

# Movement and cognition in neurodegenerative disorders: A dynamic duo

Marit Ruitenbergh, PhD

Dec 2025

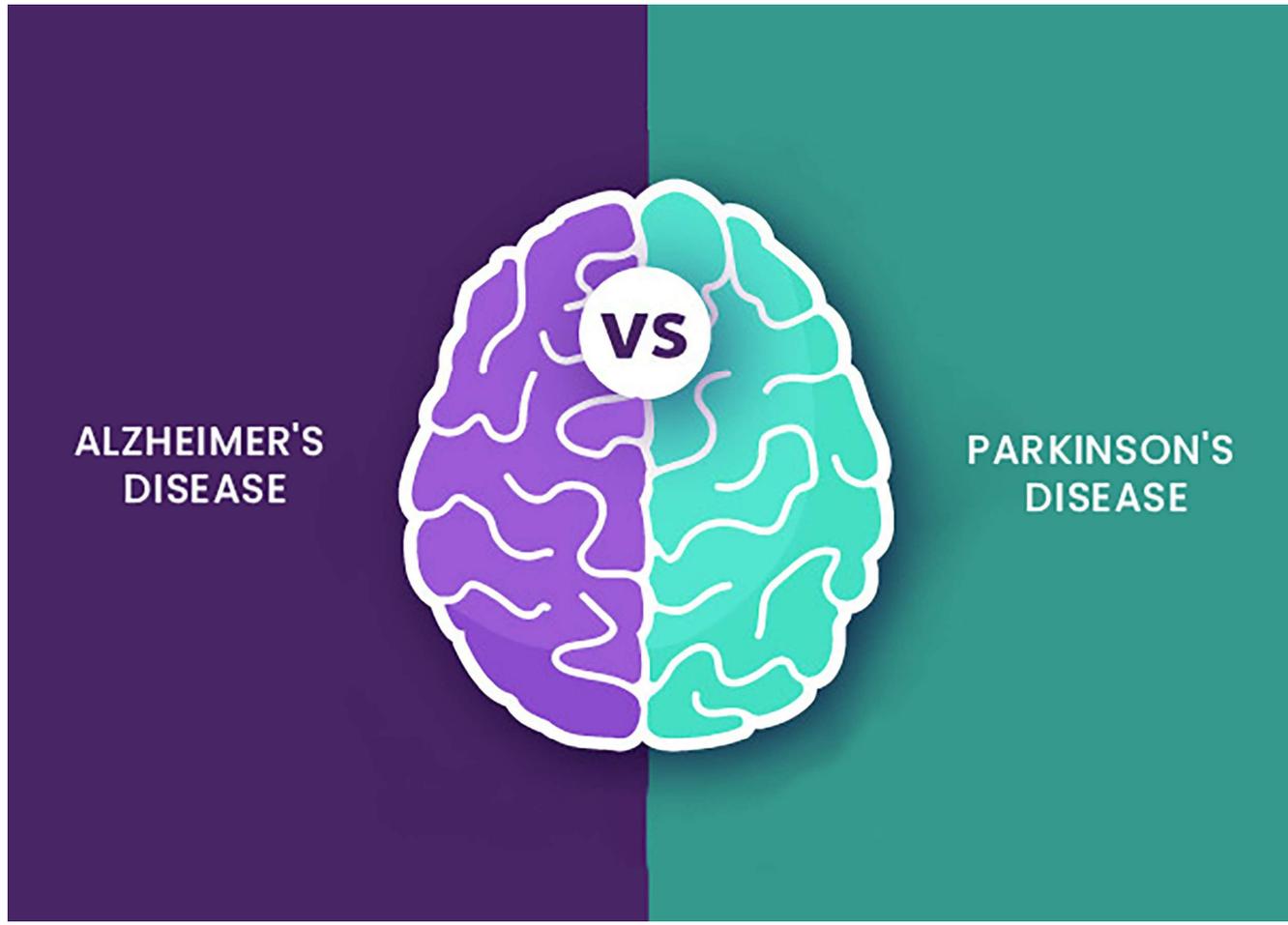


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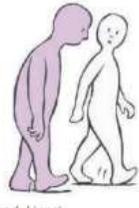
Advances in  
**Motor Learning II**



