

# Function of Gait in Movement Disorders

Seoul, Korea | October 3, 2026



International Parkinson and  
Movement Disorder Society  
Asian & Oceanian Section

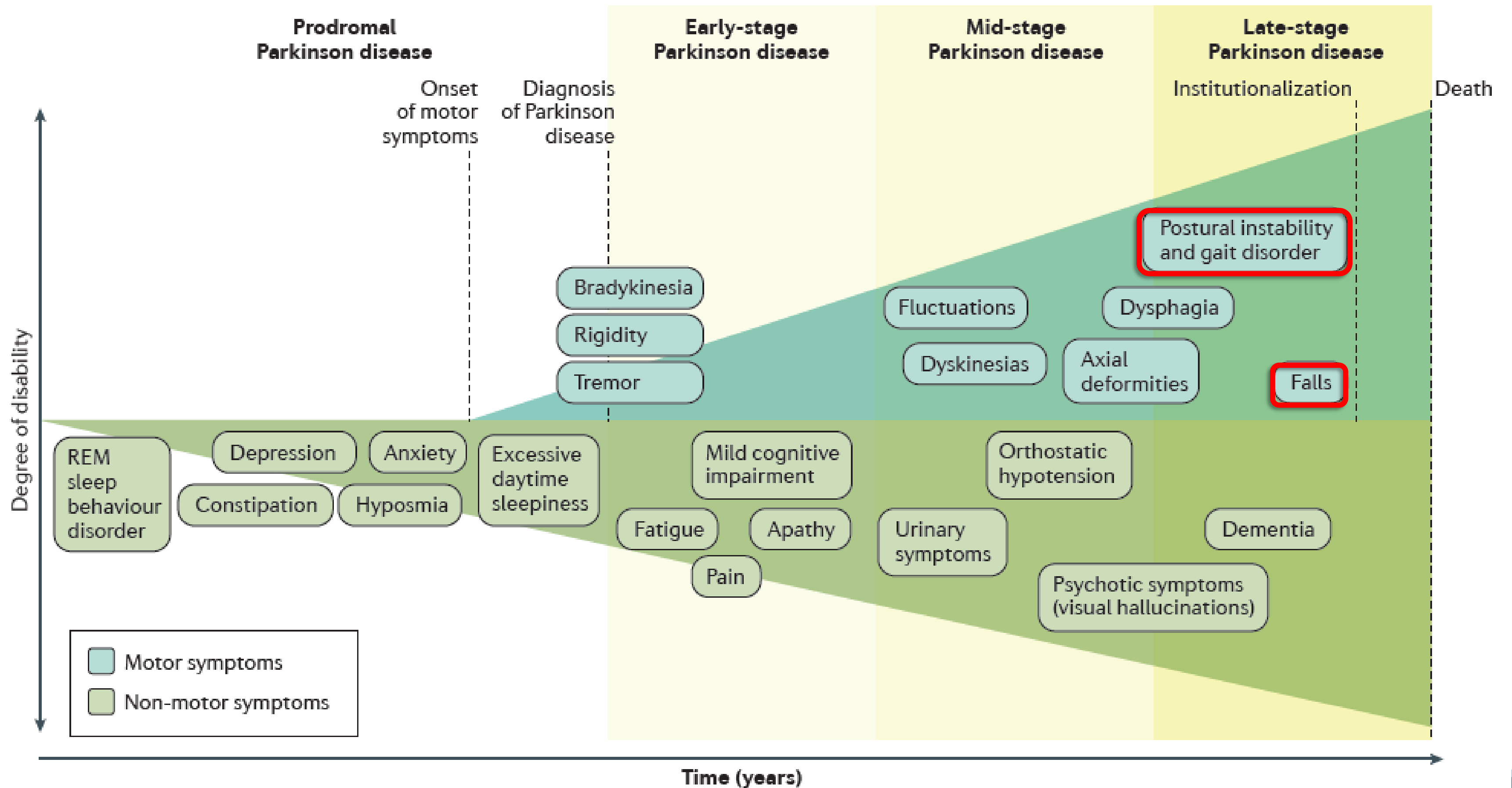
## Evidence-based strategies and technology-informed gait rehabilitation – later stages of PD

