HUMAN MOVEMENT
TRAINING AND ACTIVE AGING

NETZWERK ALTERNSFORSCHUNG

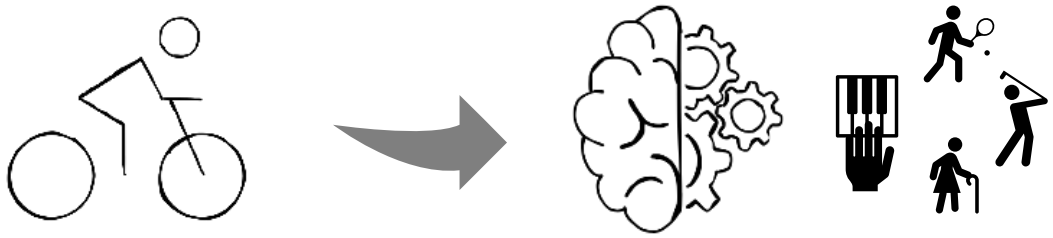
ISSW UNIVERSITÄT HEIDELBERG

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

EXERCISE-INDUCED CHANGES IN SLEEP MICROSTRUCTURE: A MECHANISM FOR ENHANCED MOTOR MEMORY CONSOLIDATION?

Advances in Motor Learning II, Birmingham, UK
12.12.2025
Prof. Dr. Simon Steib

Background



[El Sayes et al. 2019; Roig et al. 2013, 2016; Taubert et al. 2015; Tari et al. 2025; Wanner et al. 2020; Youssef et al. 2024]

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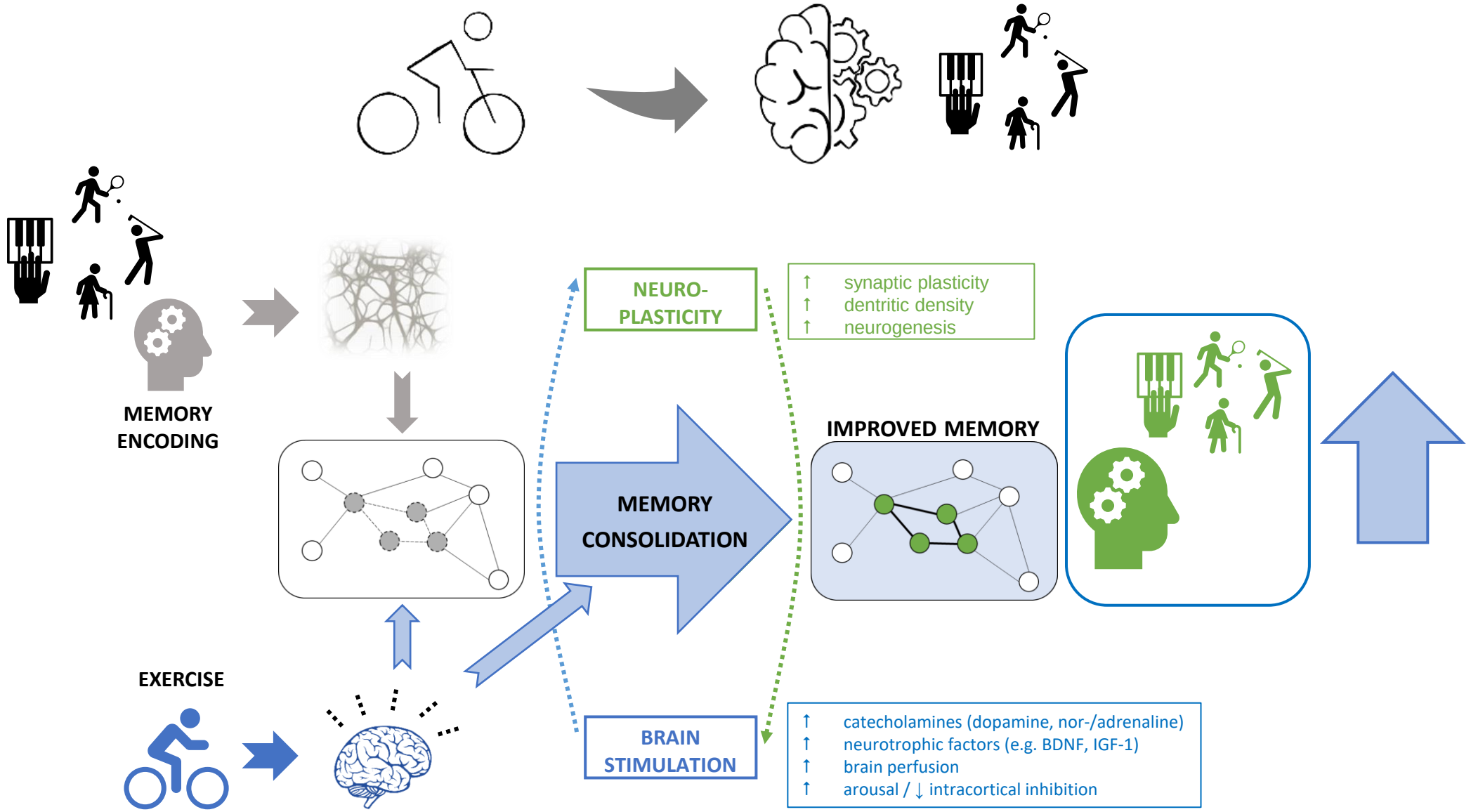

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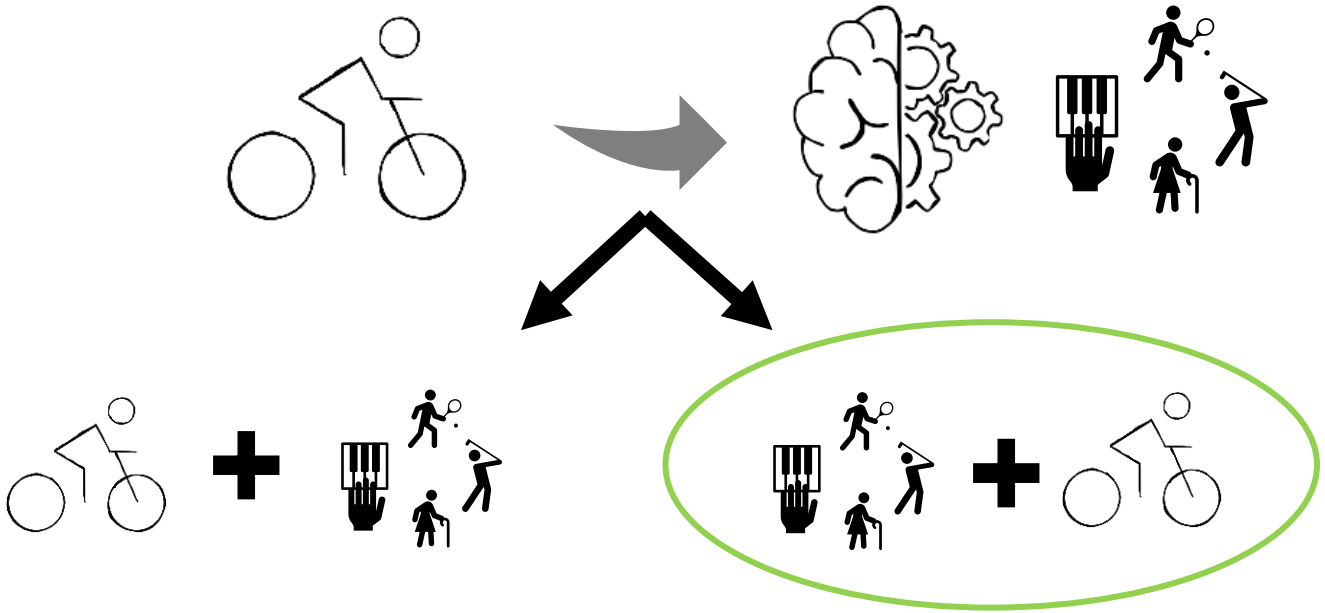

