time | ISI	SMD	95%-CI
High-intensity AAE			
Andrews et al., 2020	[Post 1 | 2ms]	0.44	[-0.01; 0.88]
Hendy et al., 2023	[Post 1 | 3ms]	0.96	[0.43; 1.49]
Nicolini et al., 2022	[Post 1 | 2ms]	0.41	[-0.04; 0.86]
Smith et al., 2014	[Post 1 | 2ms]	0.18	[-0.33; 0.69]
Smith et al., 2014	[Post 1 | 3ms]	0.33	[-0.20; 0.85]
Stavrinos & Coxon 2017	[Post 2 | 2ms]	0.65	[0.06; 1.23]
Random effects model		**0.48**	**[0.20; 0.75]**
Heterogeneity: $I^2 = 4\%$, $p = 0.39$			
Moderate-intensity AAE			
Andrews et al., 2020	[Post 1 | 2ms]	0.34	[-0.09; 0.78]
El Sayes et al., 2019	[Post 1 | 2ms]	0.32	[-0.02; 0.65]
Kuo et al., 2023	[Post 1 | 2ms]	0.31	[-0.12; 0.74]
Kuo et al., 2023	[Post 1 | 3ms]	0.26	[-0.17; 0.69]
Kuo et al., 2023	[Post 1 | 5ms]	-0.01	[-0.42; 0.40]
Lulic et al., 2017 LPA	[Post 1 | 2ms]	0.42	[-0.11; 0.95]
Lulic et al., 2017 HPA	[Post 1 | 2ms]	0.51	[-0.07; 1.09]
Mooney et al., 2016	[Post 1 | 2.5ms]	0.11	[-0.46; 0.67]
Mooney et al., 2016	[Post 2 | 2.5ms]	0.26	[-0.32; 0.83]
Morris et al., 2020	[Post 3 | 3ms]	-0.20	[-0.69; 0.29]
Neva et al., 2021	[Post 1 | 2ms]	-0.20	[-0.59; 0.19]
Neva et al., 2021	[Post 2 | 2ms]	-0.04	[-0.43; 0.35]
Singh et al., 2014	[Post 1 | 2.5ms]	0.64	[0.04; 1.24]
Smith et al., 2014	[Post 1 | 2ms]	0.35	[-0.17; 0.88]
Smith et al., 2014	[Post 1 | 3ms]	0.28	[-0.24; 0.80]
Random effects model		**0.19**	**[0.06; 0.32]**
Heterogeneity: $I^2 = 4\%$, $p = 0.41$			
Low-intensity AAE			
Yamazaki et al., 2020	[Post 1 | 2ms]	0.56	[0.04; 1.08]
Yamazaki et al., 2020	[Post 2 | 2ms]	0.15	[-0.33; 0.63]
Random effects model		**0.34**	**[-2.25; 2.94]**
Heterogeneity: $I^2 = 23\%$, $p = 0.25$			
OVERALL EFFECT $p < 0.0001$		**0.27**	**[0.16; 0.38]**
Heterogeneity: $I^2 = 16\%$, $p < 0.001$			



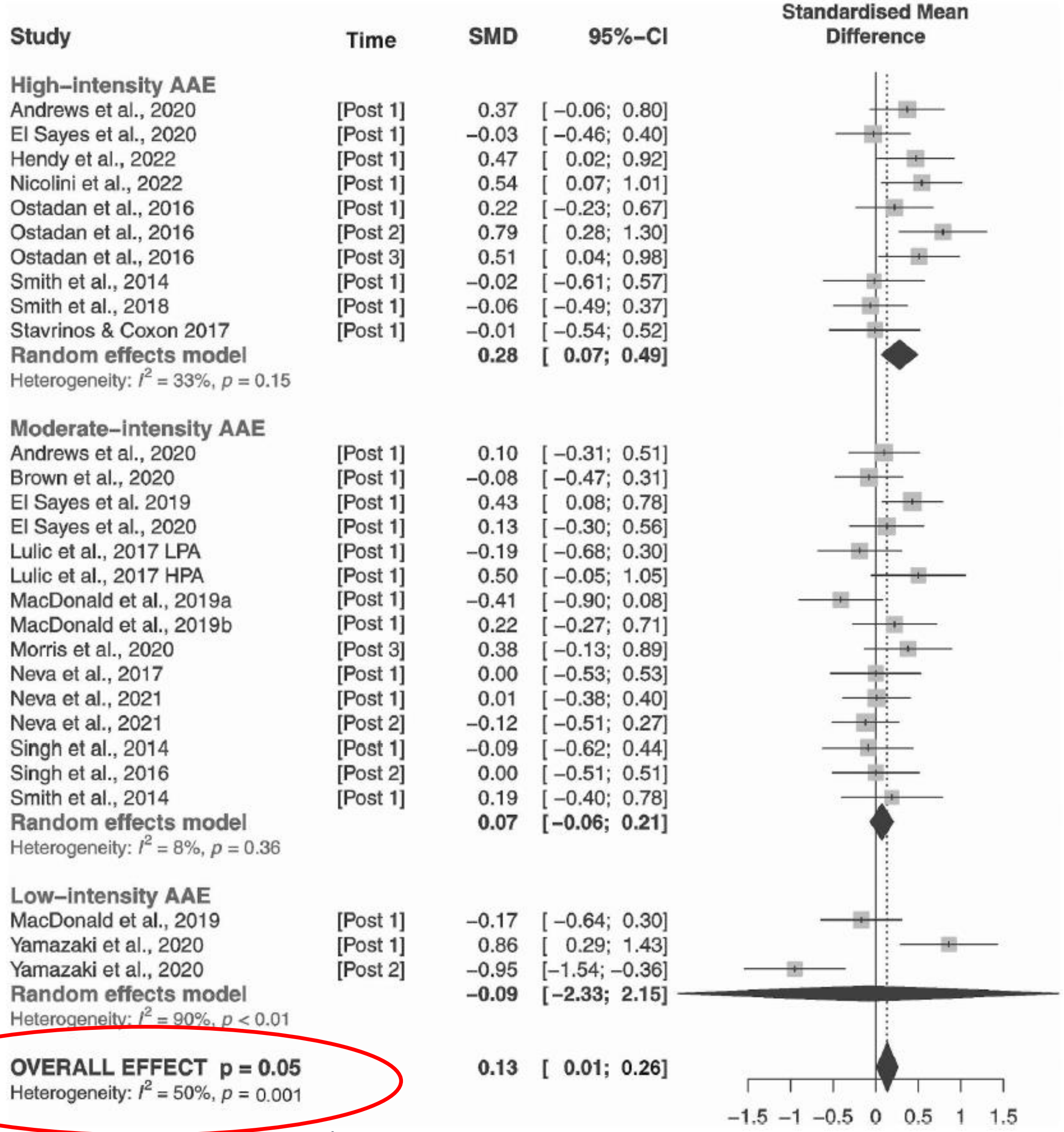
High intensity

Moderate intensity

↓ inhibition after exercise

Youssef et al., 2024
Neurosci Biobehav Rev

↑ corticospinal excitability after high intensity



High intensity

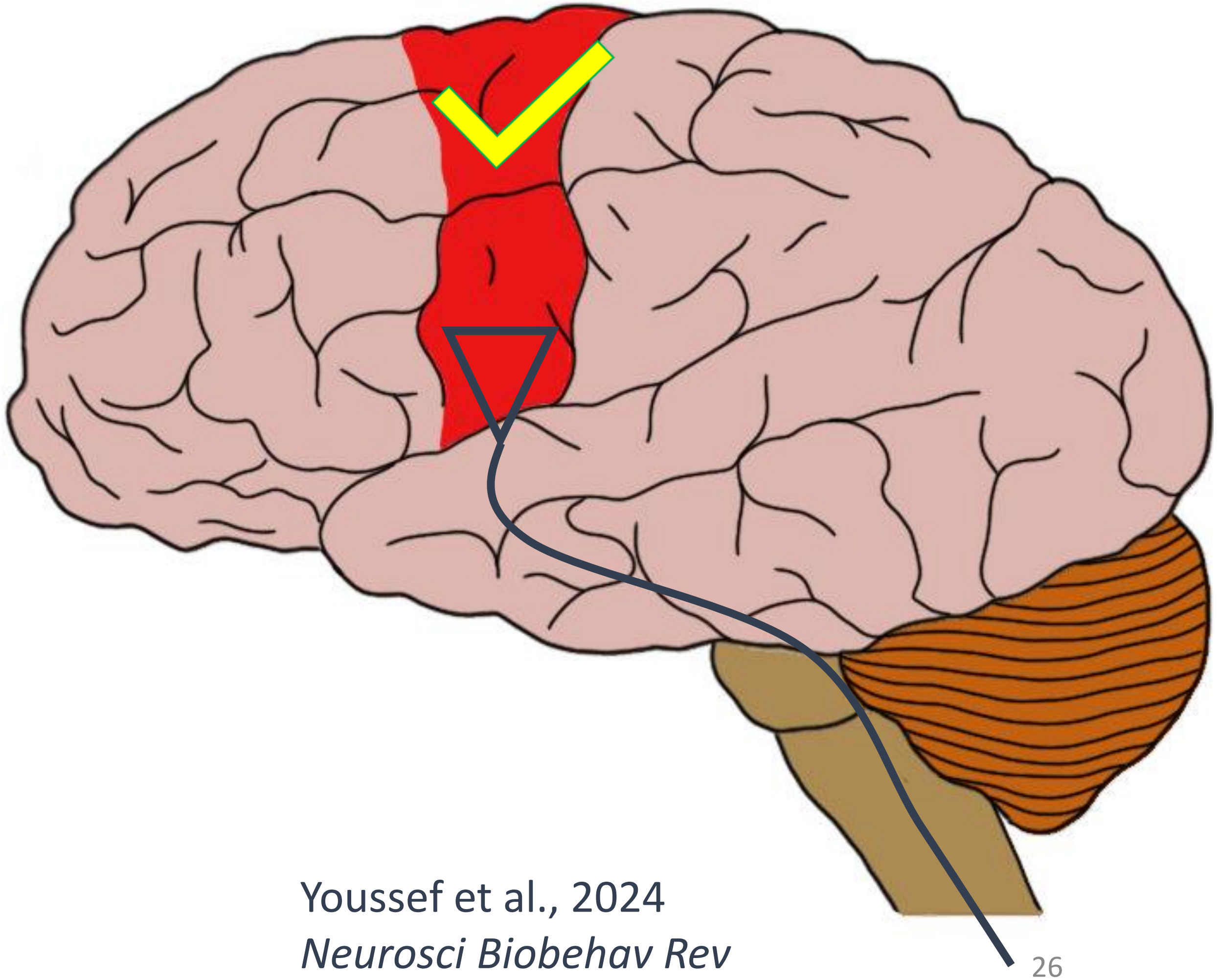
↑ excitability after exercise

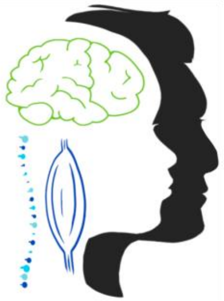
Youssef et al., 2024
Neurosci Biobehav Rev

What is the most consistent TMS measure impacted by acute exercise?

- ↓ <u>**motor cortex inhibition**</u> **(SICI)**
  - moderate-to-high intensity exercise drives the effect

- What is the effect of **exercise <u>intensity</u>?**
  - Is there a **dose-response** effect?

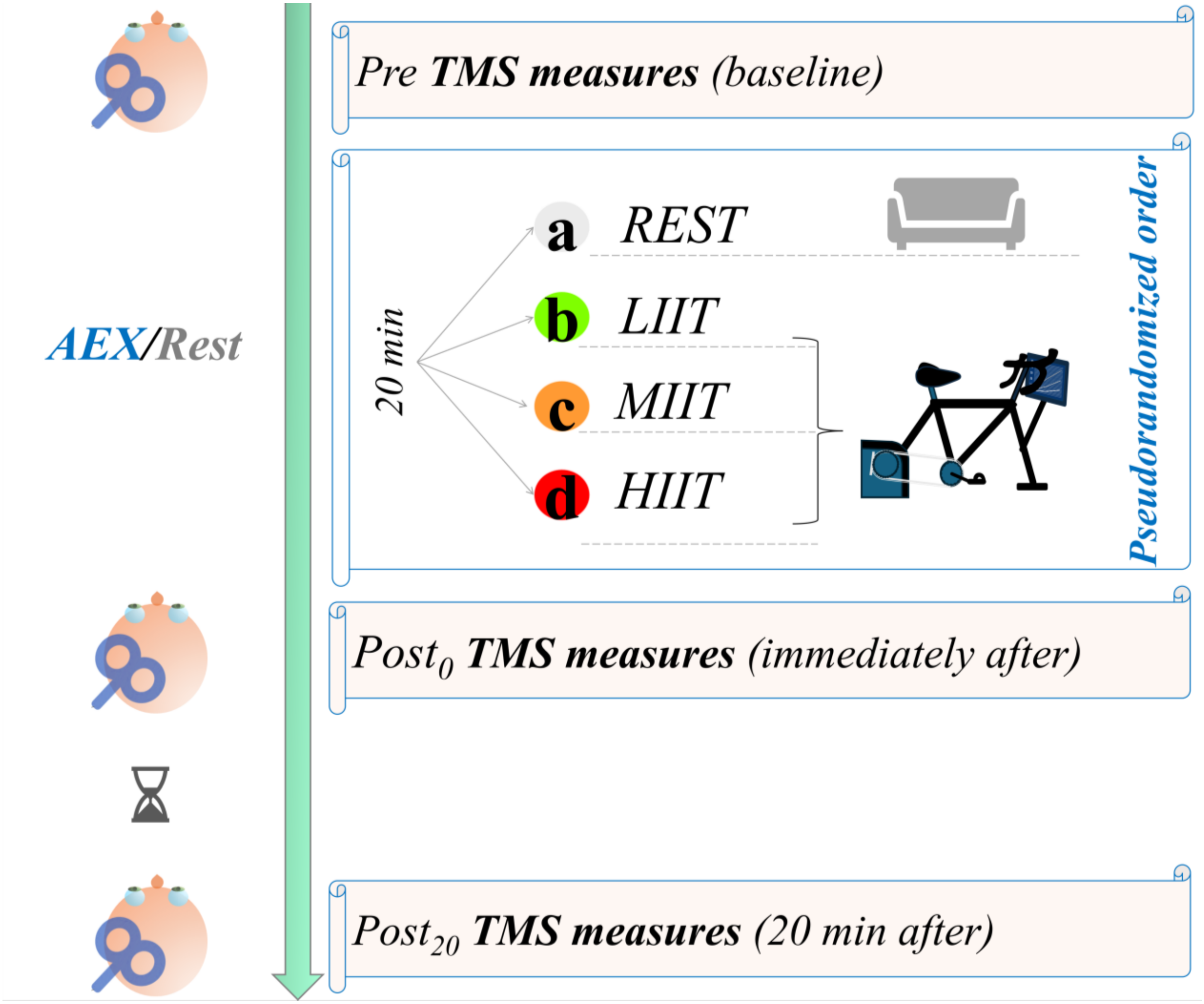




Youssef et al., 2024
Neurosci Biobehav Rev

Is there a dose-response effect of acute exercise intensity?

Experimental design



Nesrine Harroum, PhD candidate

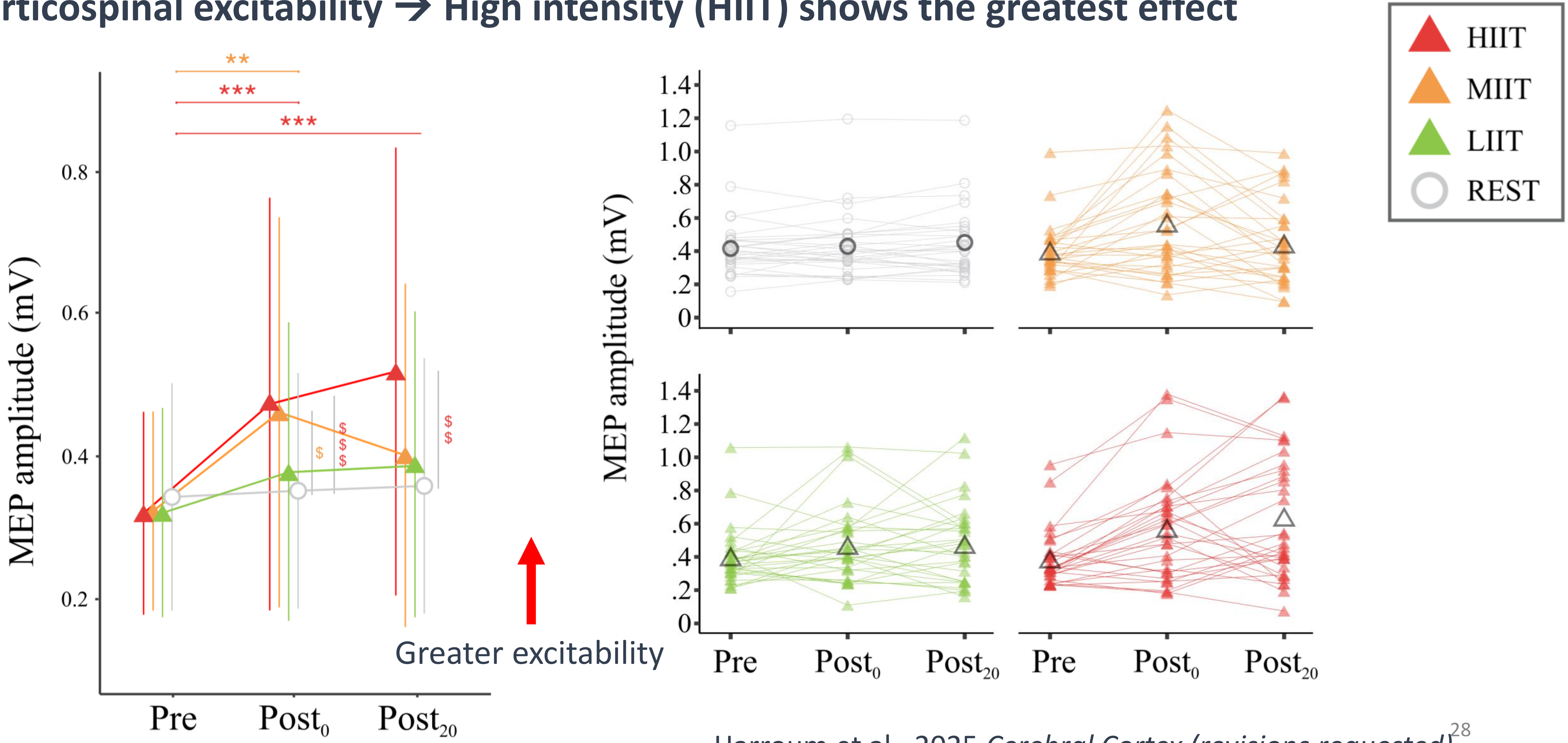
N = 30; young adults, within-subjects design

LIIT: Light-intensity interval training
MIIT: Moderate-intensity interval training
HIIT: High-intensity interval training
REST: seated rest

Harroum et al., 2025
Cerebral Cortex (revisions requested)

There is a dose-response effect of acute exercise intensity!

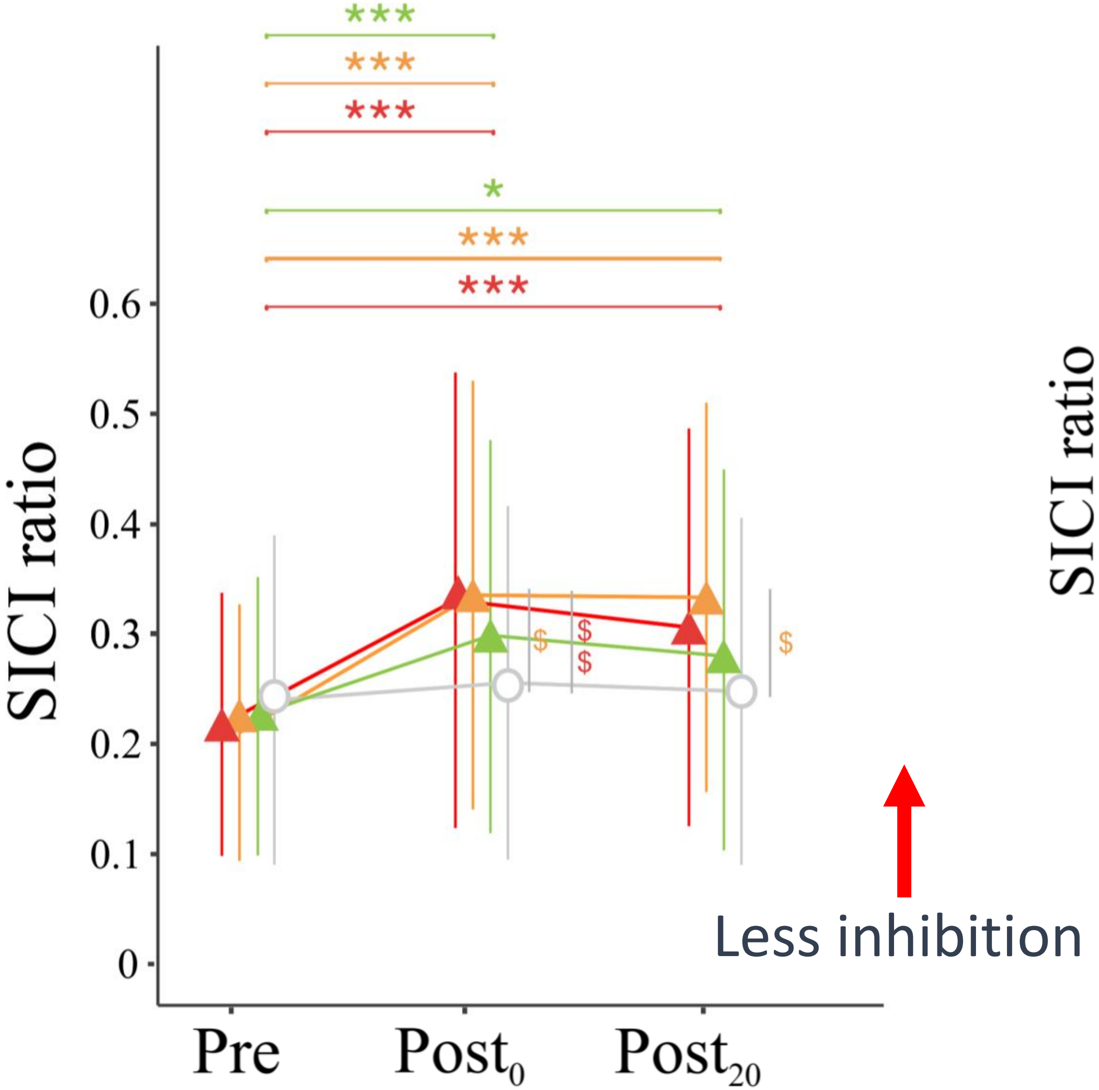
Corticospinal excitability → High intensity (HIIT) shows the greatest effect

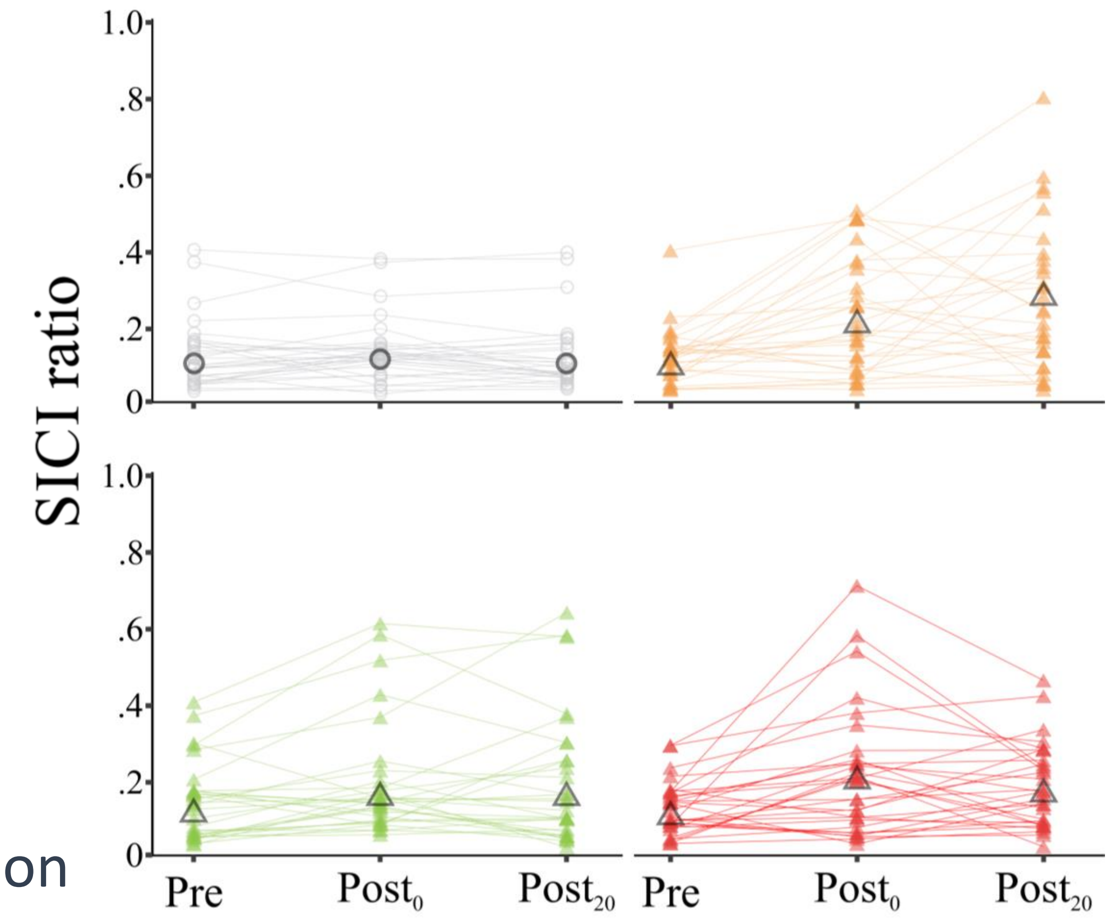


Harroum et al., 2025 *Cerebral Cortex (revisions requested)*

There is a dose-response effect of acute exercise intensity!