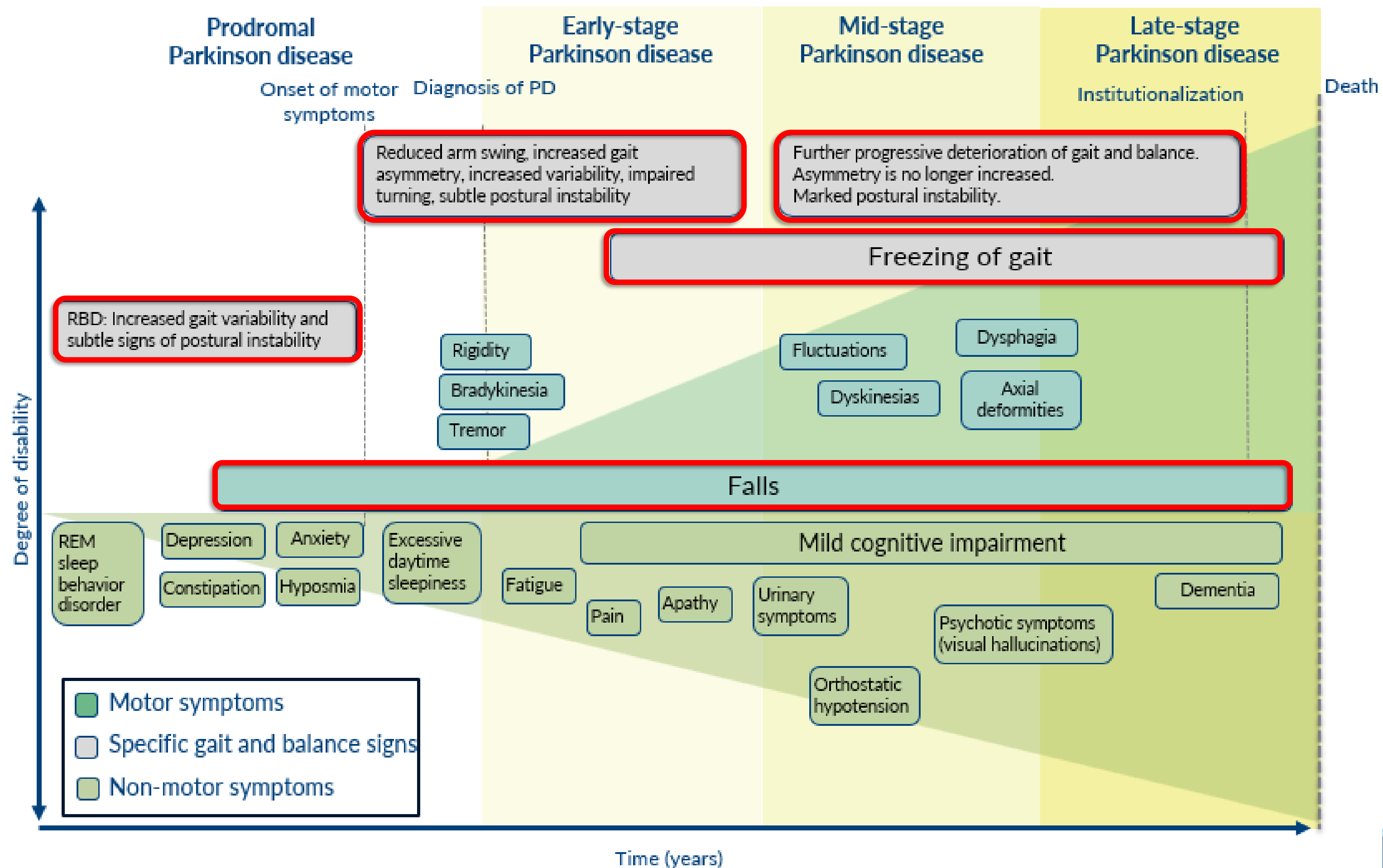
**KU LEUVEN**

Prof. (em.) Alice Nieuwboer

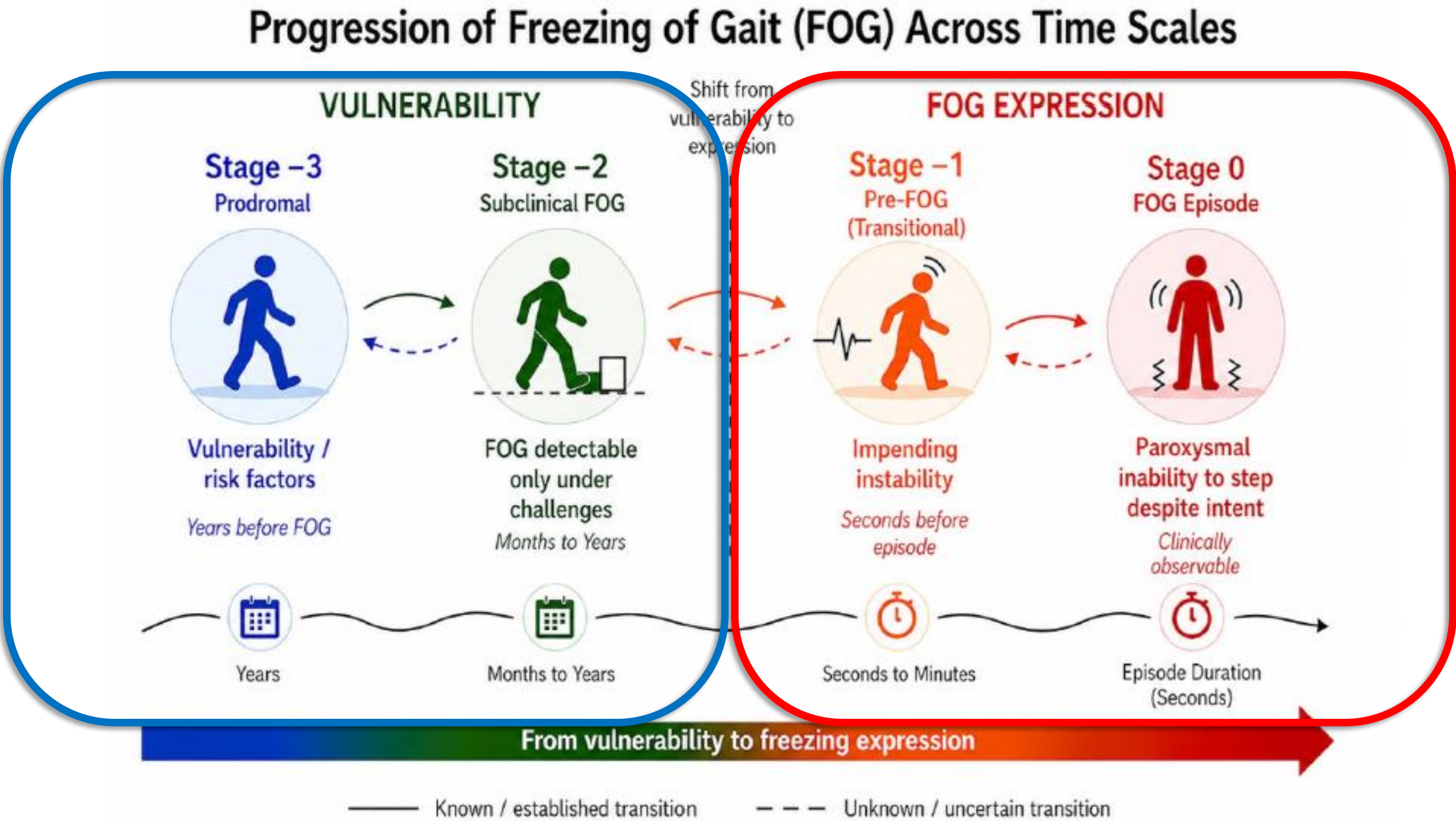
Department of Rehabilitation Science

Parkinson Research Laboratory

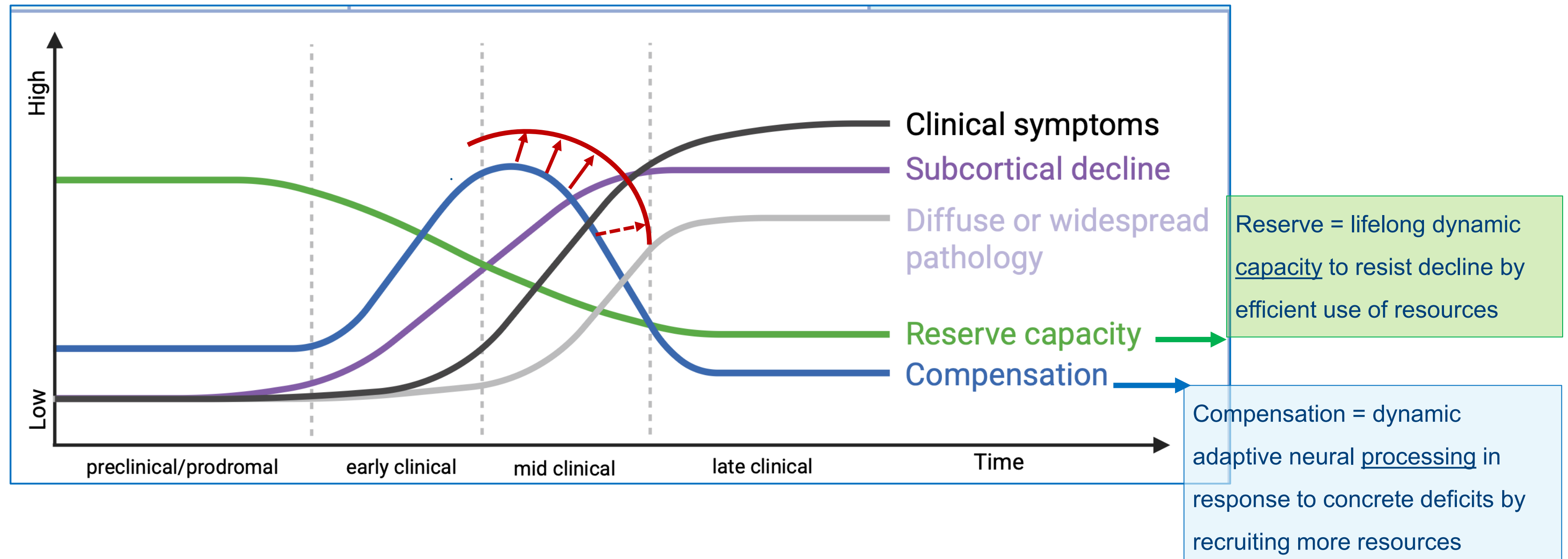




# Broadening the therapeutic window → reactive to proactive



# Time changes → compensatory recruitment in PD



Expert recommendation

 Check for updates

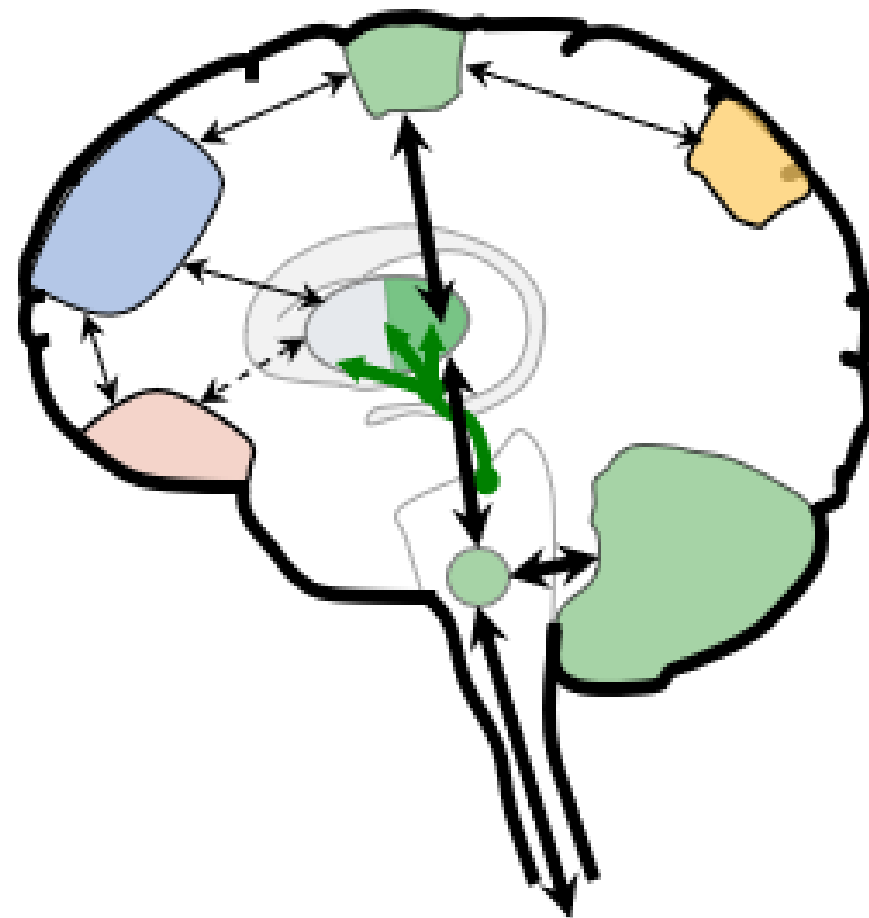
# Management of freezing of gait – mechanism-based practical recommendations

Anouk Tosserams<sup>1,2</sup>, Alfonso Fasano <sup>3,4,5</sup>, Moran Gilat <sup>6</sup>, Stewart A. Factor <sup>7</sup>, Nir Giladi<sup>8,12</sup>, Simon J. G. Lewis<sup>9</sup>,  
Caroline Moreau<sup>10</sup>, Bastiaan R. Bloem<sup>1</sup>, Alice Nieuwboer<sup>6</sup> & Jorik Nonnekes <sup>2,11</sup> 

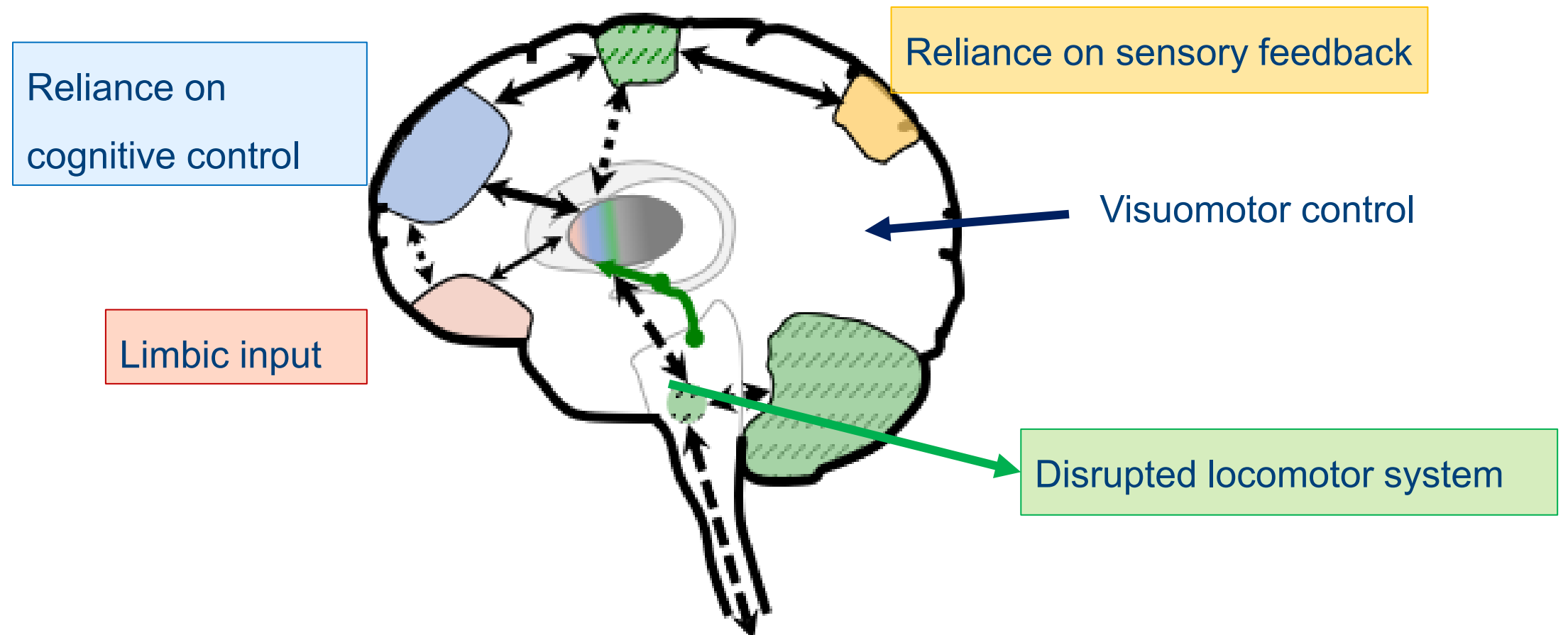
Disrupted compensatory recruitment → Rehabilitation