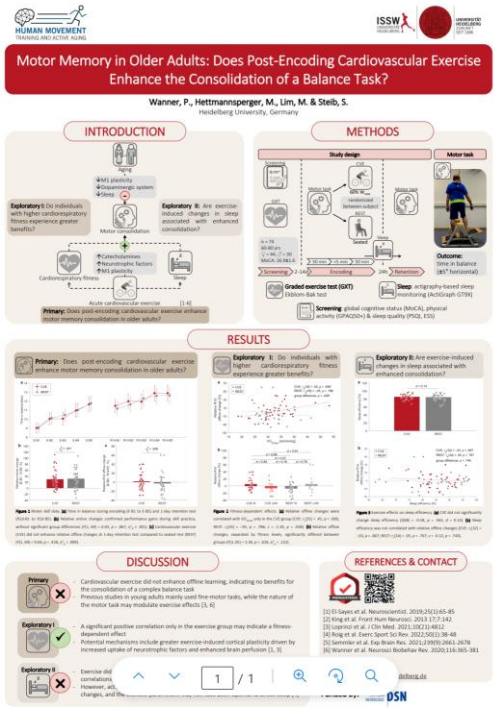

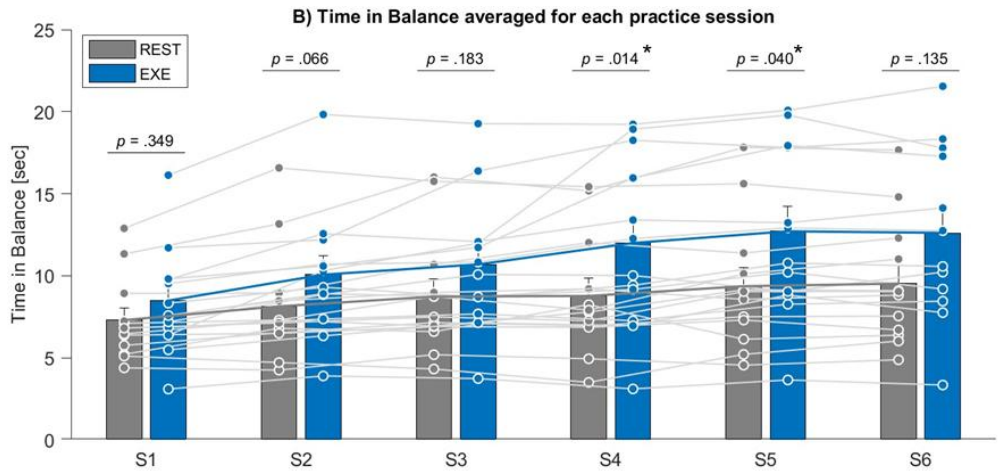

Philipp Wanner

[Wanner et al. 2025 NPJ SCI LEARN *accepted*]

[El Sayes et al. 2019; Roig et al. 2013, 2016; Taubert et al. 2015; Tari et al. 2025; Wanner et al. 2020; Youssef et al. 2024]

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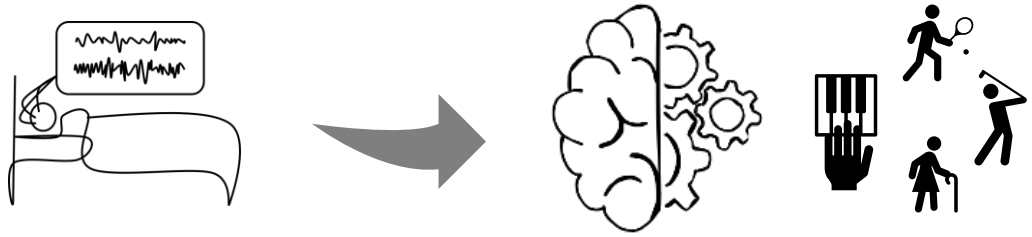
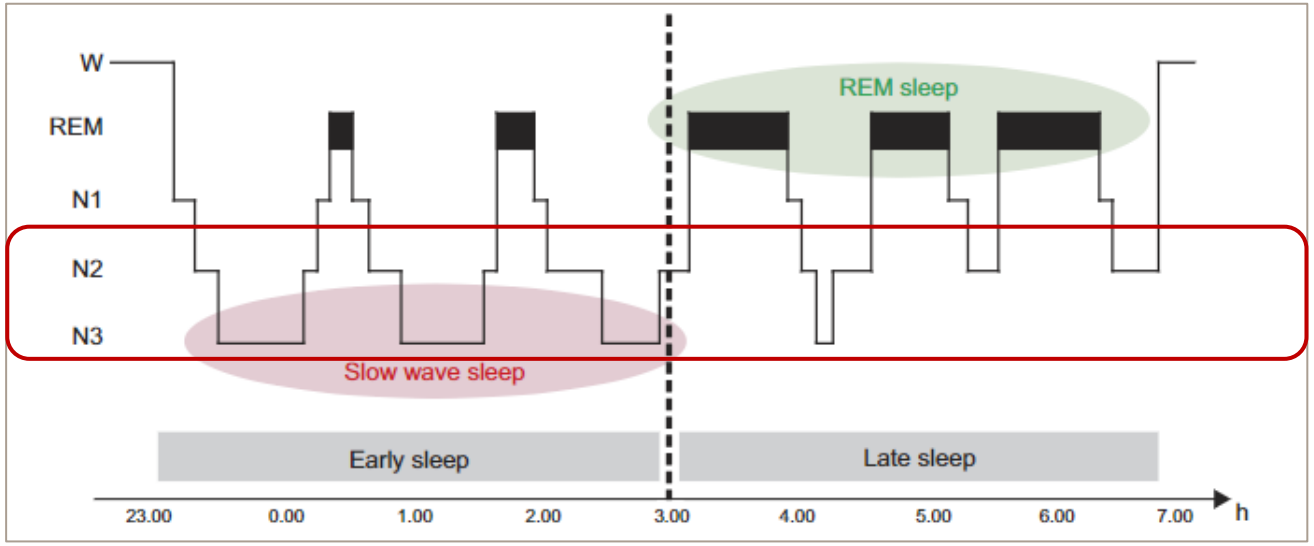
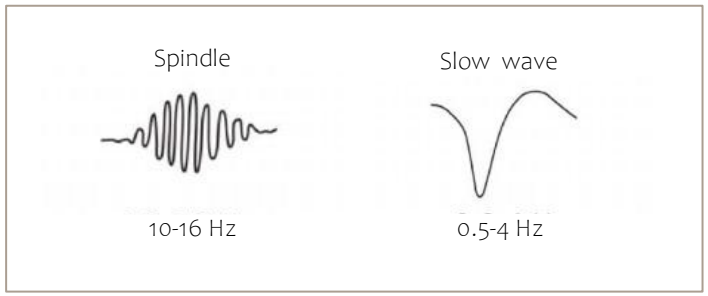




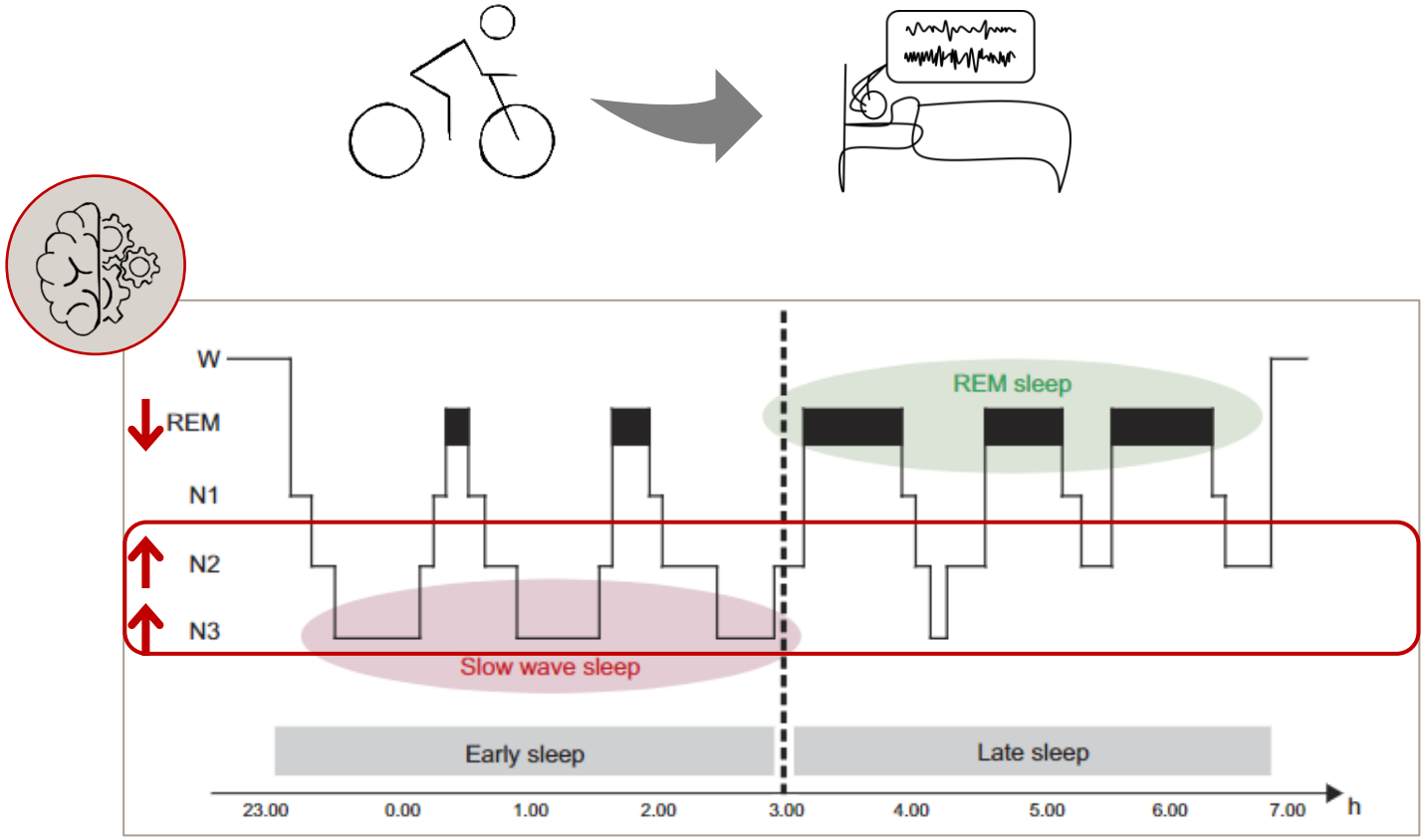
[Rasch & Born, 2013]