Cortical inhibition → Moderate intensity (MIIT) shows the greatest effect



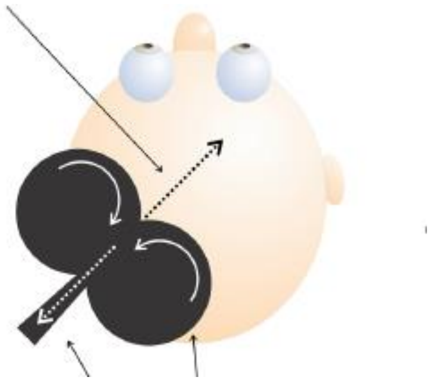


Harroum et al., 2025 *Cerebral Cortex (revisions requested)*

Is there an effect of acute exercise <u>type?</u>

Layale Youssef, PhD student

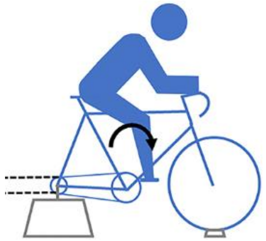
TMS



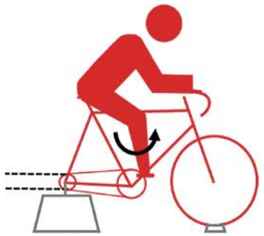
Corticospinal excitability
Cortical inhibition (SICI)

Pre

Concentric cycling (traditional)



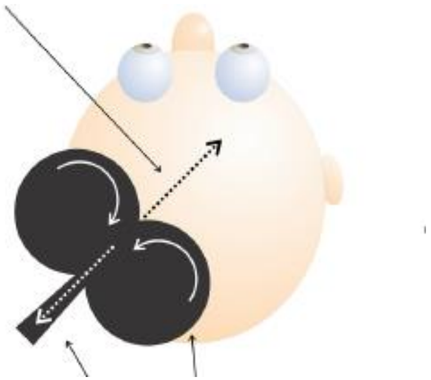
Eccentric cycling



Rest

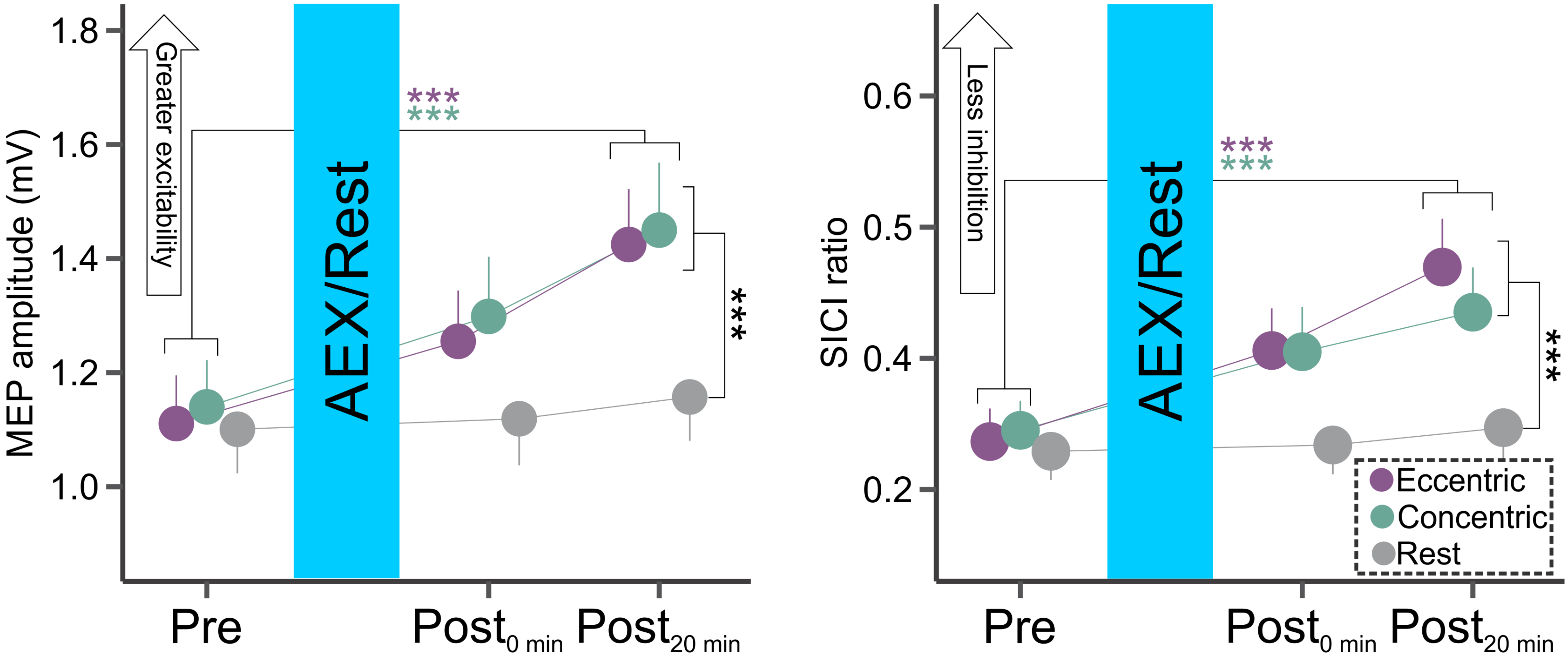
Post tests

TMS



Corticospinal excitability
Cortical inhibition (SICI)

Same effect for Eccentric and Concentric Exercise

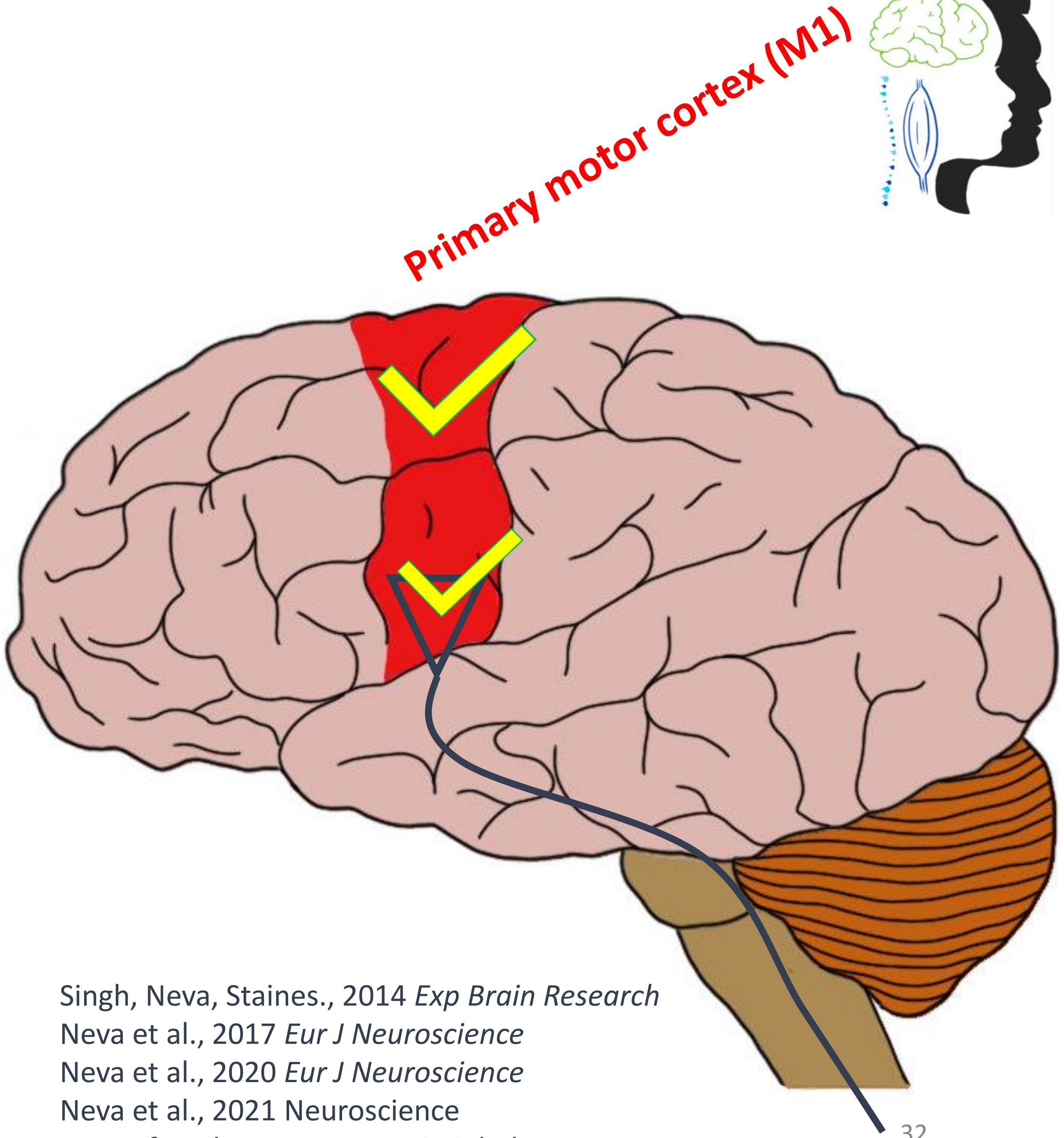


***Eccentric exercise ↑ M1 excitability and ↓ inhibition like concentric (traditional) exercise!**

How does exercise impact the brain?

- ↓ **<u>motor cortex inhibition</u>**
- ↑ **motor cortex output excitability**
  - rapid neuroplasticity
  - early motor learning stages
  - recovery of function after stroke

- **Important factors:**
  - Aerobic exercise <u>intensity</u>
  - Aerobic exercise <u>type</u>



Singh, Neva, Staines., 2014 *Exp Brain Research*
Neva et al., 2017 *Eur J Neuroscience*
Neva et al., 2020 *Eur J Neuroscience*
Neva et al., 2021 Neuroscience
Youssef et al., 2024 Neurosci Biobehav Rev

1

Aerobic Exercise:
↑ *Motor Learning*
↑ *Neuroplasticity*

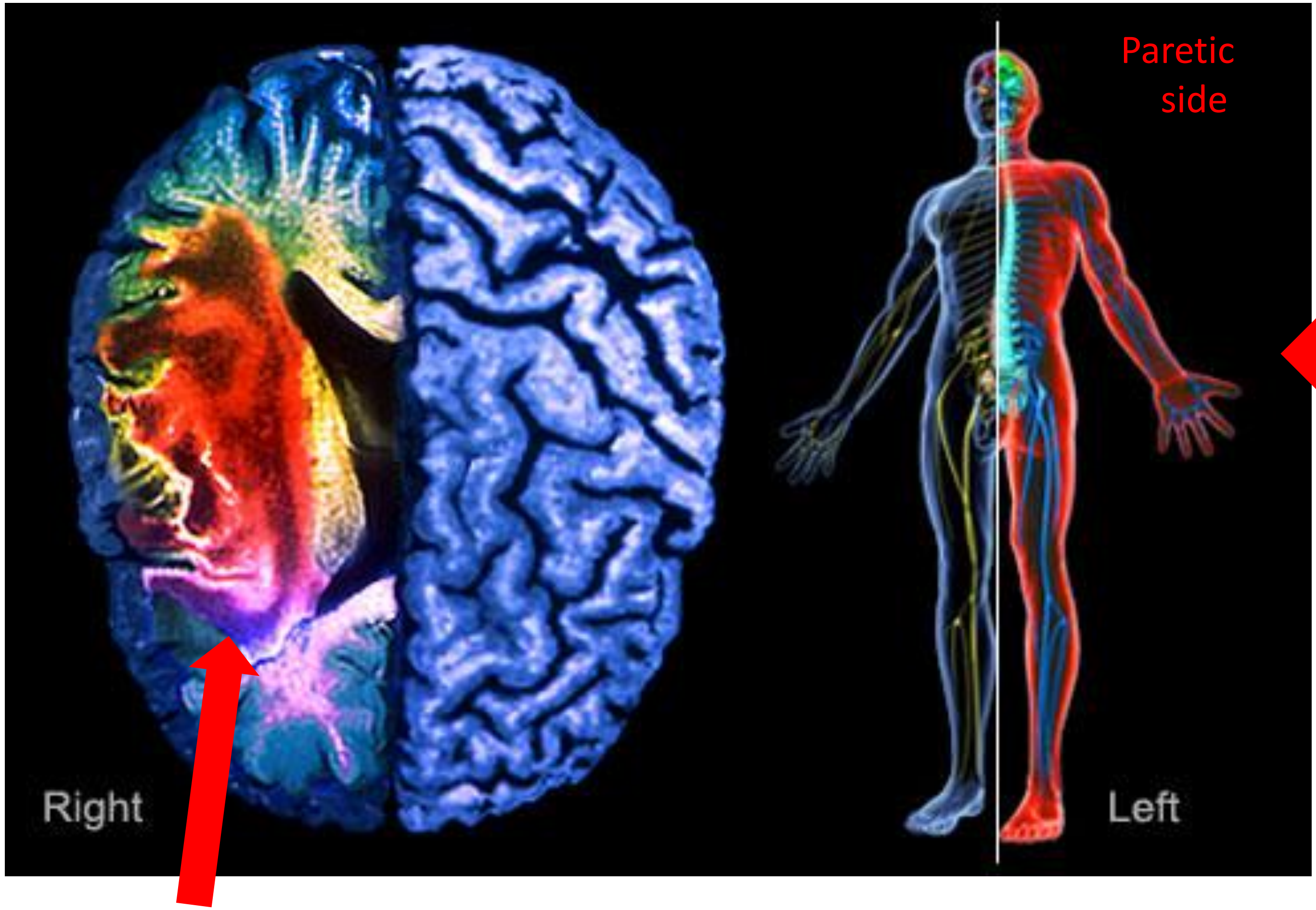
2

TMS:
Measure & Modulate the Brain

Motor impairment after stroke

Stroke ("brain attack")

- Loss of blood & oxygen to the brain
- Brain tissue damage



Stroke affected region

Contralateral ↓ motor function

~85% of Canadians live with persistent impairments into the chronic stage (< 1 year) post-stroke

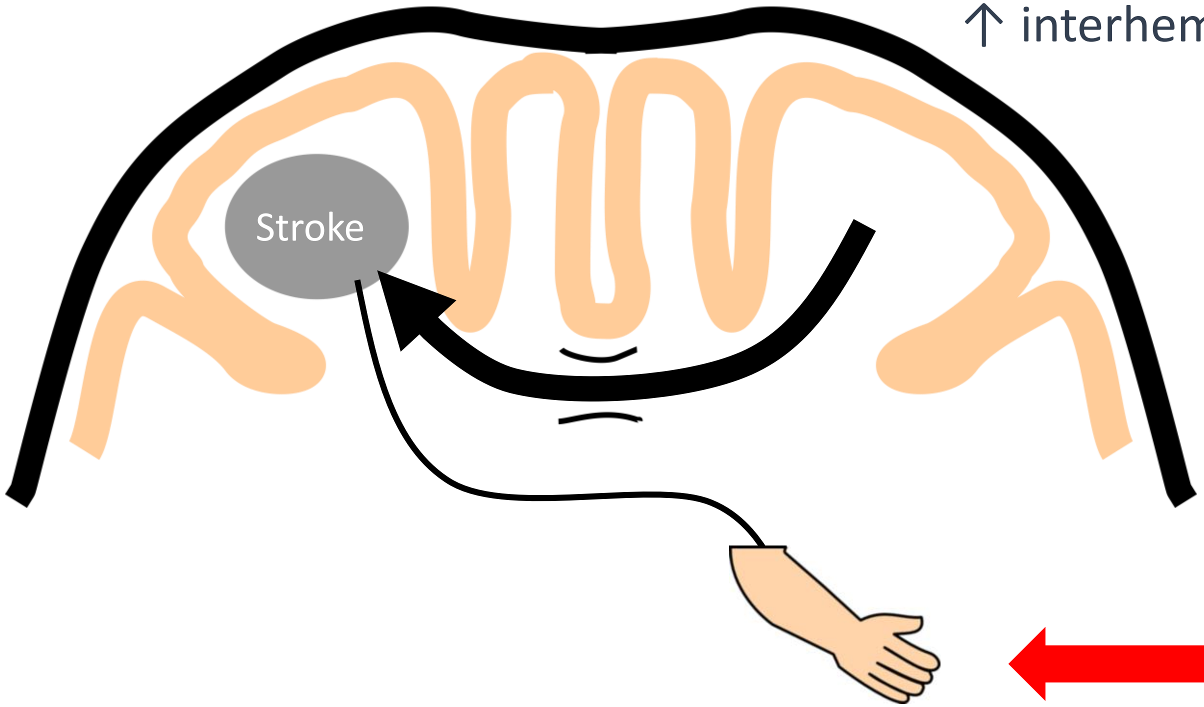
The interhemispheric competition model

↓ motor function on opposite/contralesional side

↓ cortical activity

↑ cortical activity

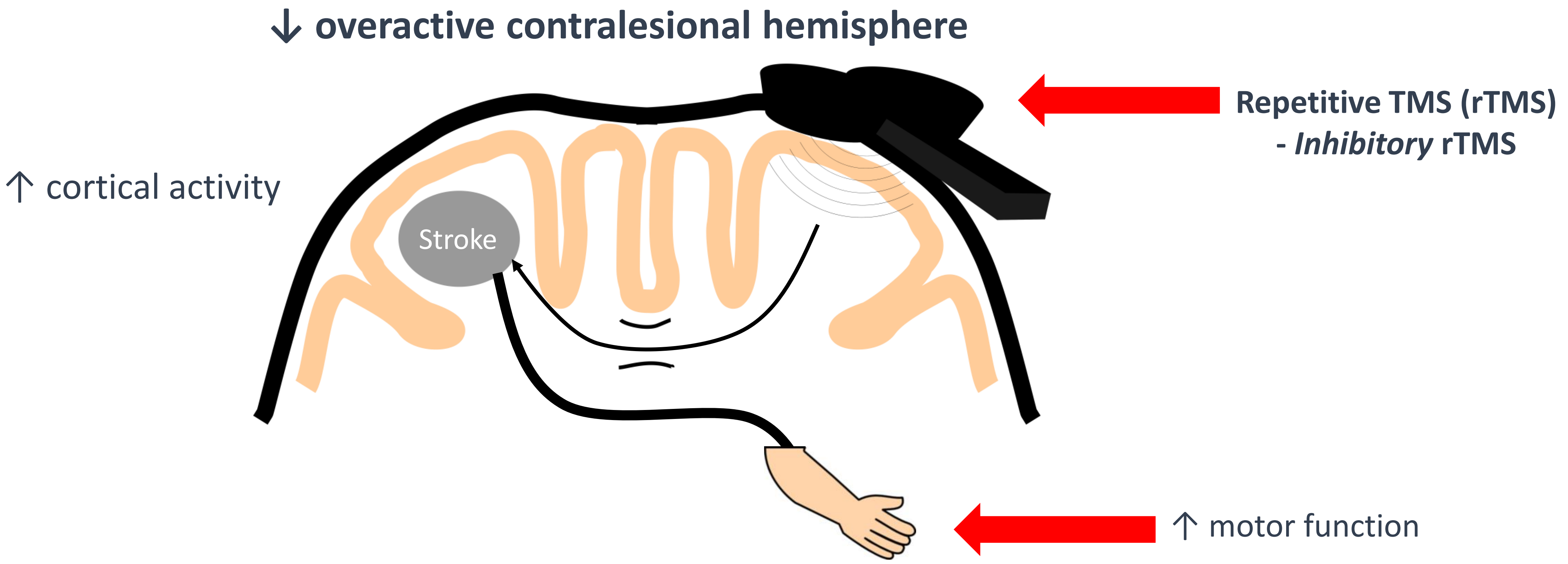
↑ interhemispheric inhibition



Poorer motor function

Neva et al., 2019 *Restorative Neurol & Neurosci*
Auriat, Neva et al., 2016 *Front Neurology*
Neva et al., 2020 *The Wiley Encyclopedia of Health Psychology, Volume III*

Counteracting interhemispheric competition



Neva et al., 2019 *Restorative Neurol & Neurosci*
Auriat, Neva et al., 2016 *Front Neurology*

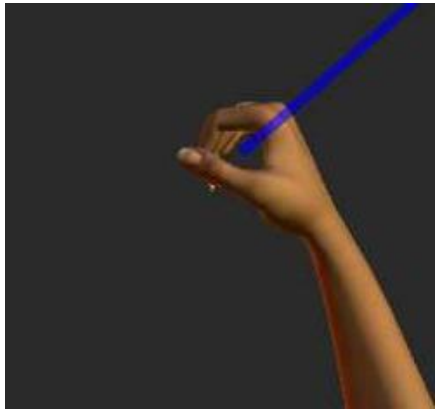
Pairing rTMS to contralesional motor cortex with paretic motor practice

Pre: motor function & motor skill

5 sessions of inhibitory rTMS (M1 or Sham) + skilled motor practice

Post: motor function & motor skill

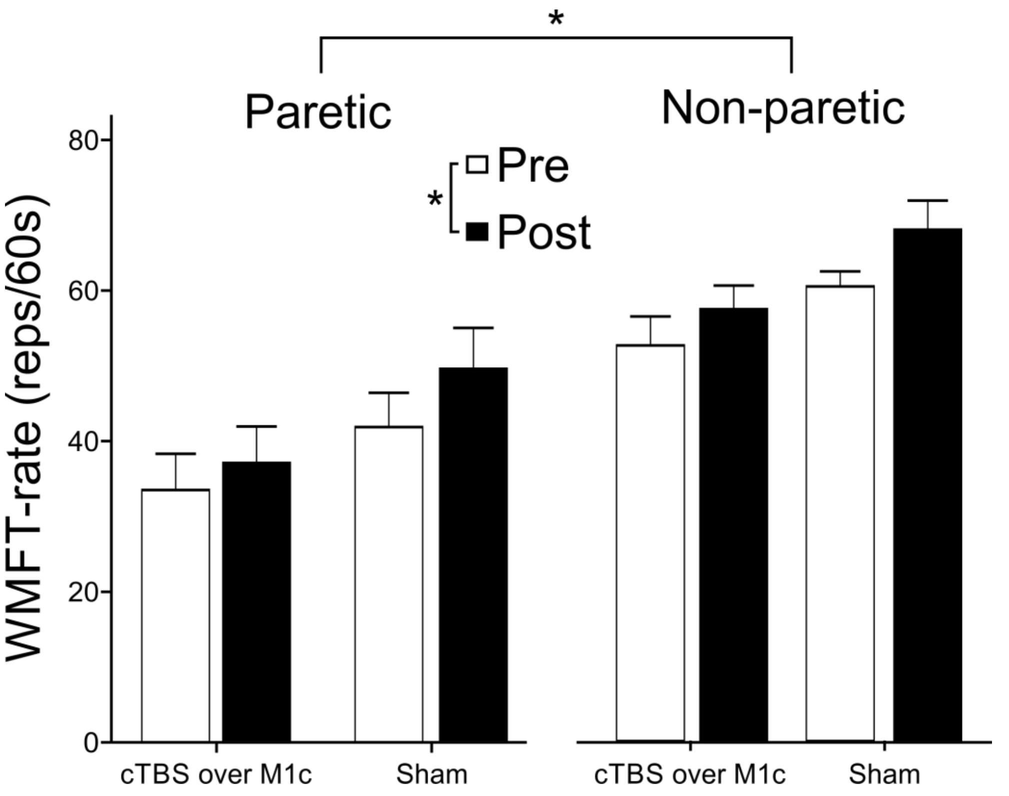
+



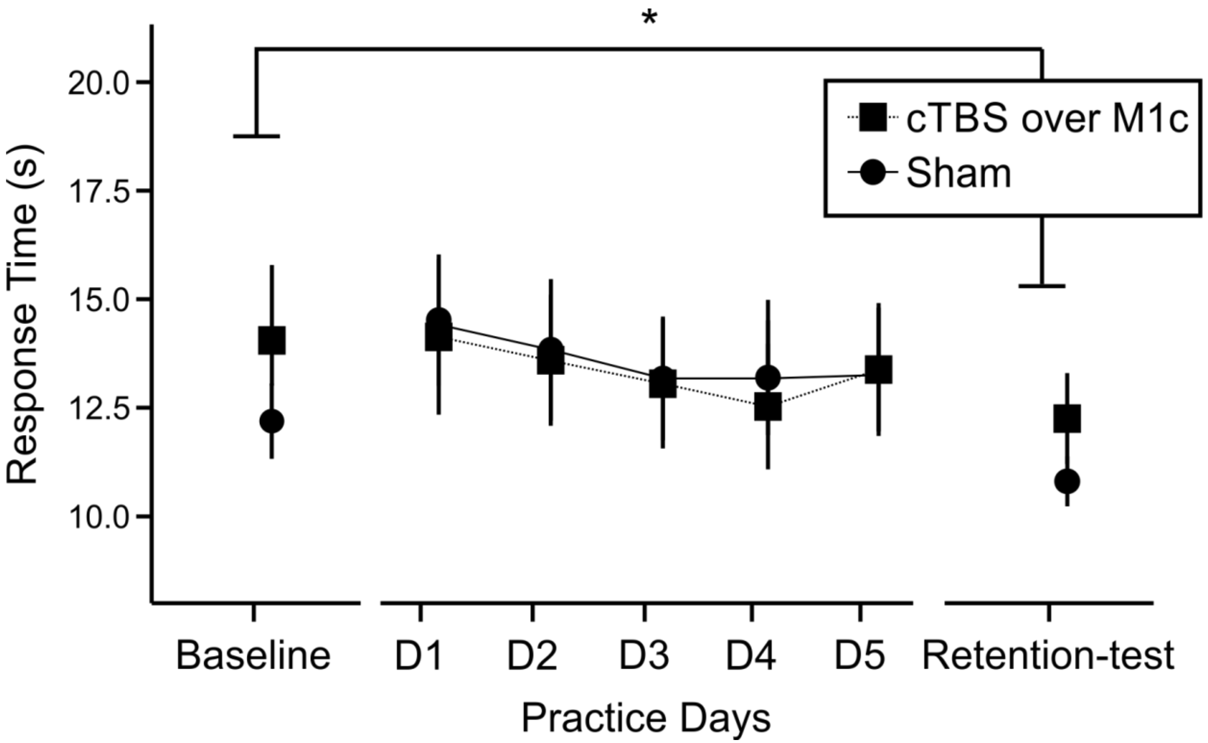
Neva et al., 2019 *Restorative Neurol & Neurosci*

