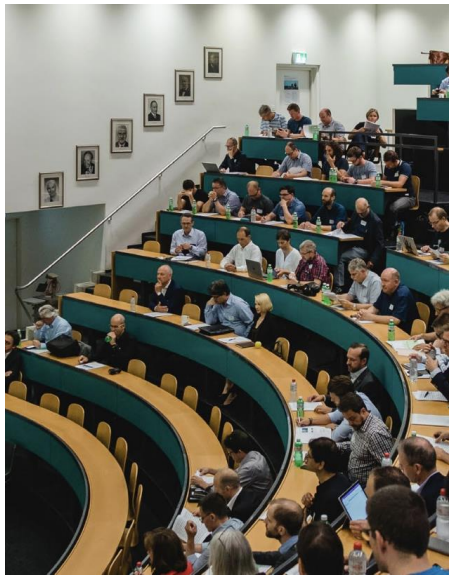
UNIVERSITÄT BERN

Vestibular perceptual learning: Past studies and future projects

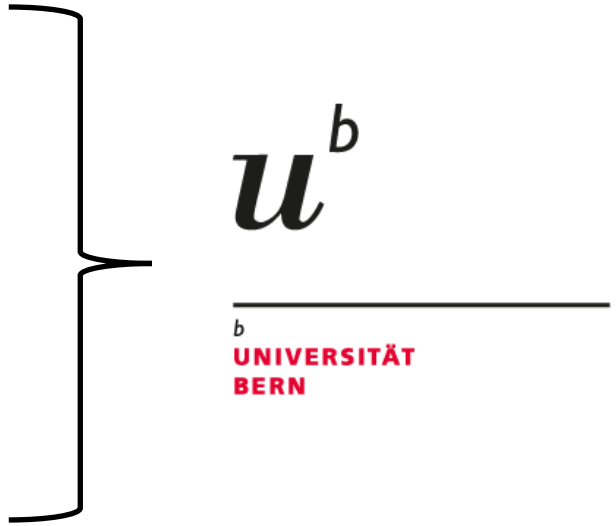


Fred Mast
University of Bern
www.kog.psy.unibe.ch

ZüMüTü 2025

Collaborators:

Matthias Ertl (now Prof. at University of Lucerne)
Daniel Fitze
Andreas Szukics
Matthias Hartmann
Corina Schöne
Sarah Merks (Furrer) (now at Swiss Federal Nuclear Safety Inspectorate)
Manuel Klaus (now at Swiss National Science Foundation)

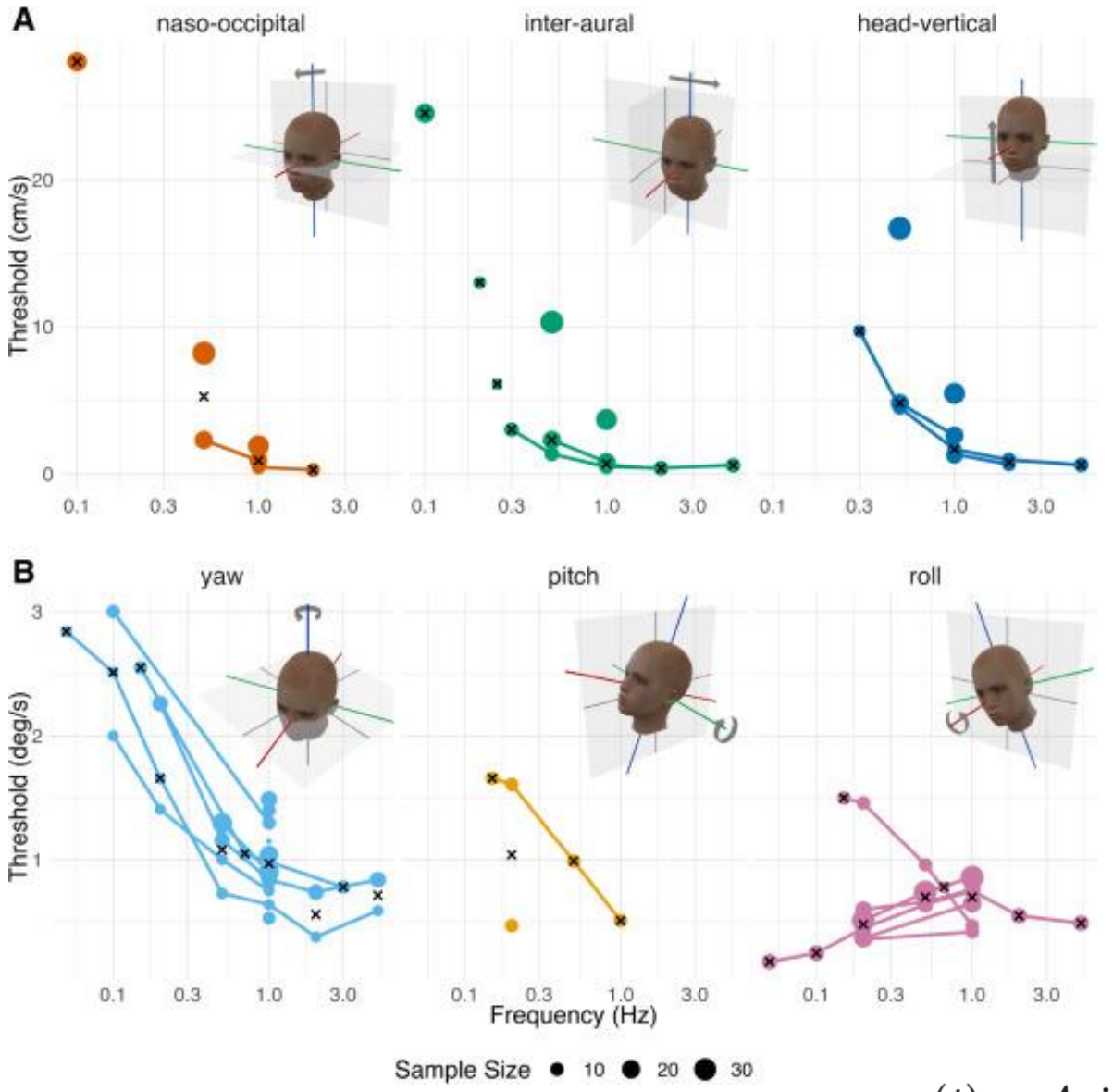


Daniel Merfeld, Ohio State University, College of Medicine
Michael Schubert, Johns Hopkins University
Michael Herzog, EPFL, Brain and Mind Institute

Passive self-motion perception thresholds

Translation

Rotation



Daniel C. Fitze, Fred W. Mast, **Matthias Ertl**, 2024: Human vestibular perceptual thresholds — A systematic review of passive motion perception. Gait & Posture, 107, 83-95, https://doi.org/10.1016/j.gaitpost.2023.09.011.

- «Vestibular» thresholds

Valko, Lewis, Priesol, & Merfeld (2012)

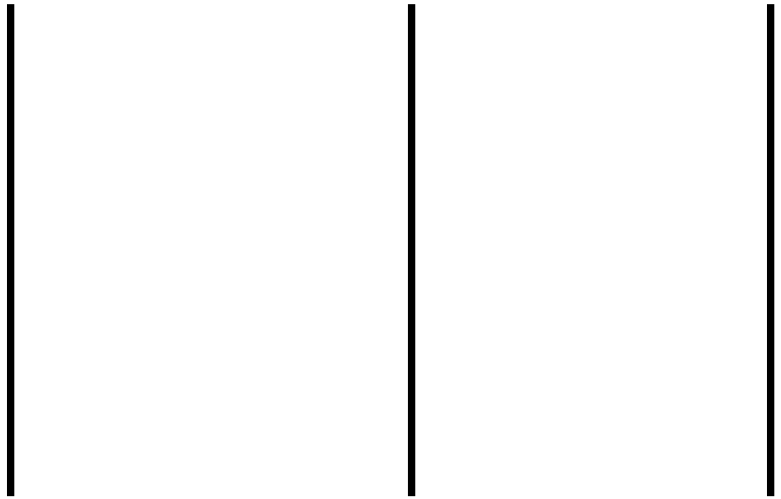
- Potential for clinical applications

$$a\,(t) = A\sin\,(2\pi ft) = A\sin\,(2\pi t/T)$$

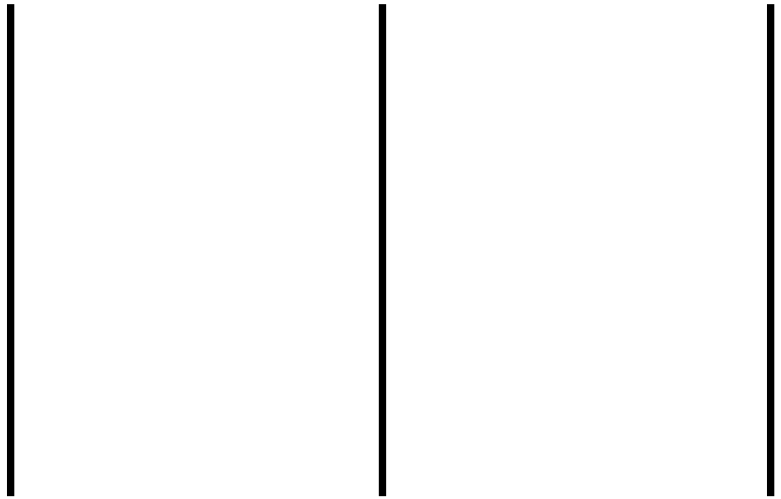
Perceptual Learning

Improvement to detect sensory information as a result of practicing specific tasks (presumably by change of signal to noise ratio)