# Parkinson's disease

## MOVEMENT

Stijver & langzamer



Minder en kleiner



Starten en stoppen



Onwillekeurig



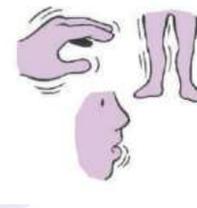
Dystonie/krampe



On-Off Freezing

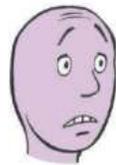


Tremor



## EMOTION & MOOD

Angst en paniek



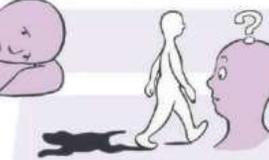
Stress



Depressie en apathie



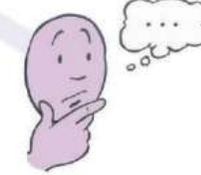
Psychosen



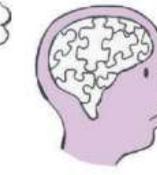
Ontremming



Denken

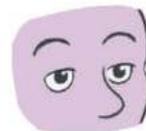


Dementie

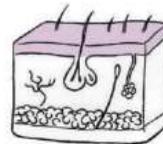


## AND MORE

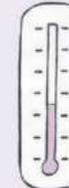
Zien



Huid



Temperatuur ervaren



Pijn



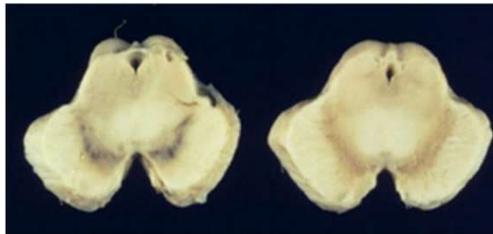
Vermoeidheid



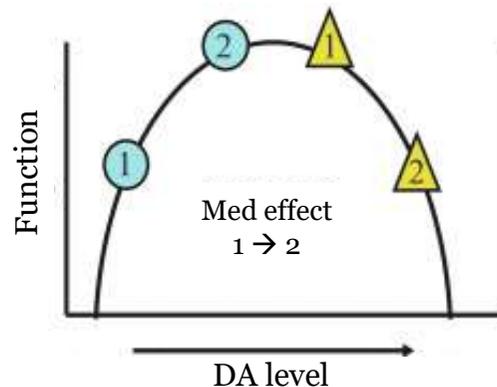
Illustraties: Handboek Parkinson symptomen

# Medication & DA asymmetry

- Loss of DA cells → lower DA levels



- Early/mild PD: DA deficiency dorsal striatum > ventral striatum
- Overdose hypothesis (e.g., Cools, 2006)

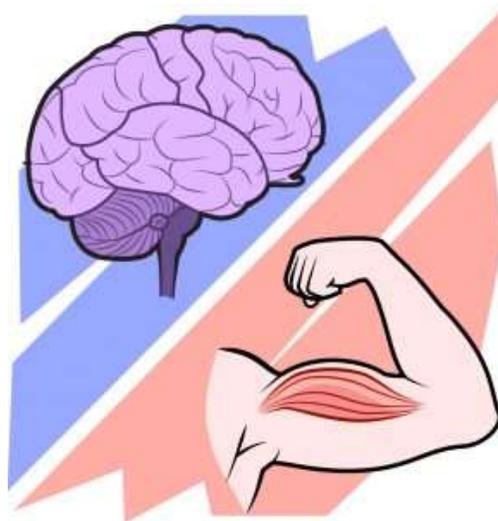


- Restores DA level in dorsal striatum  
→ *alleviates* associated functions
- ▲ Overdoses DA levels in ventral striatum  
→ *hinders* associated functions

# DA asymmetry and movement

## Planning

- pre-SMA, frontal areas
- ventral striatum
- *impaired* by medication



## Execution

- sensorimotor circuit, motor cortex M1
- dorsal striatum
- *enhanced* by medication