[Klinzing et al. 2019]

[Diekelmann & Born, 2010; King et al., 2017; Schmid et al., 2020]

Background



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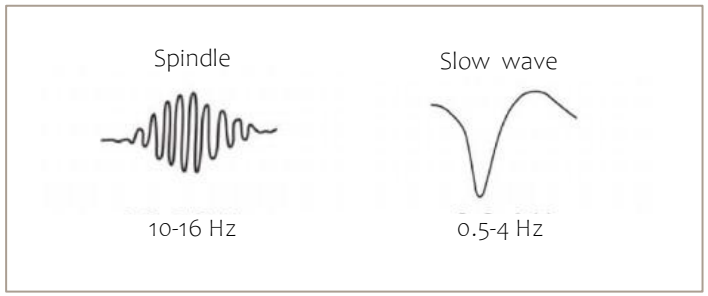

[Klinzing et al. 2019]

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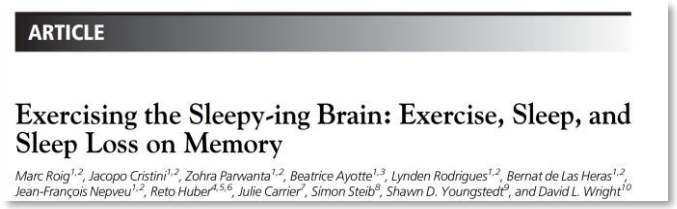
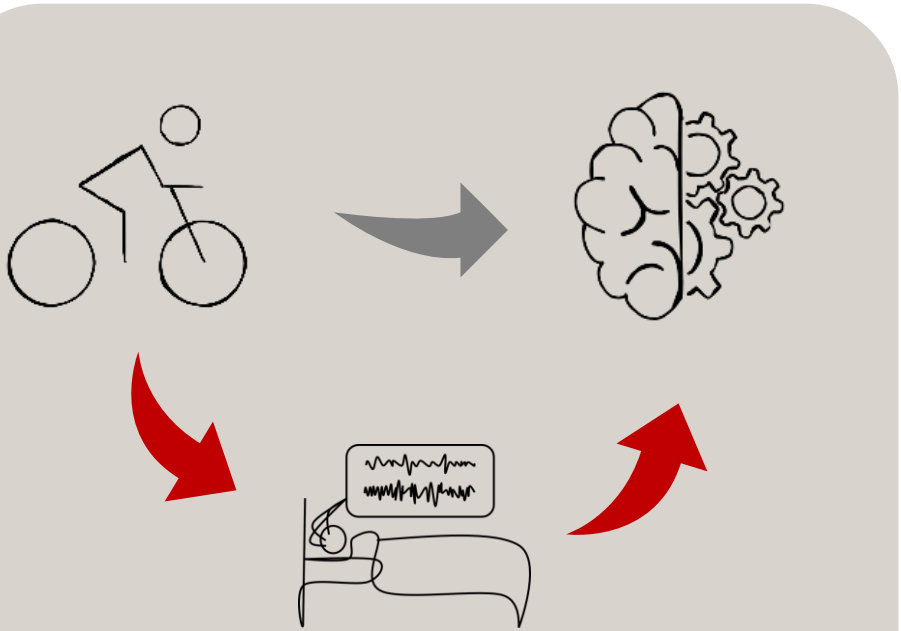
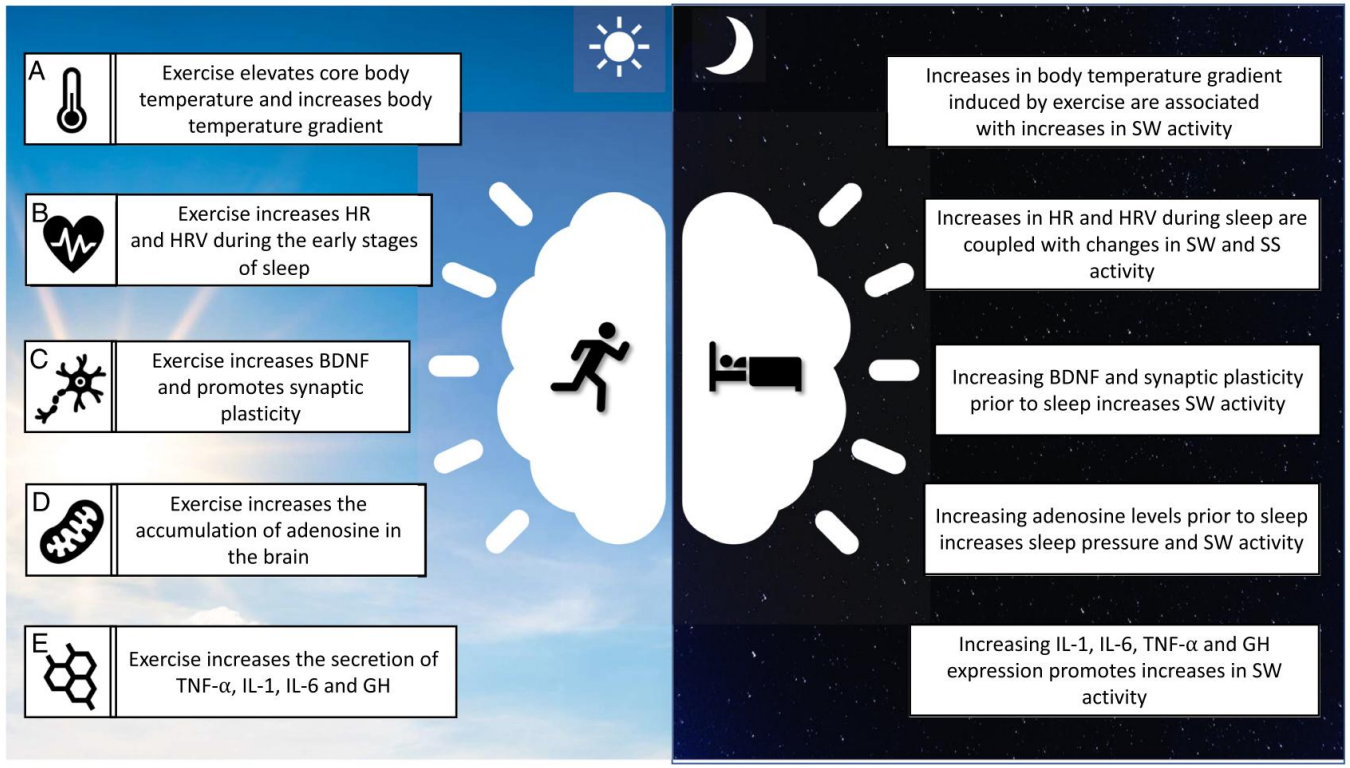

ARTICLE

Exercising the Sleepy-ing Brain: Exercise, Sleep, and Sleep Loss on Memory

Marc Roig[1,2], Jacopo Cristini[1,2], Zohra Parwanta[1,2], Beatrice Ayotte[1,3], Lynden Rodrigues[1,2], Bernat de Las Heras[1,2], Jean-François Nepveu[1,2], Reto Huber[4,5,6], Julie Carrier[7], Simon Steib[8], Shawn D. Youngstedt[9], and David L. Wright[10]

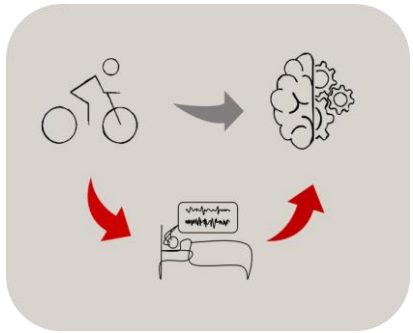


[Aritake-Okada et al., 2019; Che et al., 2024; Frimpong et al., 2021; Kredlow et al.., 2015; Yue et al., 2022]



[Roig et al. 2021 Exerc Sport Sci Rev]