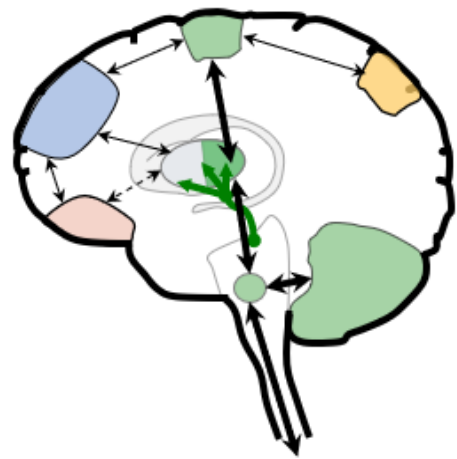
# Compensatory recruitment related to FOG

Normal automatic gait

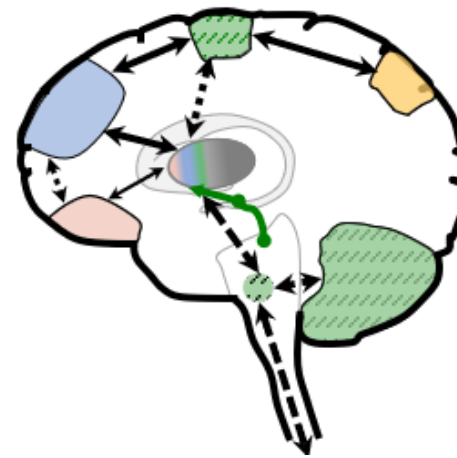


Freezing of gait in PD

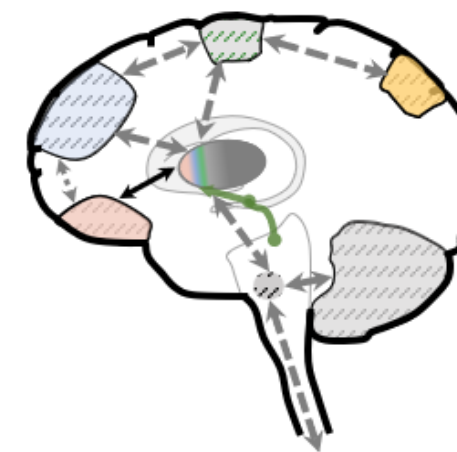




No or rare FOG → relatively intact



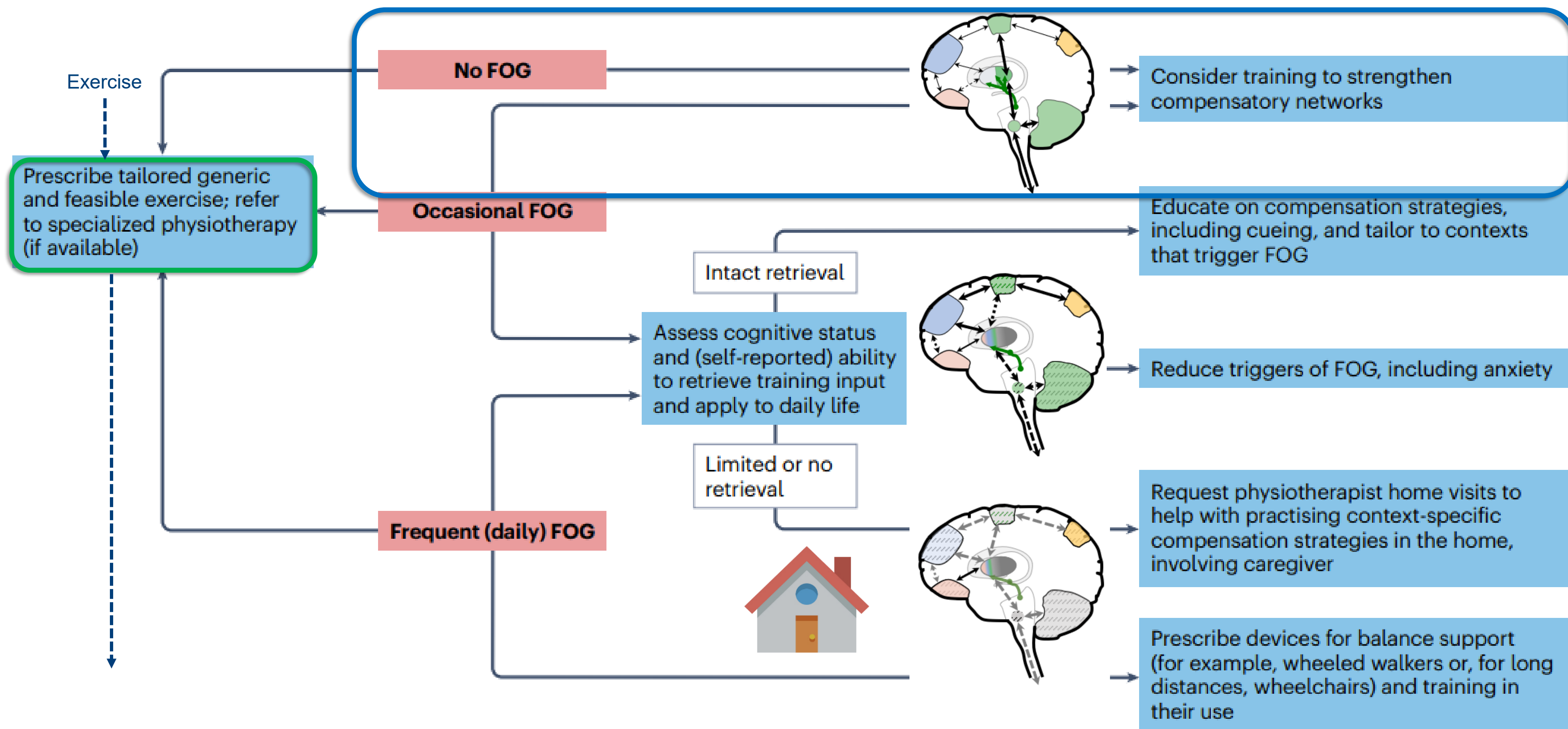
Regular FOG → insufficient or maladaptive



Frequent FOG → depleted

Optimizing compensation

Differentiated rehabilitation

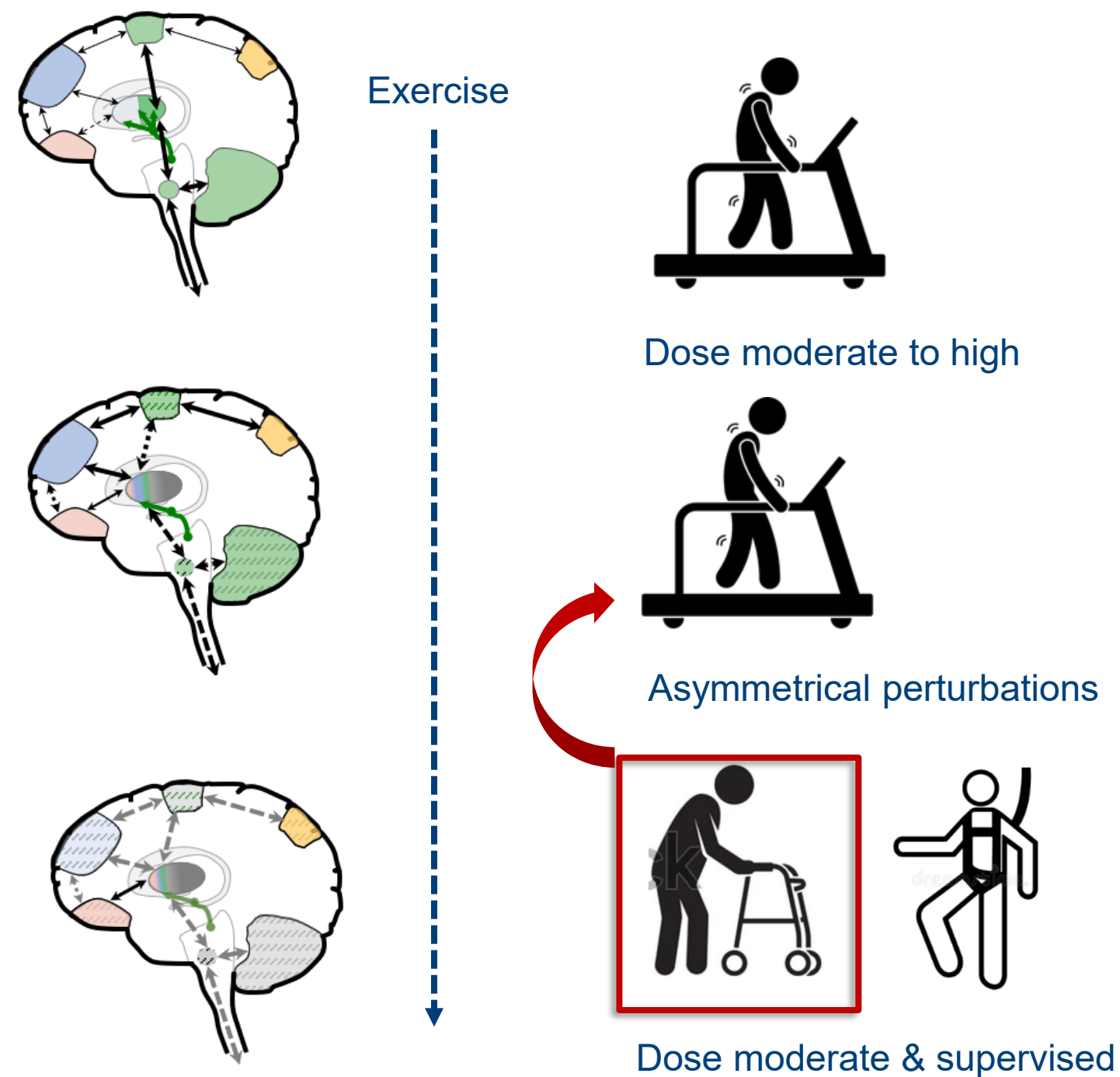


# Evidence for training effects

| Facilitation of compensatory networks |                                                                                                        |                                                                  |                           |
|---------------------------------------|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|---------------------------|
| Physical training and fall prevention | Exercise                                                                                               | Improvement<br>Insufficient data <sup>c</sup>                    | Level A1 <sup>24</sup>    |
|                                       | Physiotherapy (for example, gait, balance and turning training)                                        | Inconsistent data <sup>d</sup><br>Insufficient data <sup>c</sup> | Level A1 <sup>24,25</sup> |
|                                       | Occupational therapy (for example, home adjustment, help with daily planning)                          | Improvement<br>Insufficient data <sup>c</sup>                    | Level D                   |
|                                       | Use of walking aids (for example, wheeled walker, Nordic walking poles, wheelchair for long distances) | Improvement<br>Insufficient data <sup>c</sup>                    | Level D                   |