With:  
Elger Abrahamse  
Wout Duthoo  
Patrick Santens  
Rachael Seidler  
Wim Notebaert

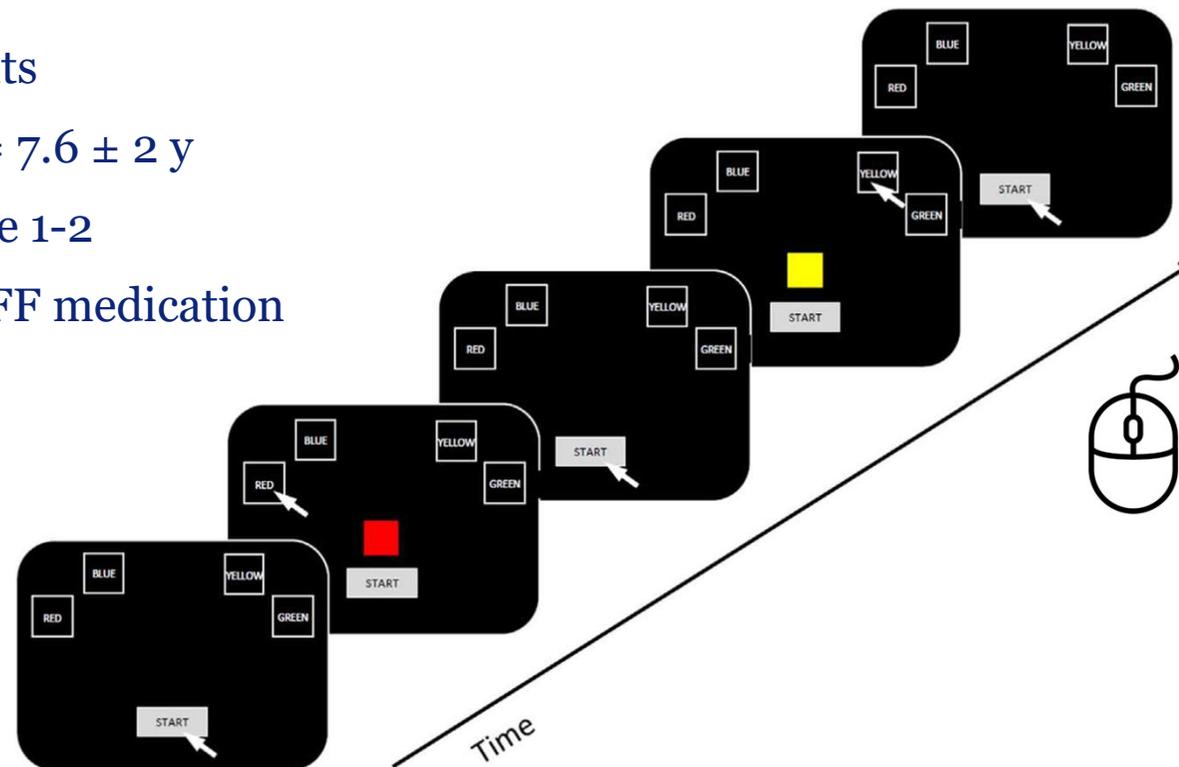


# Motor learning in PD

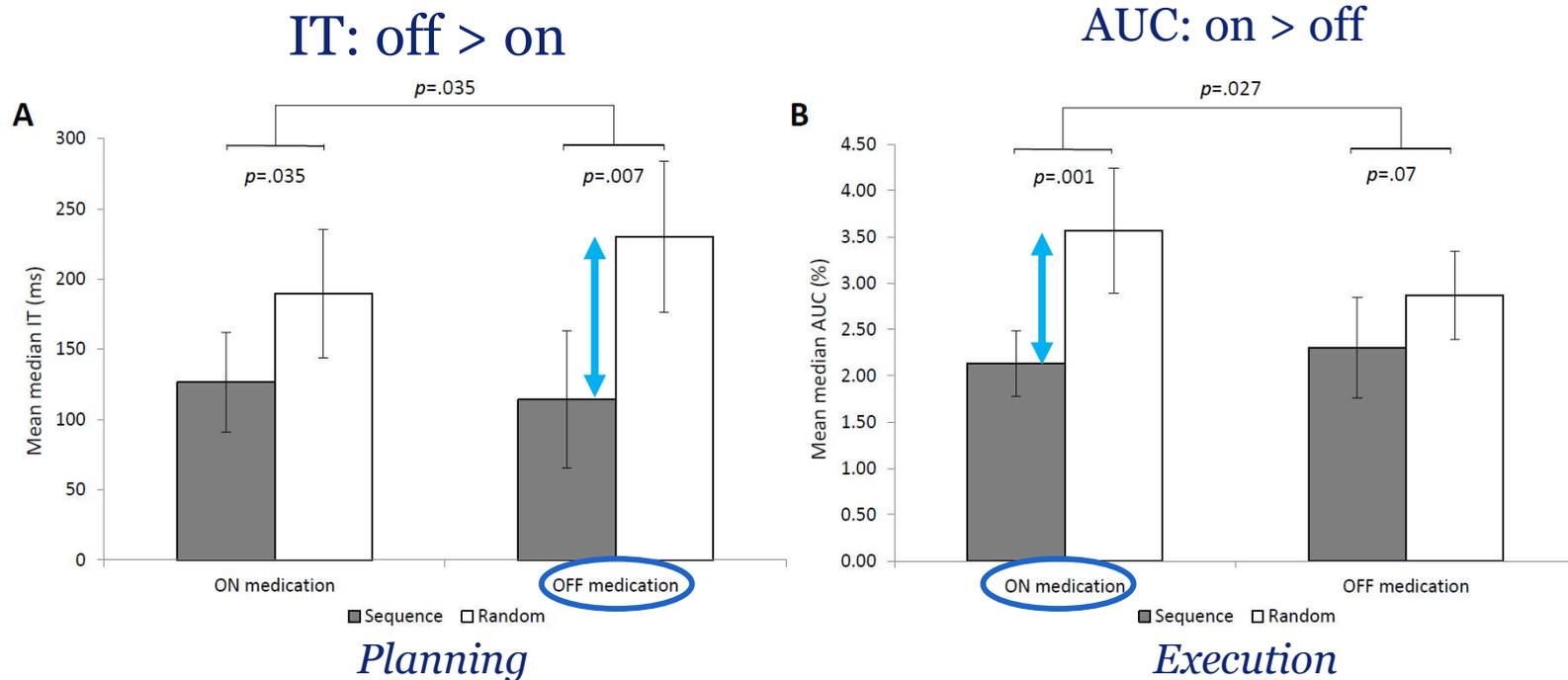
Fixed sequence vs. random sequence of mouse movements

14 PD patients