Inhibitory rTMS to contralesional **motor cortex** showed *no improvement*

No additional ↑ to motor function

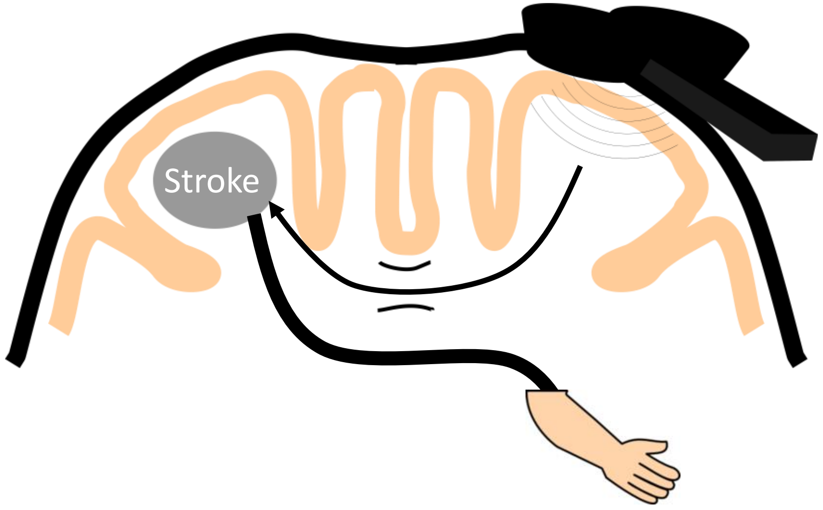


No additional ↑ to motor learning



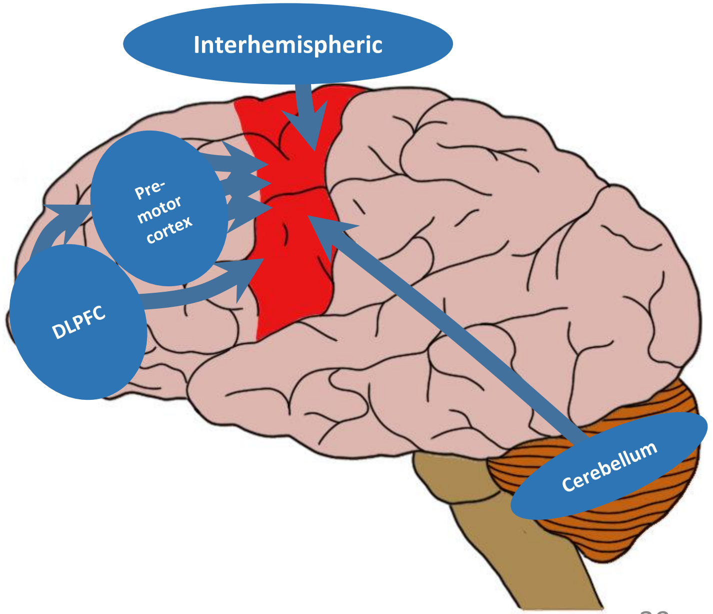
Neva et al., 2019 *Restorative Neurol & Neurosci*

Contralesional *motor* cortex suppression: *may not be the best solution…*



- Meta-analysis shows minimal effect of repetitive transcranial magnetic stimulation over the motor cortex

(Hsu et al., 2012 *Stroke*)

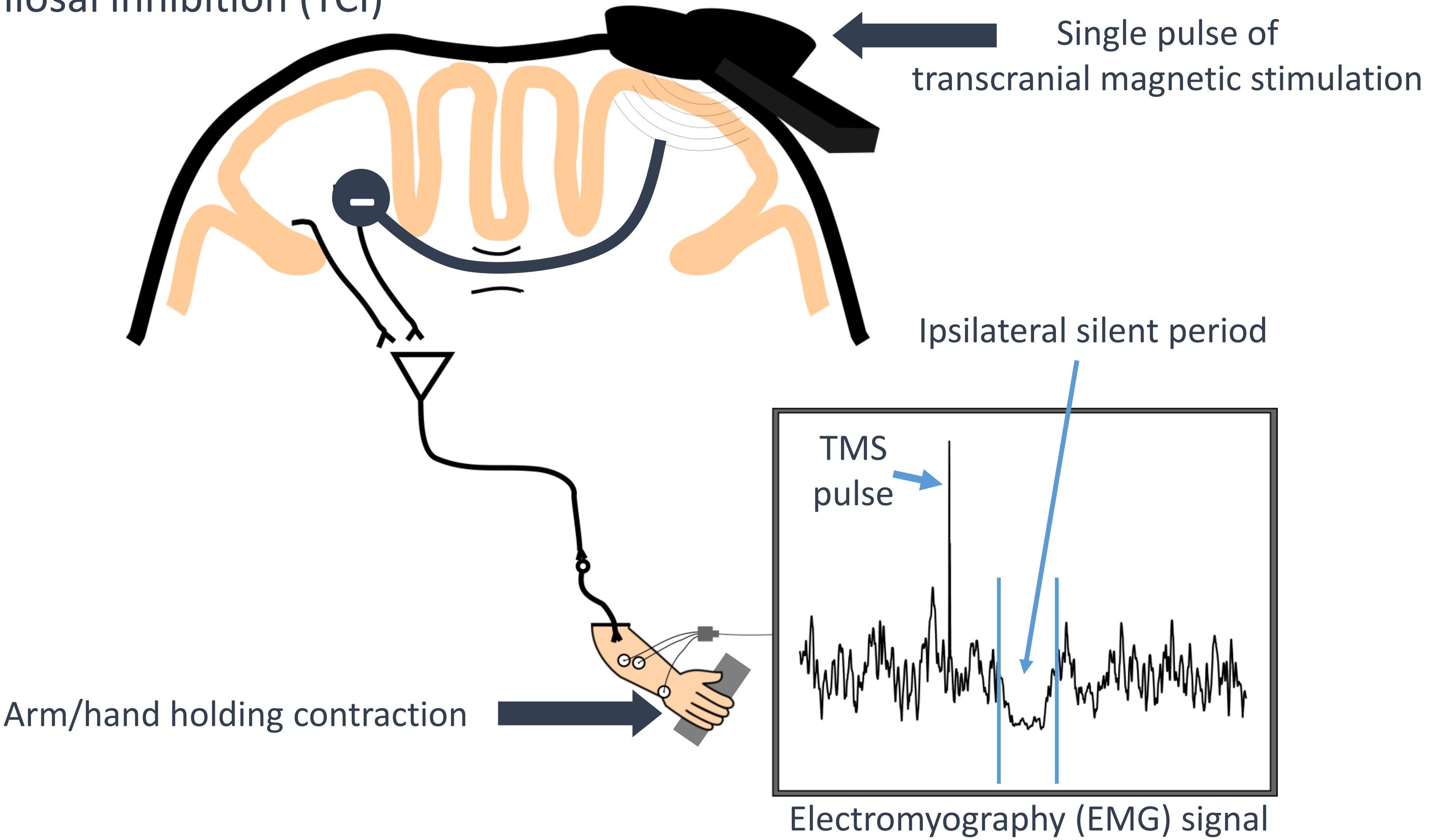


- **Executive function**, **<u>planning</u>** & **sensory feedback** cortical regions compensate for stroke-related damage to motor cortex

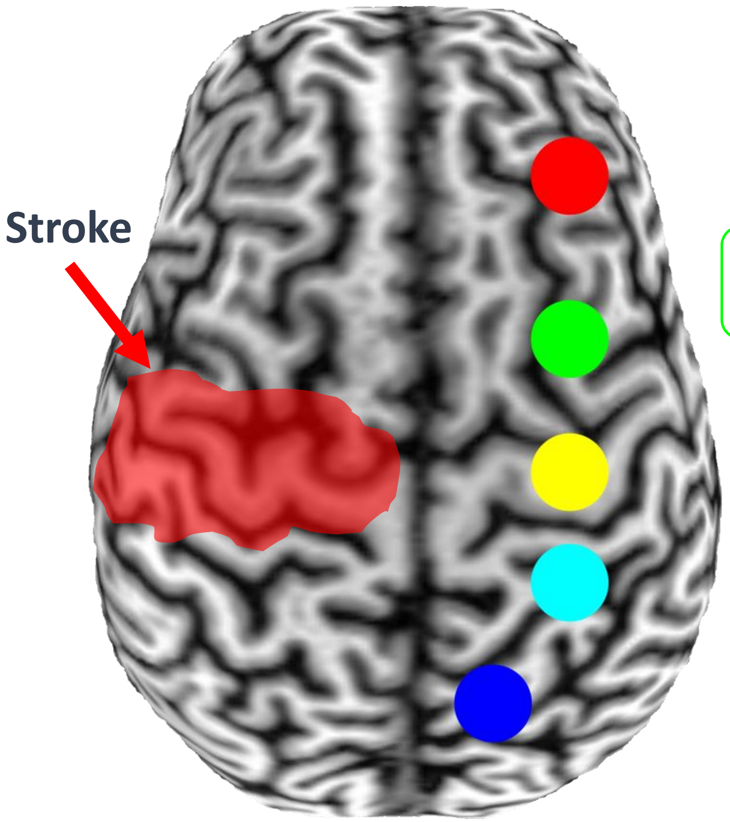
(Neva et al., 2019 *Wiley Encyclopedia of Health Psychology, Vol III*)

Measuring interhemispheric connectivity

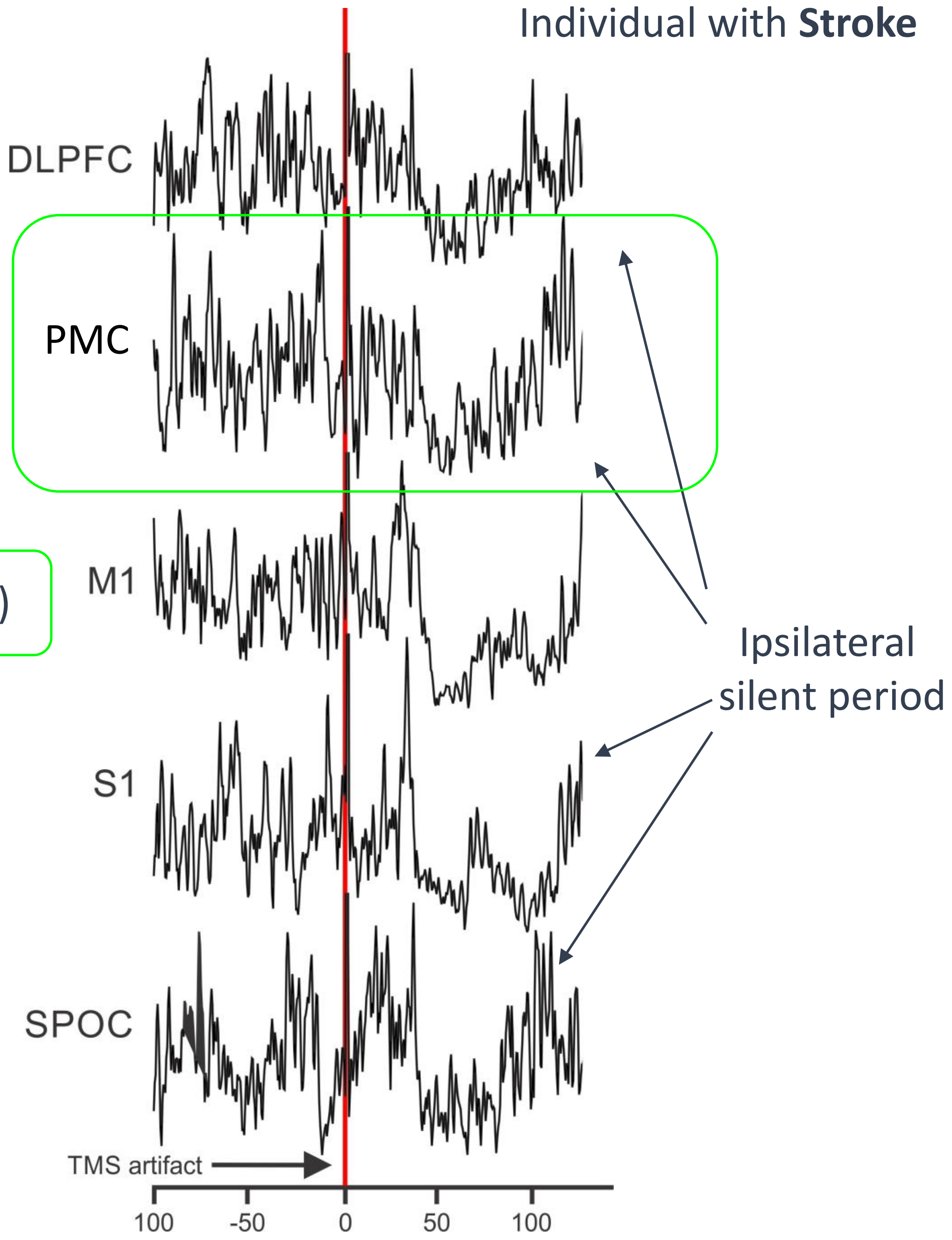
Transcallosal inhibition (TCI)



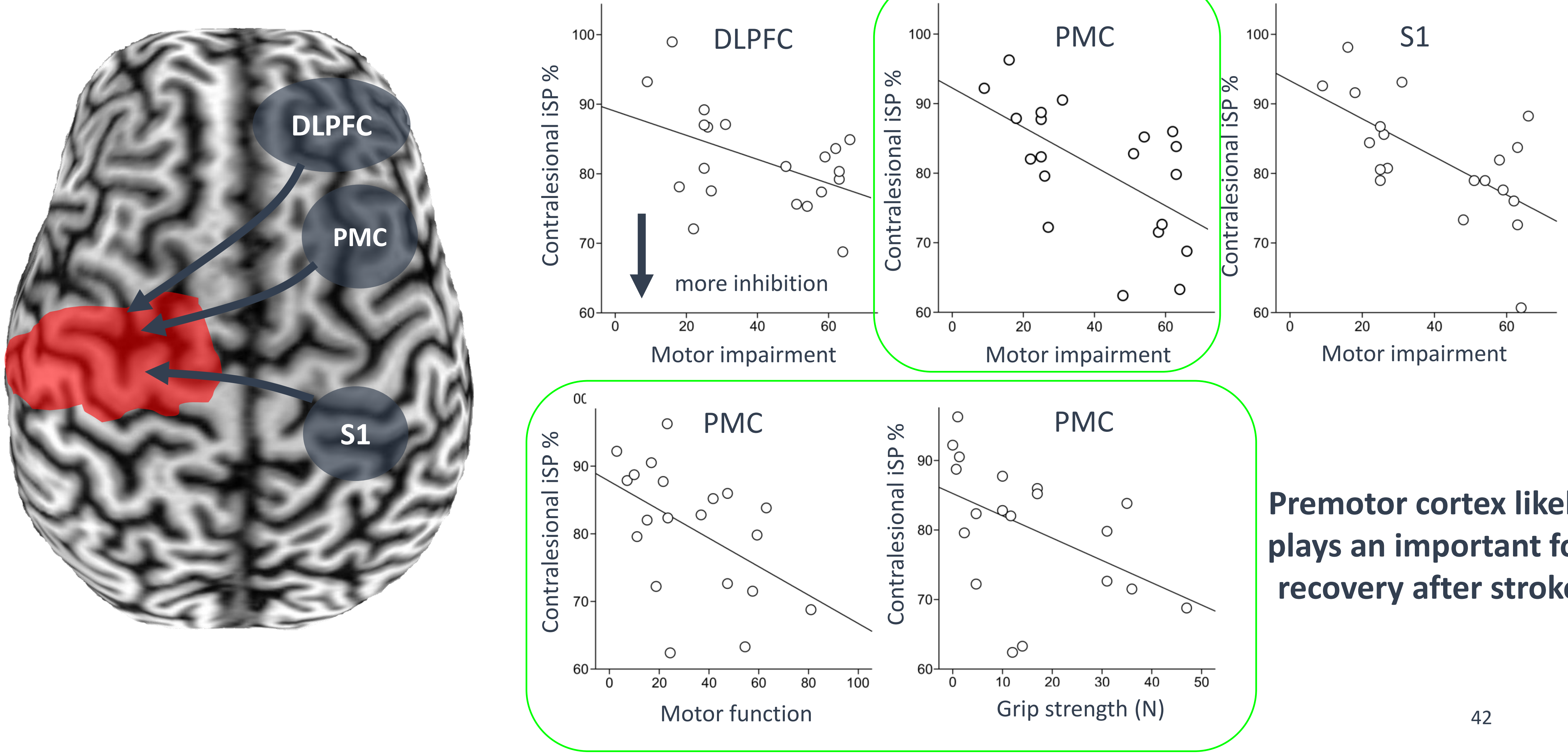
Transcallosal inhibition elicited from **frontal** & **parietal** cortical regions



- Dorsolateral prefrontal cortex (DLPFC)
- Dorsal premotor cortex (PMC)
- Primary motor cortex (M1)
- Primary somatosensory cortex (S1)
- Superior parietal-occipital cortex (SPOC)



Frontal & parietal interhemispheric communication is associated with post-stroke function

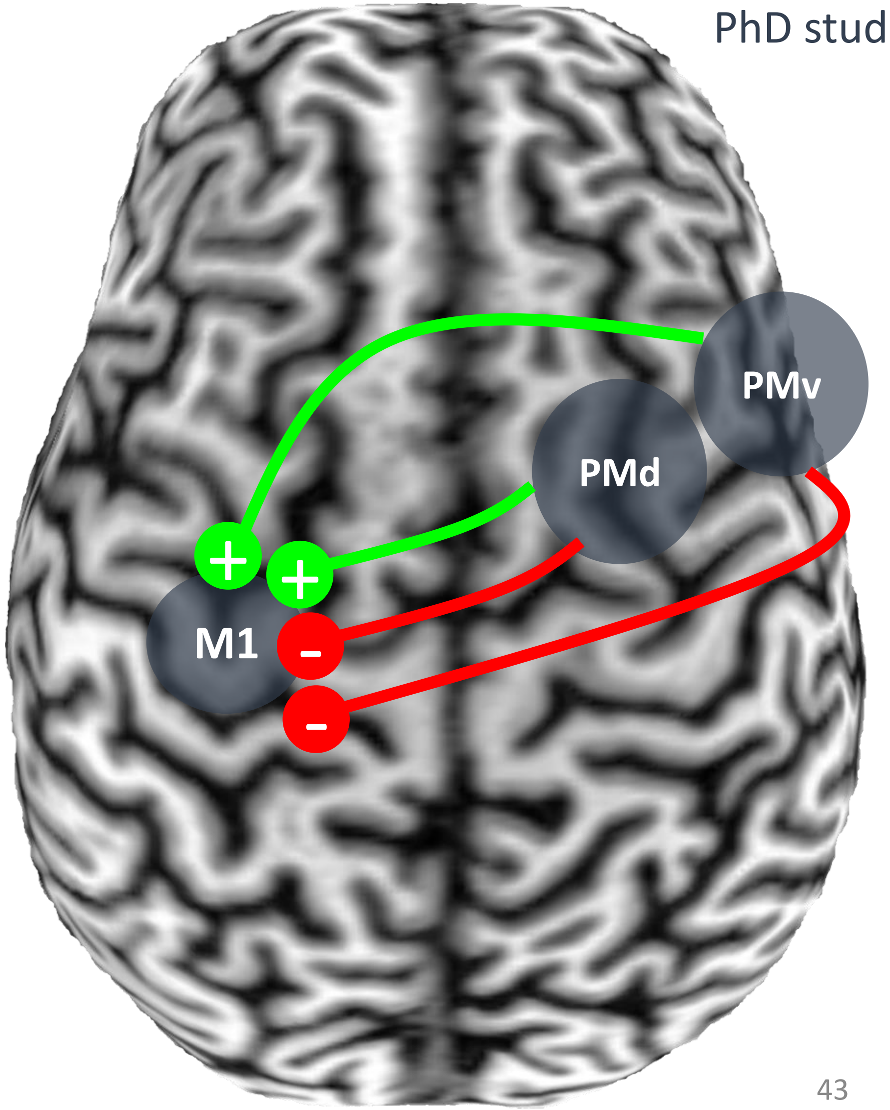


Premotor cortex likely plays an important for recovery after stroke

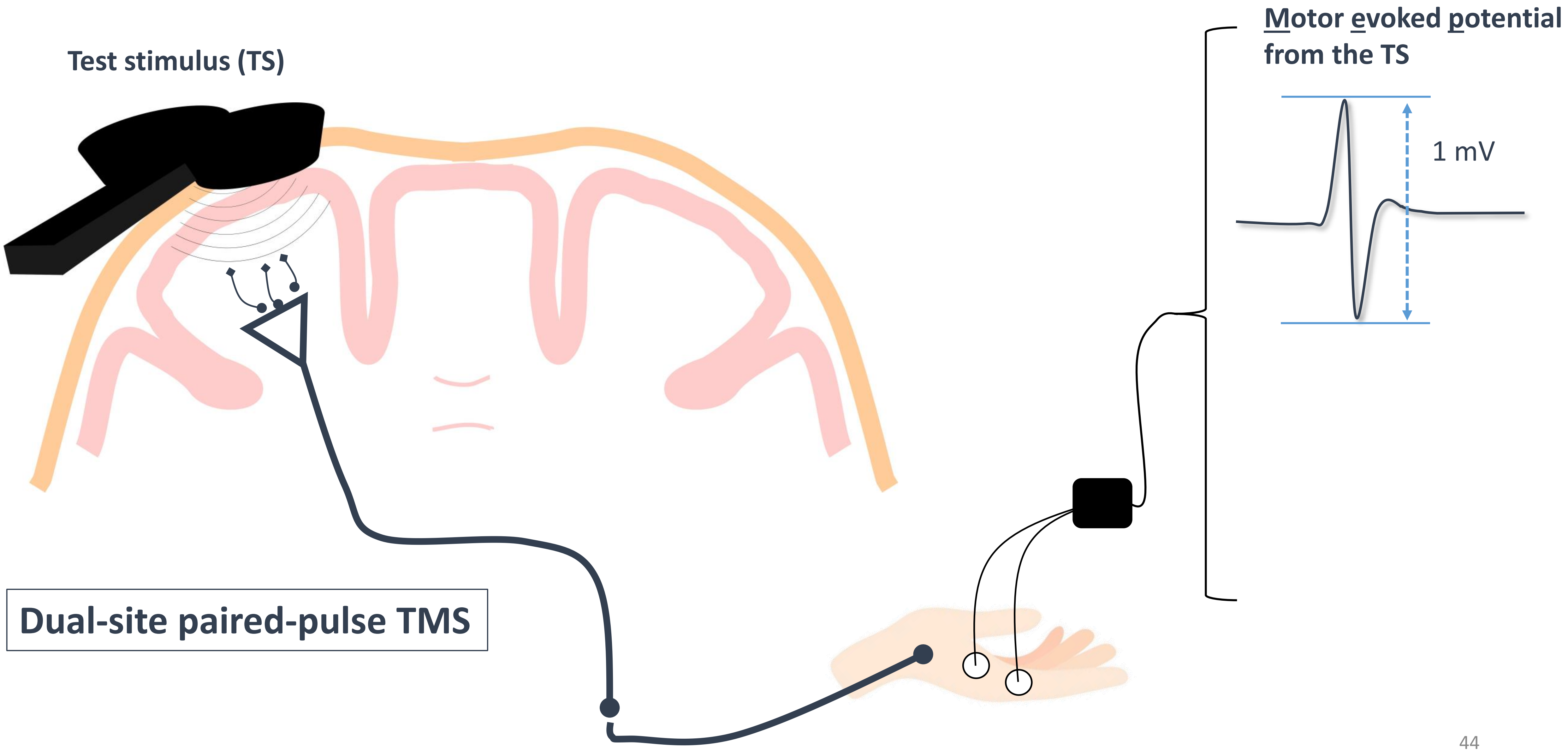
How does PMC communicate with M1?