Insufficient data = lack of studies with FOG as primary outcome

# Gait training



Overground gait velocity↑

Pre-post RsMRI → altered corticocerebellar connectivity

Pre-post TMS → normalized corticomotor inhibitory processing

Adaptive gait ↑

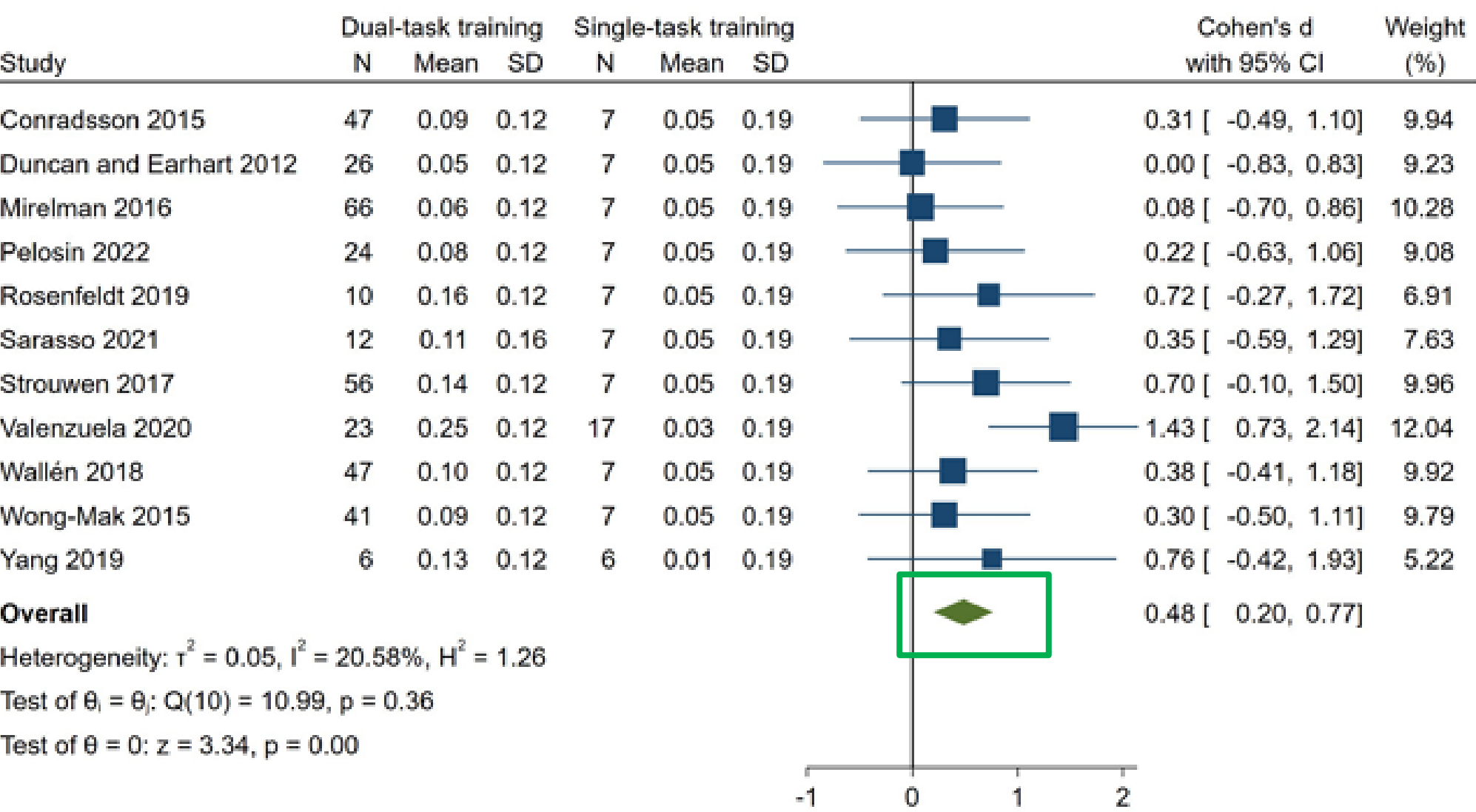
FRs & NFRs benefitted equally

FRs → self-reported FOG & falls↑ pre-post

Effects of gait training largely unknown.

# Dual task training → compensatory capacity

Dual task training vs single training (11 RCTs, N=358)

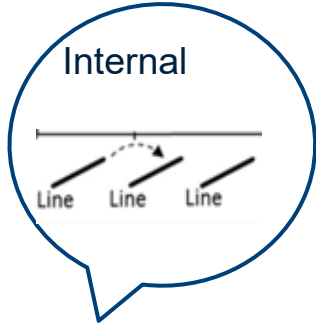
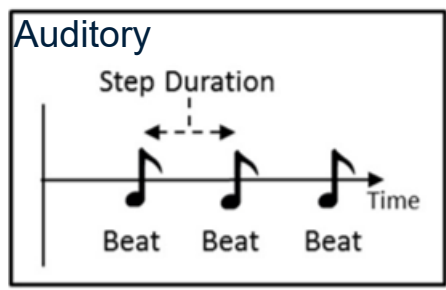
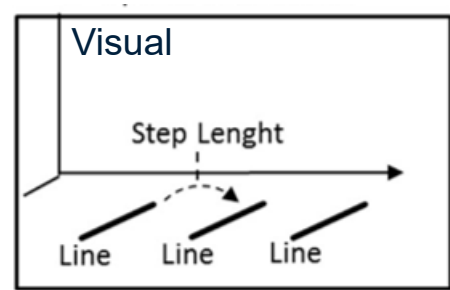


Moderate  $\Delta \uparrow$  dual task gait speed

DT>ST stronger within-NW connect. in sensorimotor, frontal & cerebellar

- Associated with  $\Delta$  DT $\uparrow$

# Cued gait training → compensatory capacity



HY I = 20

HY II = 30

HY III = 30

↑Δ  
Group effect NS

↑Δ  
FRs=NFRs

↑Δ



Cue specific effect oxygenated hemoglobin levels

Visual → Visual Cx↑ and PMCx

Auditory → Visual Cx↑

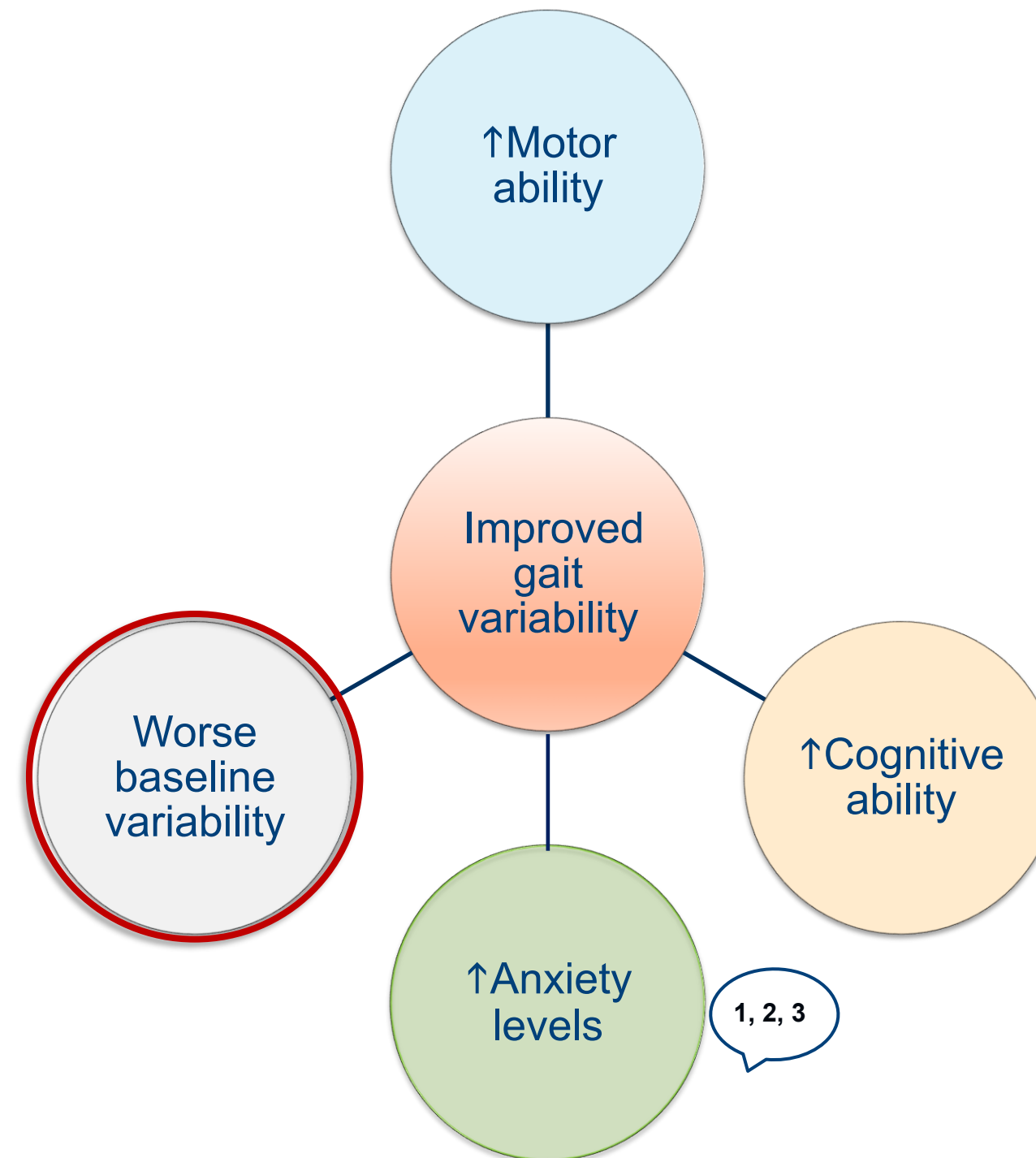
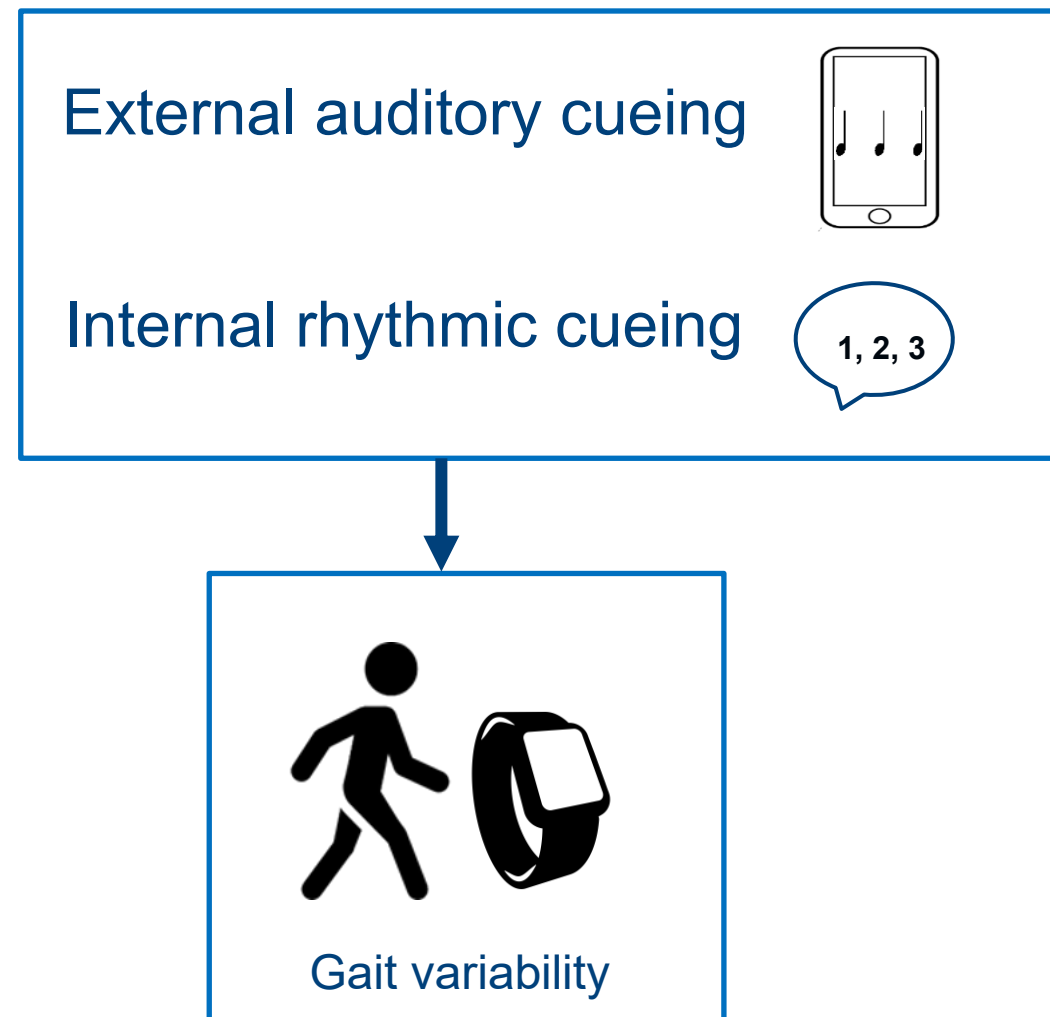
Internal → PFCx↑