Bisection Task



Bisection Task



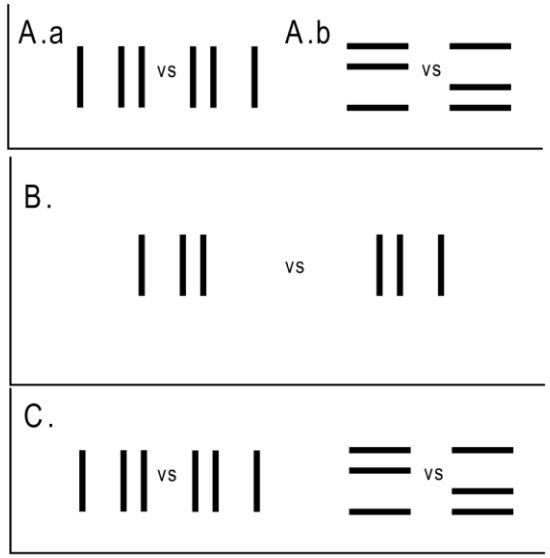
Perceptual Learning

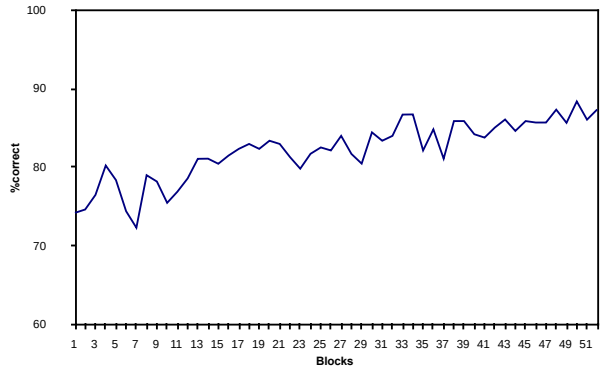
UNIVERSITÄT BERN

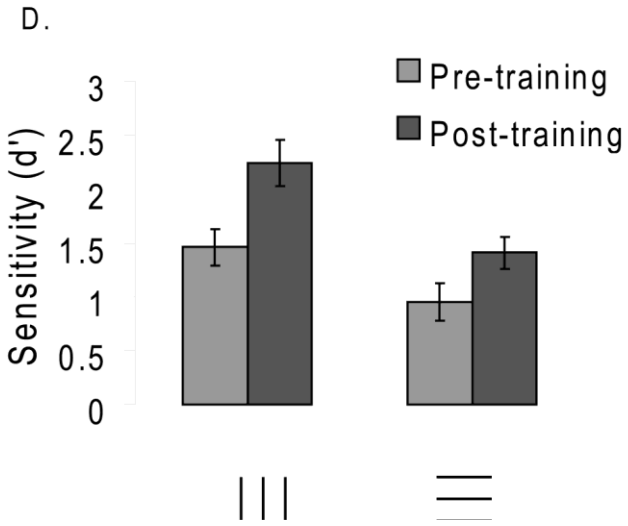
First Baseline

Training:
4160 Trials

Second Baseline







Tartaglia, E., Bamert, L., Herzog, M. & Mast, F.W. (2012)

Perceptual Learning

- Visual perception (e.g., attentional blink, visual motion detection etc.)
- Auditory perception (e.g., tone discrimination, speech recognition etc.)
- Tactile perception (e.g., Braille reading, vibrotactile sensitivity)
- Olfactory and gustatory perception (e.g., parfumer, sommelier)
- Multisensory perceptual learning (e.g. lip reading)
- Etc. etc.

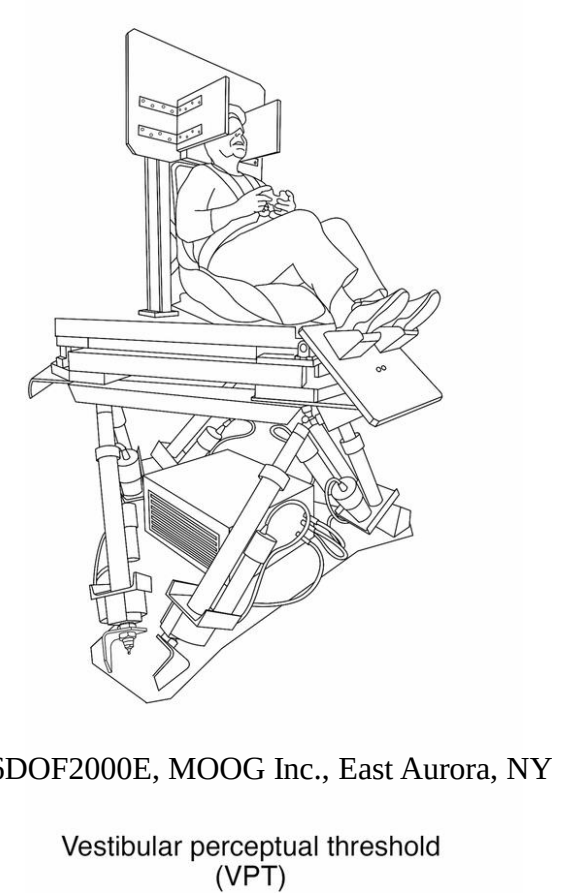
Perceptual Learning

- Visual perception (e.g., attentional blink, motion detection etc.)
- Auditory perception (e.g., tone discrimination, speech recognition etc.)
- Tactile perception (e.g., Braille reading, vibrotactile sensitivity)
- Olfactory and gustatory perception (e.g., parfume experts, somelier)
- Multisensory perceptual learning (e.g. lip reading)
- Etc. etc. …… **vestibular perceptual learning**

Vestibular perceptual learning in the dark

UNIVERSITÄT BERN

https://www.kog.psy.unibe.ch/forschung/labors/moog_lab/index_ger.html



6DOF2000E, MOOG Inc., East Aurora, NY

Vestibular perceptual threshold (VPT)

Left-right discrimination task
Training: 560 trials (8 blocks of 70 trials)
6 days ---3‘360 trials

Threshold pre- and post measurement: 3 down – 1 up adaptive procedure

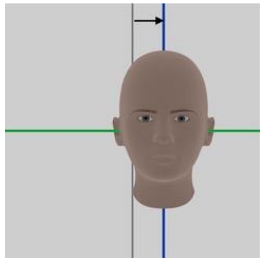
Matthias Ertl, Carlo Prelz, **Daniel C. Fitze**, Gerda Wyssen, Fred W. Mast, **PlatformCommander** — An open source software for an easy integration of motion platforms in research laboratories, SoftwareX, Volume 17, 2022,