Elnaz Allahverdloo, PhD student

- Premotor cortex (PMC) regions:
  - Dorsal (PMd) and ventral (PMv) premotor cortices
  - Distinct communication with M1
    - PMd → more interhemispheric inhibition
    - PMv → mix of inhibition & facilitation
  - PMC → *contralateral* M1 communication not well understood
  - **Objective**: *To investigate how PMd/PMv impact contralateral M1 excitability*
    - Examine the different *neurophysiological pathways* of communication with contralateral M1
  - **Highly relevant to stroke-rehabilitation**

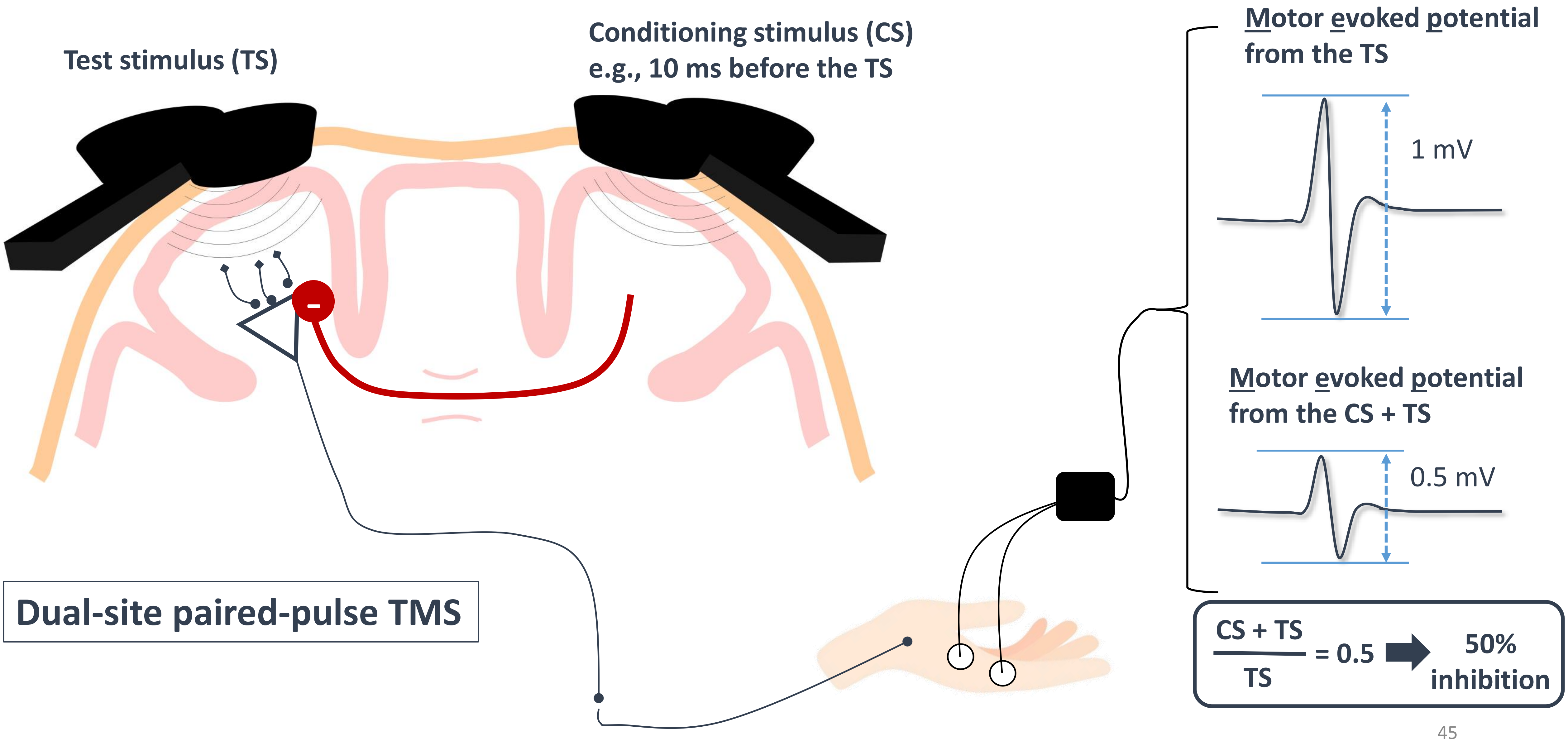


Measuring interhemispheric connectivity



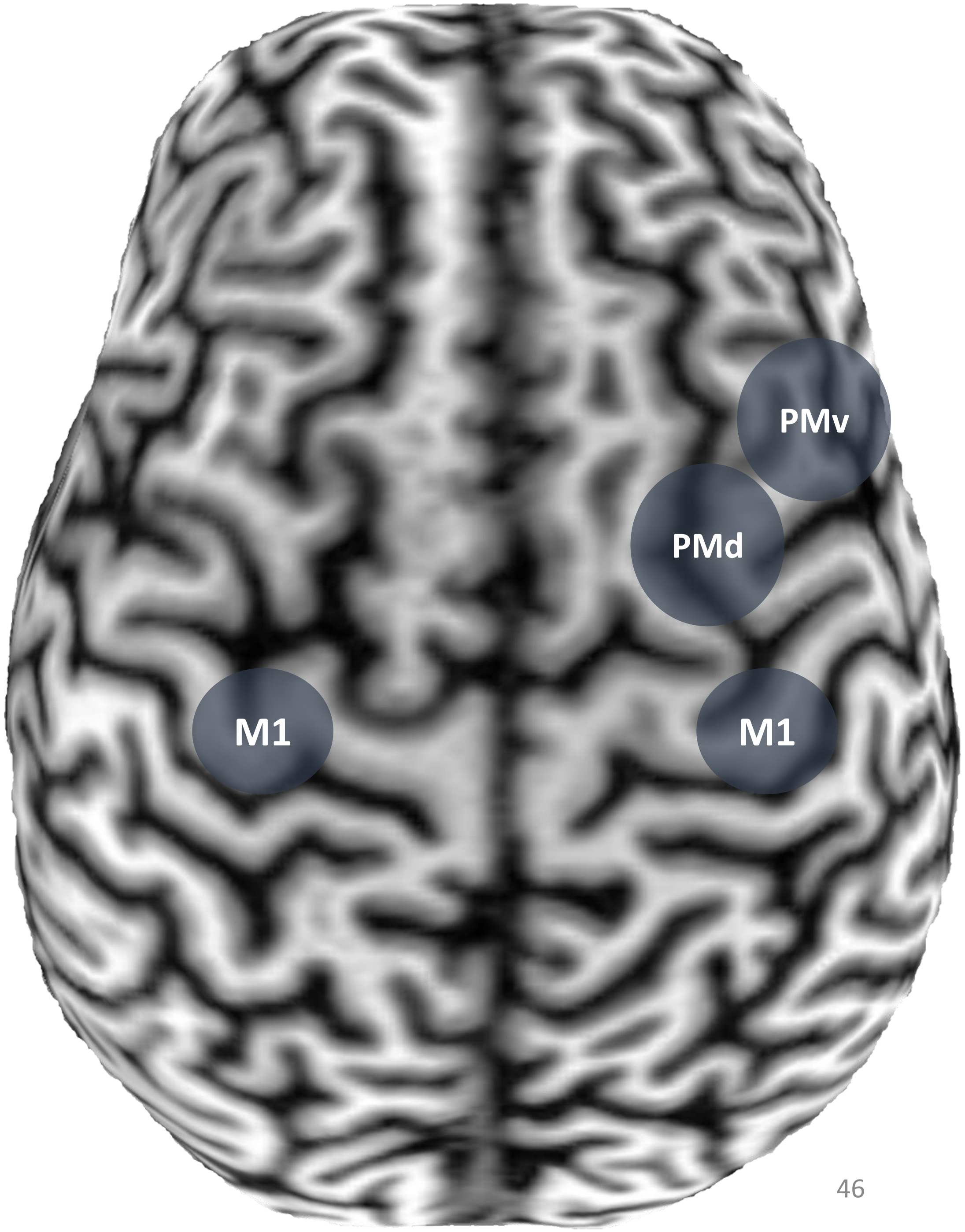
Dual-site paired-pulse TMS

Measuring interhemispheric connectivity

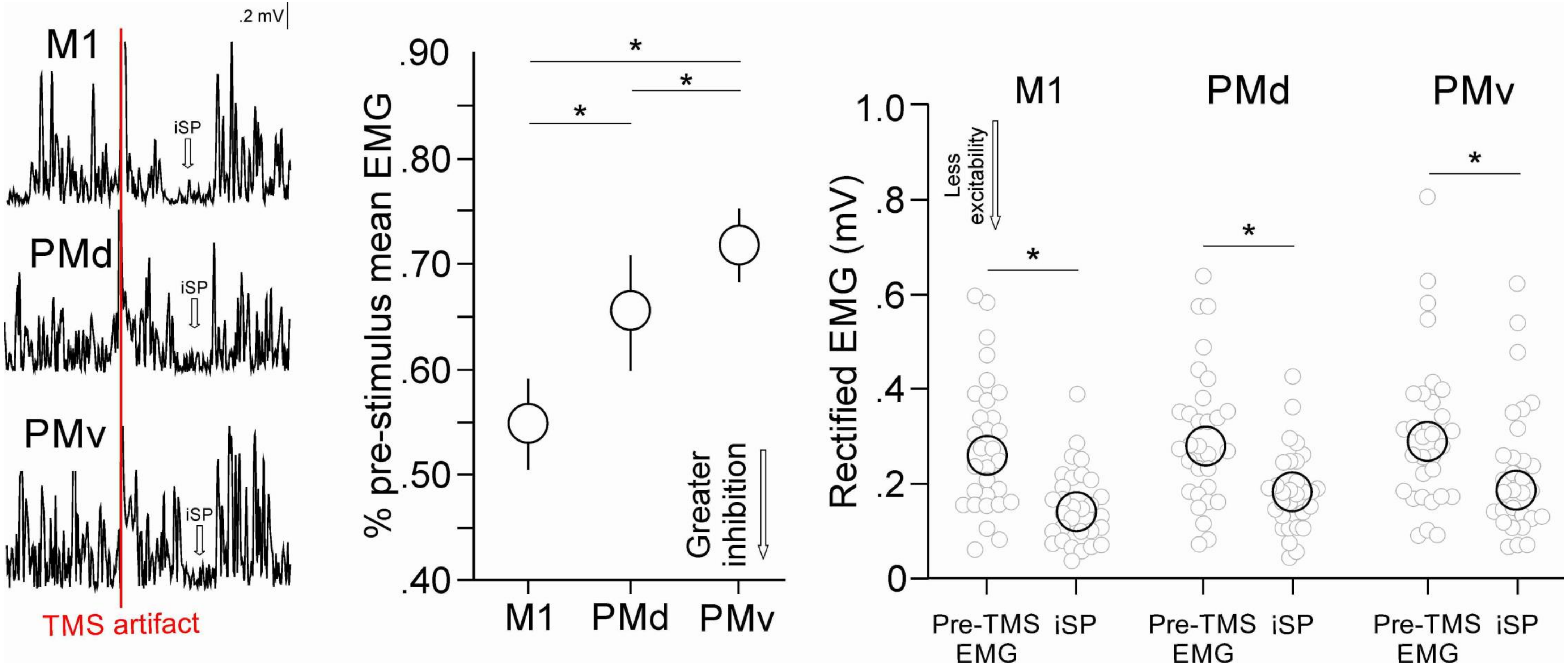


Methods

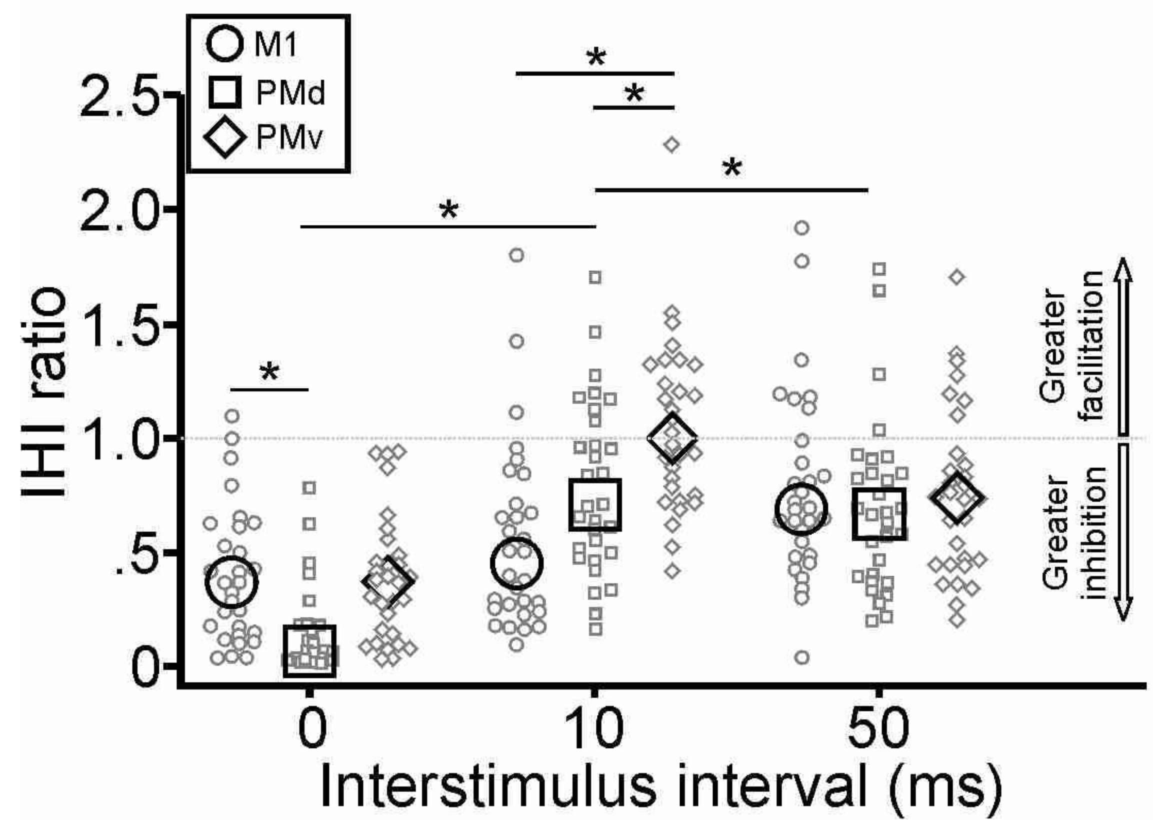
- 30 healthy young adults
- 3 sessions
  - 1st: MRI
  - 2nd: PMC→M1 connectivity
  - 3rd: M1→M1 connectivity (control)
- Neurophysiological pathways of PMd/PMv → M1 communication
  - Single-pulse TMS: ipsilateral silent period (iSP)
  - Dual-site TMS: Interstimulus intervals:
    - 0 ms (subcortical pathway)
    - 10 ms (<u>short</u> transcallosal pathway)
    - 50 ms (<u>long</u> transcallosal pathway)

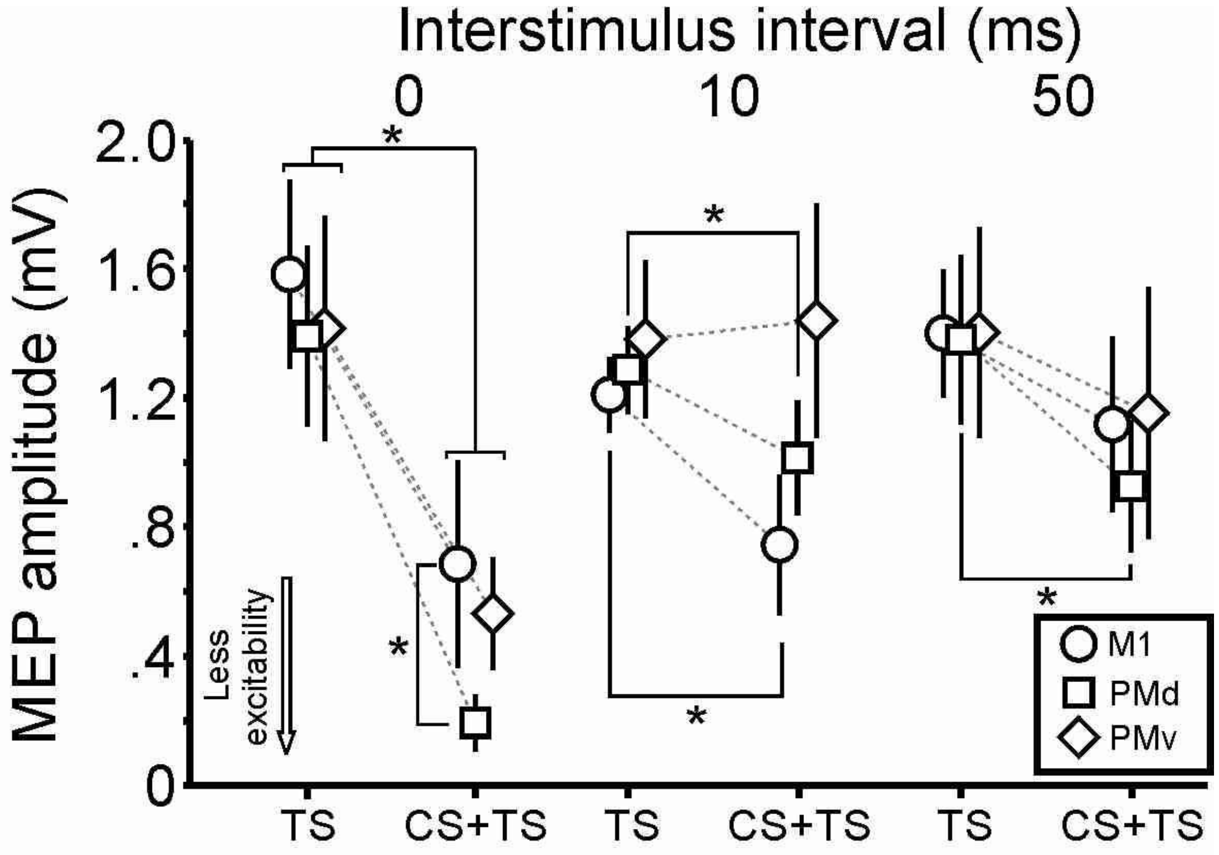


iSP: PMd & PMv *inhibit* contralateral M1



Dual-site: PMd *inhibits* contralateral M1 the most!

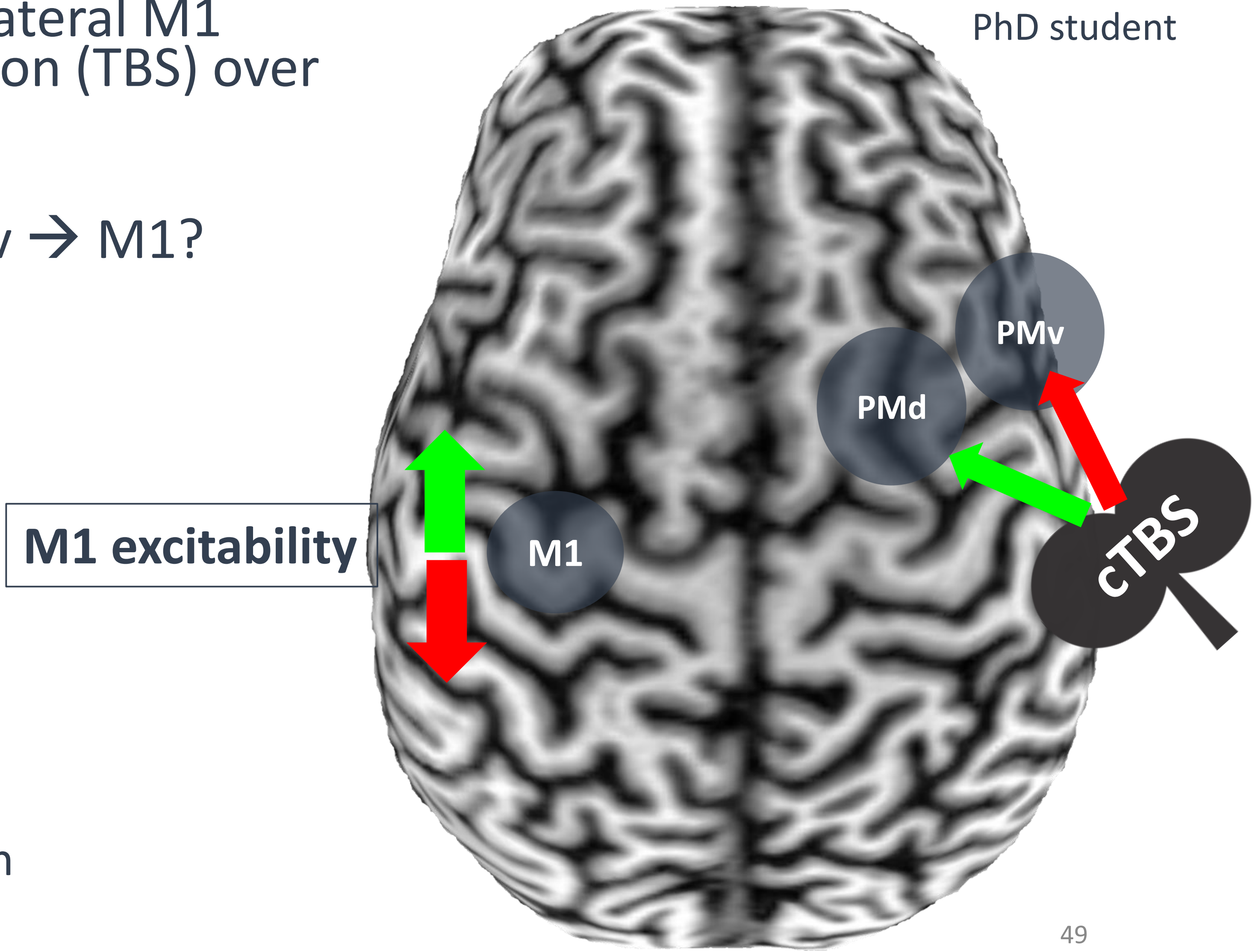




Can we modulate PMC → M1 connectivity?