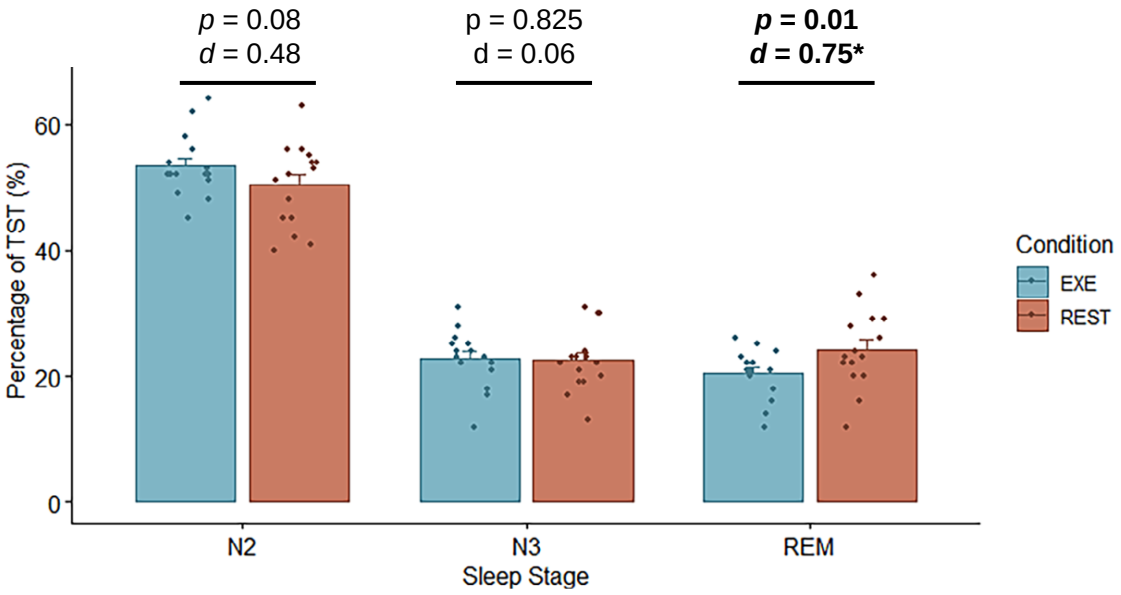
Background

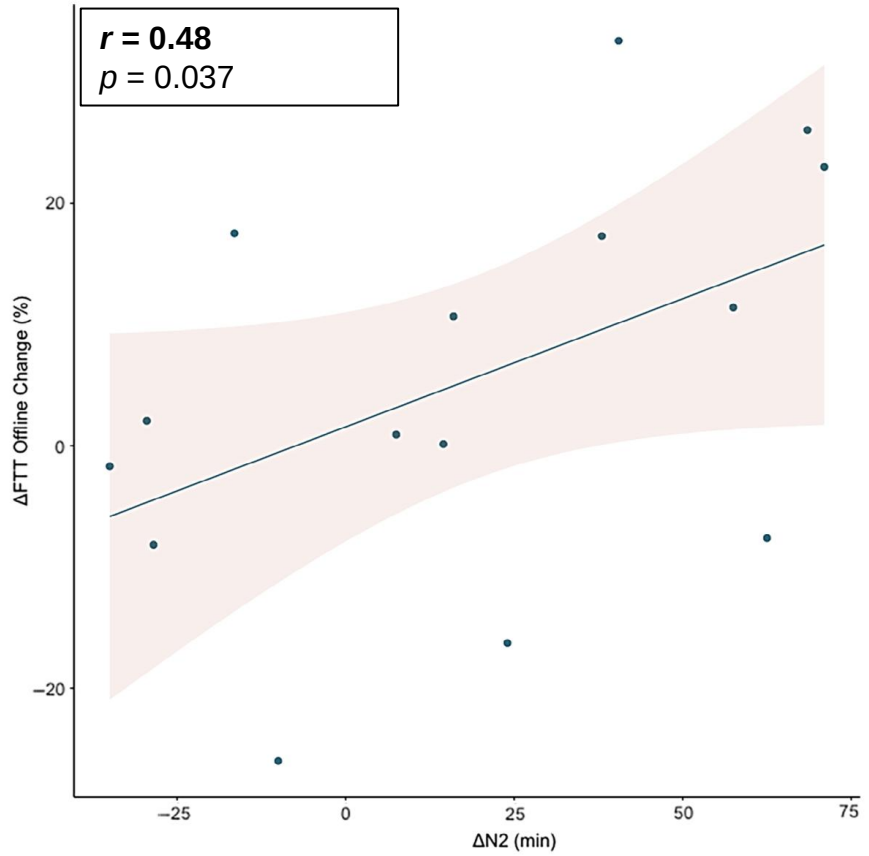


N = 19; age: *M* = 23.68 ± 3.97 years; 10 females

VO_{2max}: *M* = 52.26 ± 8.38; PSQI: *M* = 6.21 ± 2.57

Nicole Frisch

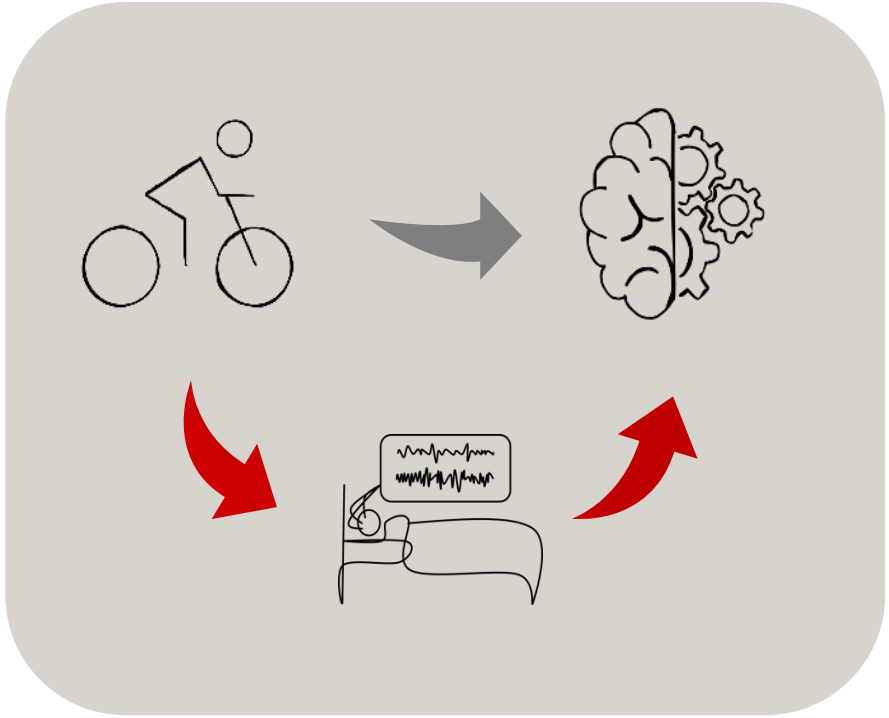




[Frisch et al. 2023 J Sleep Res]

TRANSFORM

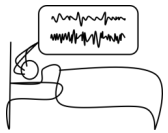
Effects of High-Intensity Interval **Tra**ining (HIIT) on **S**leep-Related Memory **Form**ation



Aims & Hypotheses

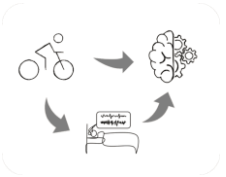
Aims
Examine the effects of intensive evening exercise on nocturnal sleep architecture, and how these effects potentially interact with procedural memory formation

Hypotheses



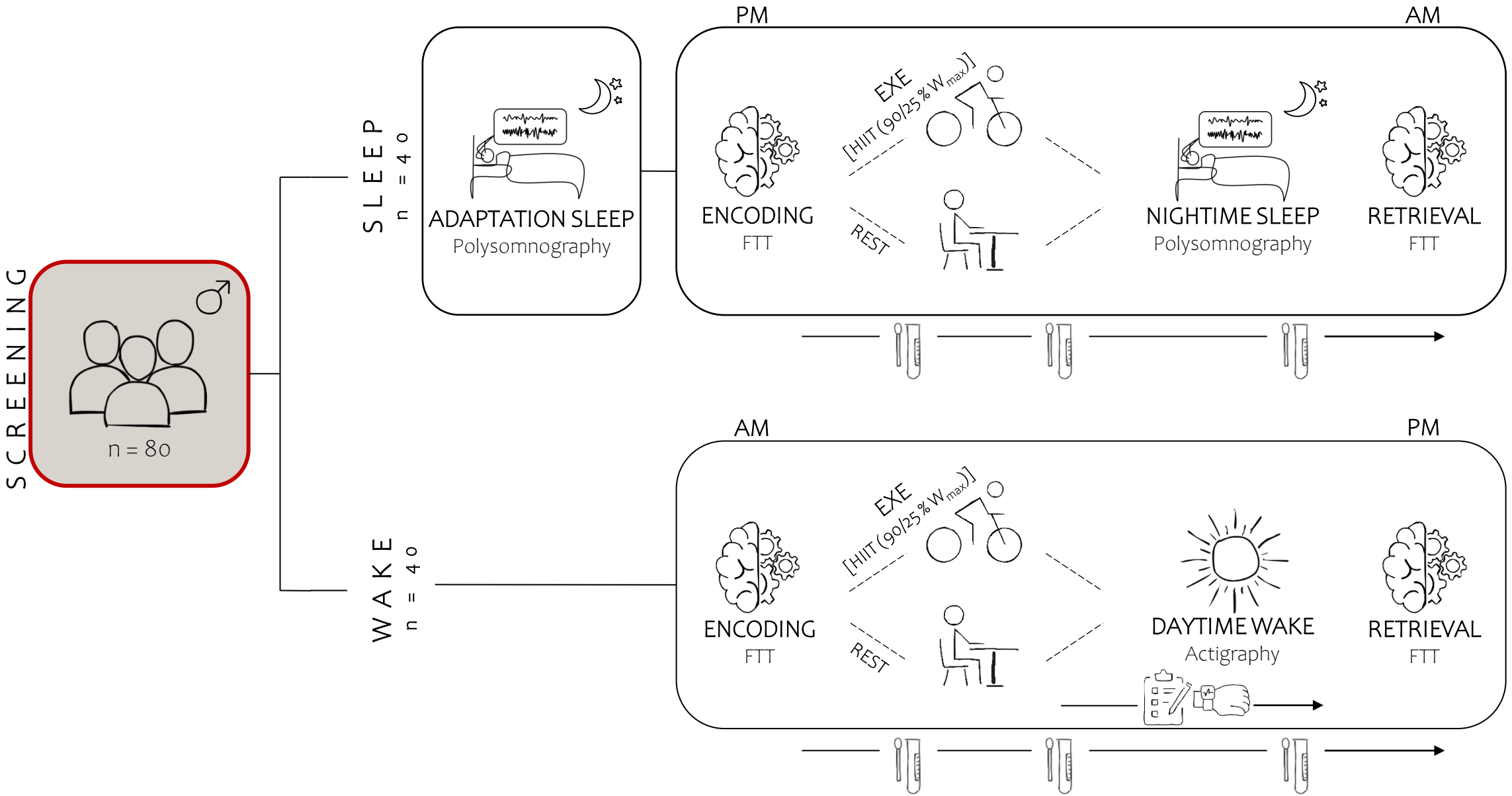
- **H1**. Exercise ➔ increased N2 sleep
- **H2**. Exercise ➔ N2 sleep spindle amount + activity