30 self-reported freezers

# Cued gait training → responsiveness

N= 277 HY II-III

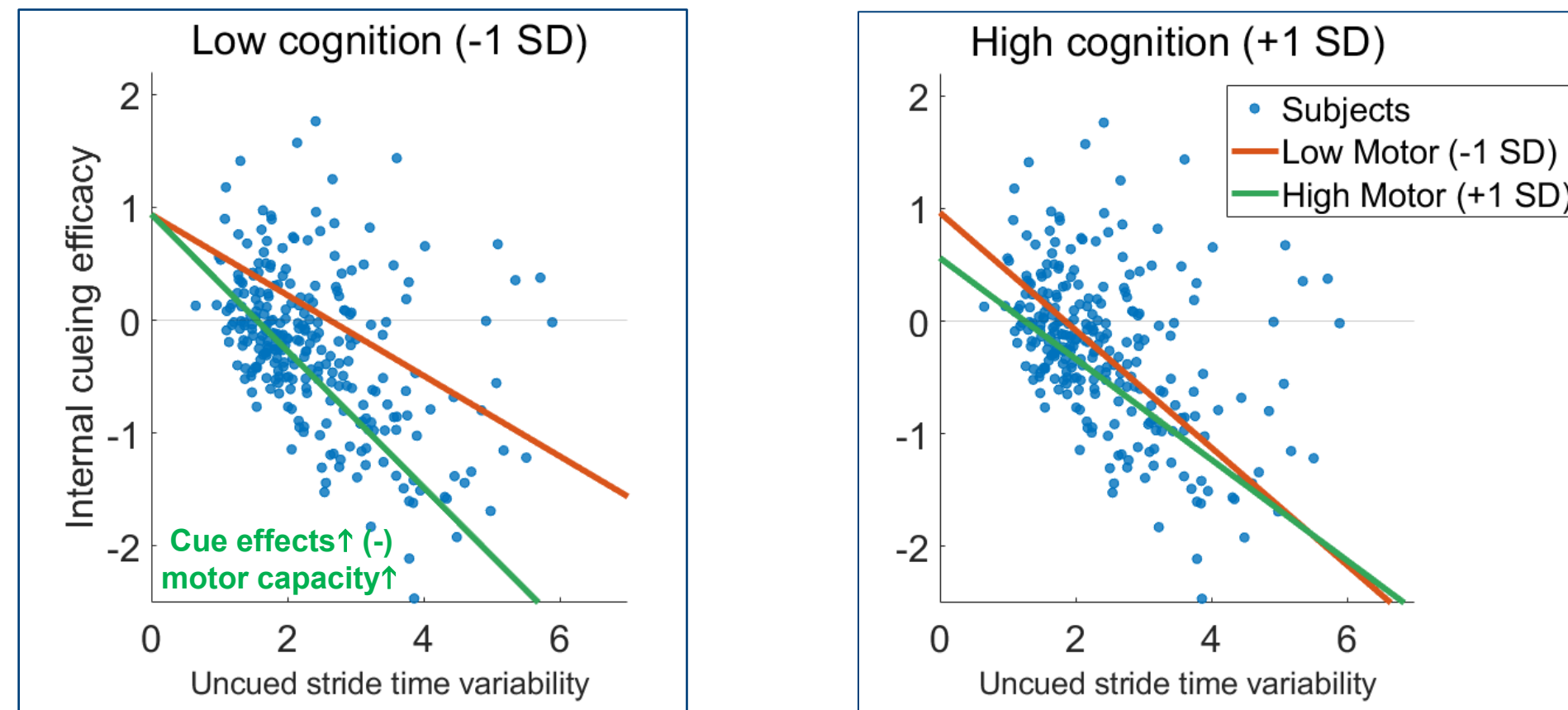
39% freezers



1, 2, 3

For internal cueing → motor-cognitive interaction for cue responsiveness

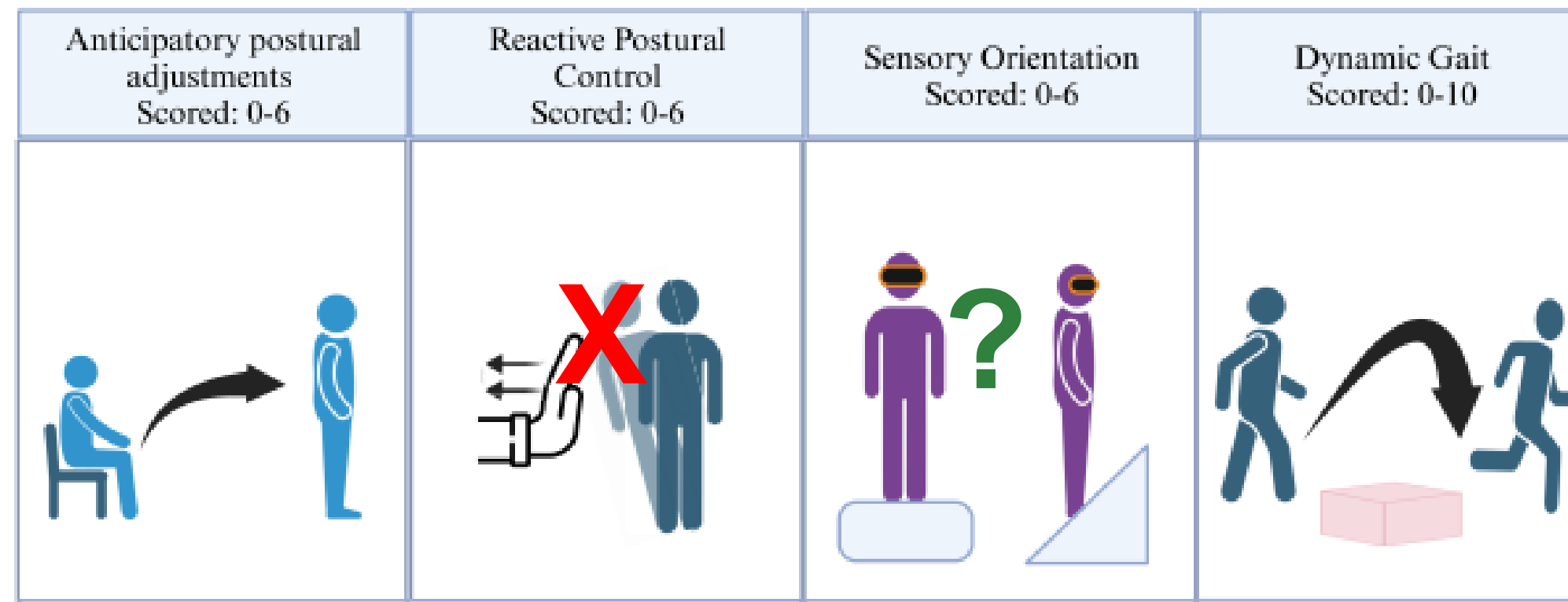
In low cognition group only: those with higher motor capacity were most cue responsive



Cognition-dependent allocation of compensatory resources

# Balance training – specificity?

High dose multimodal balance training is effective in those with initial low balance scores → exergames and VR↑