Elnaz Allahverdloo, PhD student

- Can we remotely modulate contralateral M1 excitability via theta burst stimulation (TBS) over PMd/PMv?
- Can we modulate *interhemispheric communication* between PMd/PMv → M1?
- Conditions:
  1. Continuous TBS over PMd
     - Suppress cortical excitability
  2. Intermittent TBS over PMd
     - Increases cortical excitability
  3. Continuous TBS over PMv
  4. Intermittent TBS over PMv
  5. Sham
- Measures:
  - Bilateral M1 corticospinal excitability
  - PMC→M1 interhemispheric inhibition



1

Aerobic Exercise:
↑ *Motor Learning*
↑ *Neuroplasticity*

2

TMS:
Measure & Modulate the Brain

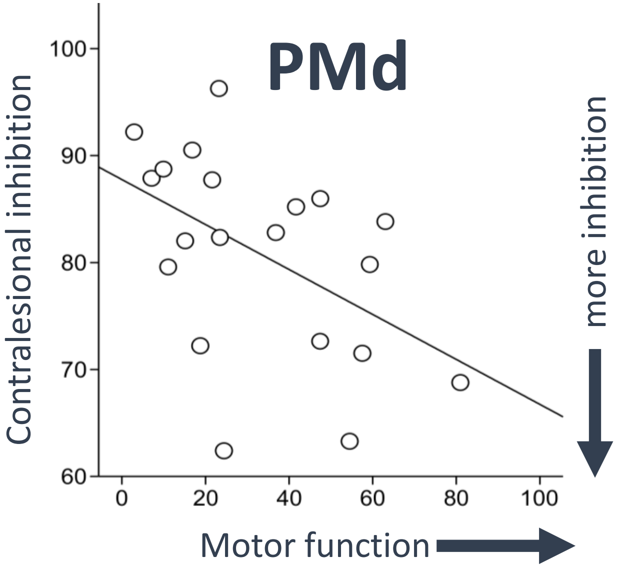
3

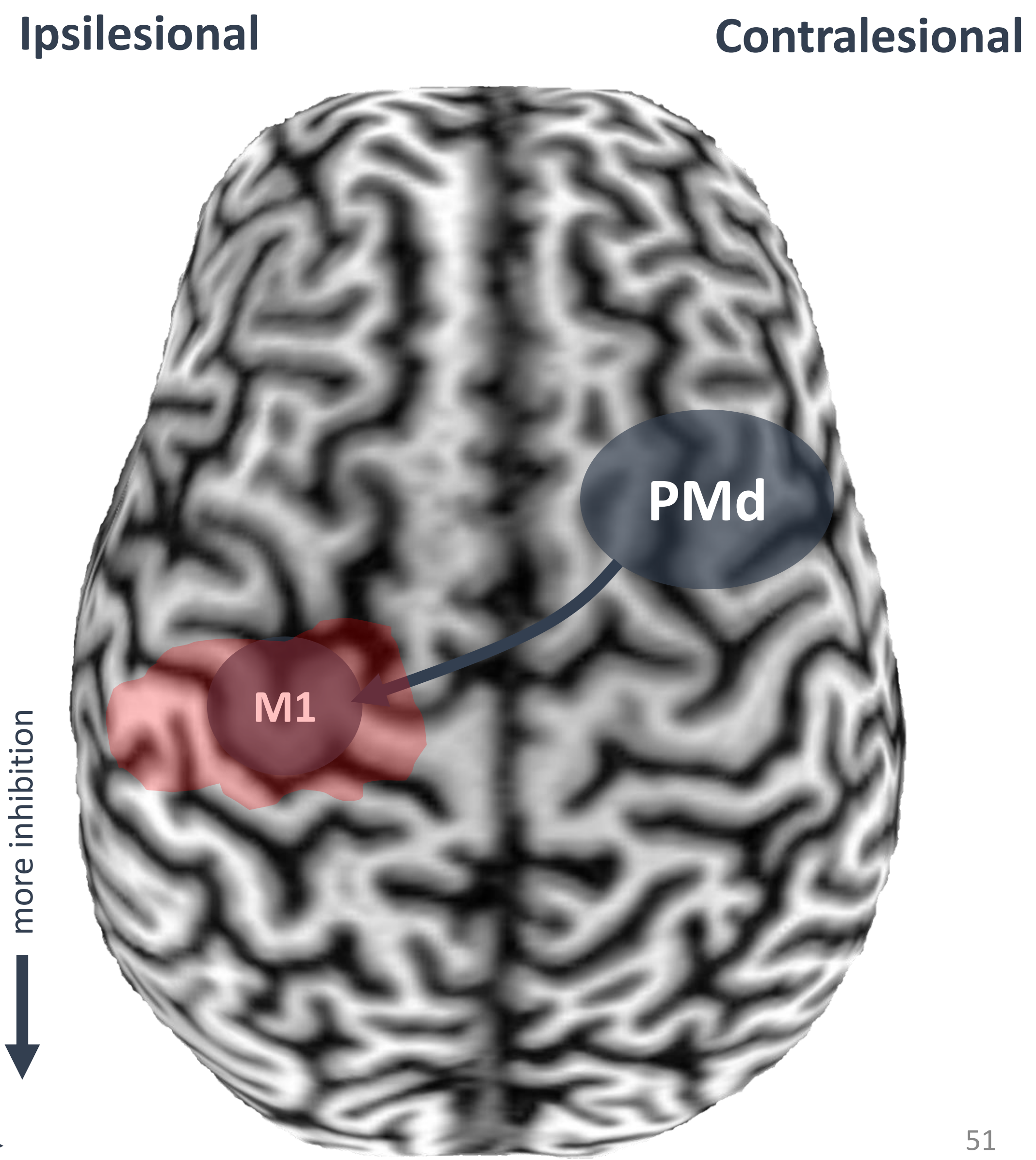
Clinical Application & Future Work

The Role of Premotor Cortex (PMC) in Stroke Recovery

- Increasing contralesional PMC excitability can ↑ motor function
- *Increased inhibition* from contralesional PMC is associated with *better* motor function
- PMd demonstrates *strongest* connectivity with contralateral M1 *(healthy adults)*

Contralesional PMd may play an important role in recovery & is a viable target for rTMS!

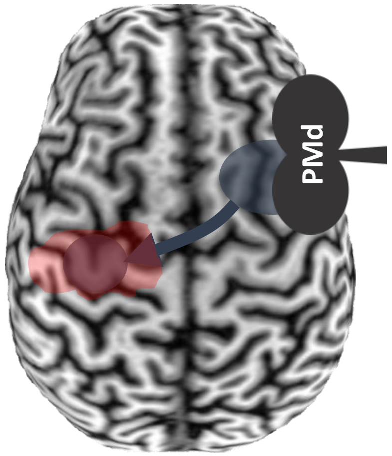




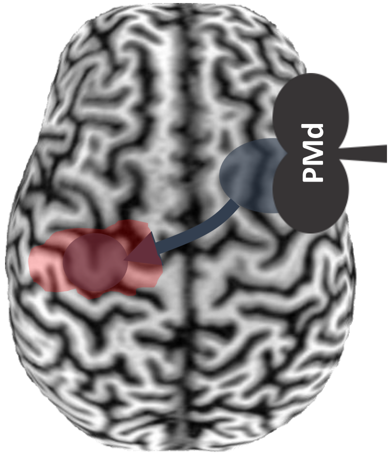
Methods: Participants & Pilot Design

- Participants:
  - Recruit 30 individuals, subacute phase of stroke from IUGM Intensive Rehabilitation Unit
  - 50% F, aged 50-85 yo
  - Subacute stage (1-3 mo) after first-time middle cerebral artery stroke
  - Fugl-Meyer 15-55 (motor impairment)
  - No contraindications to TMS
- 3 Intervention Groups (n=10/group)
  1. Continuous Theta Bust Stimulation (cTBS) to contralesional dorsal premotor cortex (cPMd)
     - *Inhibition* of contralesional cortex
  2. Intermittent TBS (iTBS) to cPMd
     - *Facilitation* of contralesional cortex
  3. Sham TBS (control)
     - No active stimulation

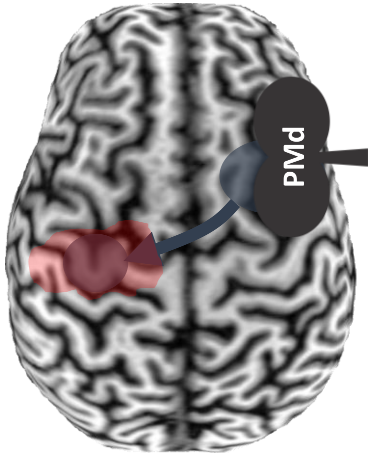
Group 1: cTBS to cPMd



Group 2: iTBS to cPMd

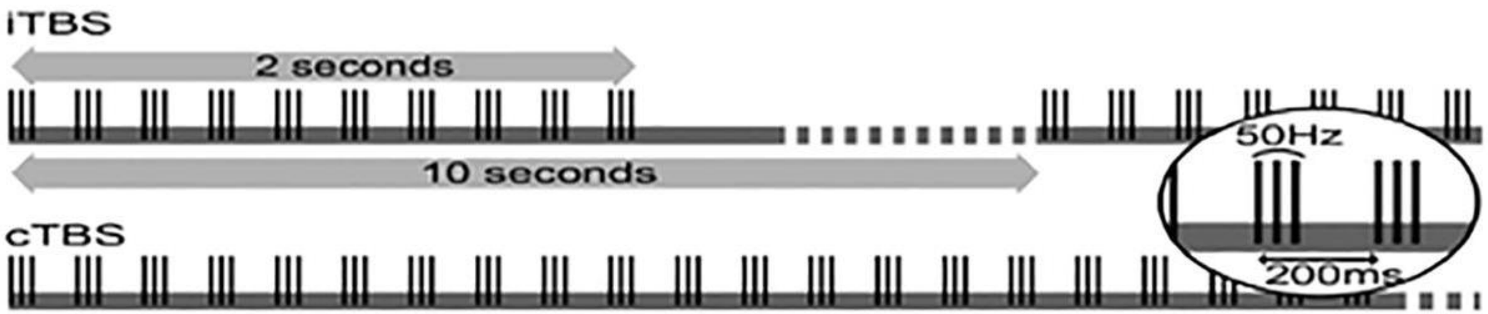


Group 3: Sham TBS



Methods: Interventions & Visits

- Theta Burst Stimulation (TBS)
  - Continuous theta burst stimulation (cTBS) – ↓ excitability
  - Intermittent theta burst stimulation (iTBS) – ↑ excitability



- Visits

Visit 1:
Clinical Motor Function Assessments (e.g., FM, WMFT, BBT)

→

Visit 2:
Neuroplasticity Assessment (pre-post TBS)

→

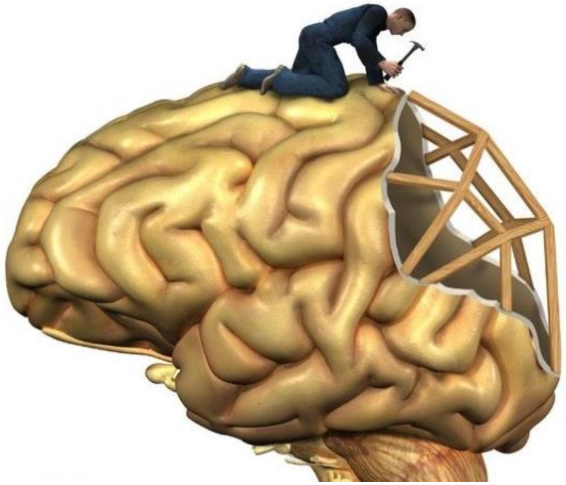
Visits 3-5:
Motor Learning Assessment (TBS+practice)

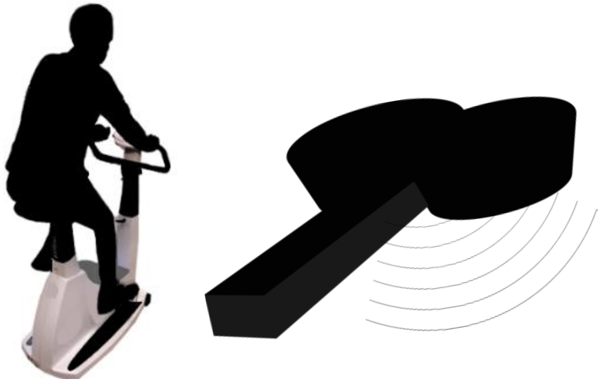
→

Visit 6:
24 h retention test, Clinical Motor Function Assessments

Neuroplasticity mechanisms supporting motor learning

Neuroplasticity





Motor skill learning
(healthy brain)

Re-learning function
(e.g. stroke, PD)

How to capitalize on the benficial effects of acute aerobic exercise?

Acute exercise

Kinesiologist or
Exercise physiologist

Brain *primed* for
neuroplasticity

Practice, training or
motor therapy

Physiotherapist,
occupational
therapist or trainer

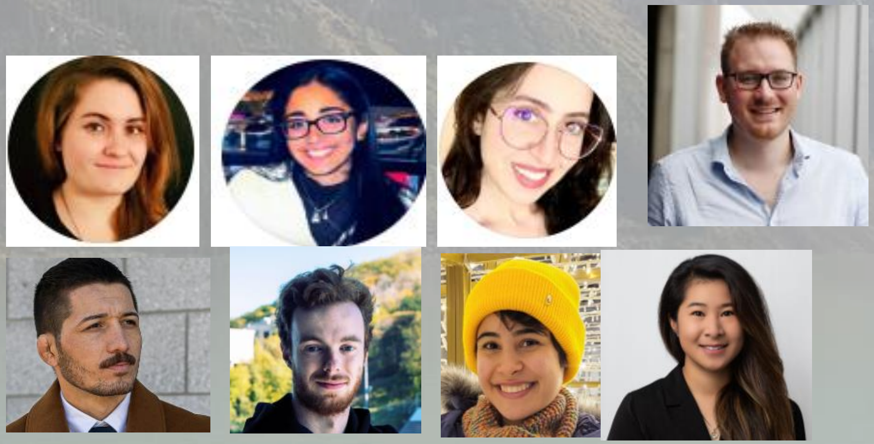
**↑ performance,
motor learning &
benefits from therapy**

Neva, 2025 Exercise-Induced Neuroplasticity
Encyclopedia of the Human Brain, 2nd Edition.

ELPN lab

Effort Learning Performance Neuroplasticity

Thank you!



Collaborators

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- Dr. Alexandru Hanganu (Psychology, UdeM; CRIUGM)
- Dr. Dorothy Barthélemy (Rehabilitation, UdeM; CRIR)
- Dr. Julie Messier (Kinesiology, UdeM; CRIUGM)
- Dr. Ana Ines Ansaldo (Language Pathology, UdeM; CRIUGM)
- Dr. Daniel Gagnon (Kinesiology, UdeM; EPIC)
- Dr. Lara Boyd (University of British Columbia)
- Dr. Cameron Mang (University of Regina)
- Dr. Richard Staines (University of Waterloo)
- Dr. Doris Doudet (University of British Columbia)
- The CanStim working group
- Dr. Michael Vesia (USA)
- Dr. Kate Hayward (AUS)

Centre de recherche iugm Institut universitaire de gériatrie de Montréal

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CIRCA CENTRE INTERDISCIPLINAIRE DE RECHERCHE SUR LE CERVEAU ET L'APPRENTISSAGE

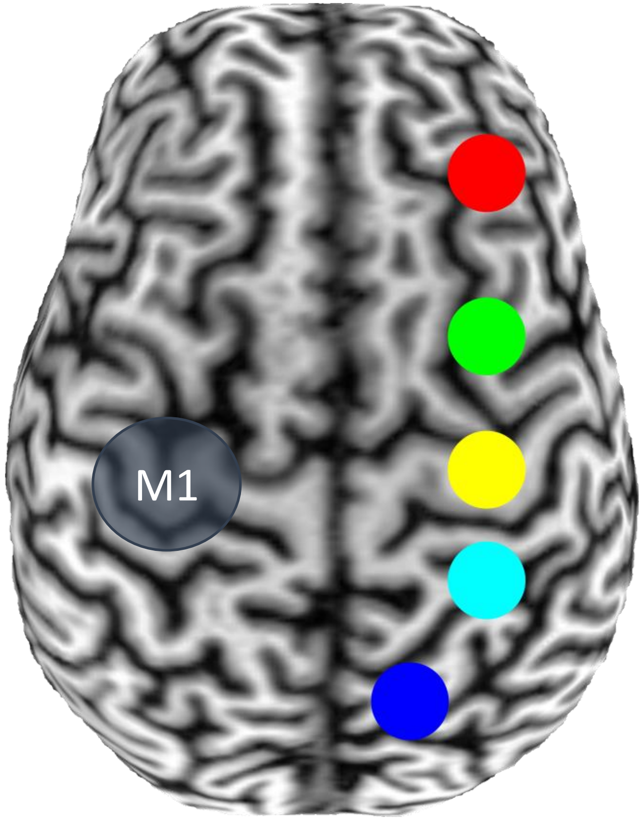
INNOVATION Canada Foundation for Innovation Fondation canadienne pour l'innovation

RBIQ RÉSEAU DE BIO-IMAGERIE DU QUÉBEC

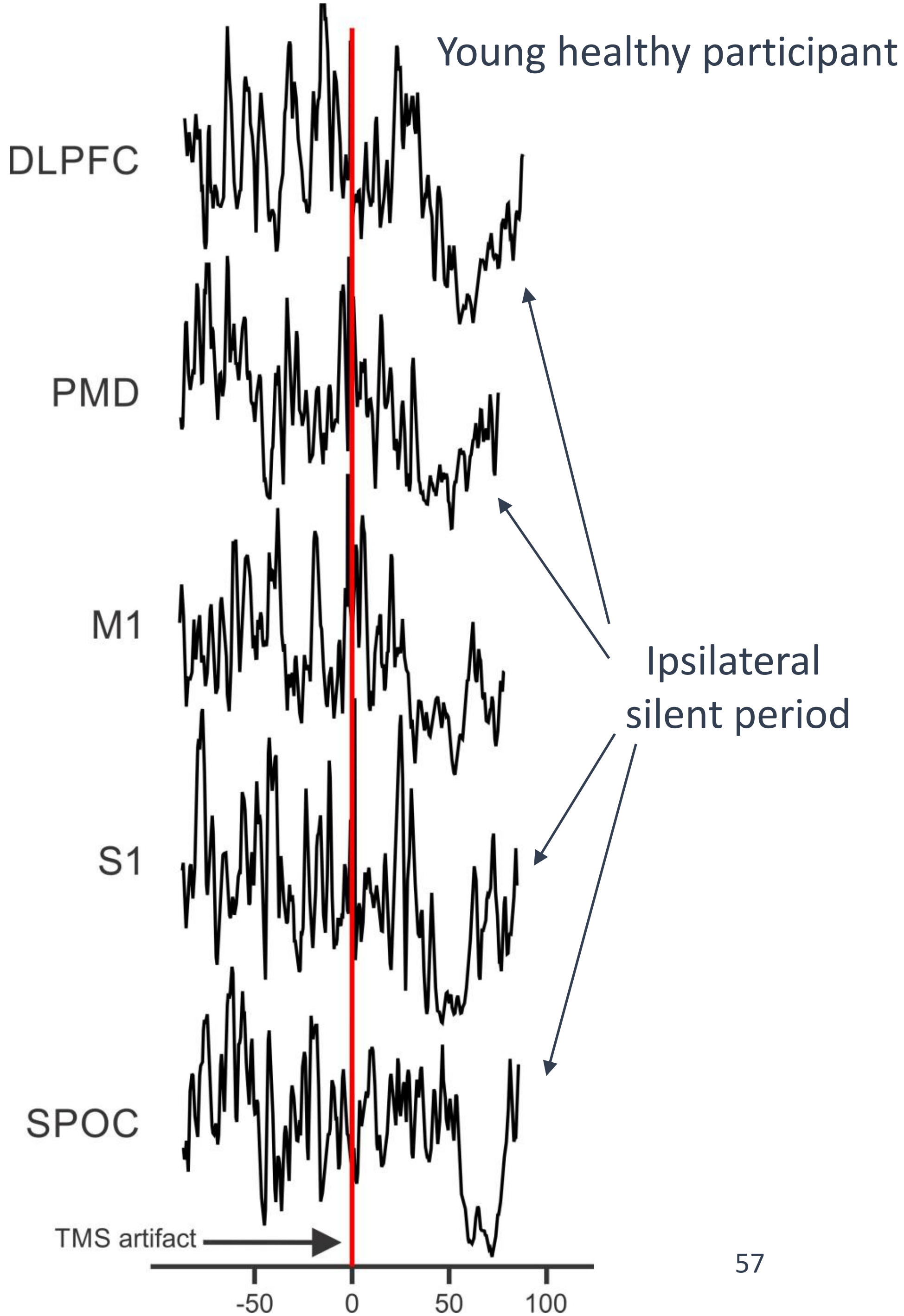
Fonds de recherche Santé Québec

Université de Montréal

Transcallosal inhibition elicited from **frontal** & **parietal** cortical regions



- Dorsolateral prefrontal cortex (DLPFC)
- Dorsal premotor cortex (PMD)
- Primary motor cortex (M1)
- Primary somatosensory cortex (S1)
- Superior parietal-occipital cortex (SPOC)



Neva et al., 2020d (in preparation)

1 Exercise and Learning (↑ *motor learning*)

2 The Brain on Exercise (↑ *neuroplasticity*)

3 Key Takeaways and Clinical Application

- ↑ skill acquisition
- ↑ motor learning

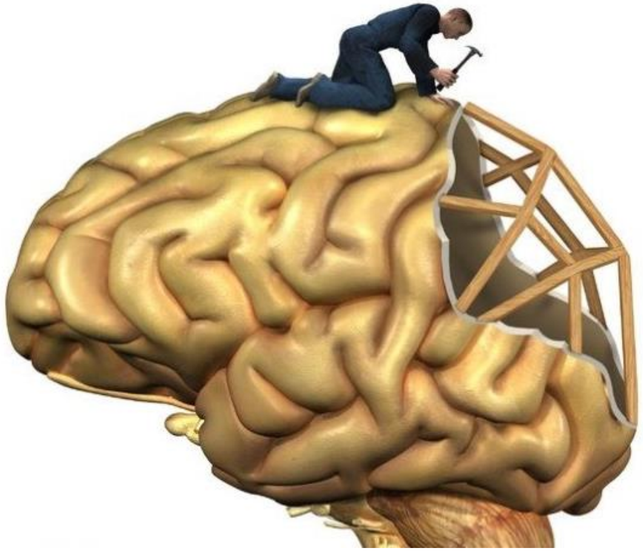
- ↑ output excitability from motor cortex
- ↓ cortical inhibition
- ↑ prefrontal contribution to motor cortex plasticity

- Positive effects of acute exercise
- Eccentric exercise promising avenue for future research and clinical application

Exercise *intensity* and *type* are very important factors to consider

The beneficial impact of acute exercise

Acute aerobic exercise

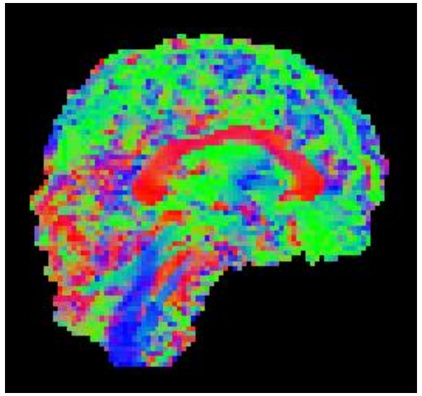


↑ Neuroplasticity

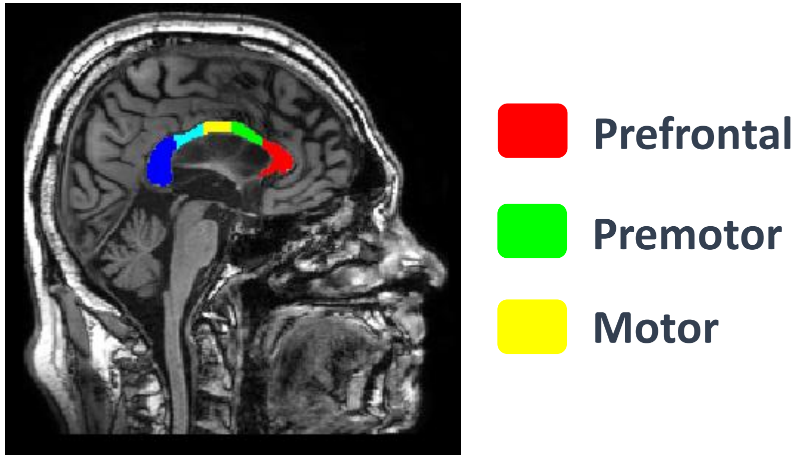
- ↑ Blood flow, dopamine, BDNF
- ↓ Inhibition within brain regions
- ↑ Prefrontal-motor cortex connectivity

↑ re-learning, rehabilitation (e.g., aging, stroke)

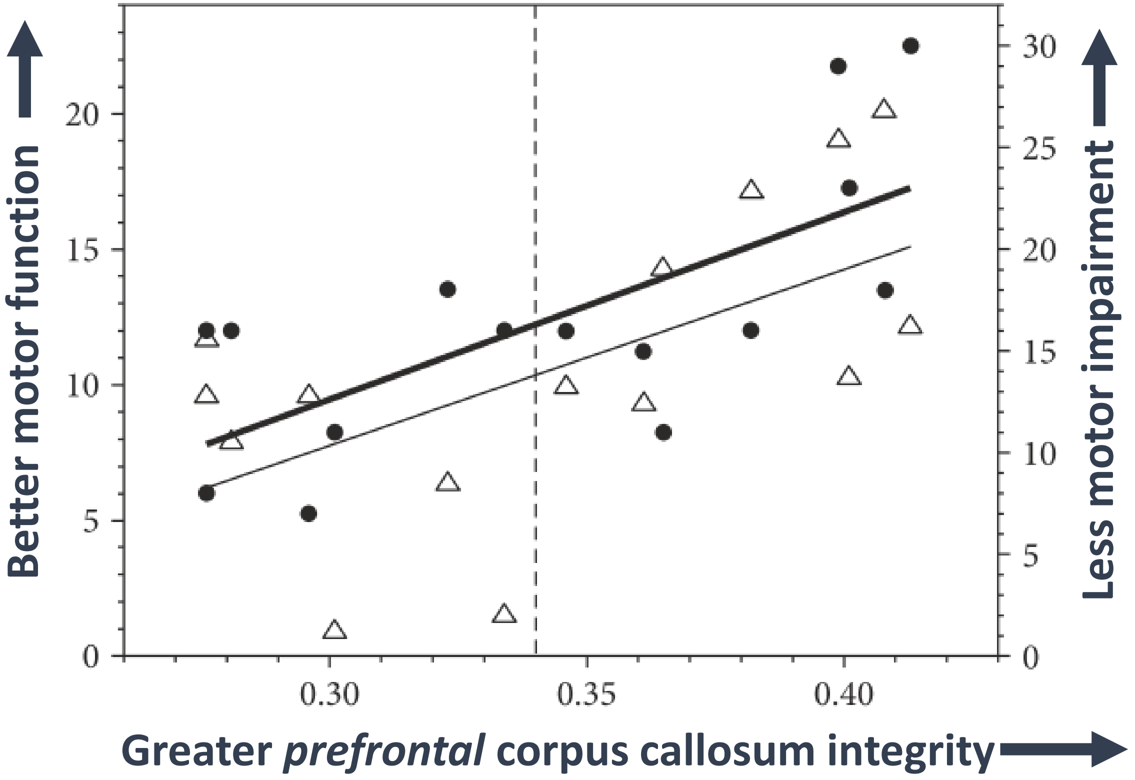
Frontal white matter structural integrity is vital for motor function after stroke