- $M_{\text{duration}} = 7.6 \pm 2 \text{ y}$
- H&Y stage 1-2
- ON vs. OFF medication



# Motor learning in PD

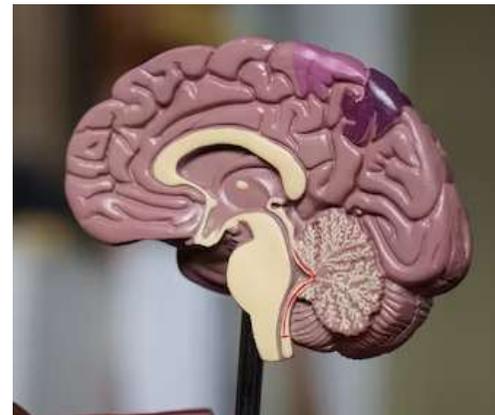
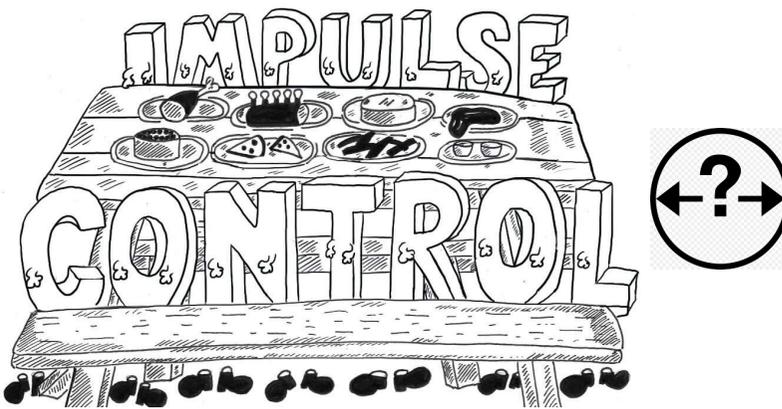


Differential effects of DA medication on cognitive and motor aspects of movement!