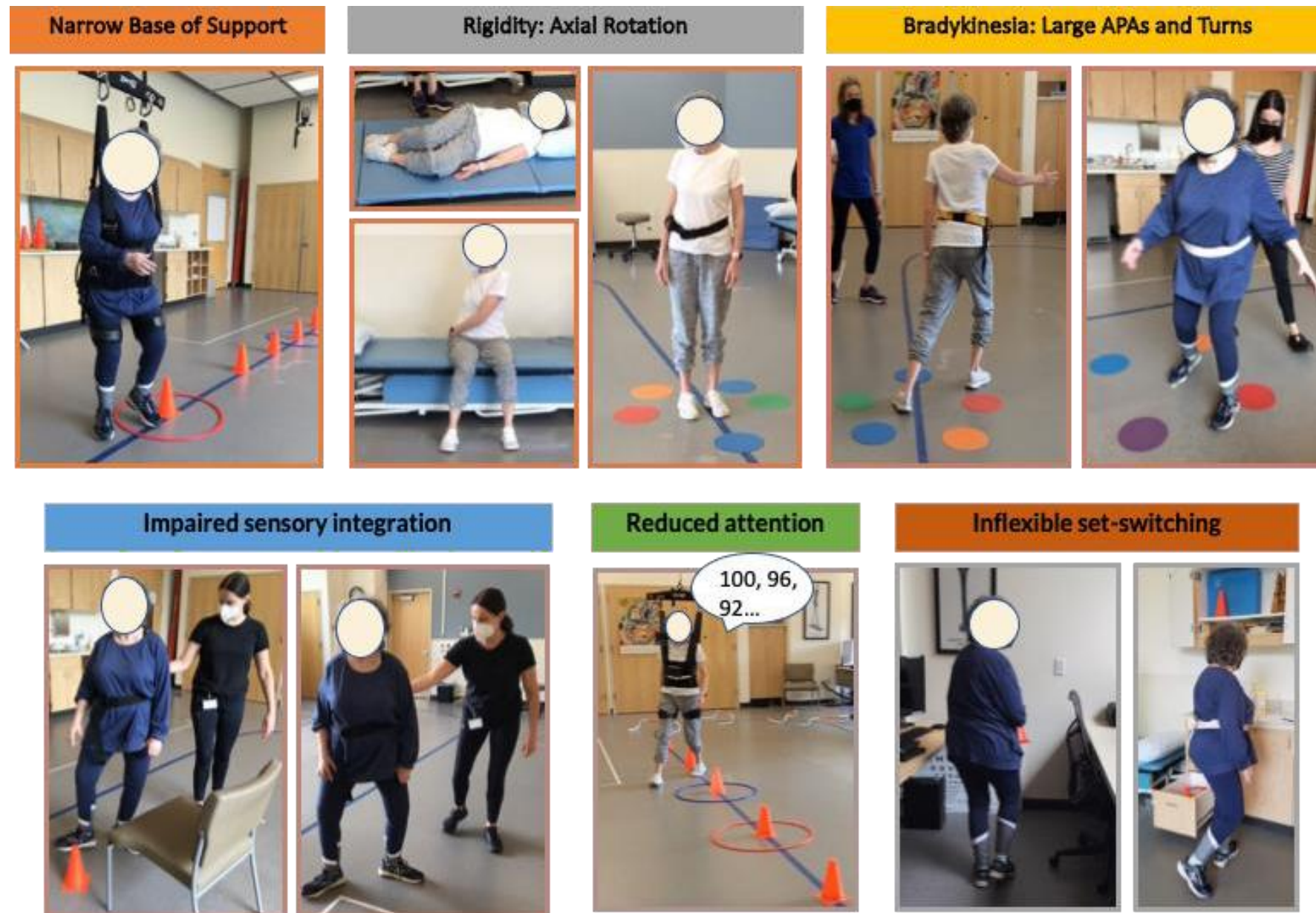
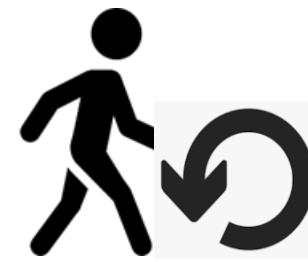


←Mini-Best scores decline faster in FRs > NFRs

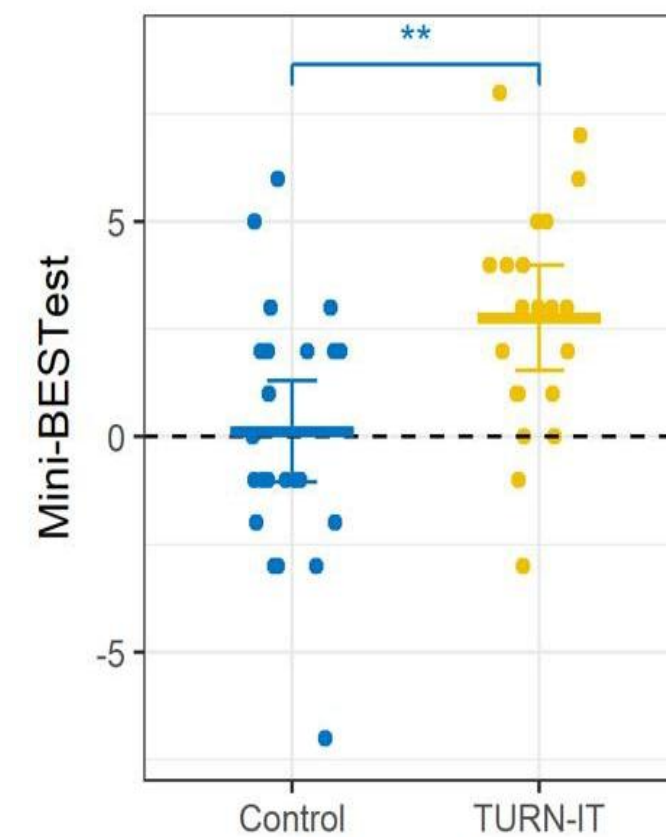
Unique deficits of APA and step initiation in FRs → ML amplitude & timing↓

Dynamic balance decline (12 m.) predicts conversion to FOG

# Turning training



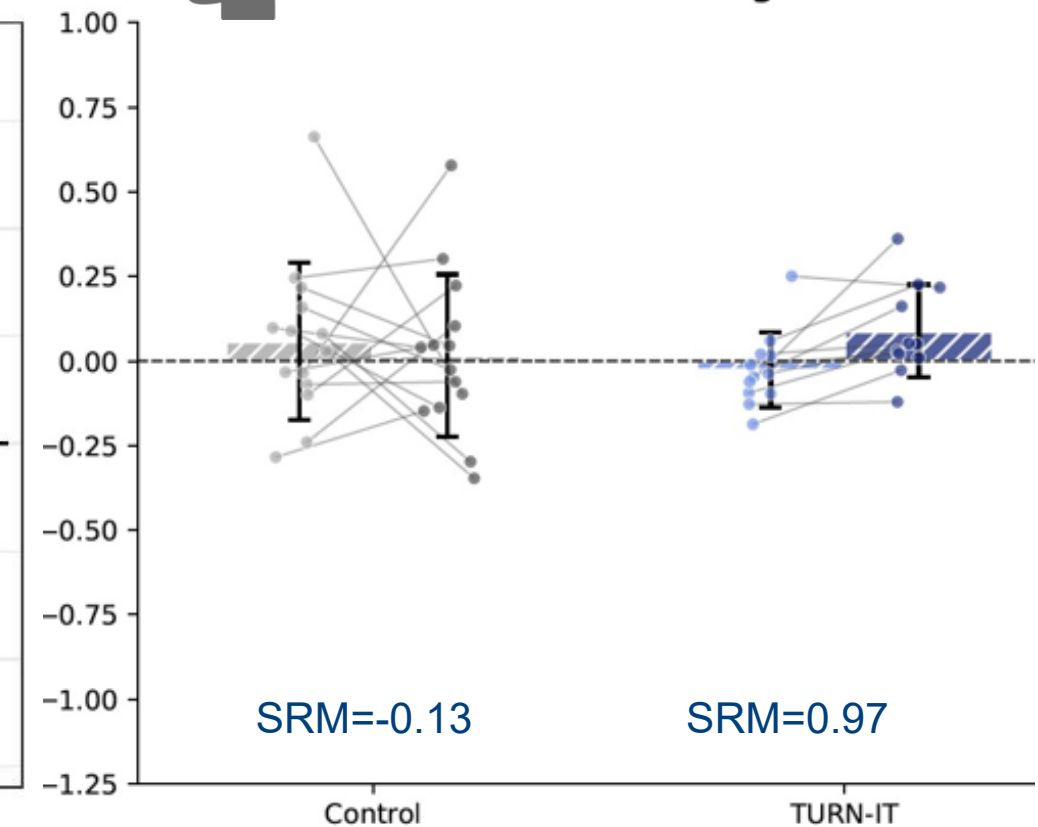
$\Delta$  scores in all subjects



In freezers only

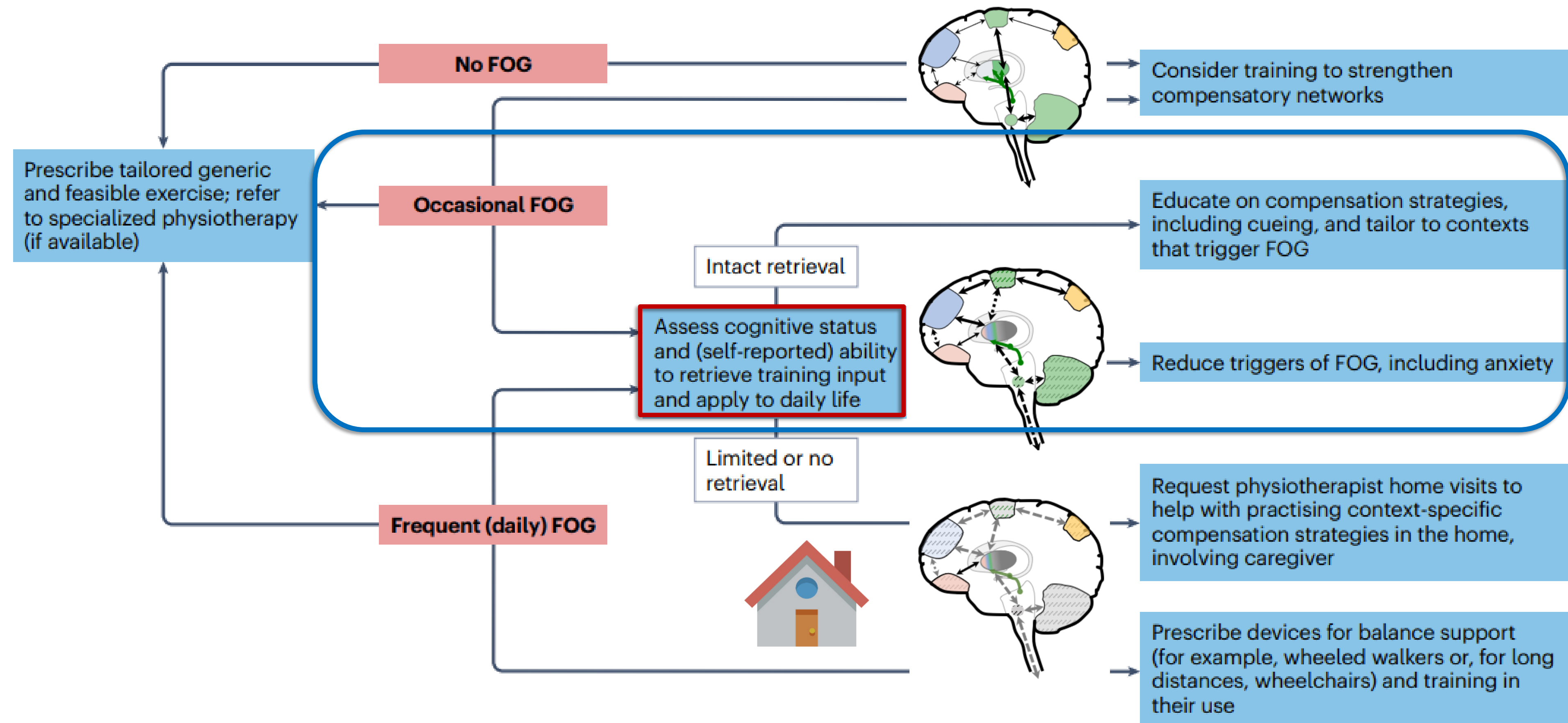
PFC HbO<sub>2</sub> ( $\mu$ M)