Diffusion tensor imaging (DTI)



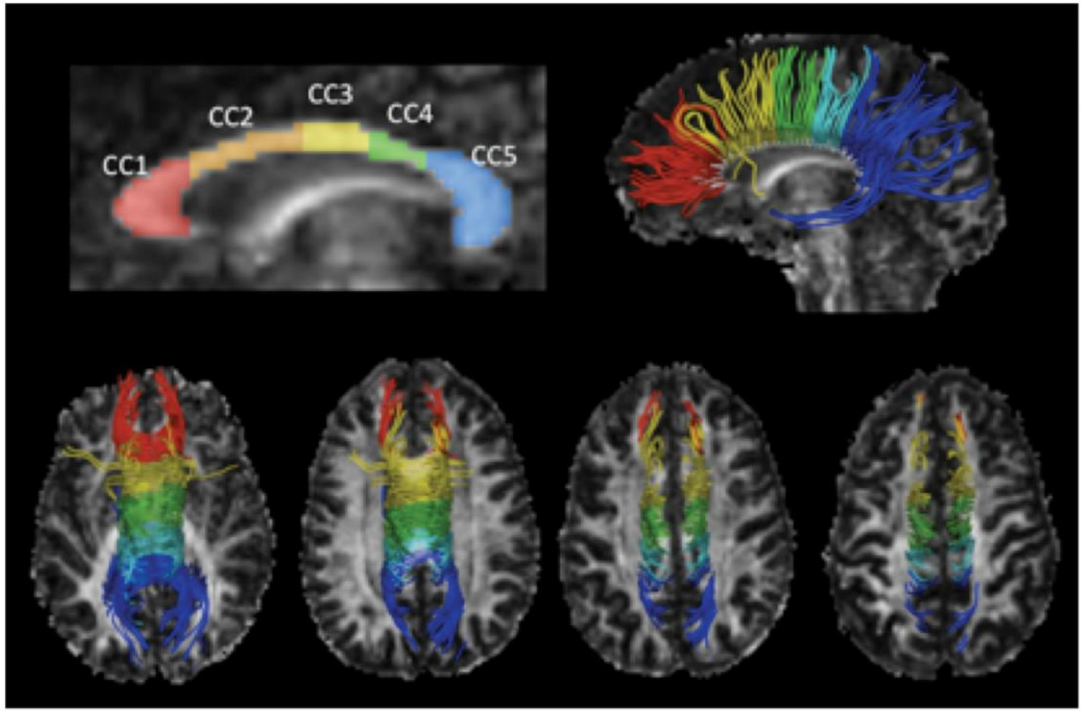
Fractional anisotrophy
of frontal corpus callosum regions



Hayward, Neva et al., 2017 *Neural Plasticity*

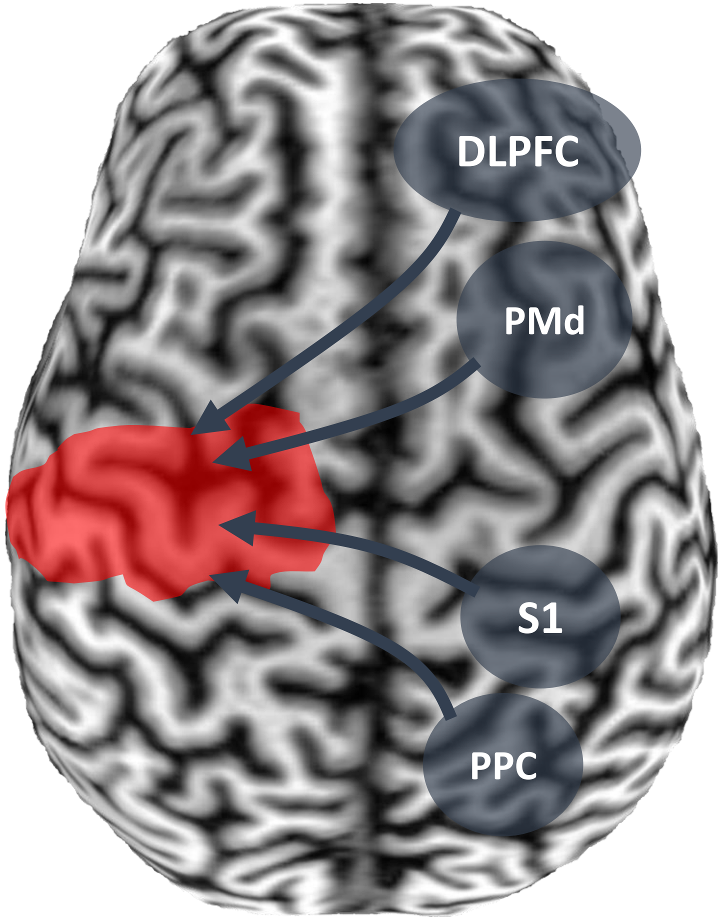
Frontal & parietal brain regions in stroke

Brain *structure*



Hayward, Neva et al., 2017 *Neural Plasticity*

Brain *function*



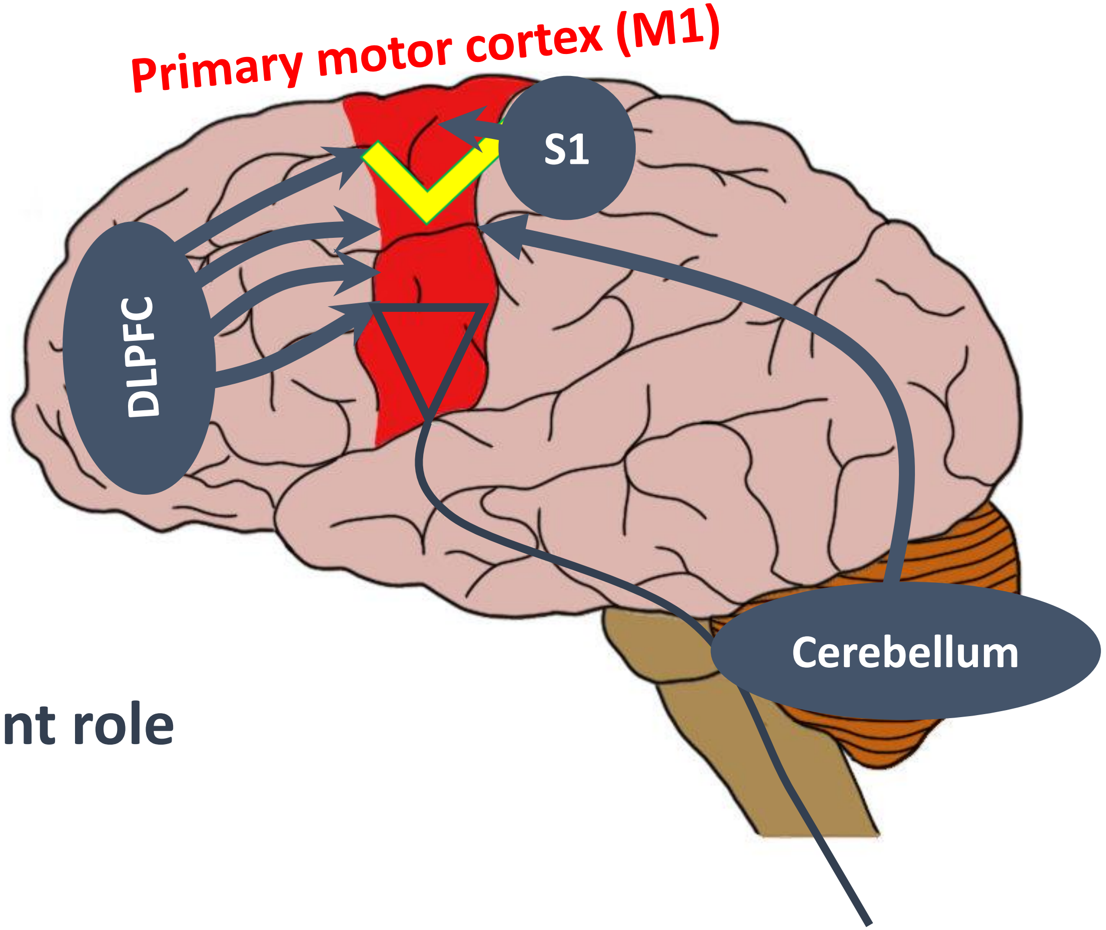
Neva et al., 2020d (in preparation)

Brain circuits contribute to exercise-induced motor cortex plasticity?

Acute exercise impact on brain excitability & neuroplasticity

Summary of findings

- **↓ motor cortex inhibition**
- **↑ motor cortex output excitability**
- **several other brain circuits are impacted**
  - sensorimotor integration
  - cerebellar inhibition & plasticity
  - unique motor cortex interneurons

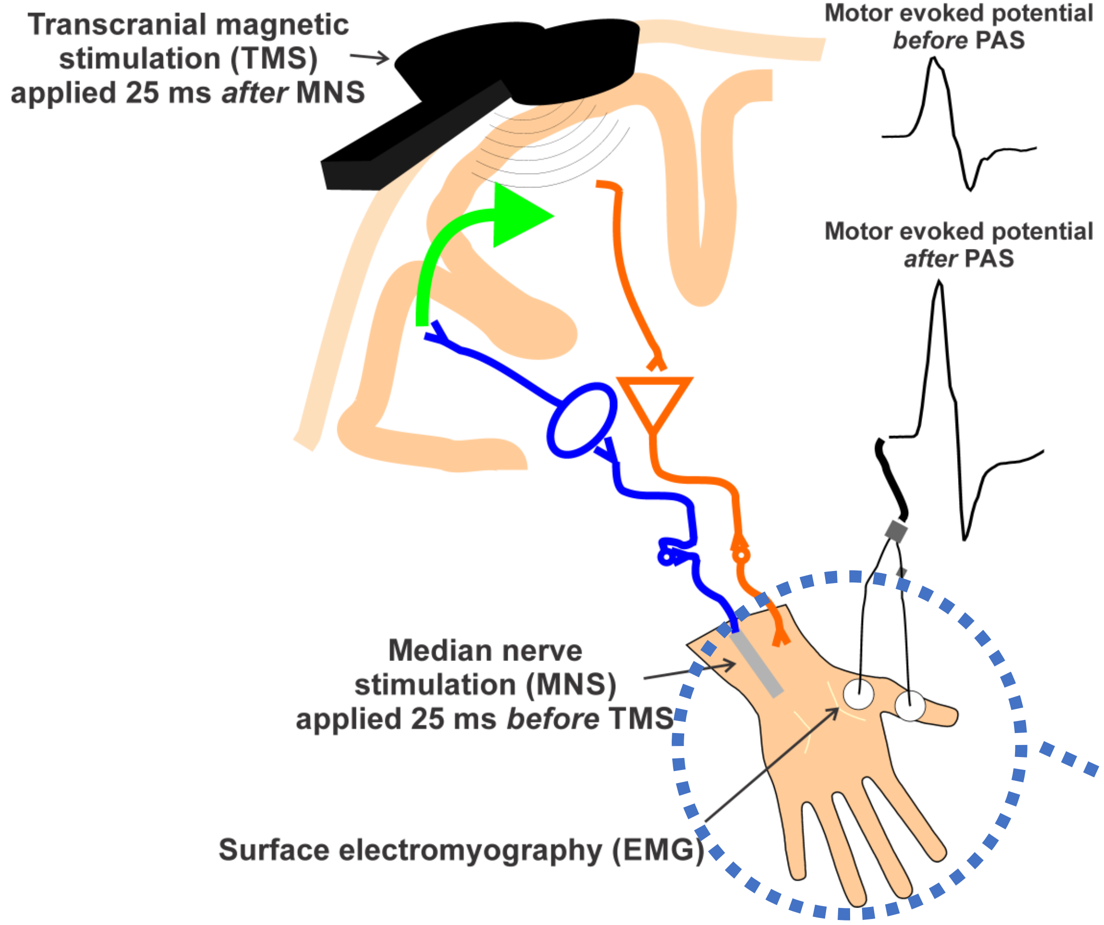


- **Prefrontal cortical circuits may play an important role in exercise-induce motor cortex neuroplasticity**

Neva, 2025 Exercise-Induced Neuroplasticity
Encyclopedia of the Human Brain, 2nd Edition.

Prefrontal circuits play a role in exercise-induced motor cortex plasticity?

Paired Associative Stimulation (PAS) – Motor cortex neuroplasticity



Attention (task-relevant)

PAS response

Stefan et al., 2004 *J Neurophys*

Acute exercise

PAS response

Singh, Neva, Staines 2014 *Exp Brain Res*
Mang et al., 2014 *J App Phys*

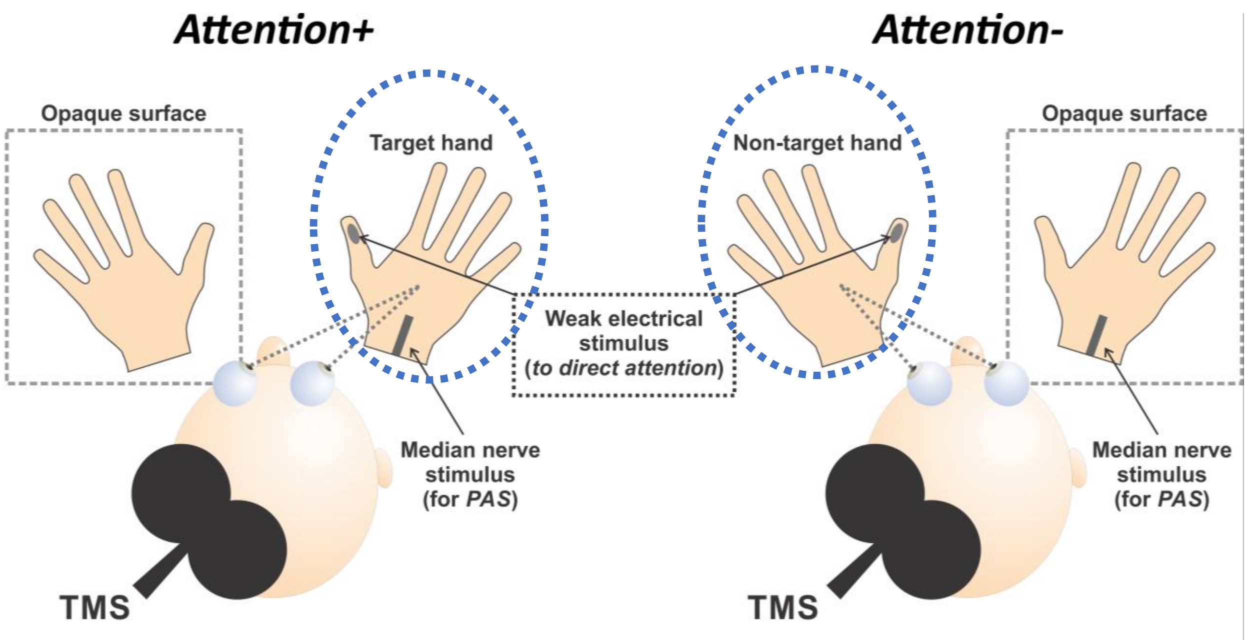
Amanda O'Farrell, PhD candidate

Previous studies did not control for the contribution of attention during PAS.

Thus, *the contribution of attention-related brain circuits to motor cortex neuroplasticity remains unknown.*

Prefrontal circuits play a role in exercise-induced motor cortex plasticity?

Paired Associative Stimulation (PAS) – Attention conditions



PAS with task-relevant attention to target hand

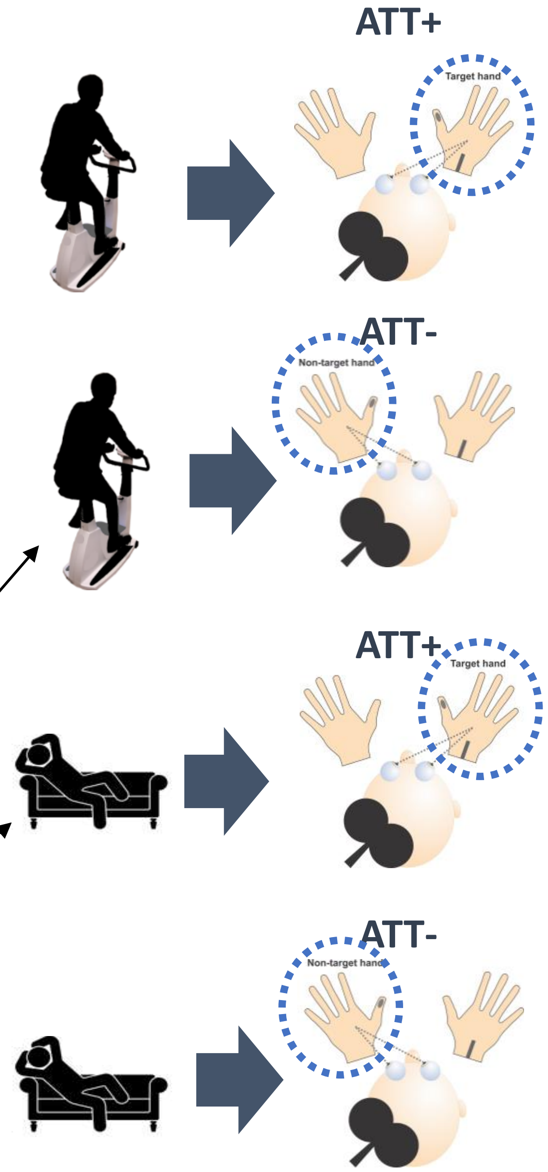
PAS with task-irrelevant attention to non-target hand

Amanda O'Farrell,
PhD candidate

Experimental design

4 conditions:

1) Exercise + PAS_{ATT+}
2) Exercise + PAS_{ATT-}
3) Rest + PAS_{ATT+}
4) Rest + PAS_{ATT-}

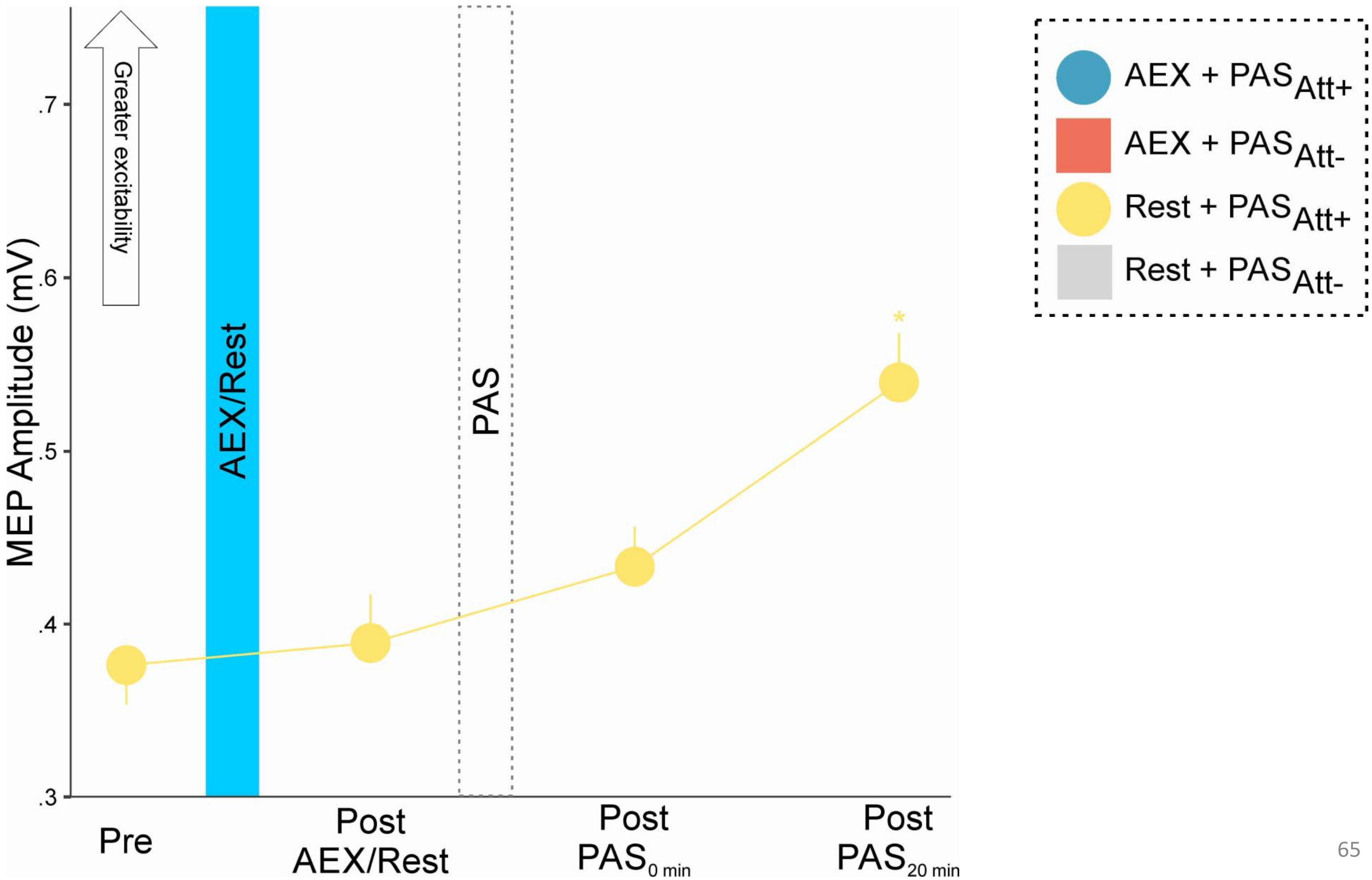


Acute moderate intensity exercise

Rest

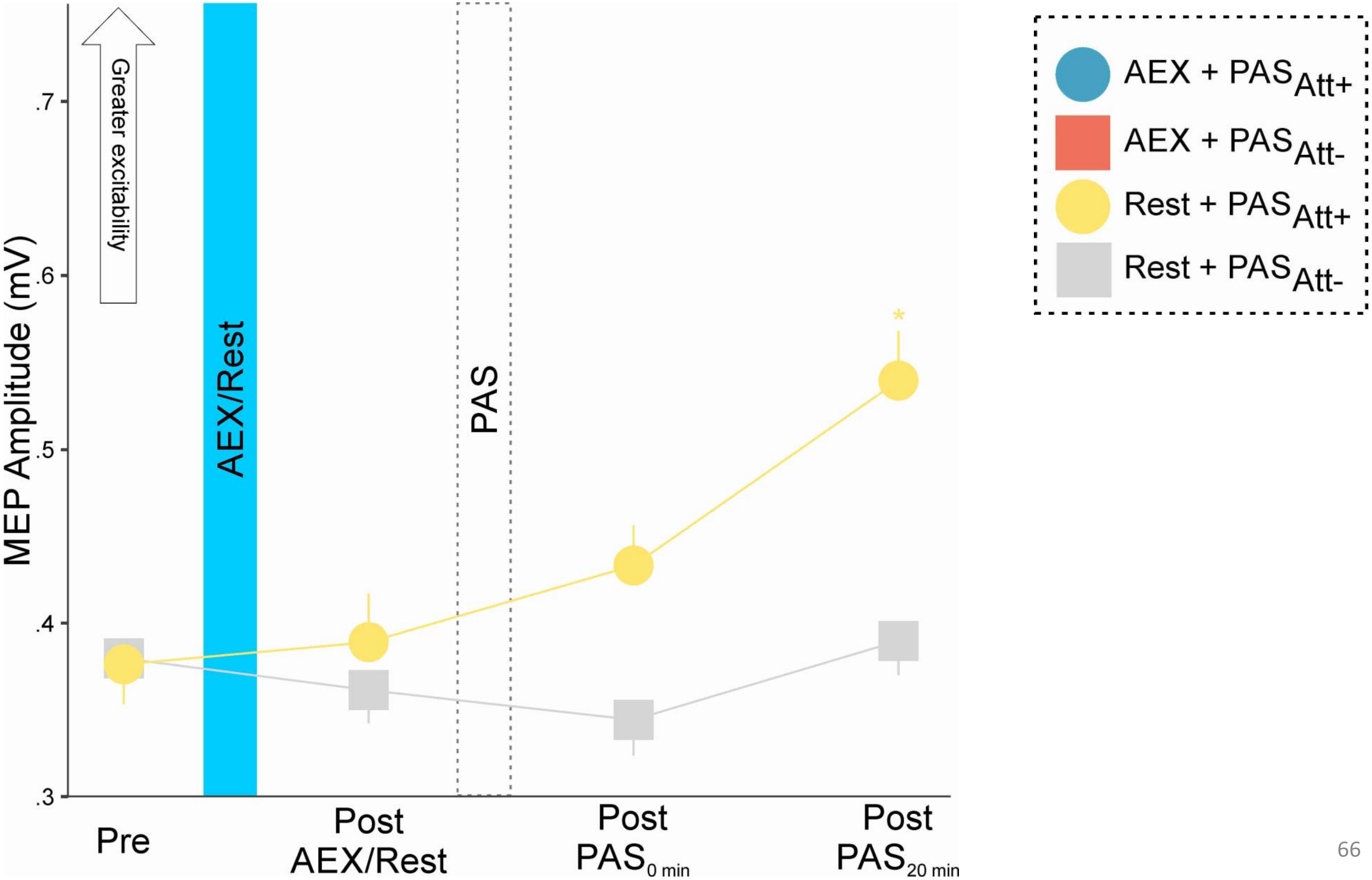
Prefrontal circuits play an essential role in exercise-induced M1 plasticity!