- **H3**. Exercise ➔ improved consolidation of MSL
- **H4**. Exercise-induced improved consolidation ➔ larger in sleep vs. wake condition

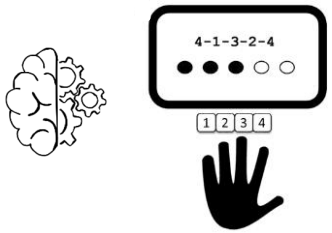


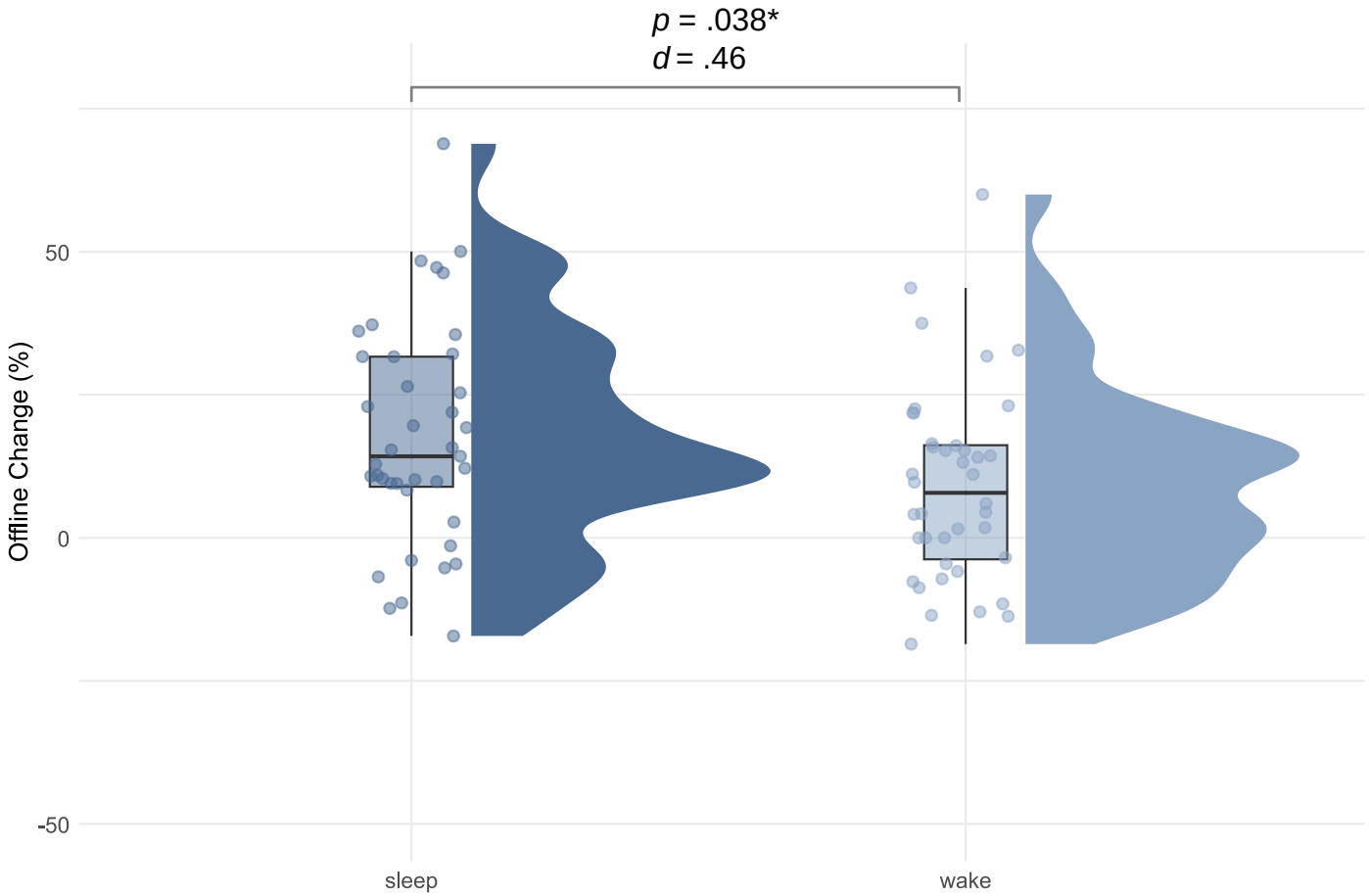
- **H5**. Exercise ➔ increased N2 duration ➔ improved MSL
- **H6**. Exercise ➔ increased N2 spindle activity ➔ improved MSL

Methods

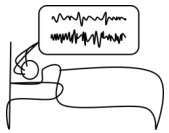

SCREENING
n = 80
SLEEP
n = 40
ADAPTATION SLEEP
Polysomnography
PM
AM
ENCODING
FTT
EXE
[HIIT (90/25% W_{max})]
REST
NIGHTIME SLEEP
Polysomnography
RETRIEVAL
FTT
WAKE
n = 40
AM
PM
ENCODING
FTT
EXE
[HIIT (90/25% W_{max})]
REST
DAYTIME WAKE
Actigraphy
RETRIEVAL
FTT