https://gitlab.com/KWM-PSY/platform-commander

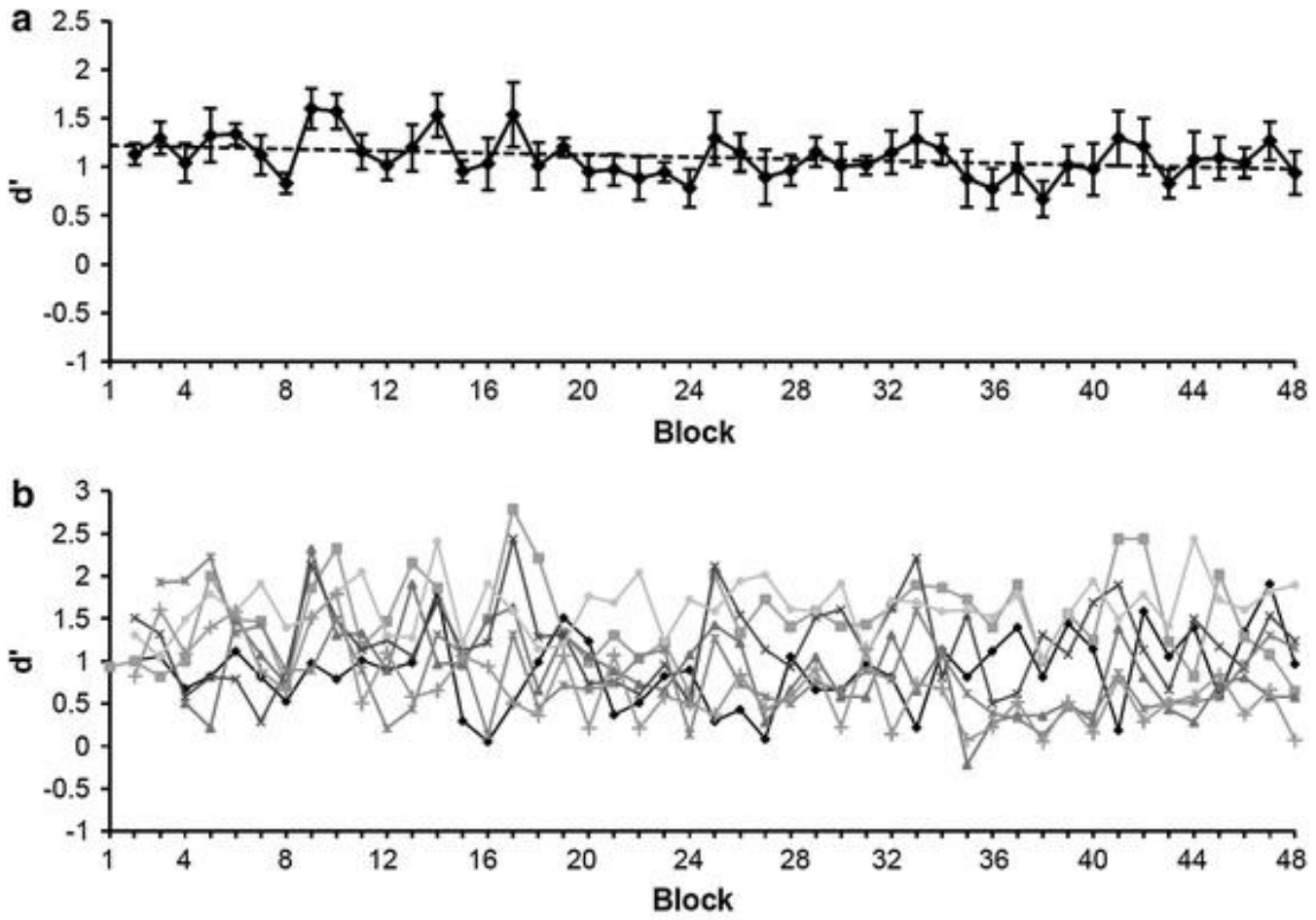
https://tube.switch.ch/channels/Zn0XXPs2tt