Amanda O'Farrell, PhD candidate



Prefrontal circuits play an essential role in exercise-induced M1 plasticity!

Amanda O'Farrell,
PhD candidate



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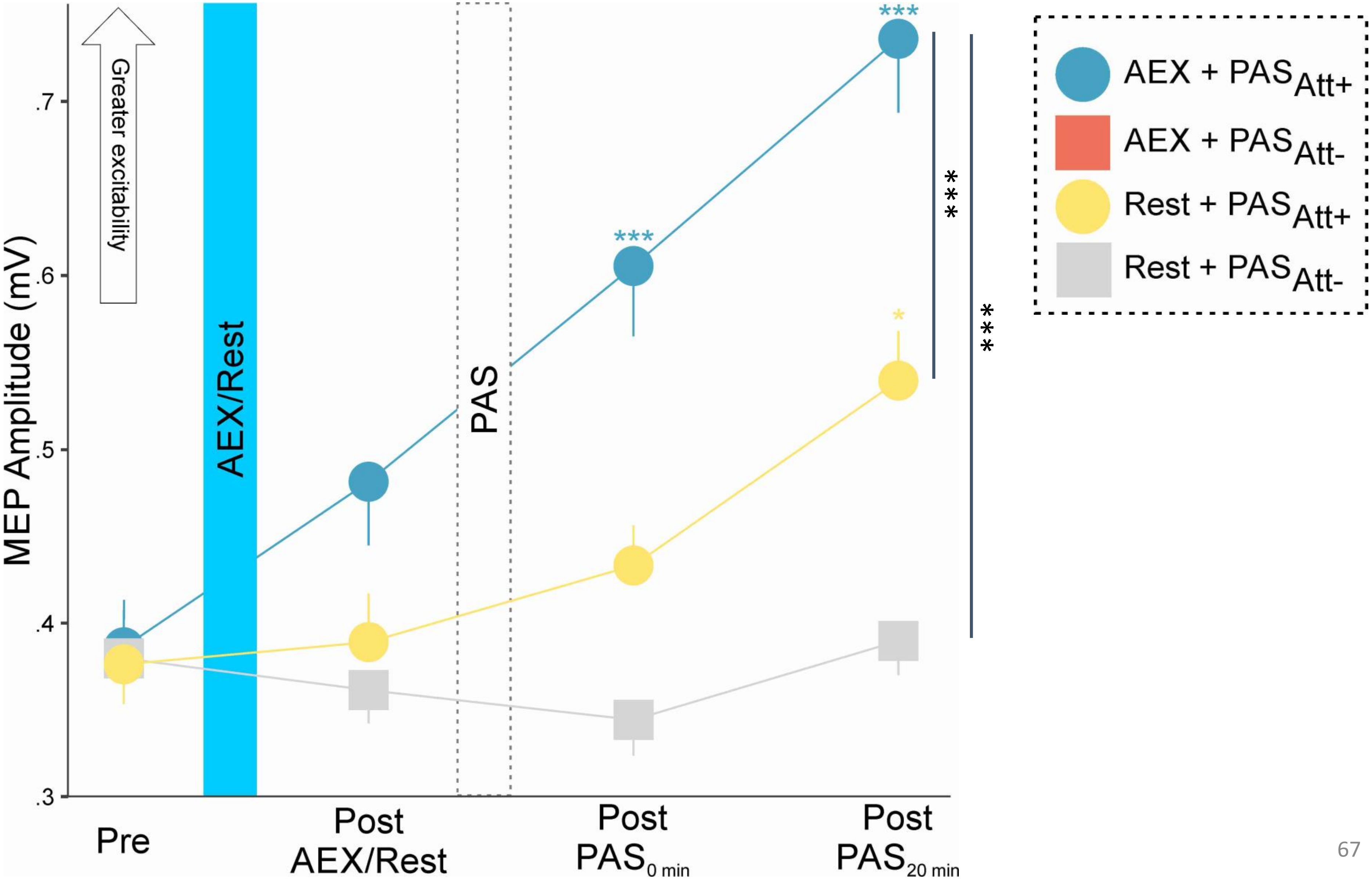

Prefrontal circuits play an essential role in exercise-induced M1 plasticity!

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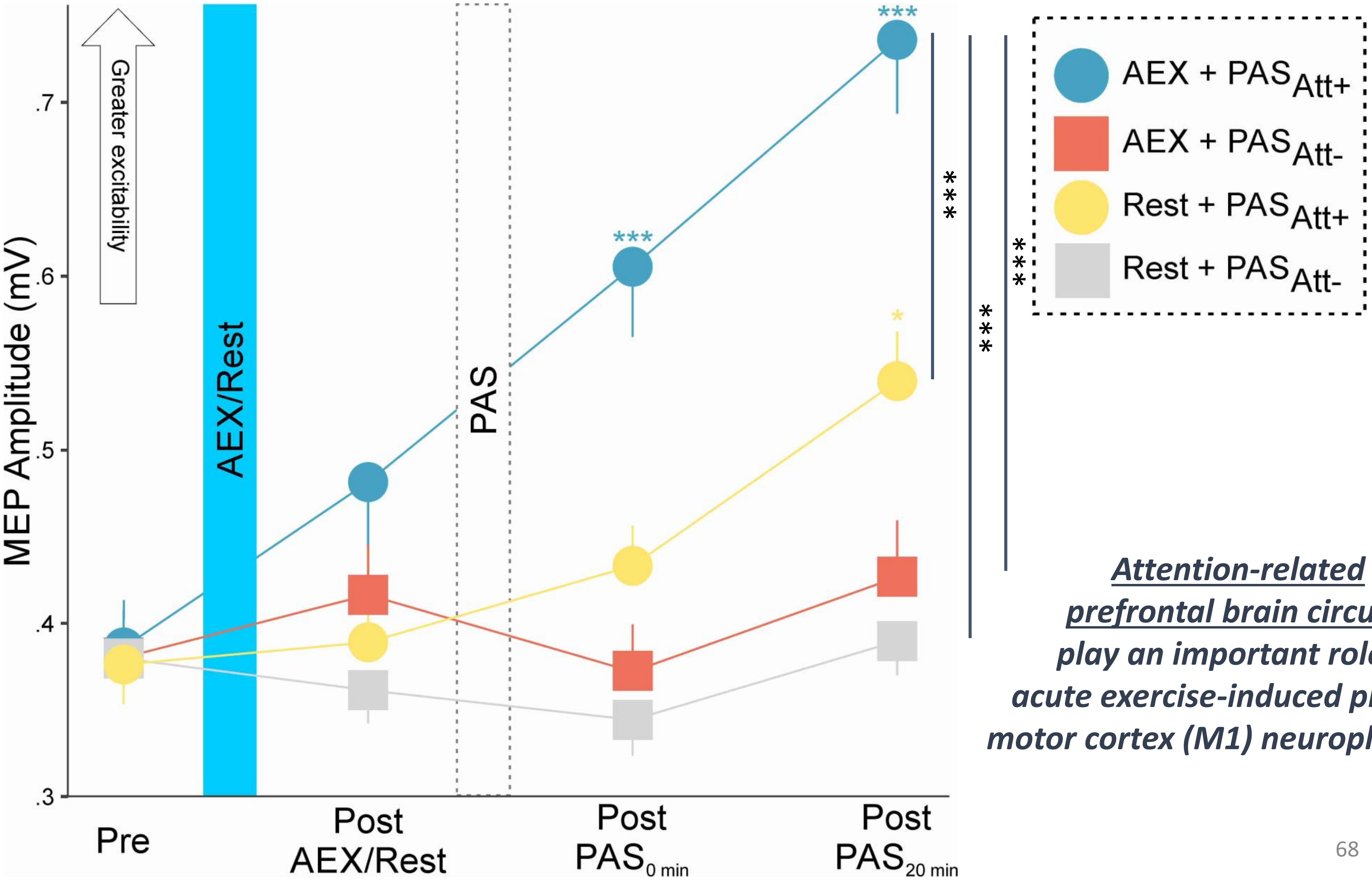
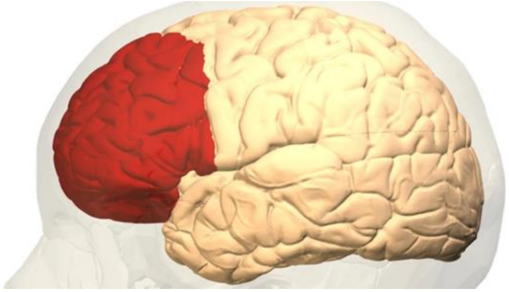
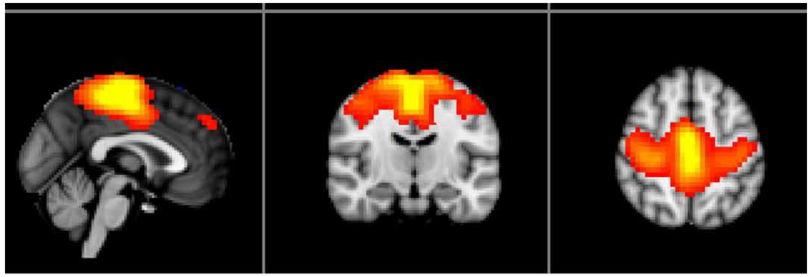


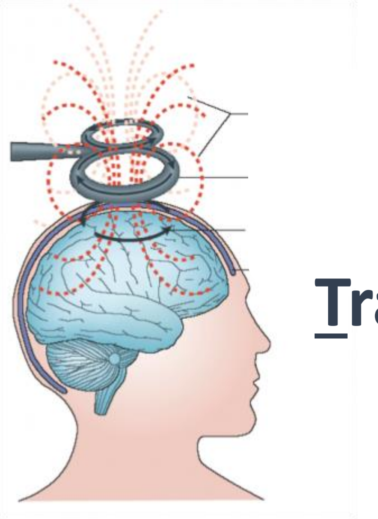
__Attention-related__
__prefrontal brain circuits__
play an important role in
acute exercise-induced primary
motor cortex (M1) neuroplasticity!

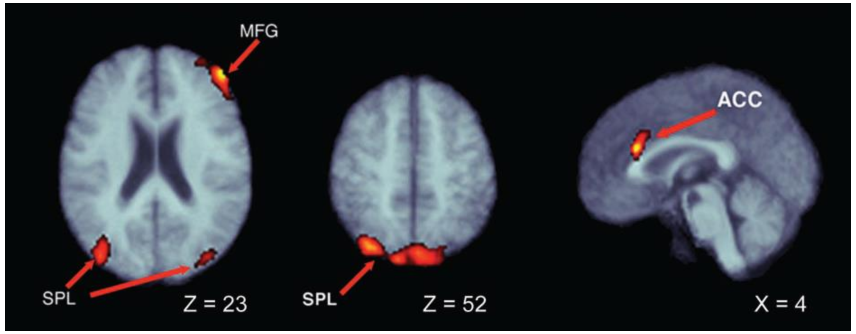
Aerobic Exercise Enhances Brain Function & Plasticity

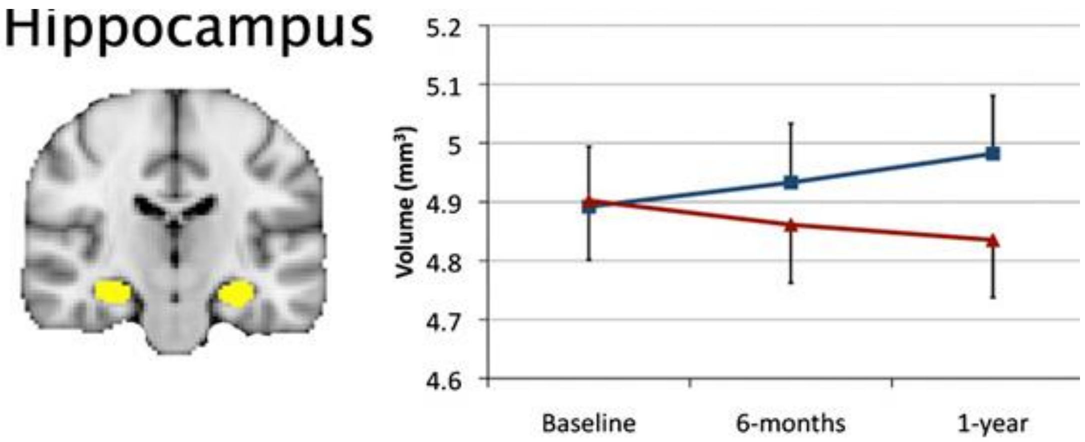


↑frontal blood flow







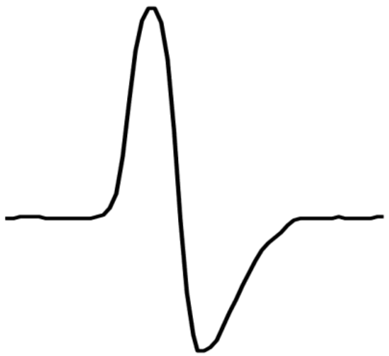


Transcranial Magnetic Stimulation (TMS)

Modulating neuroplasticity mechanisms

Repetitive Transcranial Magnetic Stimulation (rTMS)

- ↑ or ↓ cortical excitability transiently after stimulation

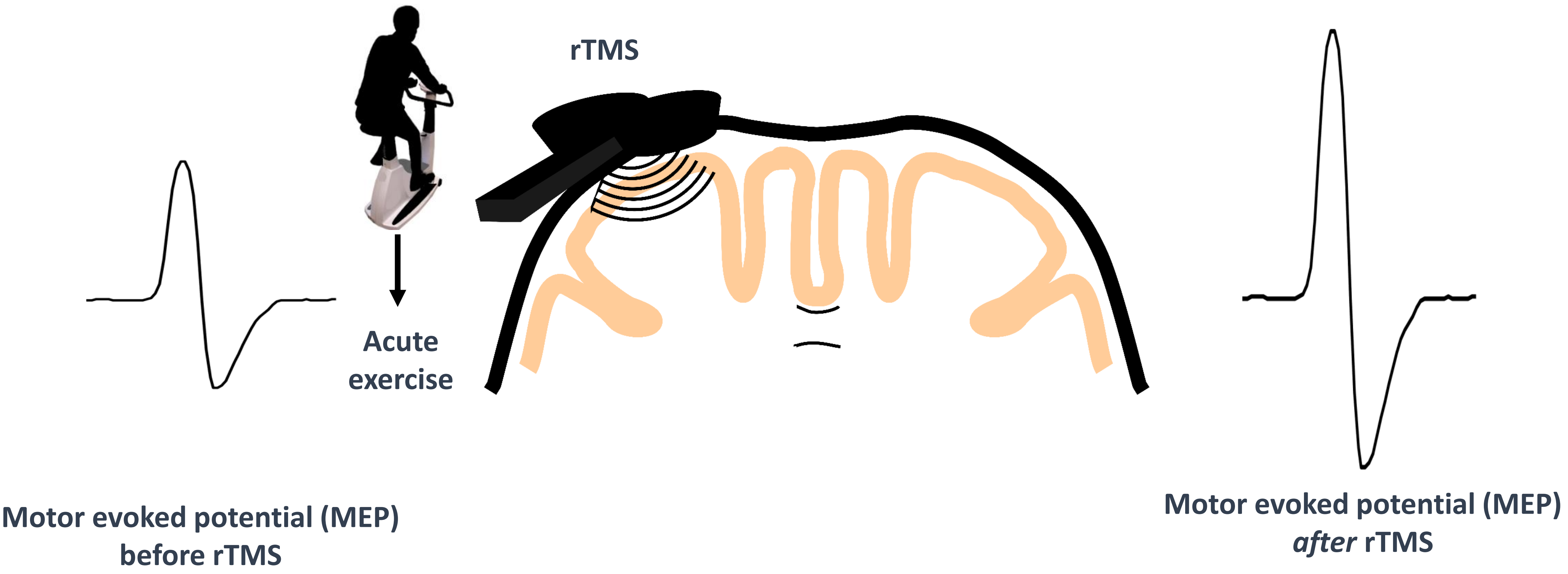


Motor evoked potential (MEP) before rTMS

Motor evoked potential (MEP) *after* rTMS

Brown e et al., 2014; Auriat et al., 2015; Neva et al., 2020 Wiley Encyclopedia

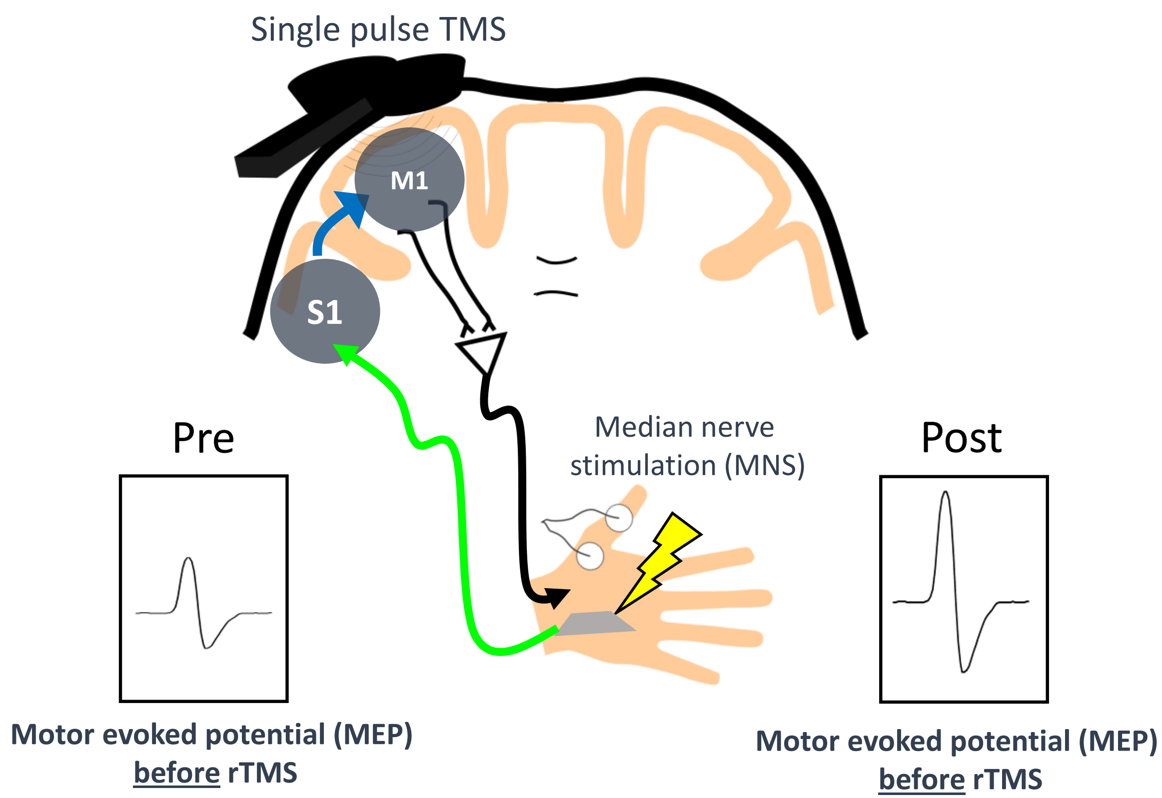
Acute exercise ‘primes’ neuroplasticity induction



Neva et al., 2020 *Wiley Encyclopedia*
Neva 2025 *Encyclopedia of the Human Brain*

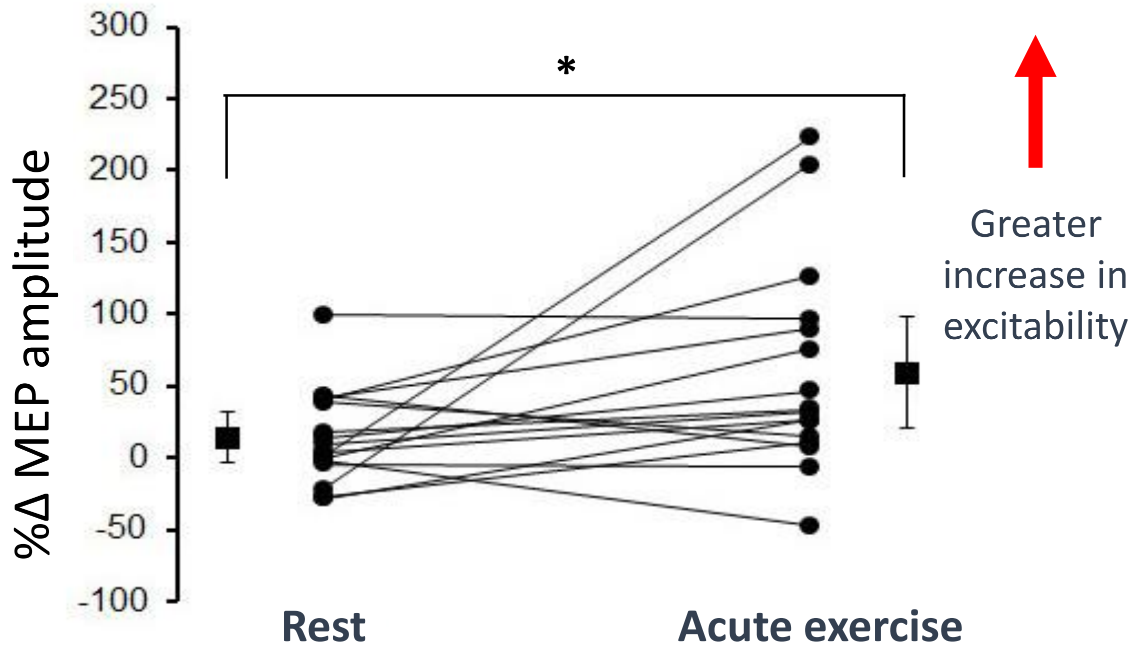
Singh et al., 2014 *Exp Brain Res*
Mang et al., 2014 *J Appl Physiol*

Acute exercise ↑response to Paired-Associative Stimulation (PAS)



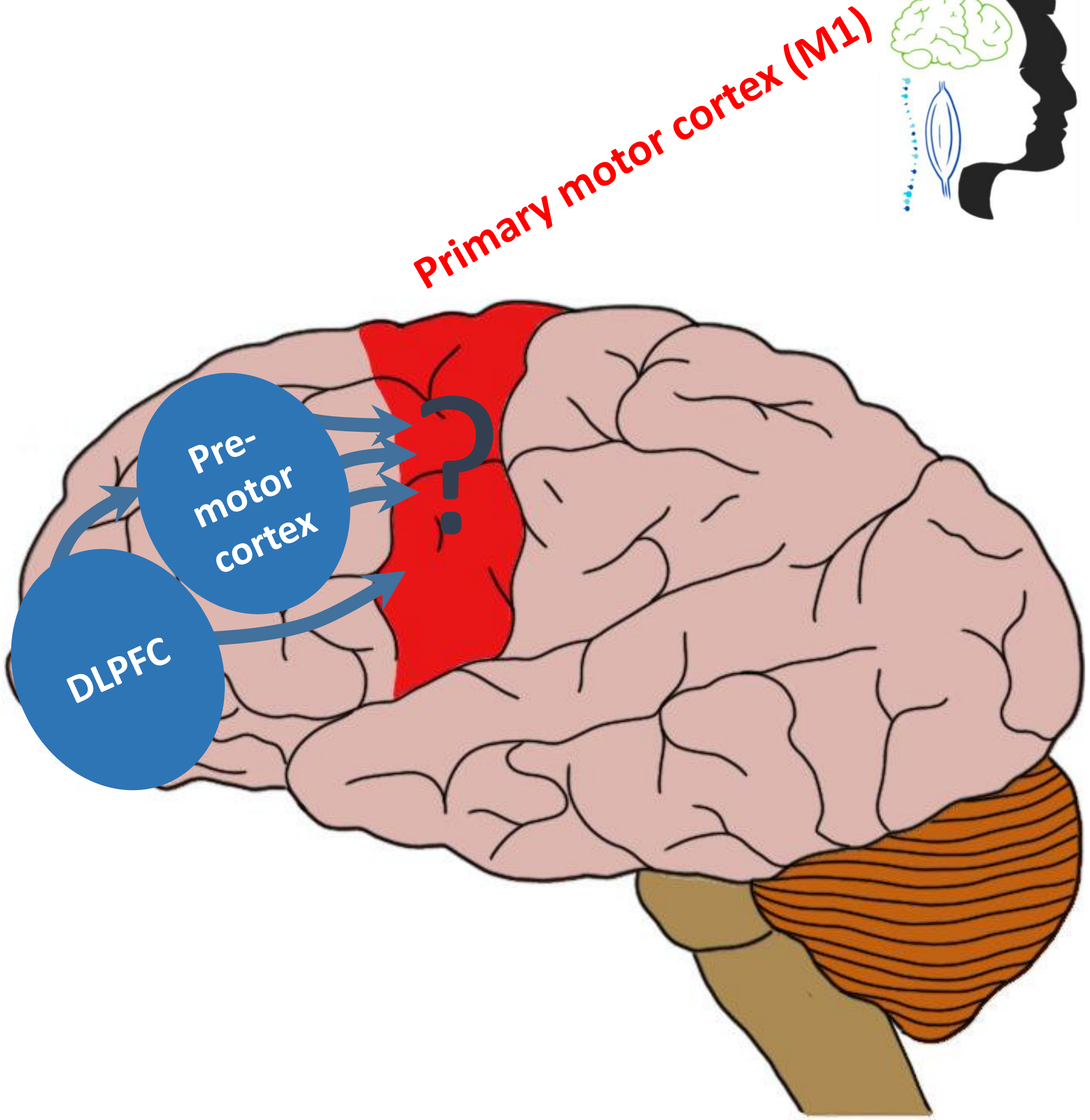
Paired-Associative Stimulation (PAS)
(25 ms interval between SNM + TMS, total of 200 paired stimuli)

Exercise ↑ PAS response



Acute exercise increases neuropalsticity

How does exercise improve motor learning?