Ruitenber *et al.* (2016), *Neuropsychologia*

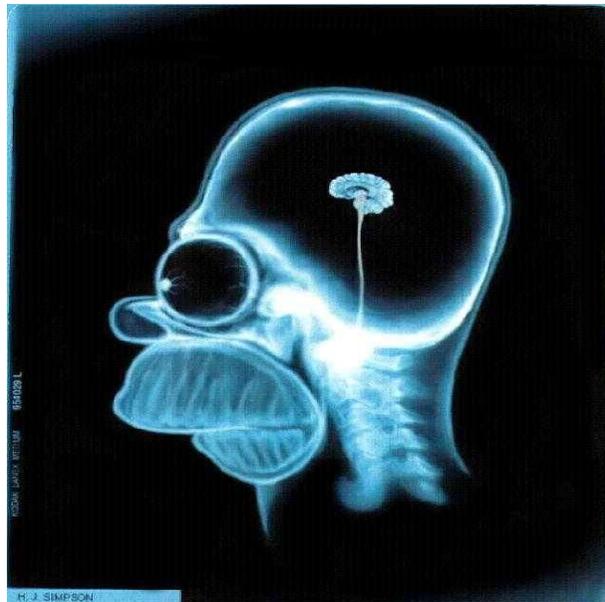
# Impulse control in PD

- Up to 45% develops disorder
- Difficulty resisting impulses, loss of voluntary control
  - Excessive hedonistic behavior
- Harmful to self and/or others



# Neuroimaging: MRI vs. fMRI

**MRI studies brain  
anatomy = structure**



**fMRI studies the brain  
at work = function**

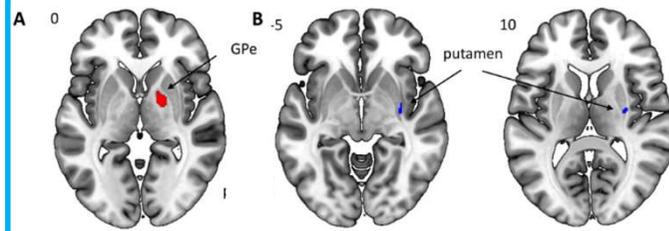


# Brain mechanisms

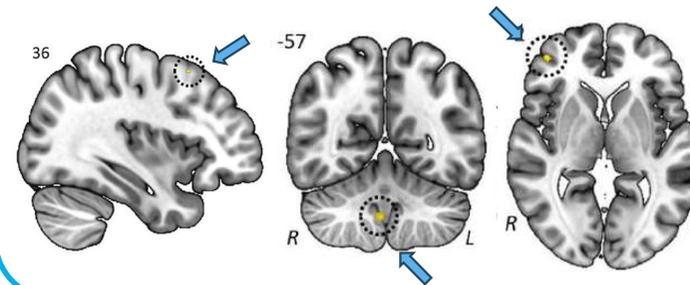
Ruitenbergh et al. (2018; *Front in Neurol*)

Ruitenbergh et al. (2022; *Exp Brain Res*)