NO SIGN OF PERCEPTUAL LEARNING

Y-Translation

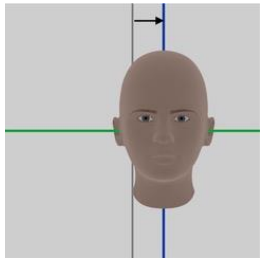


5 female, 2 male, age range from 21 to 28

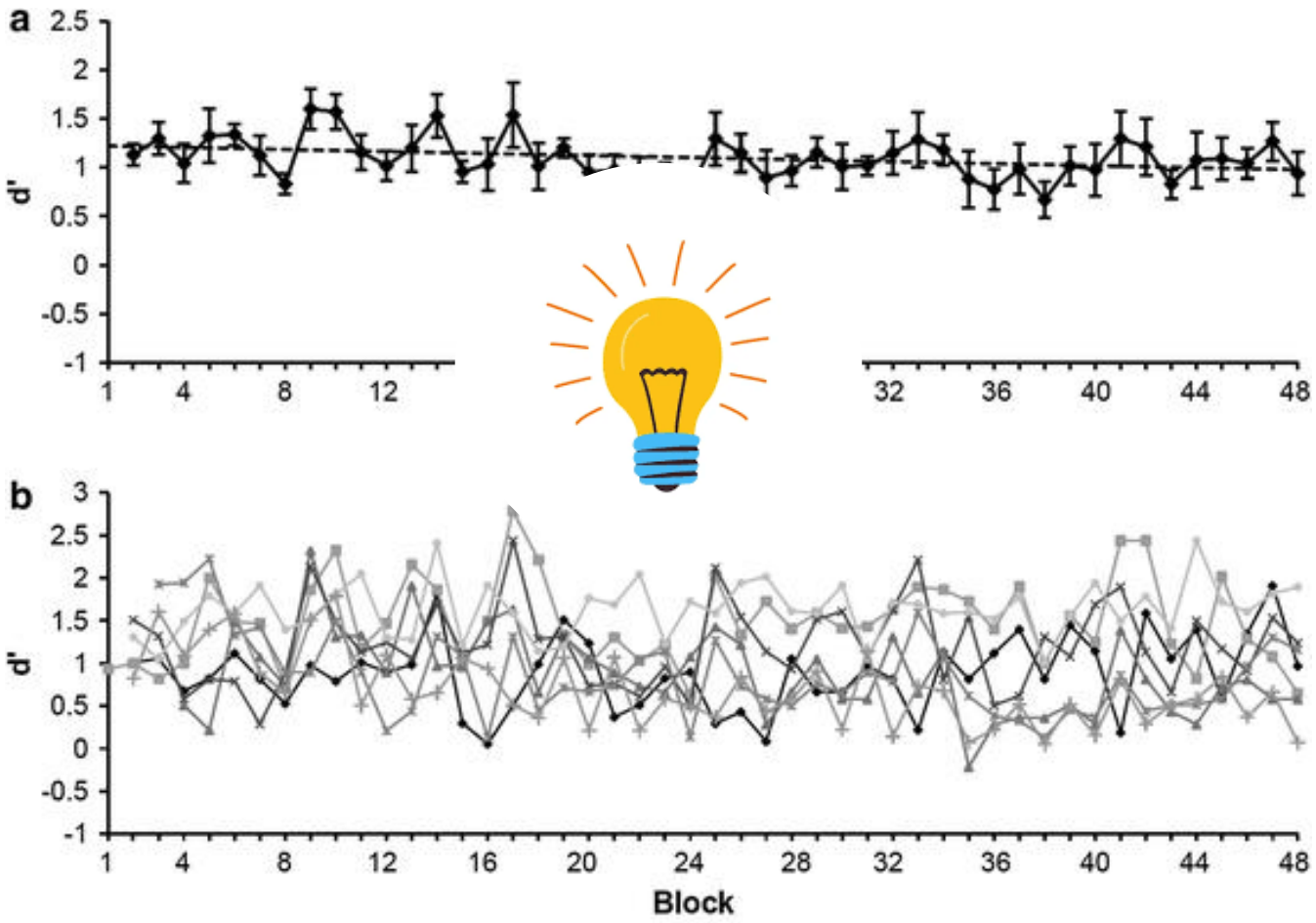


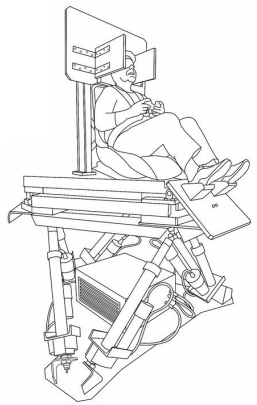
NO SIGN OF PERCEPTUAL LEARNING

Y-Translation



5 female, 2 male, age range from 21 to 28

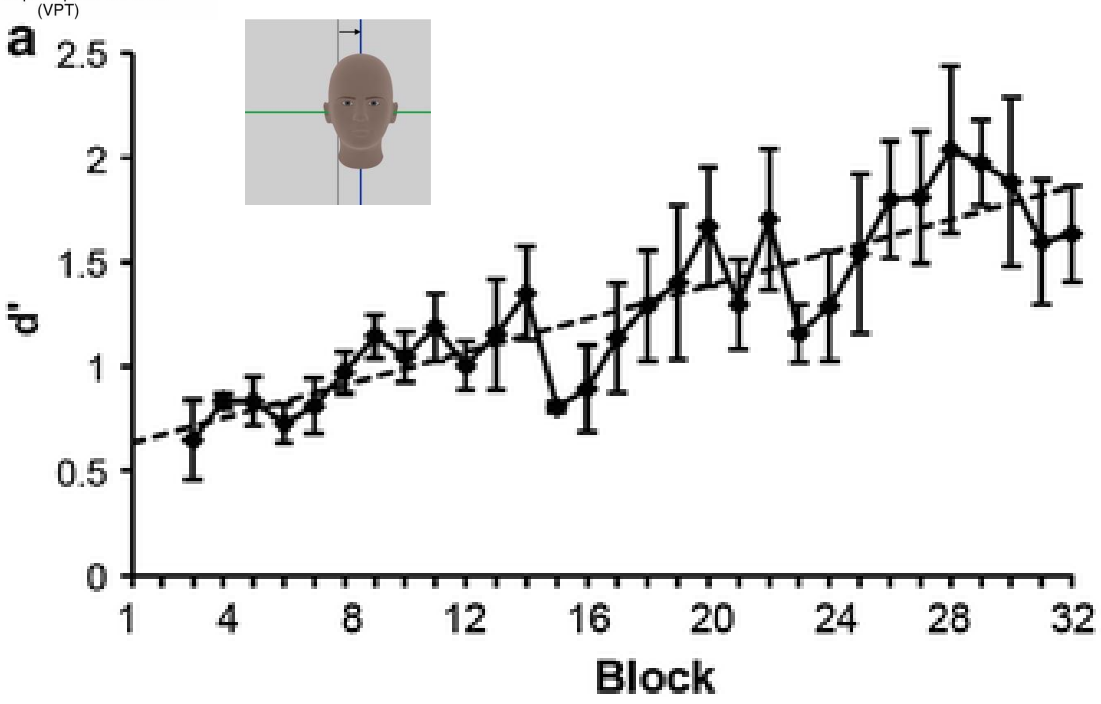


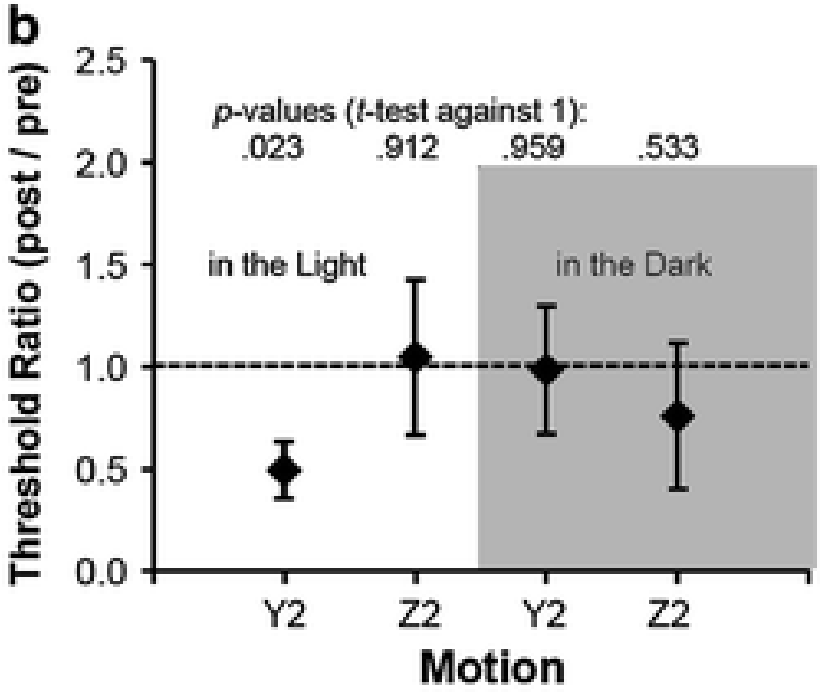


Vestibular perceptual threshold (VPT)

Participants viewed a structured visual environment

Hartmann, M., Furrer, S., Herzog, M.H. *et al.* Self-motion perception training: thresholds improve in the light but not in the dark. *Exp Brain Res* 226, 231–240 (2013). https://doi.org/10.1007/s00221-013-3428-1