Results

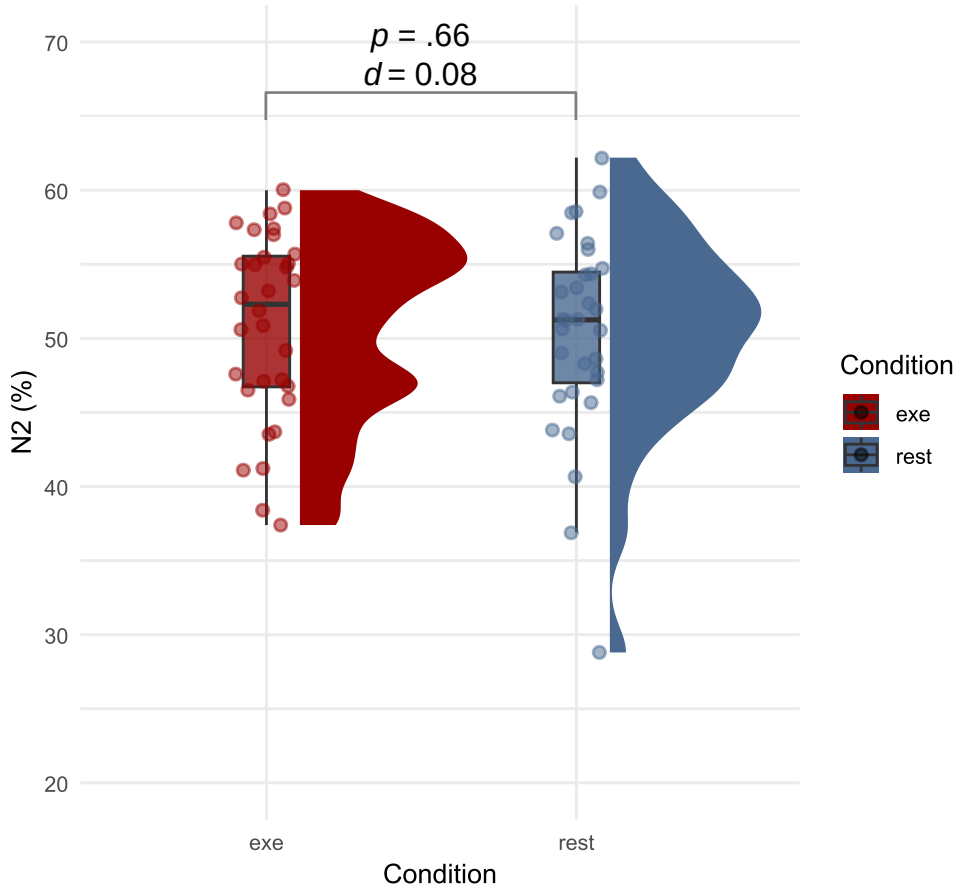


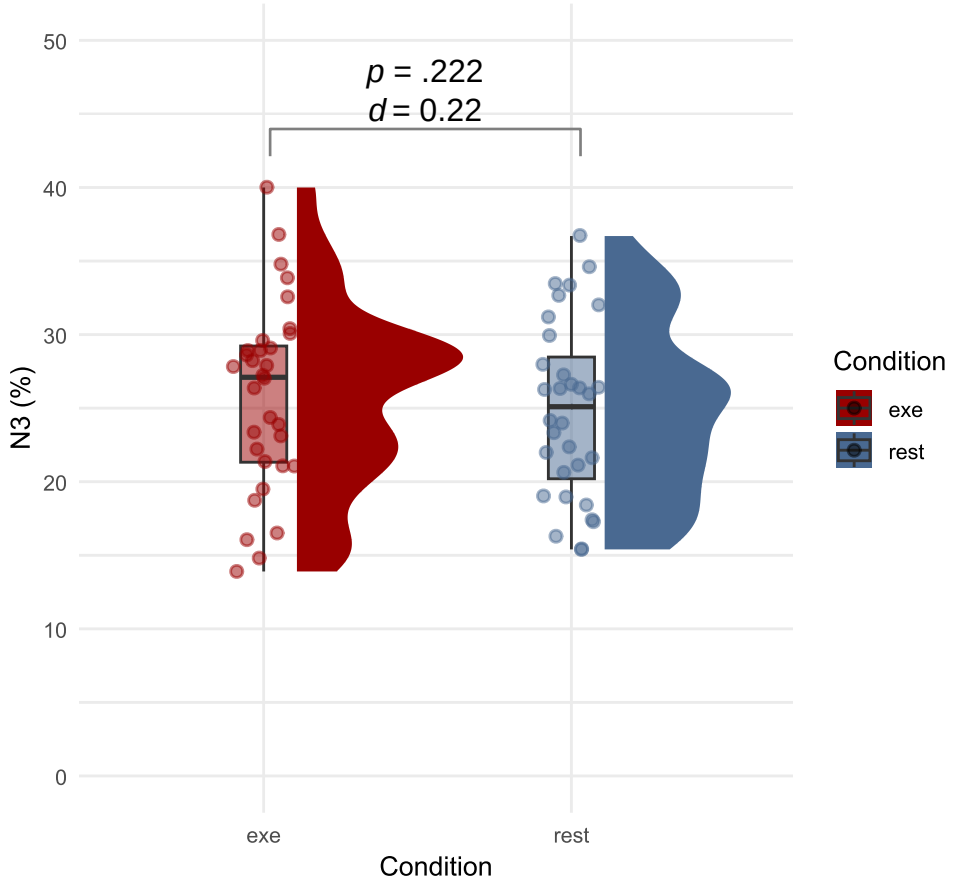


Results

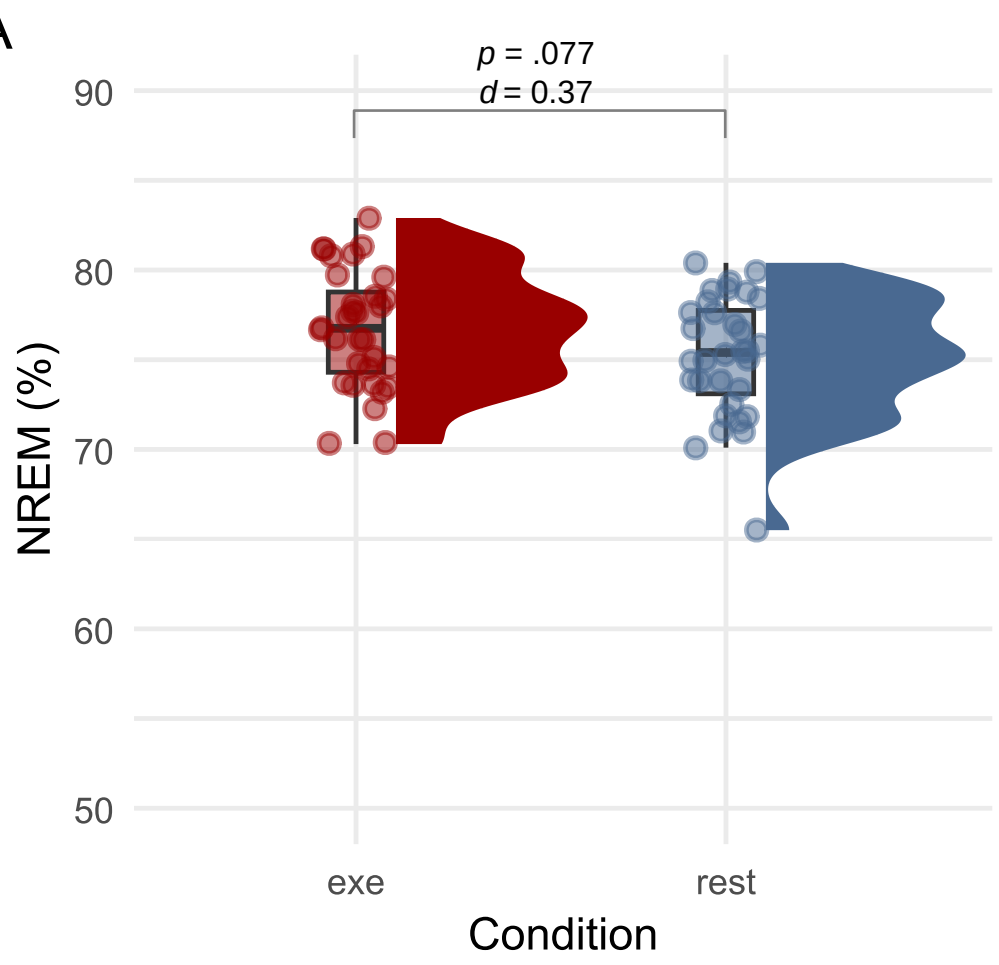


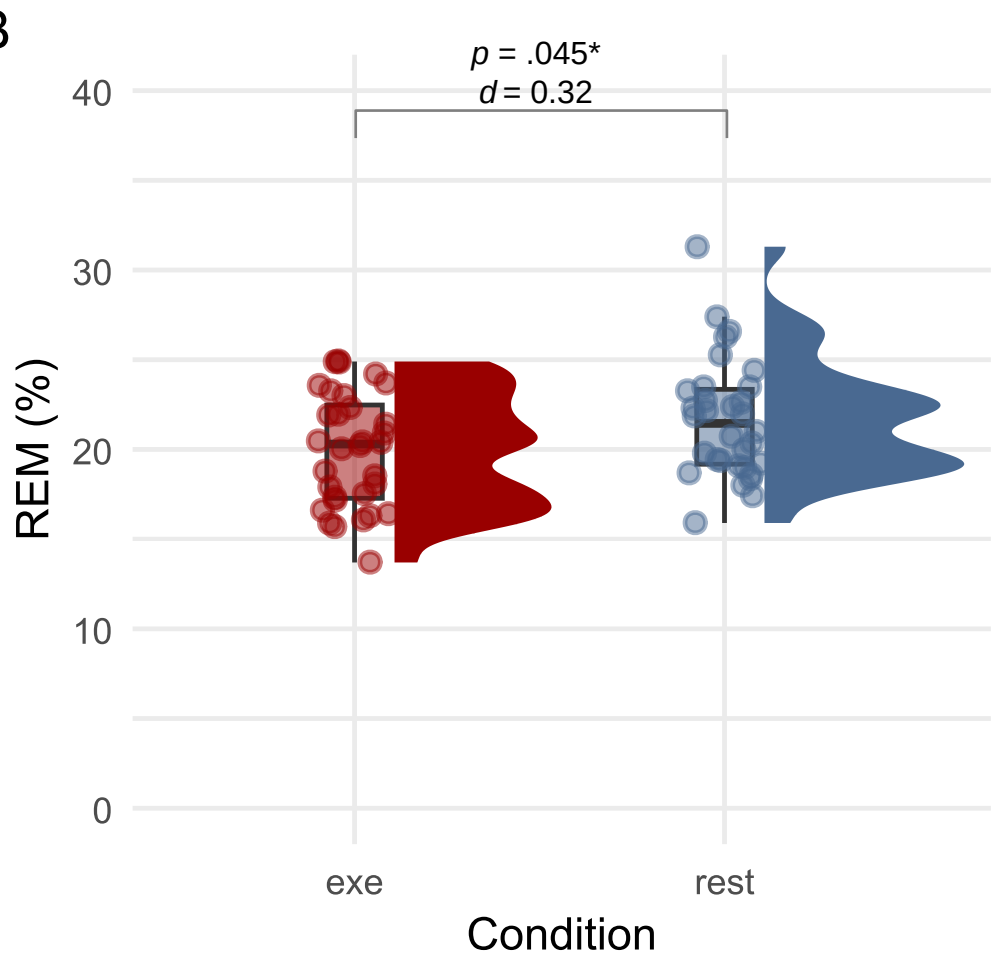
H1. Exercise ➔ increased N2 sleep



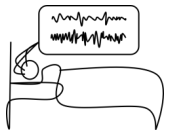


Results


A
p = .077
d = 0.37
90
80
70
60
50
NREM (%)
exe
rest
Condition


B
p = .045*
d = 0.32
40
30
20
10
0
REM (%)
exe
rest
Condition

Results

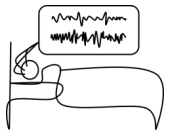


H2. Exercise ➔ N2 sleep spindle amount + activity

Spindle analyses (significant effects, *ps* <.05)