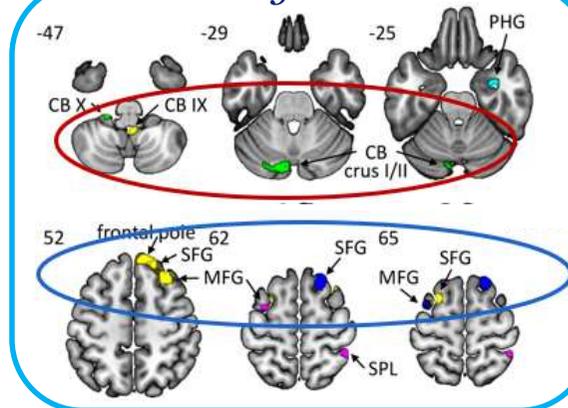
## Volume



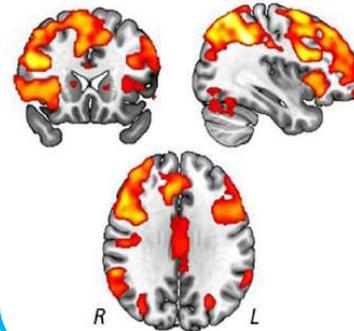
## Activity



## Connectivity



## Behavior



## Two mechanisms:

Affective pathways →  
impaired decision-making,  
selection of risky or  
inappropriate actions

Sensorimotor pathways →  
greater propensity to act

# Interim summary – PD

- PD is associated with problems with (a.o.) movement, cognition, and impulse control
  - *More than a motor disorder*
- Medication can ameliorate or worsen symptoms
  - *Depending on neural structure*
- Brain mechanisms of impulse control problems
  - *Involved both motor and affective / reward pathways*



Neuroscience & Biobehavioral Reviews

Volume 169, February 2025, 106026



## Impulse control in Parkinson's disease: Distinct effects between action and choice

Aliya C.M. Warden <sup>a b</sup>, Craig McAllister <sup>a b</sup>, Marit F.L. Ruitenber <sup>c d 1</sup>,

Hayley J. MacDonald <sup>a e 1</sup>  

# MCI & Alzheimer's disease

## Motor Dysfunction in Mild Cognitive Impairment and the Risk of Incident Alzheimer Disease

Neelum T. Aggarwal

Walking While Talking and Risk of Incident Dementia  
 Poor Gait Performance and Prediction of Dementia: Results From a Meta-Analysis

Mirnova E. Ceide M.D.<sup>c</sup>  
 M.B.B.S.<sup>a</sup>

Olivier Beauchet MD, PhD<sup>a b c</sup>  , Cédric Annweiler MD, PhD<sup>d</sup>, Michele L. Callisaya PhD<sup>e f</sup>,

Anne-Marie C  
 PhD<sup>f</sup>, Jean-P  
 MD, PhD<sup>k l</sup>

**Grip Strength and the Risk of Incident Alzheimer's Disease**

Aron S. Buchman<sup>a, b</sup> Robert S. Wilson<sup>a-c</sup> Patricia A. Boyle<sup>a, c</sup> Julia L. Bienias<sup>d</sup>

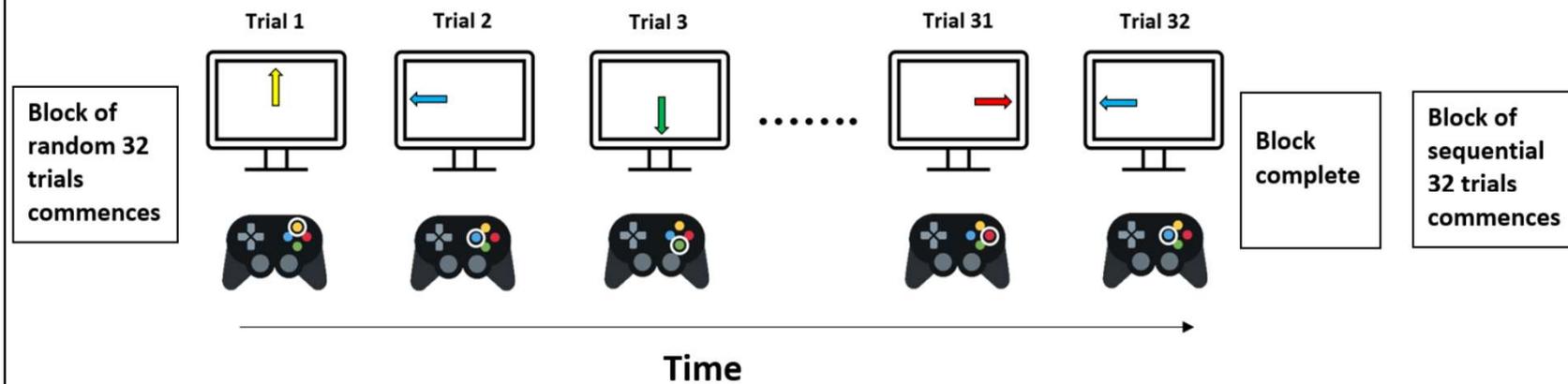
David A. Br

Delayed and More Variable Unimanual and Bimanual Finger Tapping in Alzheimer's Disease: Associations with Biomarkers and Applications for Classification