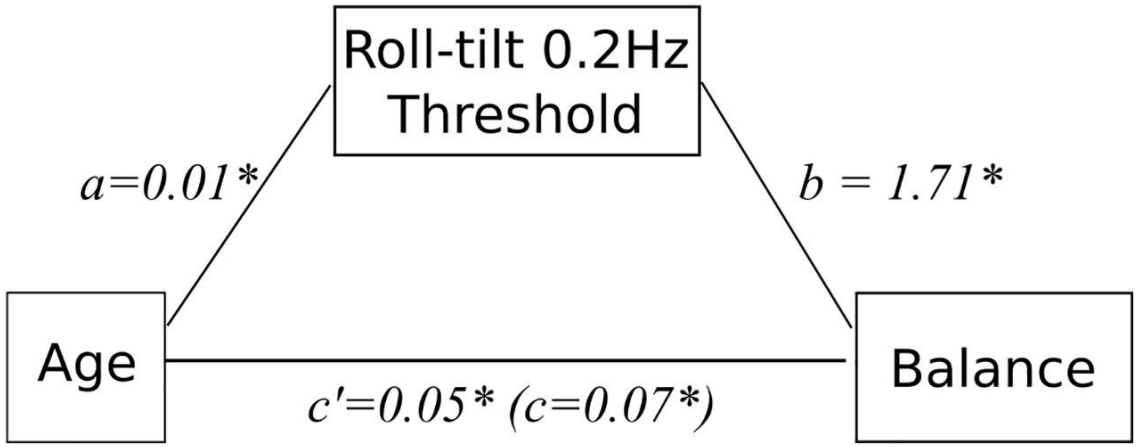




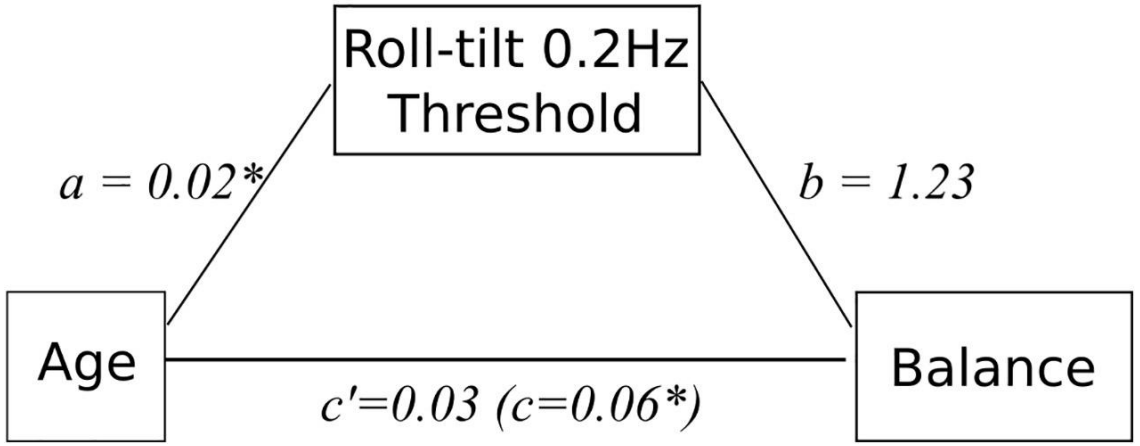
UNIVERSITÄT
BERN

UNIVERSITÄT BERN

A **All subjects**

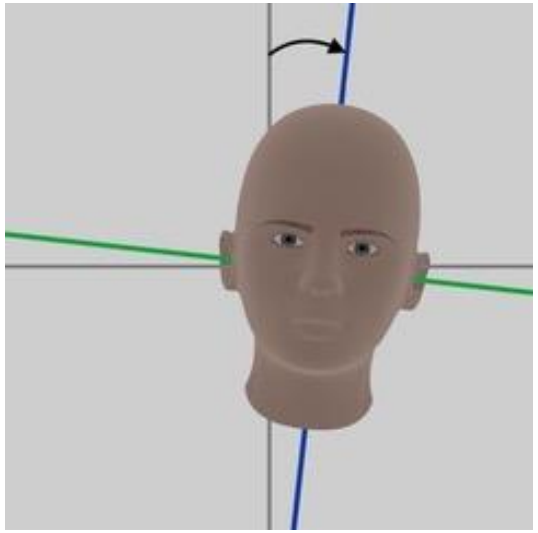


B **Subjects above the age 40**



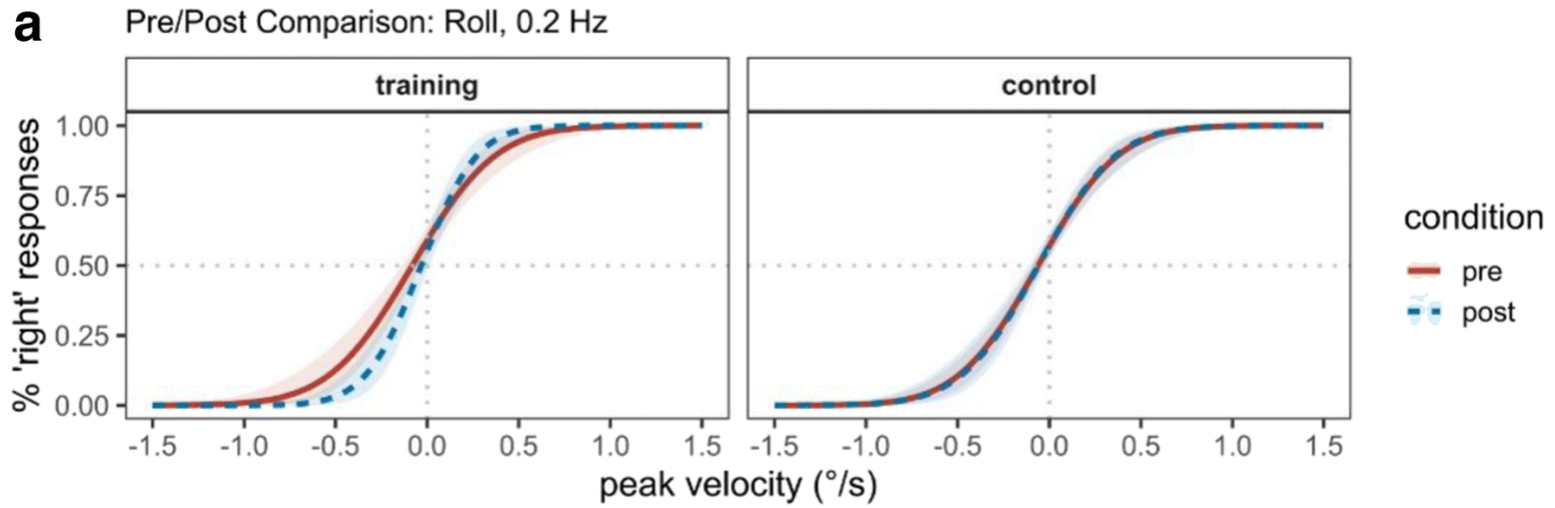
Beylergil, S.B., Karmali, F., Wang, W., Bermúdez Rey, M.C. & Merfeld, D.M. (2019). *Vestibular roll tilt thresholds partially mediate age-related effects on balance*, Progress in Brain Research, Vol. 248, 249-267.

Klaus, M.P., Schöne, C.G., Hartmann, M. *et al.* **Roll tilt self-motion direction discrimination training:** First evidence for perceptual learning. *Atten Percept Psychophys* **82**, 1987–1999 (2020). https://doi.org/10.3758/s13414-019-01967-2