	N2
ALL	Frequency (C3)
FAST (Pz)	Frequency
SLOW (Fz)	SPI

Results



H2. Exercise ➔ N2 sleep spindle amount + activity

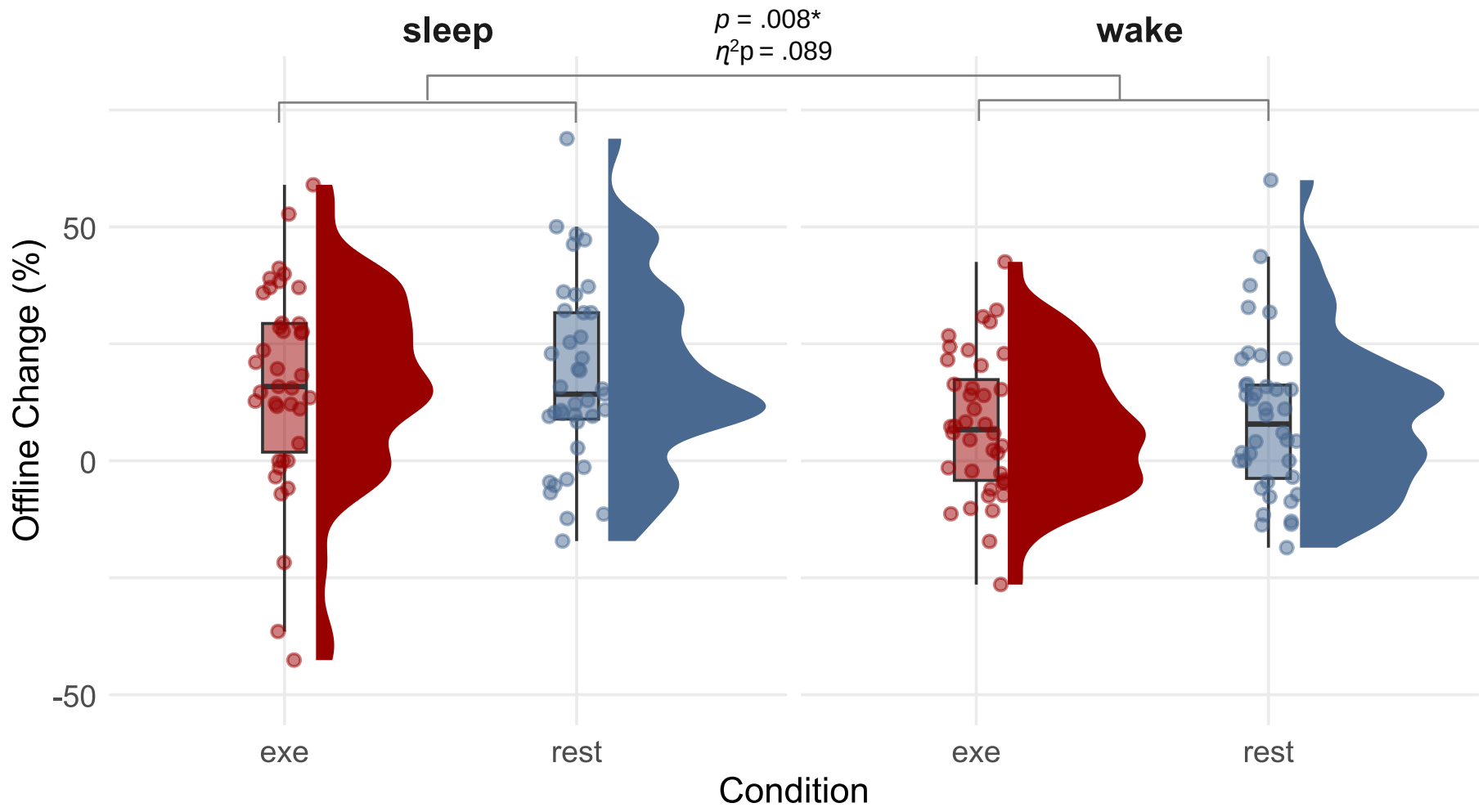
Spindle analyses (significant effects, *ps* <.05)

	N2	N3	NREM
ALL	Frequency (C3)	Density (C3,C4)	Density (C4)
		Frequency (C3)	Frequency (C4)
FAST (Pz)	Frequency	Frequency	Frequency
		Density	
		Duration	
SLOW (Fz)	SPI	Count	SPI
		Density	Duration