Vincent Koppelmans<sup>a, b, \*</sup>, Marit F.L. Ruitenber<sup>c, d</sup>, Sydney Y. Schaefer<sup>e</sup>, Jace B. King<sup>f</sup>, John M. Hoffman<sup>g</sup>, Amanda F. Mejia<sup>h</sup>, Tolga Tasdizen<sup>i</sup> and Kevin Duff<sup>j, k</sup>

# Sequence learning in MCI & AD

Fixed sequence vs. random sequence of responses



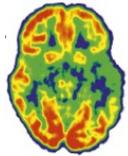
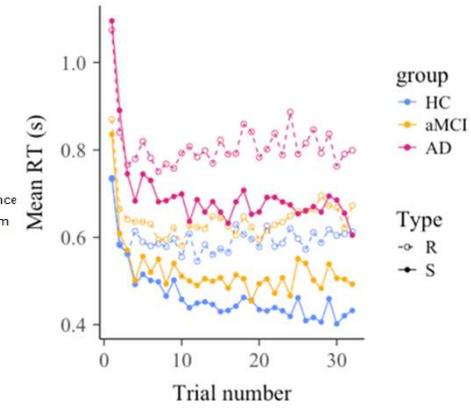
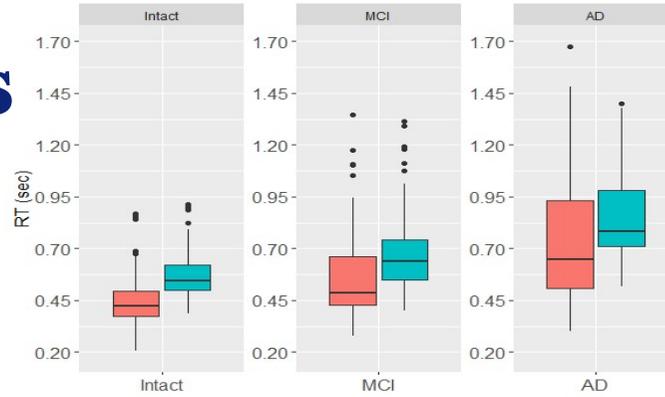
113 participants:

- 28 individuals with AD
- 33 individuals with MCI
- 52 healthy controls

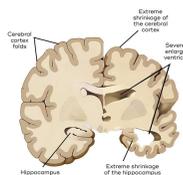
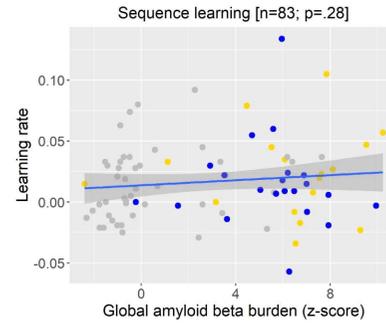
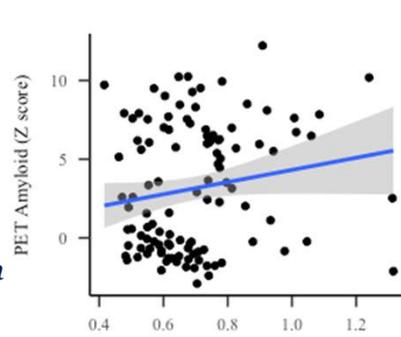
*With:*  
 Vincent Koppelmans  
 Kevin Duff