Dual Task Walking



RCT 6 weeks of supervised multicomponent training

N=55 H&Y II-III



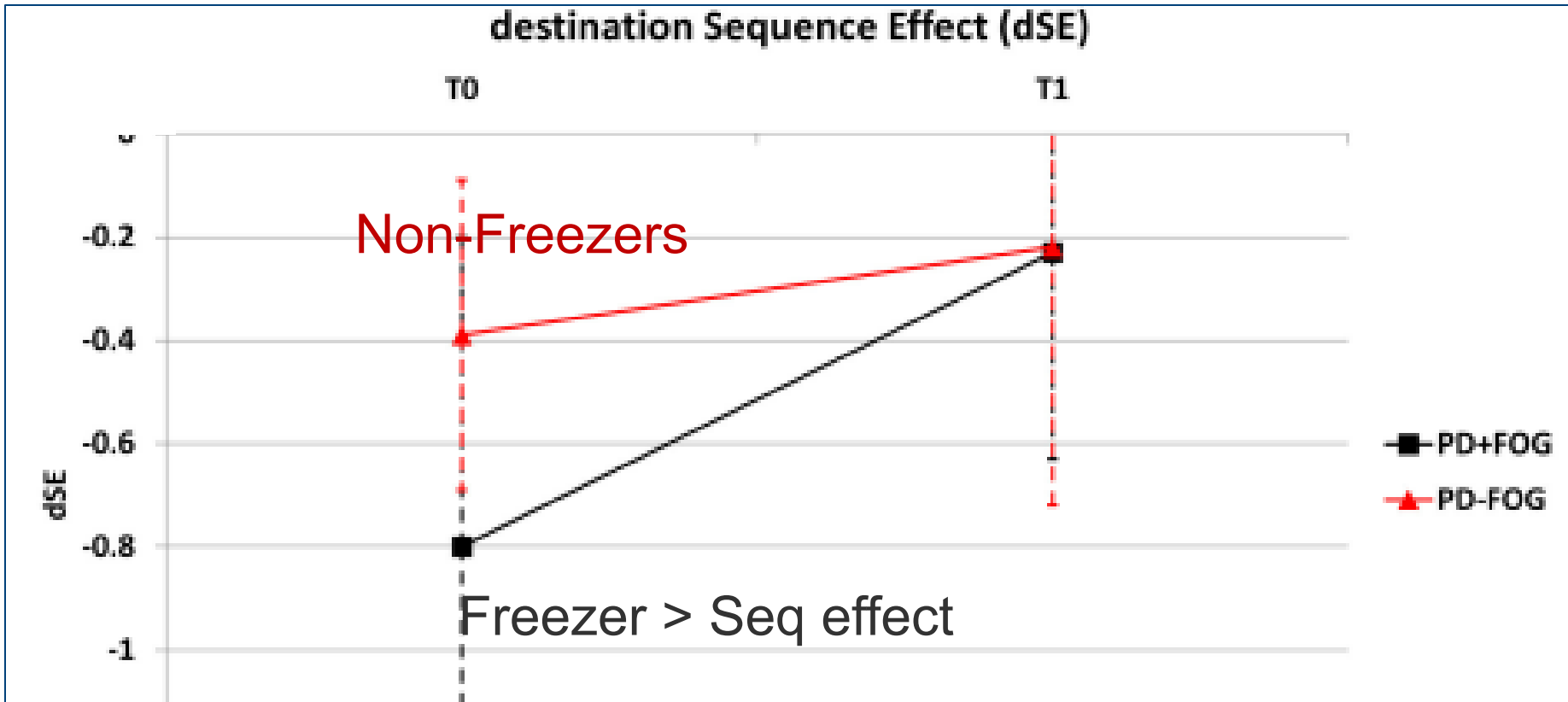
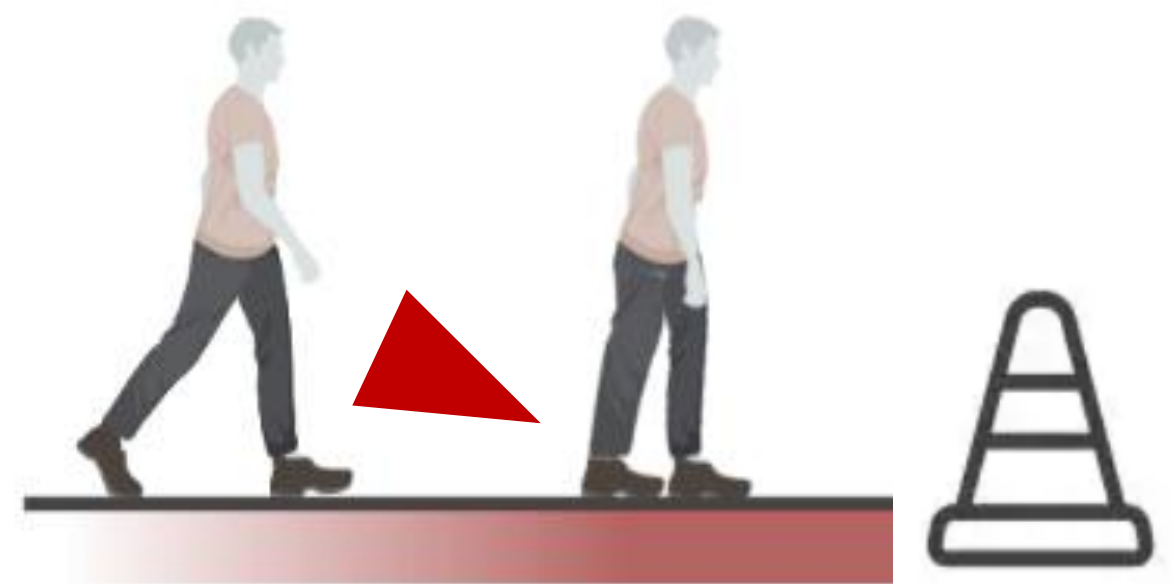
Facilitation of compensatory networks

|                                                  |                               |                                                                  |                              |
|--------------------------------------------------|-------------------------------|------------------------------------------------------------------|------------------------------|
| Targeting non-motor symptoms associated with FOG | Dual-task gait training       | Improvement<br>Insufficient data <sup>c</sup>                    | Level A2 <sup>c142,176</sup> |
|                                                  | Cognitive behavioural therapy | No improvement<br>Insufficient data <sup>c</sup>                 | Level B <sup>178</sup>       |
|                                                  | Antidepressants (SSRIs)       | Insufficient data <sup>c</sup><br>Inconsistent data <sup>d</sup> | Level C <sup>c182,183</sup>  |

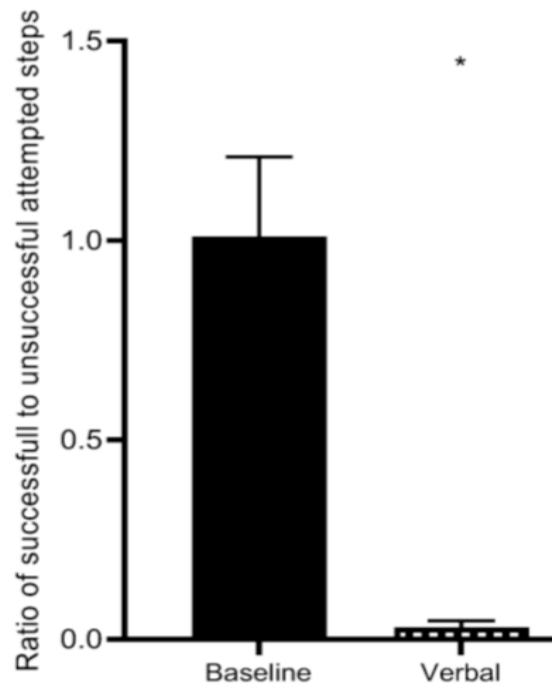


DT-training studies → similar or better DT-outcomes in FRs>NFRs  
DT-training studies → falls↓ and executive function↑ in FRs=NFRs  
FOG did not improve

Training to reduce the sequence effect



Training volitional weight-shifting → to improve APAs and reduce anxiety



# Unsuccessful gait initiation attempts ↓

# Compensatory strategies

## Available strategies



### External cues

[read more](#)



### Internal cues

[read more](#)



### Action observation and motor imagery

[read more](#)



### Changing the balance requirements

[read more](#)



### Altering the mental state

[read more](#)