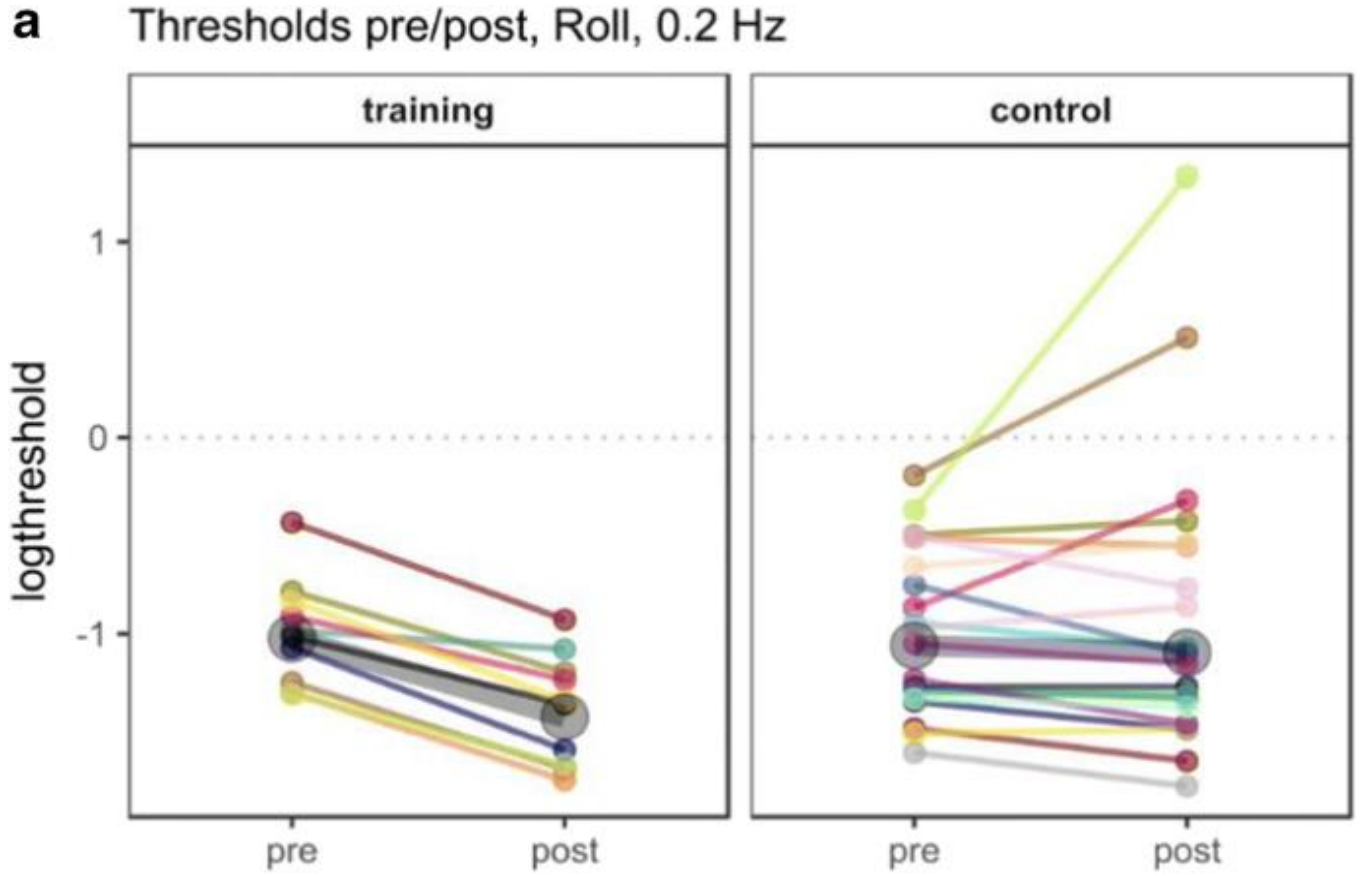


Roll Rotation: **Combined otolith and semicircular canal stimulus**

7 sessions of training, each 400 trials with feedback



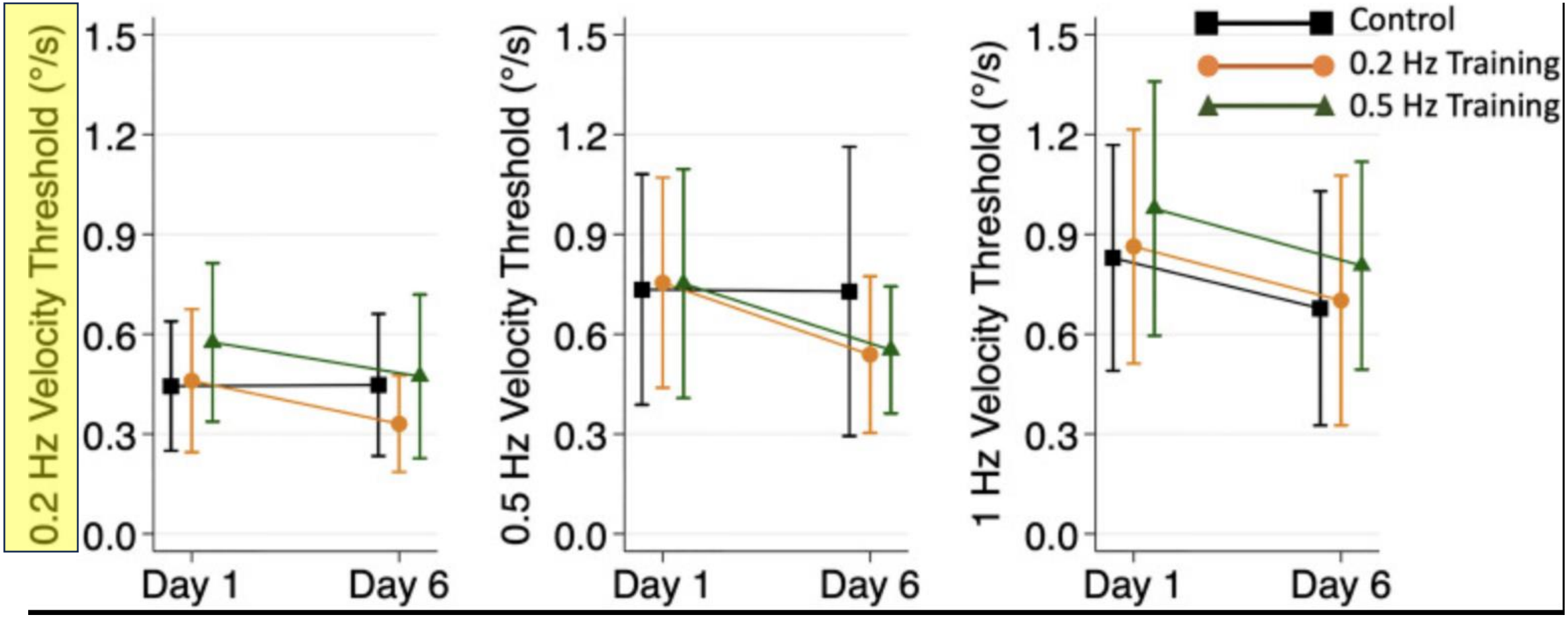
Improved Sensitivity after 9 hour roll tilt perception training



0.2 Hz Roll rotation threshold
0.36°/sec → 0.24°/sec
Control condition:
0.35°/sec → 0.33°/sec

No transfer to Pitch 0.2 Hz
No transfer to Pitch 1 Hz
No transfer to 0.2 Hz y-translation

Transfer to 1 Hz Roll rotation threshold:
0.42°/sec → 0.29°/sec
But:
improvement in the 1 Hz Roll rotation control condition
0.26°/sec → 0.21°/sec



Wagner AR, Kobel MJ, Tajino J, Merfeld DM. Improving self-motion perception and balance through roll tilt perceptual training. J Neurophysiol. 2022 Sep 1;128(3):619-633. doi: 10.1152/jn.00092.2022. Epub 2022 Jul 27. PMID: 35894439; PMCID: PMC9448335.

- Evidence for perceptual learning of roll rotation discrimination in young and healthy participants

- Improved sensitivity in trained stimuli and no transfer to untrained different stimuli (but some transfer across frequencies)

- Roll rotation thresholds mediates the influence of age on balance Beylergil, S.B., Karmali, F., Wang, W., Bermúdez Rey, M.C. & Merfeld, D.M. (2019).

- Vestibular thresholds decline with age Wagner A.R., Akinsola, O., Chaudhari, A.M.W., Bigelow, K.E., Merfeld, D.M. (2021)

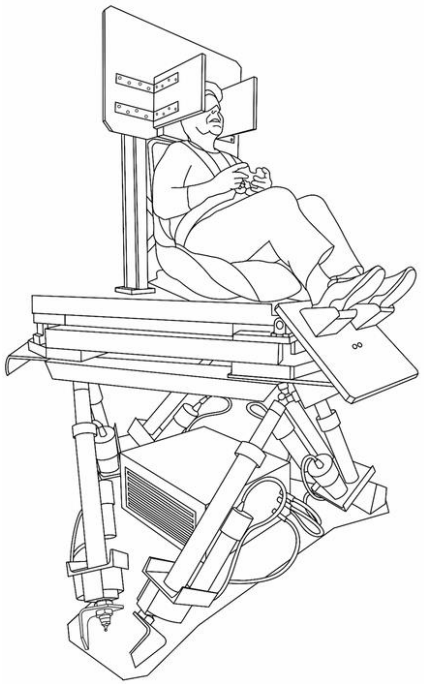
UNIVERSITÄT BERN

Perceptual vestibular learning in Age 70+

A

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Assessment: • VPT • Posturography • Gait analysis	**Group 1: Roll training** 400 trials / day			**Assessment:** • VPT • Posturography • Gait analysis	**Group 1: Roll training** 400 trials / day				**Assessment:** • VPT • Posturography • Gait analysis
	Group 2: Inter-aural training 400 trials / day				**Group 2: Inter-aural training** 400 trials / day				

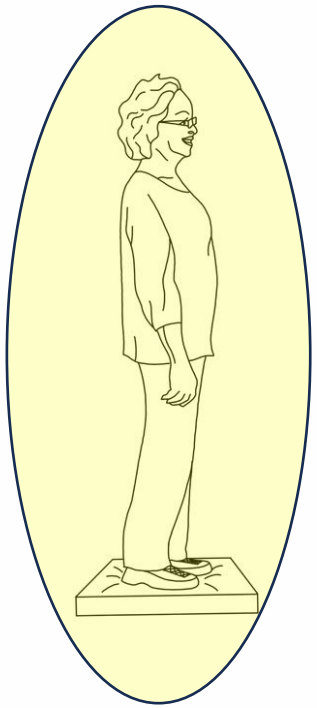
B



Type 9286BA; Kistler, Winterthur, Switzerland

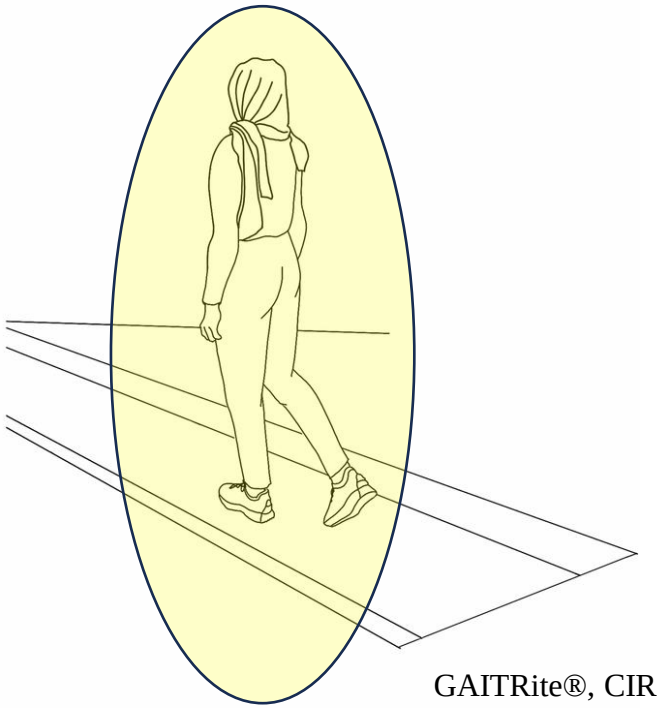
Vestibular perceptual threshold (VPT)