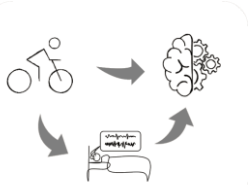
Results

H3. Exercise ➔ improved consolidation of MSL

H4. Exercise-induced improved consolidation ➔ larger in sleep vs. wake condition

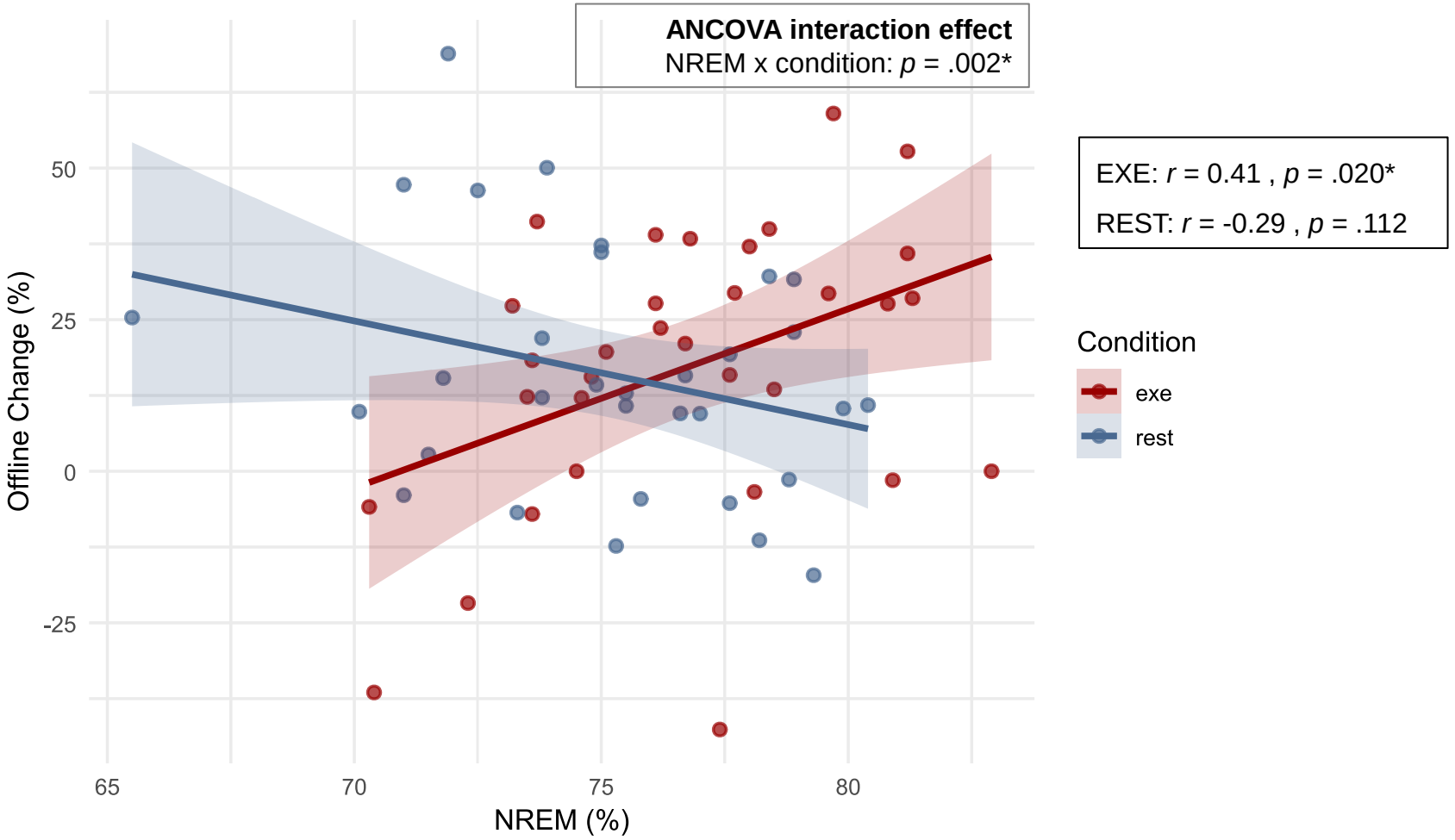


Results

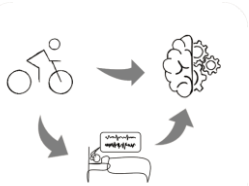


H5. Exercise ➔ increased N2 duration ➔ improved MSL

H6. Exercise ➔ increased N2 spindle activity ➔ improved MSL



Results



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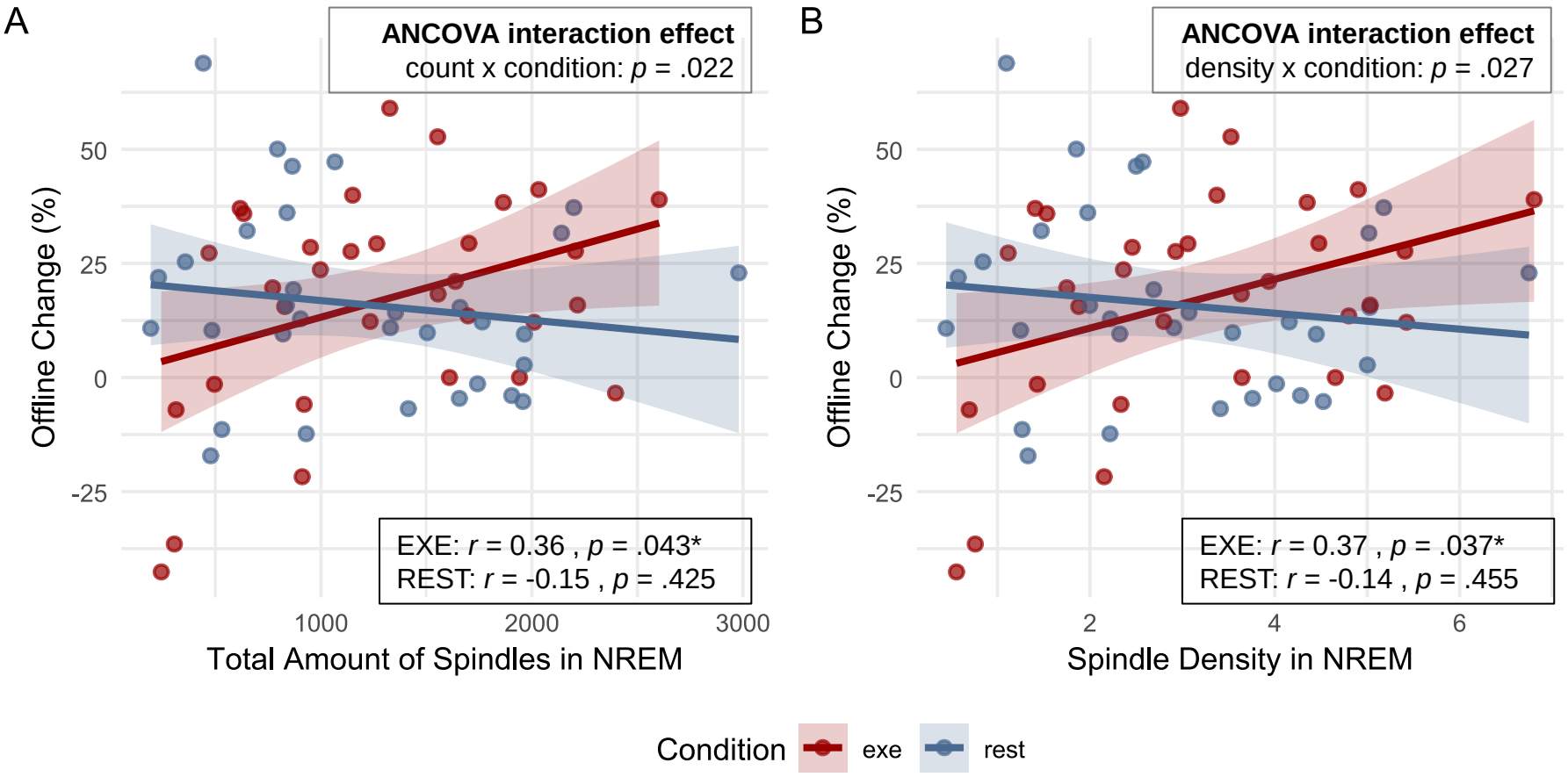

Discussion

- Exercise did not have a general effect on motor memory consolidation
  - Majority of studies reporting positive findings use fine-motor tracking tasks [Wanner et al. 2020]
  - Session order ➔ potential ceiling effects [Frisch et al. 2023]

- Exercise manipulated sleep macro (REM↓, NREM↑) and micro (spindle density & frequency) structure
  - Microstructural changes in NREM target for other memory domains (e.g. **declarative**) and persons with sleep disturbances [Frisch et al. 2024; Roig et al. 2022]
  - Might enhance post-sleep memory encoding (**synaptic homeostasis hypothesis**) [Tononi & Cirelli, 2003; Ramirez-Butavad et al. 2025]

- NREM correlated to consolidation exclusively in exercise condition
  - EXE may **"prime" sleep** for plasticity ➔ molecular upregulation (BDNF, catecholamines, …) may interact with NREM sleep oscillations [Roig et al. 2022]
  - EXE may increase salience of newly encoded traces (↑ **synaptic tagging**) ➔ more susceptible to sleep-related modulation [Frey & Morris, 1997; Loprinzi et al. 2018]

- Further analyses to explore underlying mechanisms
  - Sleep microarchitecture (i.a. SO-spindle coupling) [Hahn et al. 2020; 2022]
  - Physiological markers (e.g., temperature, cortisol) [Aritake-Okada et al. 2019; Dote-Montero et al. 2021; Hötting et al. 2016]

Outlook

Ongoing projects

ExMem

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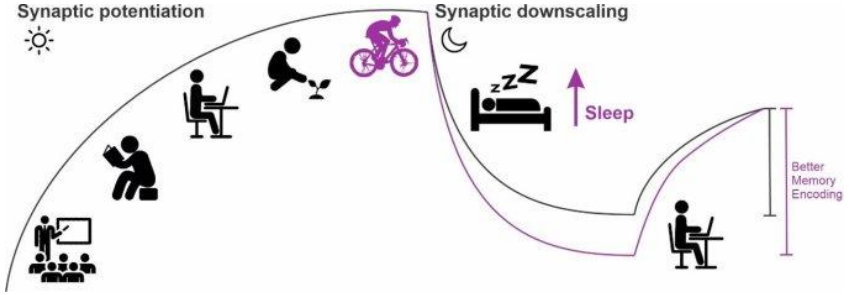
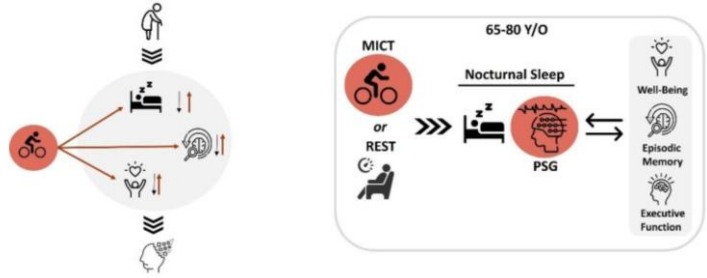
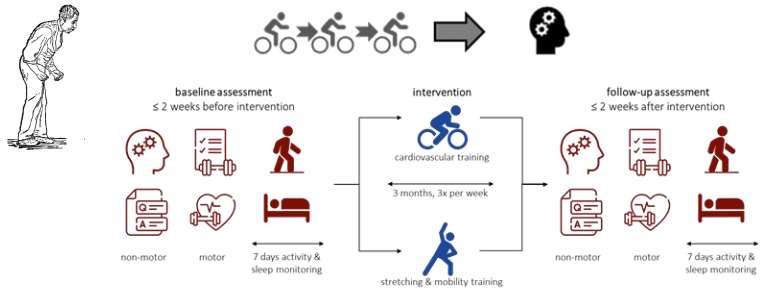


PASCEI



EMCo – Exploring the Effects of Exercise on Memory and Cognition in Parkinson's Disease

DEUTSCHE STIFTUNG NEUROLOGIE DSN



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Thank you!

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Dr. Marc Roig

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McGill UNIVERSITY

PARIS LODRON UNIVERSITÄT SALZBURG

Zentralinstitut für Seelische Gesundheit

DFG Deutsche Forschungsgemeinschaft