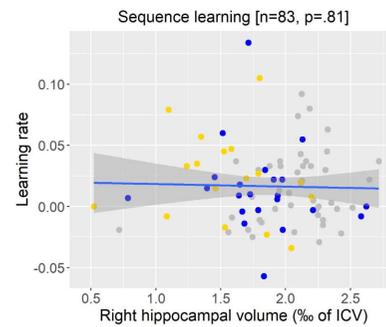
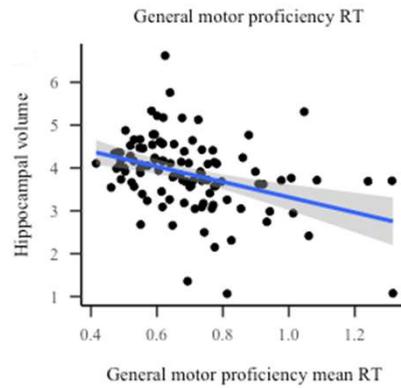
# Results



amyloid deposition via PET imaging



hippocampal volume via MRI



Sequence learning seems relatively preserved

Potential as behavioral biomarker?

Esp. broader motor proficiency may be useful

# Take home message

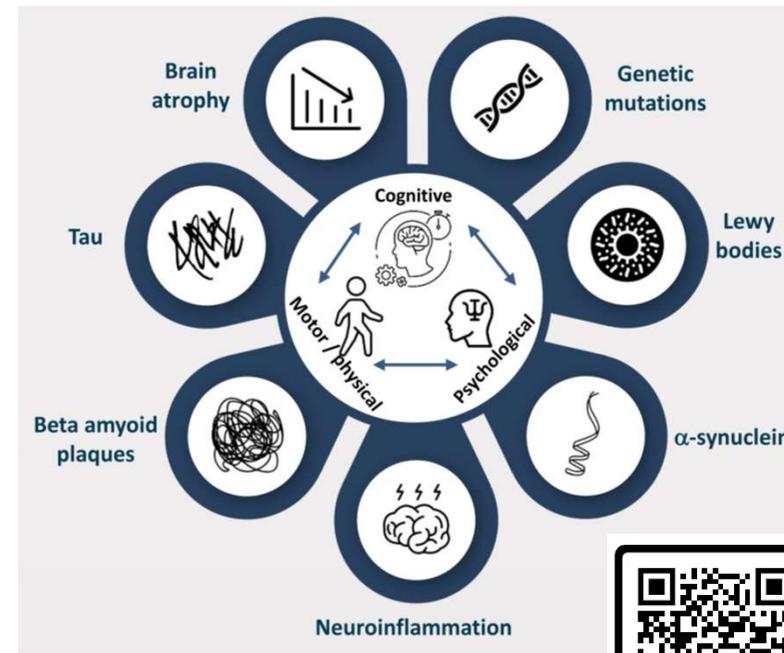
- Interplay between cognition and movement

“motor” disorders also affect cognition

“cognitive” disorders also affect movement

Dichotomy → Multidimensional

- Better alignment with broader phenomenology
- Evidence for overlap in neuropathology (e.g., Compta & Revesz, 2021)
- Enriching understanding of patients, family members, and society



Thanks to: Patrick Santens, Wim Notebaert, Elger Abrahamse, Rachael Seidler, Paula Carmona, Kevin Duff, Vincent Koppelmans



# Call for papers – join us!

## Special Issue: Call for Papers

**Motor Learning and Function in Clinical Populations**



GUEST EDITORS  
**Marit Ruitenber**  
 Leiden University  
**Vincent Koppelmans**  
 University of Utah  
Submission Deadline  
**May 15, 2026**

**Guest Editors:** Marit Ruitenber, Leiden University and Vincent Koppelmans, University of Utah

**Submission Deadline:** May 15, 2026

Chronic clinical conditions in humans often share the common element of impairing motor function. This Special Issue explores commonalities and differences in motor impairments observed in various clinical populations, shedding light on the underlying mechanisms to inform evidence-based approaches for enhancing motor learning and function in individuals living with clinical conditions.

Interested? Questions? Brainstorm?  
[m.f.l.ruitenber@fsw.leidenuniv.nl](mailto:m.f.l.ruitenber@fsw.leidenuniv.nl)