C



Posturography

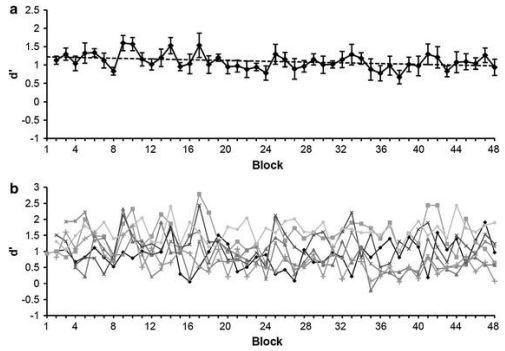
D



Gait Analysis

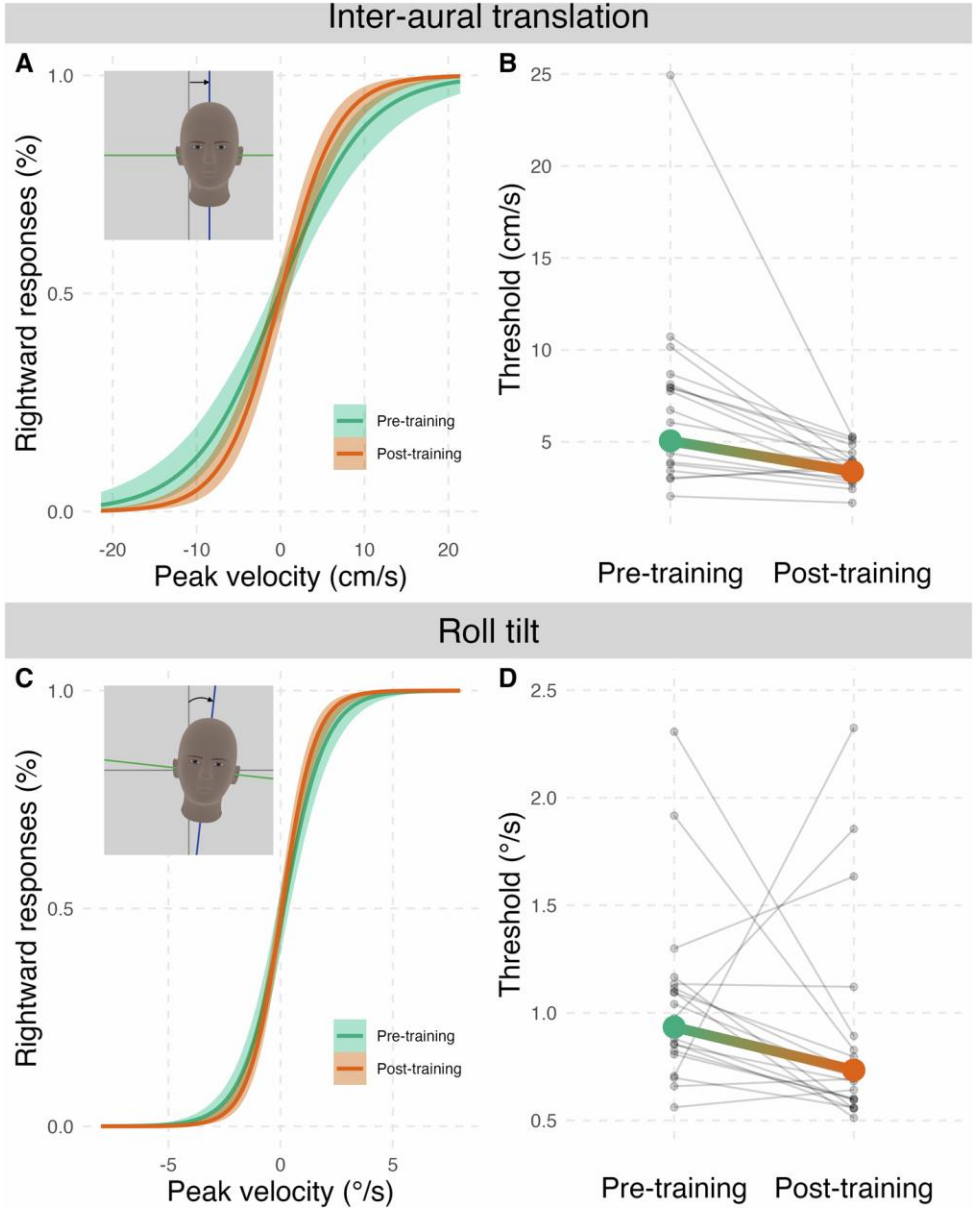
20 participants (70+) in **roll rotation training:** Number of trials etc.

Active control condition: **interaural translation** because it did not show any evidence for perceptual learning (Hartmann et al., 2013)

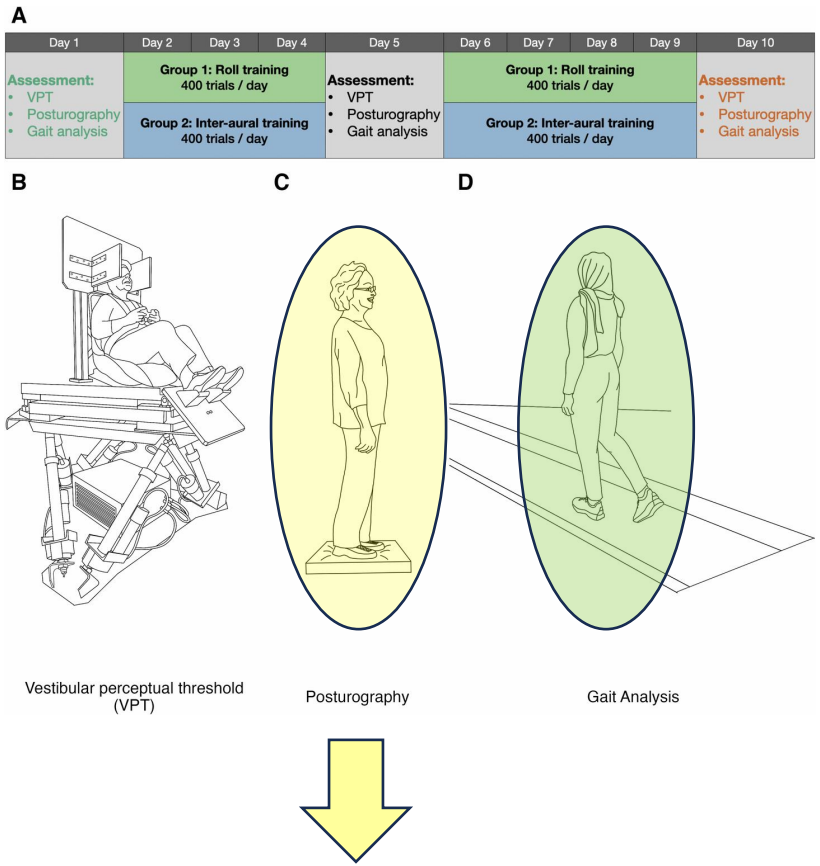


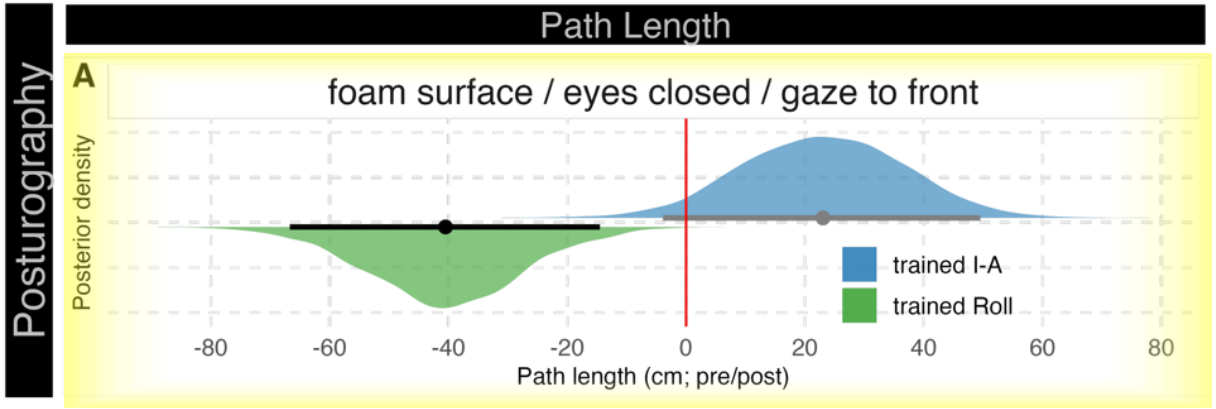
GAITRite®, CIR System, Sparta, NJ, USA

Fitze, D.C., Ertl, M., Radlinger, L. *et al.* Vestibular perceptual learning improves self-motion perception, posture, and gait in older adults. *Commun Biol* **7**, 1087 (2024). https://doi.org/10.1038/s42003-024-06802-5