Aerobic Exercise Enhances Neuroplasticity

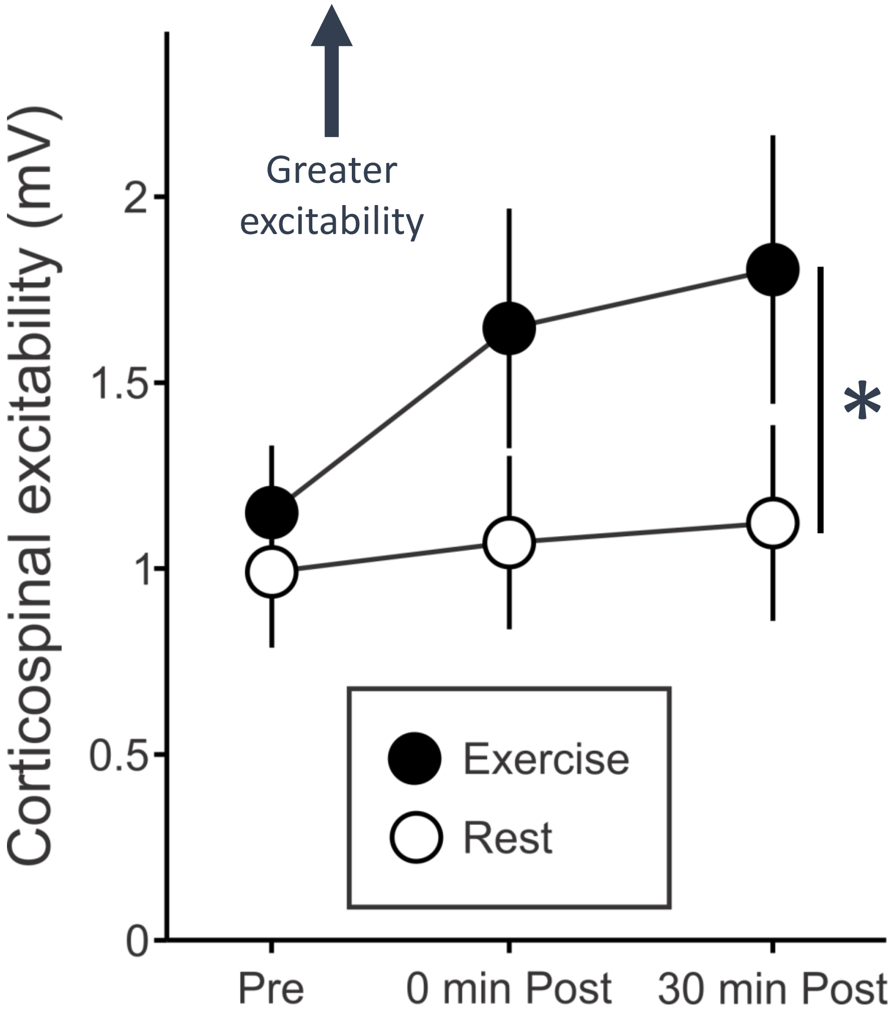
Add image of TMS and brain

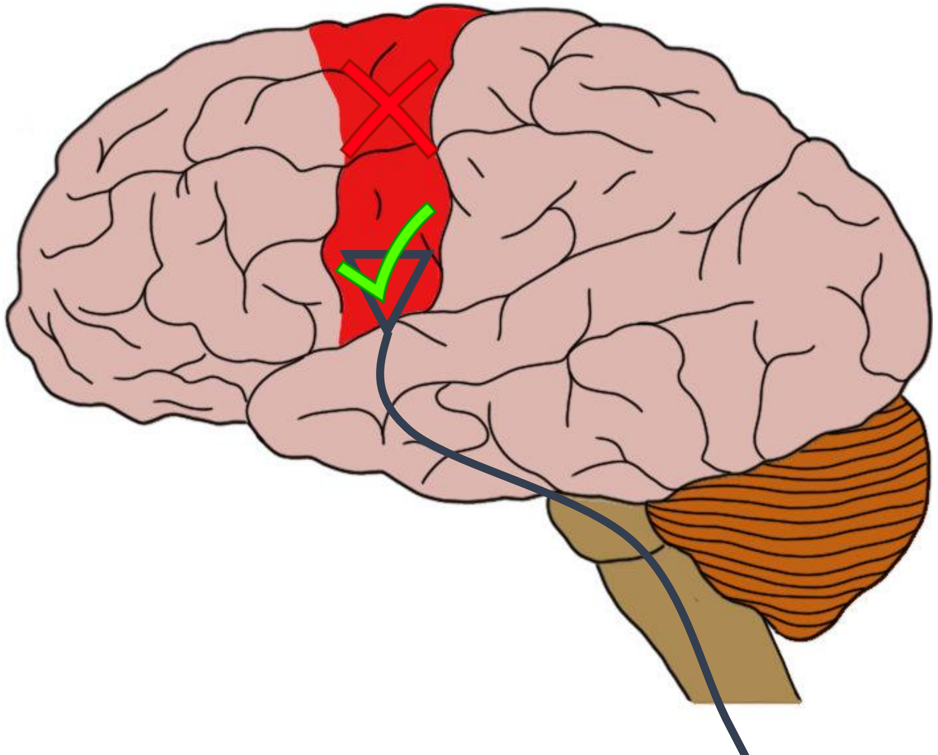
rTMS (make it look like rTMS and
Single pulse too….

Transition right to typical TMS slide

Add image of MEPs, arm and EMG

Healthy **older** people: Exercise ↑ corticospinal excitability





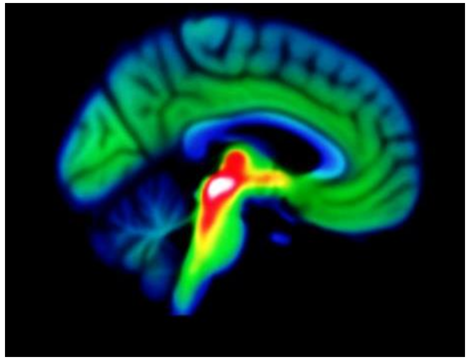
Acute exercise may
effect cortical excitability
differently ***across the lifespan***

Neva et al., 2022 *Medicine & Science in Sports & Exercise*

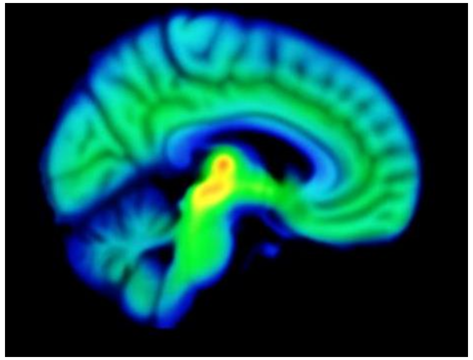
Parkinson's disease (PD)

- Neurodegenerative disorder
- Bradykinesia, instability, tremor and rigidity
- ↓ motor cortex neuroplasticity
- ↓ motor learning on tasks requiring **cognitive strategy** and **attention**

Individual with PD



Healthy individual

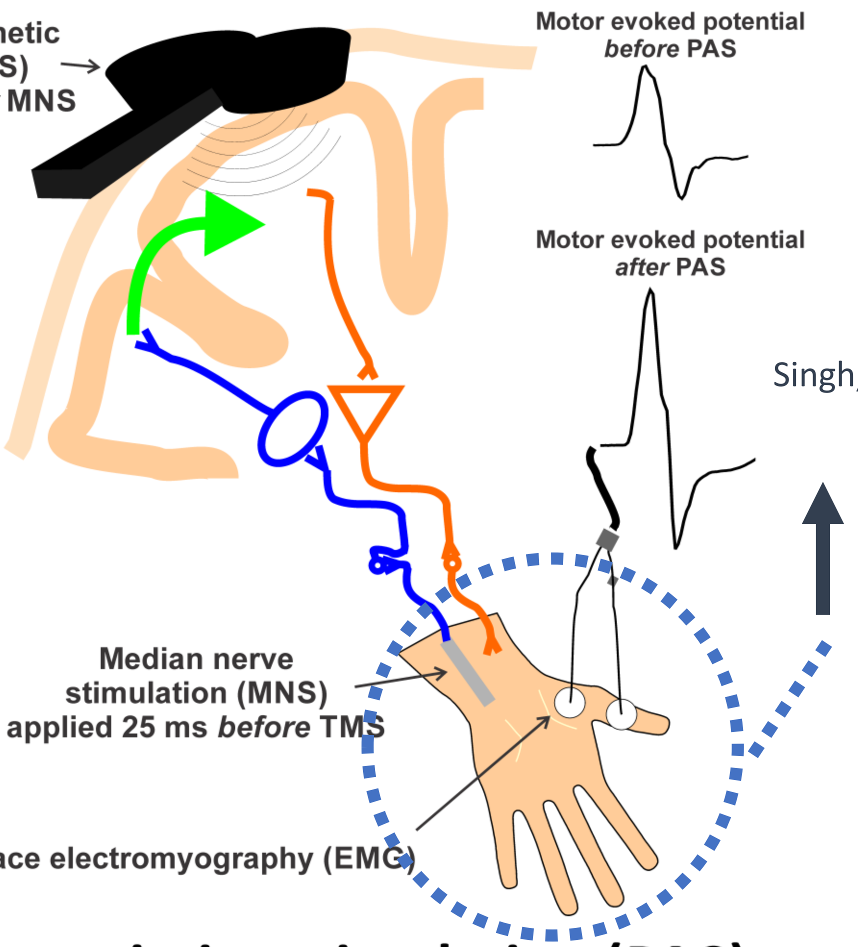


Person with PD
Basal ganglia affected

Aerobic exercise may improve PD-related symptoms

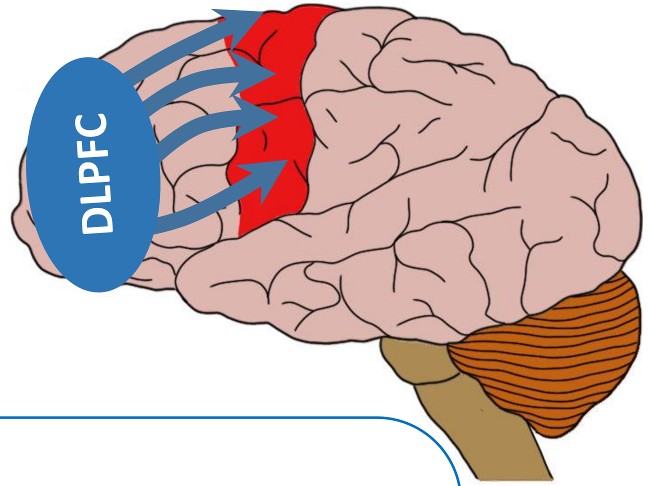
Parkinson’s disease & attention:
Exercise-induced neuroplasticity

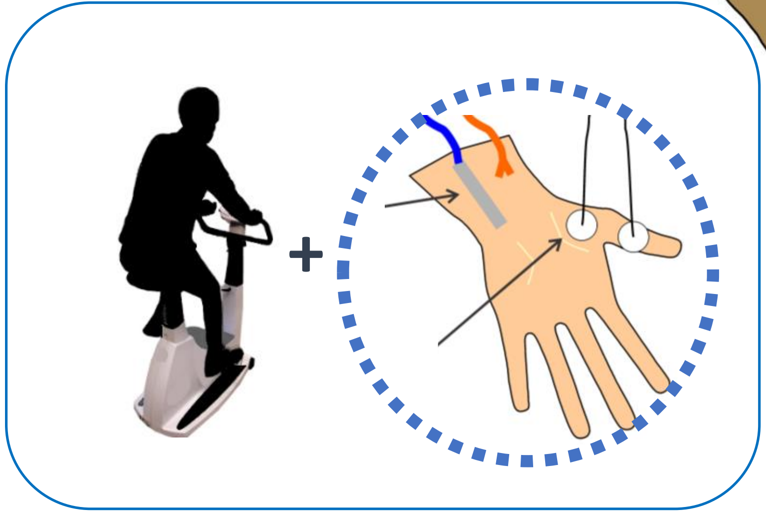
Amanda O’Farrell,
PhD student



A. Paired-associative stimulation (PAS)

Singh, Neva, Staines 2014 *EBR*

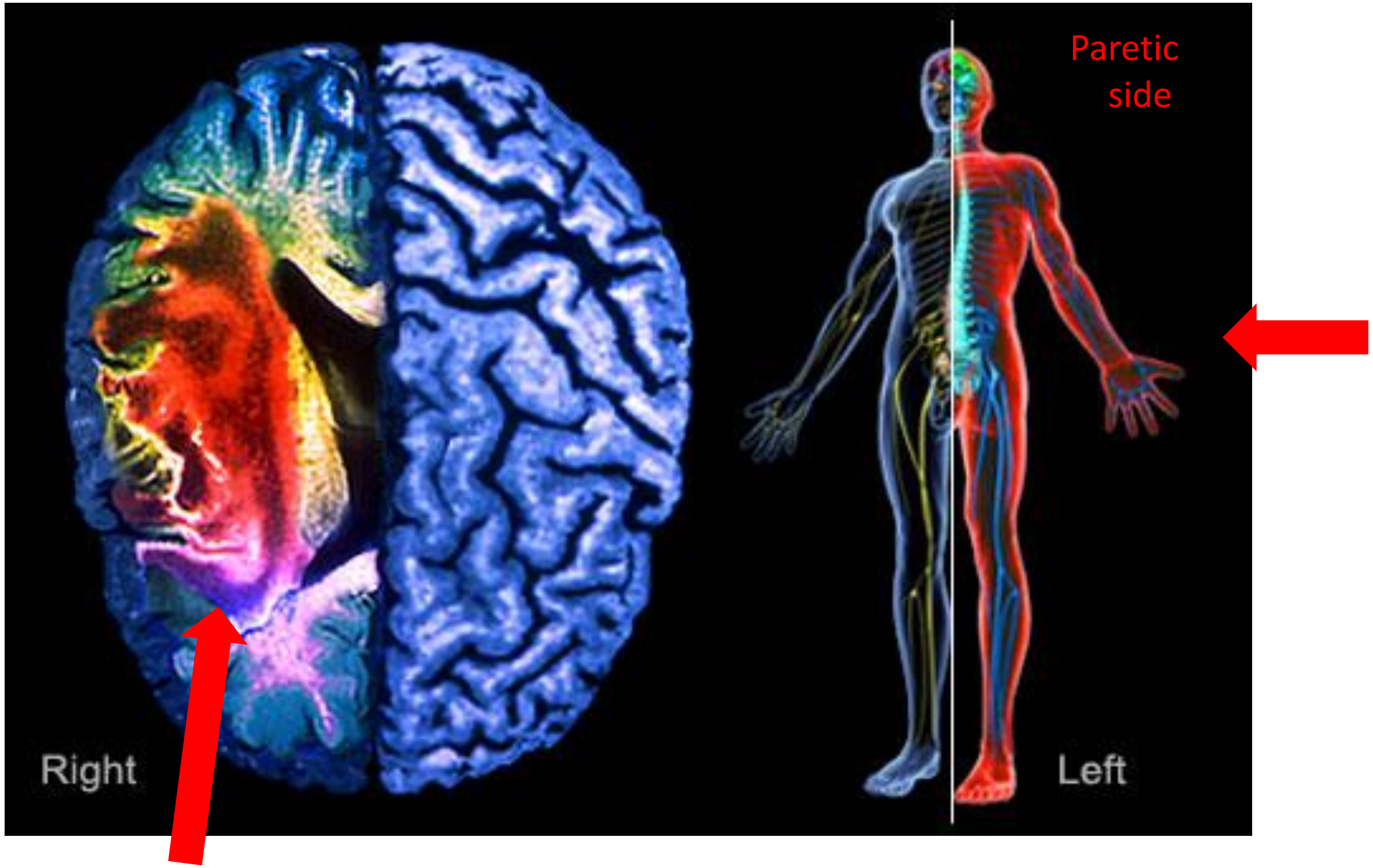




Stroke

"Brain attack"

- Loss of blood & oxygen to the brain
- Brain tissue damage



Contralateral
↓ motor function

Stroke affected region

~85% of Canadians live with persistent impairments into the chronic (< 1 year) post-stroke

Neva et al., 2019, Restorative Neurology & Neuroscience;
Neva et al., 2020 *Wiley Encyclopedia of Health Psychology, Vol III*

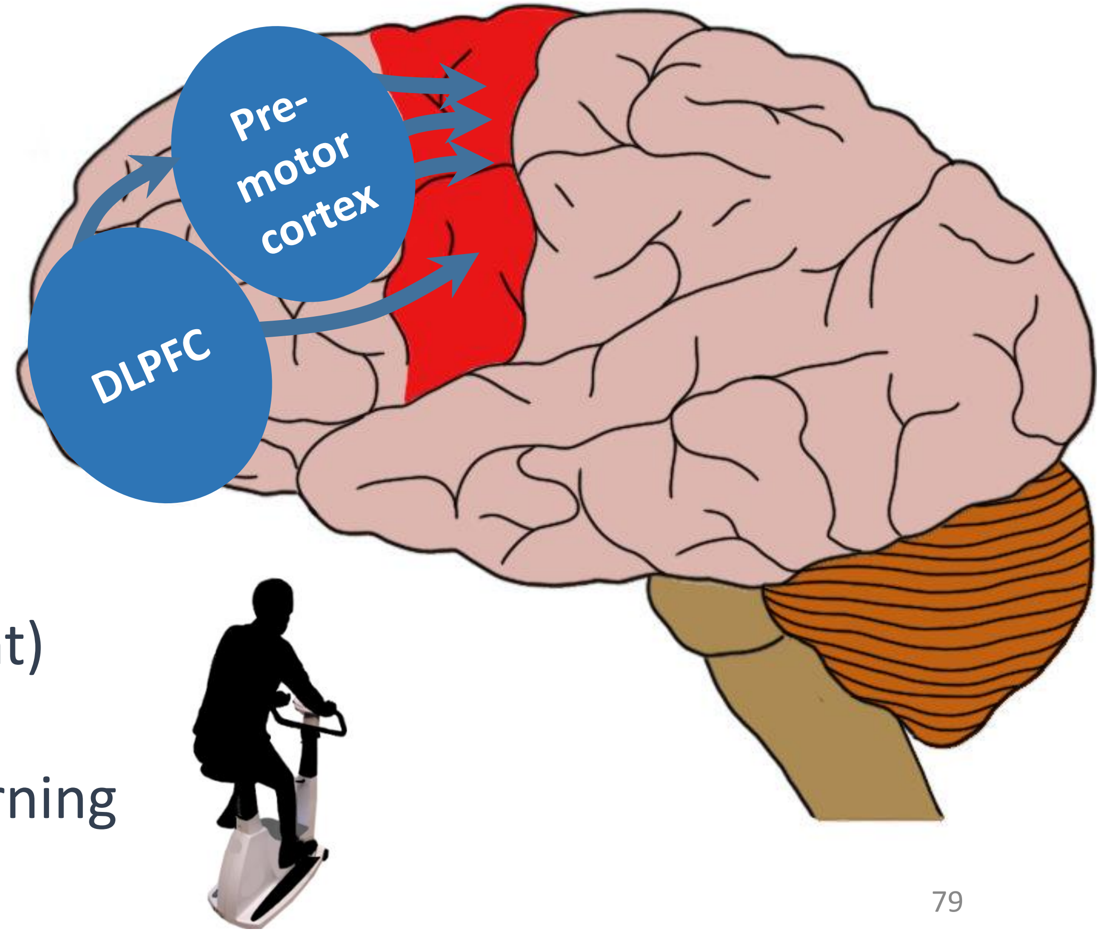
3

Stroke

- Cortical resources associated with **planning** and **cognitive strategy** contribute to recovery of function following stroke

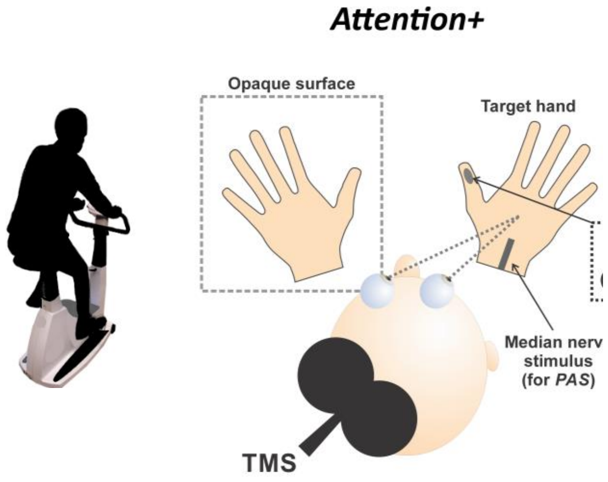
- Specifically, how these regions interact with the motor cortex after middle cerebral artery **stroke** (motor-related damage/impairment)

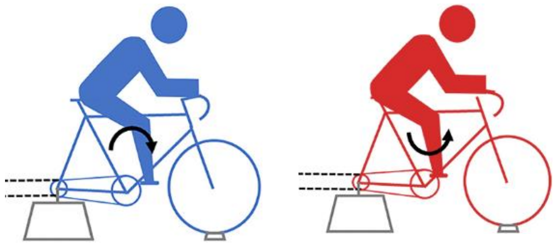
- Acute exercise: ↑ neuroplasticity + ↑ motor learning



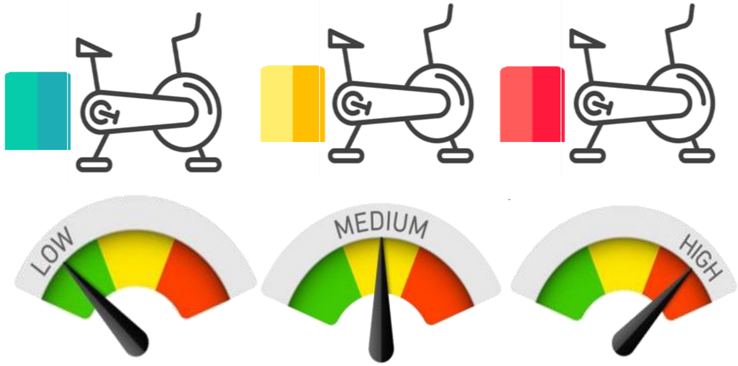
Stroke & attention:
Exercise-induced neuroplasticity

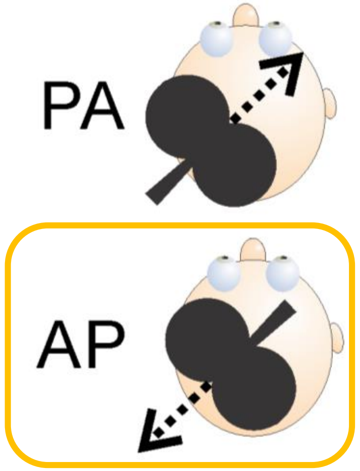
Future work





Eccentric vs concentric





- Preparation
- Attention
- Adaptation

Interneurons & exercise-induced neuroplasticity