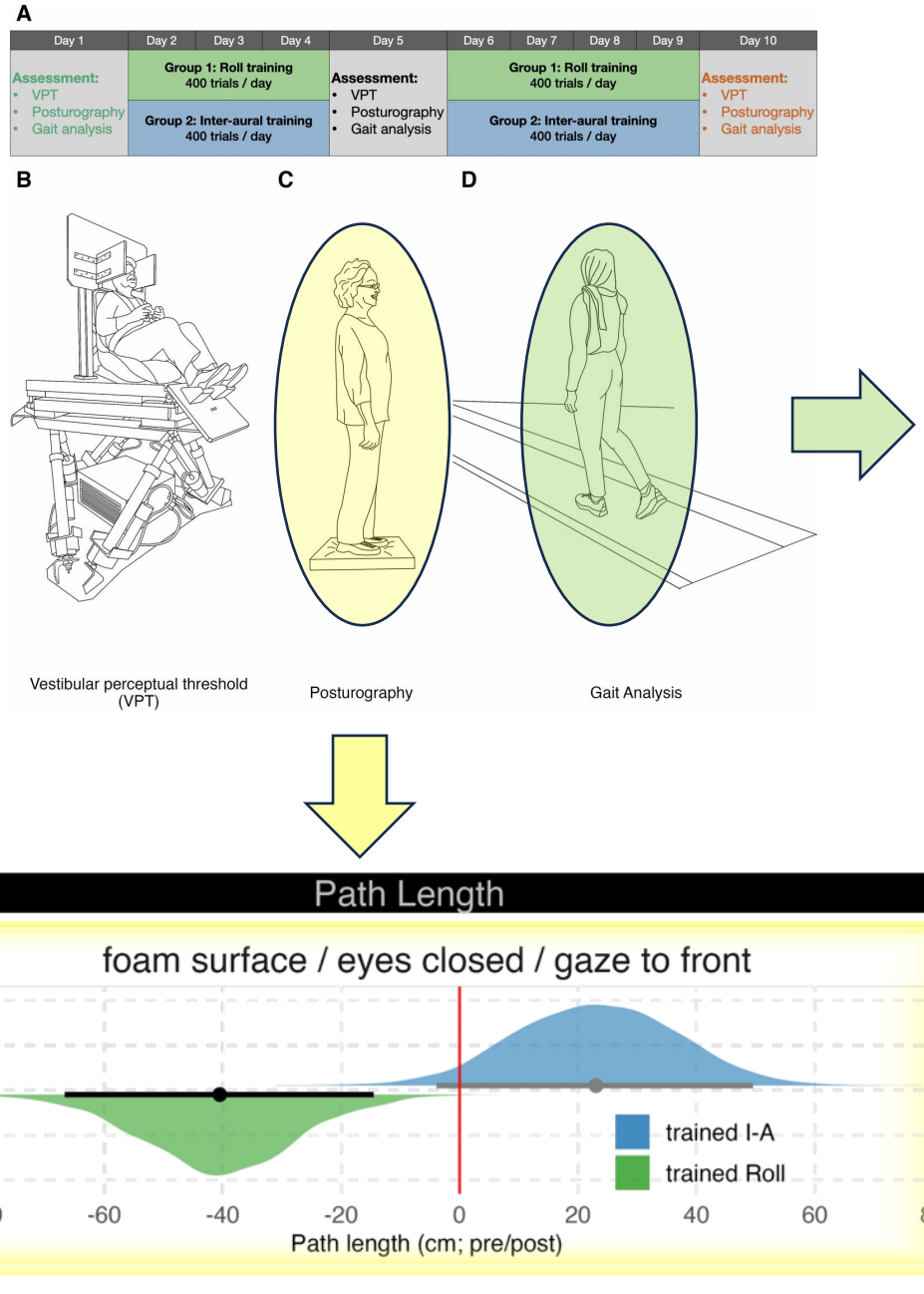


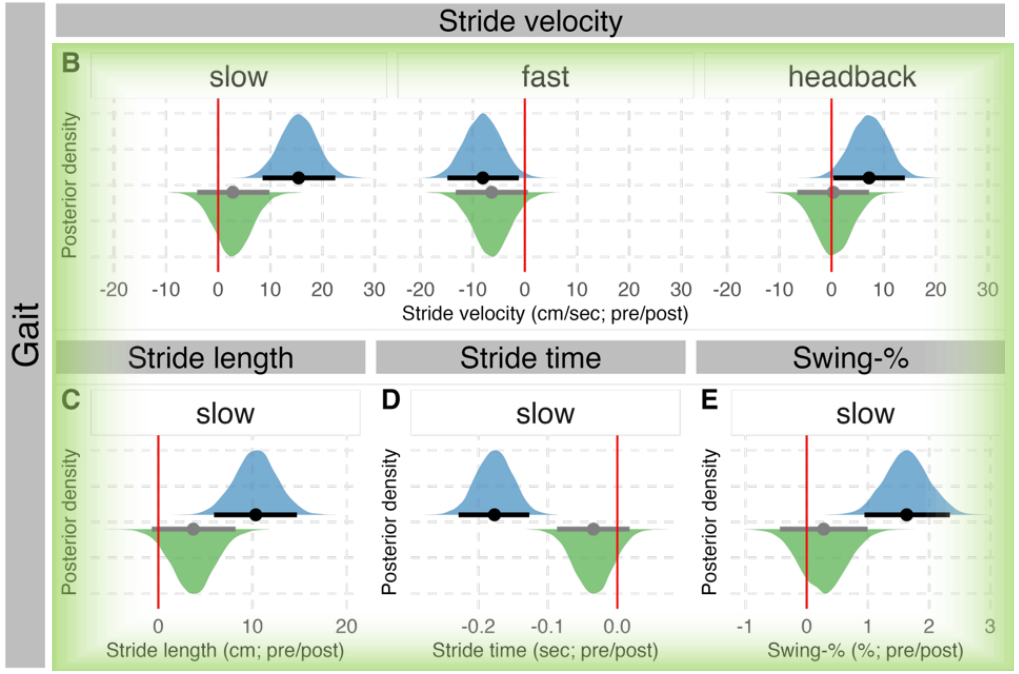
Fitze, D.C., Ertl, M., Radlinger, L. *et al.* Vestibular perceptual learning improves self-motion perception, posture, and gait in older adults. *Commun Biol* **7**, 1087 (2024). https://doi.org/10.1038/s42003-024-06802-5





Fitze, D.C., Ertl, M., Radlinger, L. *et al.* Vestibular perceptual learning improves self-motion perception, posture, and gait in older adults. *Commun Biol* **7**, 1087 (2024). https://doi.org/10.1038/s42003-024-06802-5





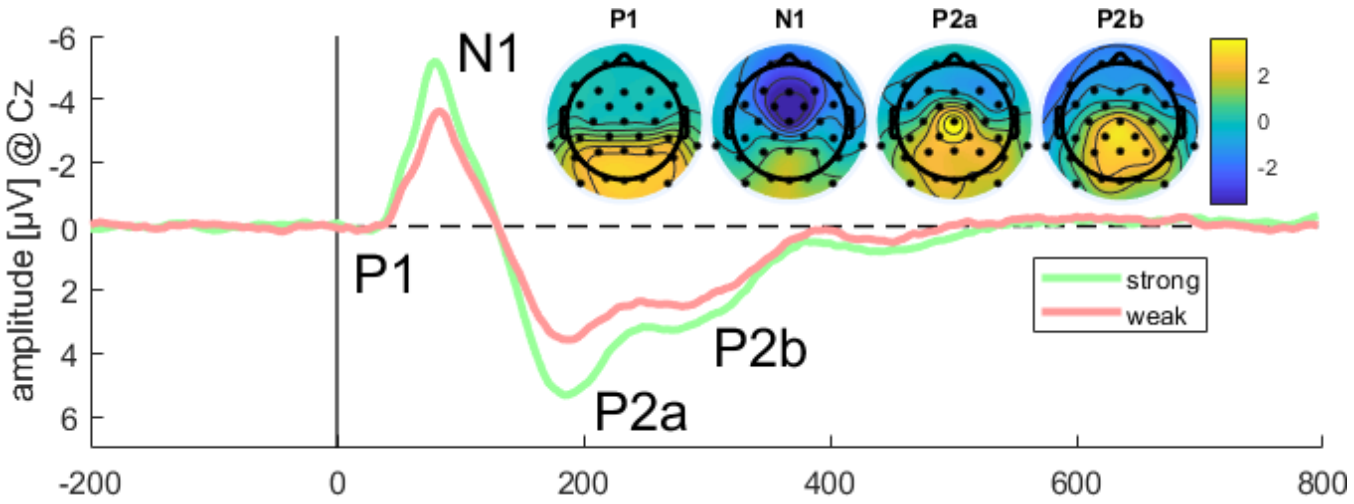
Fitze, D.C., Ertl, M., Radlinger, L. *et al.* Vestibular perceptual learning improves self-motion perception, posture, and gait in older adults. *Commun Biol* **7**, 1087 (2024). https://doi.org/10.1038/s42003-024-06802-5

Ongoing study

Participants (90, aged 65 and older)

(1) Self-motion perception training (10 one-hour sessions of roll-rotation training)
(2) Tai Chi training
(3) Passive control condition

Pre- and post-training assessments:
motion thresholds
Follow-up measurements
Posturography and gait measures
vestibular-evoked potentials (VestEPs)
rsMRI



To sum up:

Perceptual learning in the vestibular domain – it exists

Perceptual learning in the vestibular domain – it improves balance and gait measures

Perceptual learning in the vestibular domain – it can be novel tool to prevent falls in older adults