### Adopting a new gait

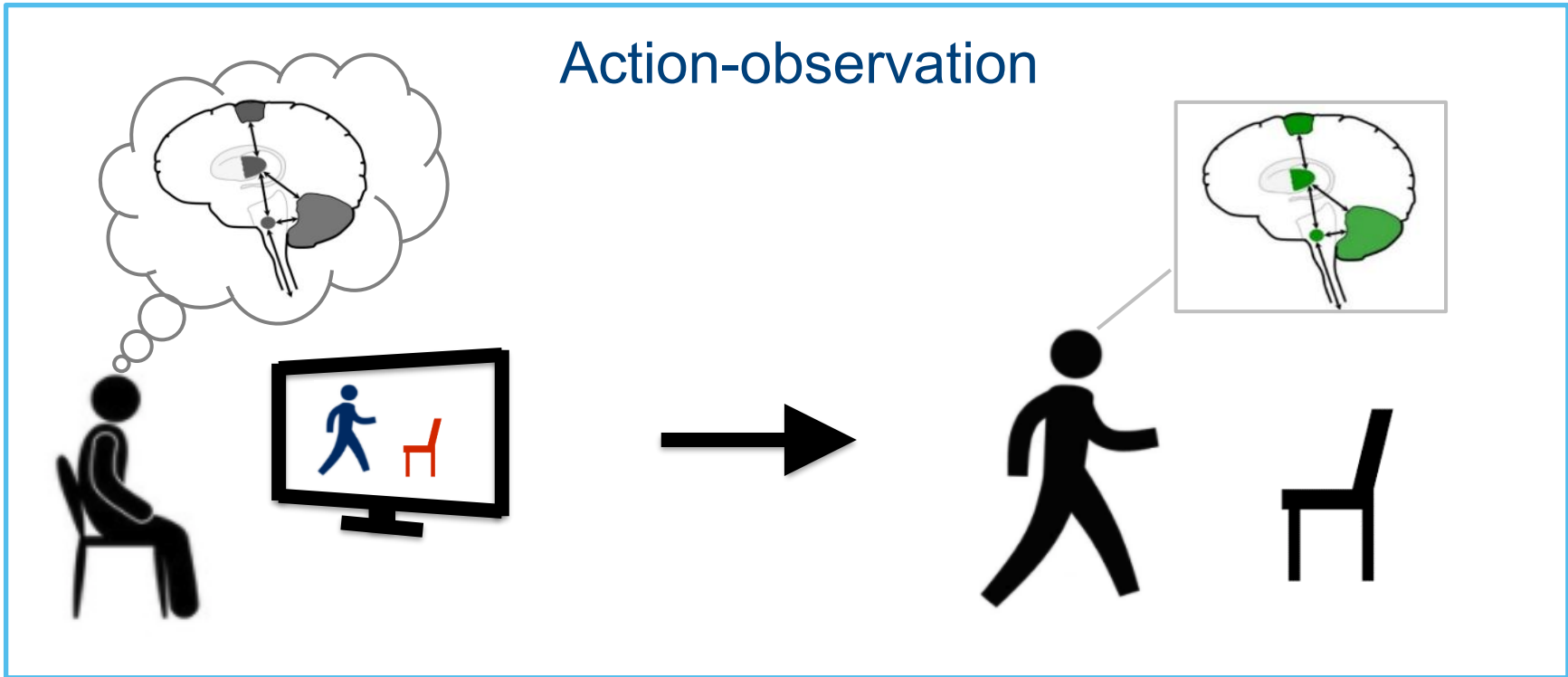
[read more](#)

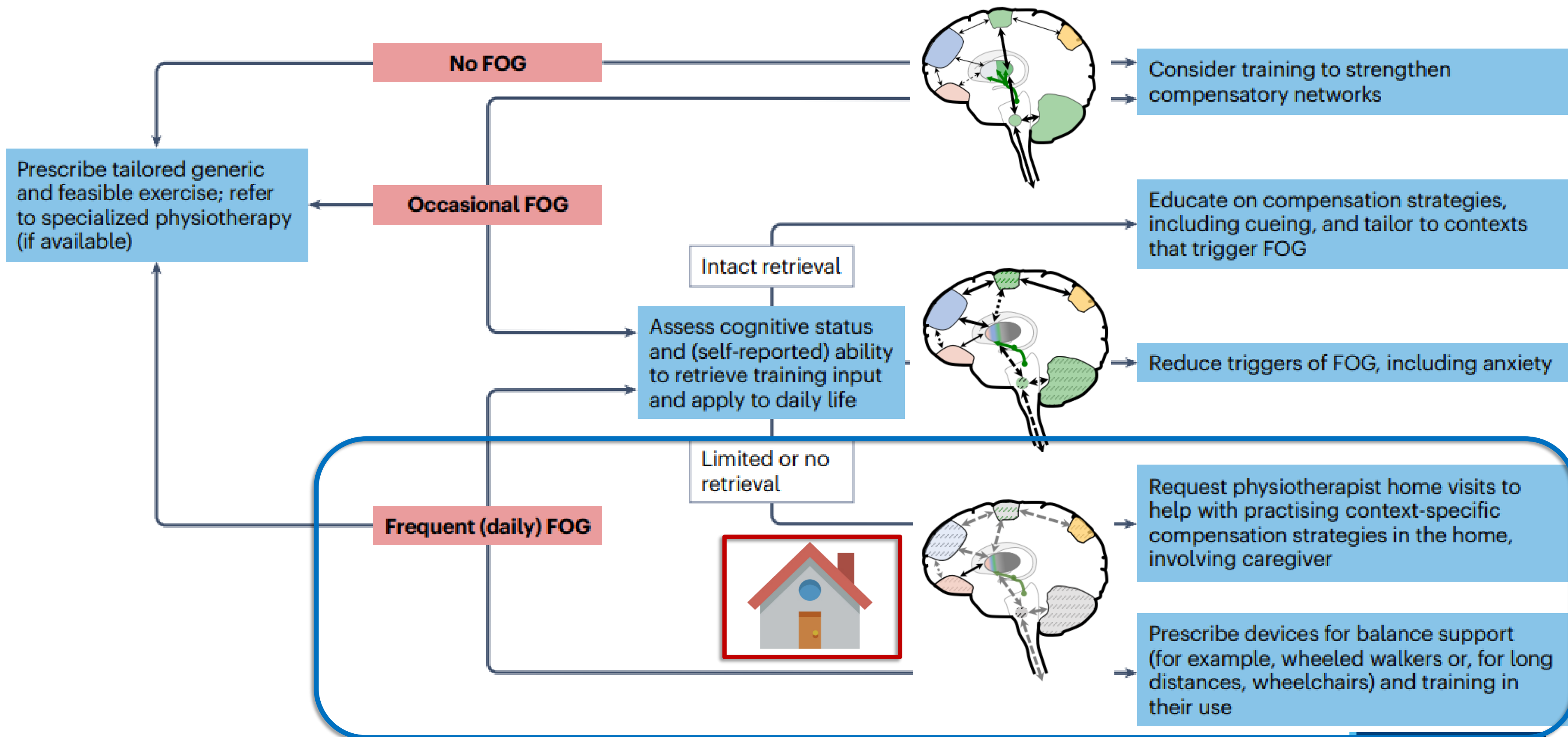


<https://www.radboudumc.nl/en/patientenzorg/aandoening-en/ziekte-van-parkinson/walking-with-parkinson>

Facilitation of compensatory networks

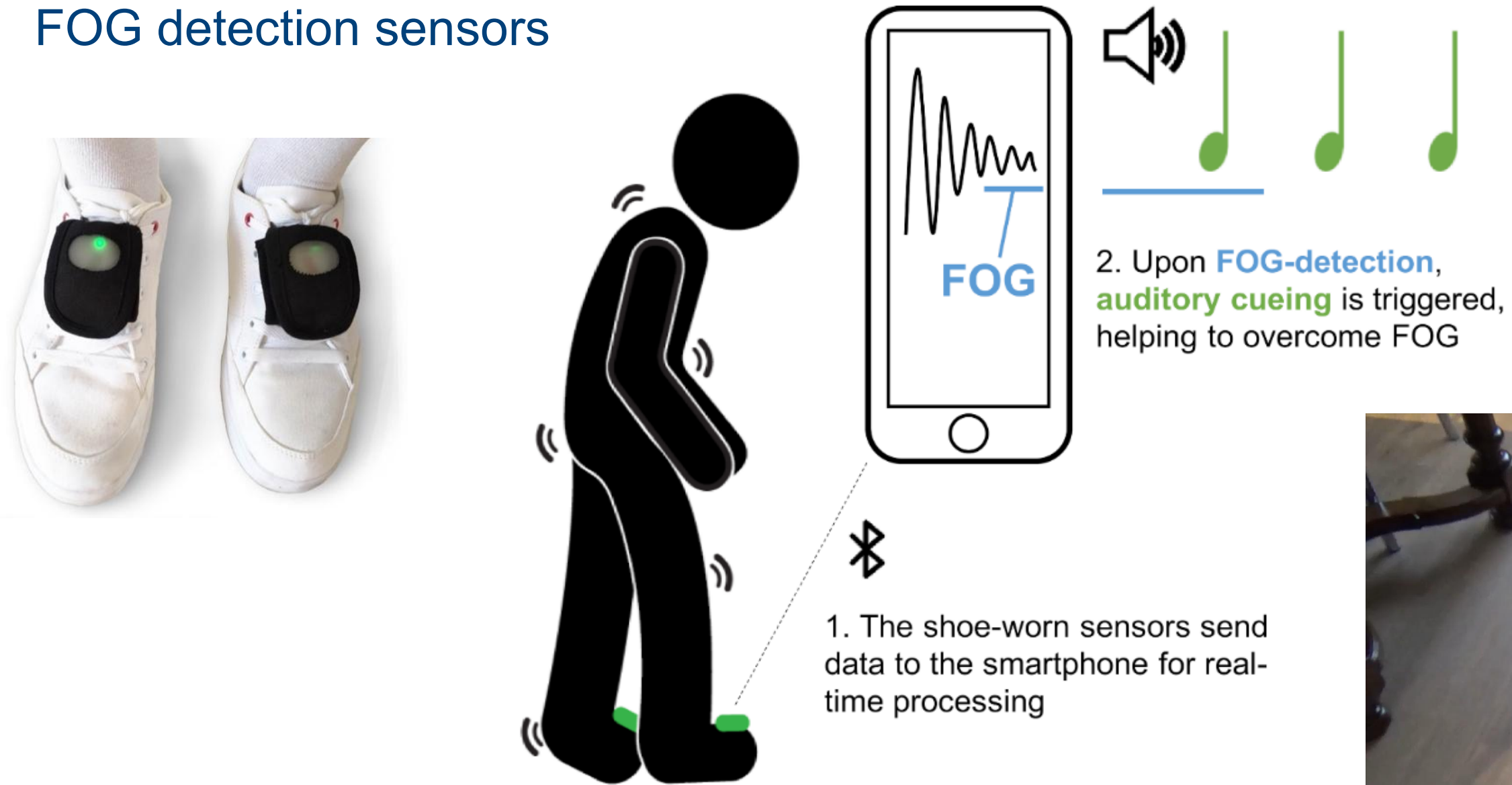
|                                  |                                                                                                       |                                                     |                                |
|----------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------|--------------------------------|
| Applying compensation strategies | Expert education on complex strategies (e.g., negotiating a doorway)                                  | Improvement<br>Insufficient data <sup>c</sup>       | Level D                        |
|                                  | Compensation strategies (for example, cueing, weight shifting, action observation)                    | Improvement<br>Insufficient data <sup>c</sup>       | Level A1 <sup>157</sup>        |
|                                  | Device-aided cueing strategies (for example, laser shoes, vibrating socks, augmented reality glasses) | Insufficient data<br>Inconsistent data <sup>d</sup> | Level C <sup>163,164,168</sup> |
|                                  | Other device-aided interventions (for example, soft robotic apparel)                                  | Insufficient data <sup>c</sup>                      | Level C <sup>166</sup>         |



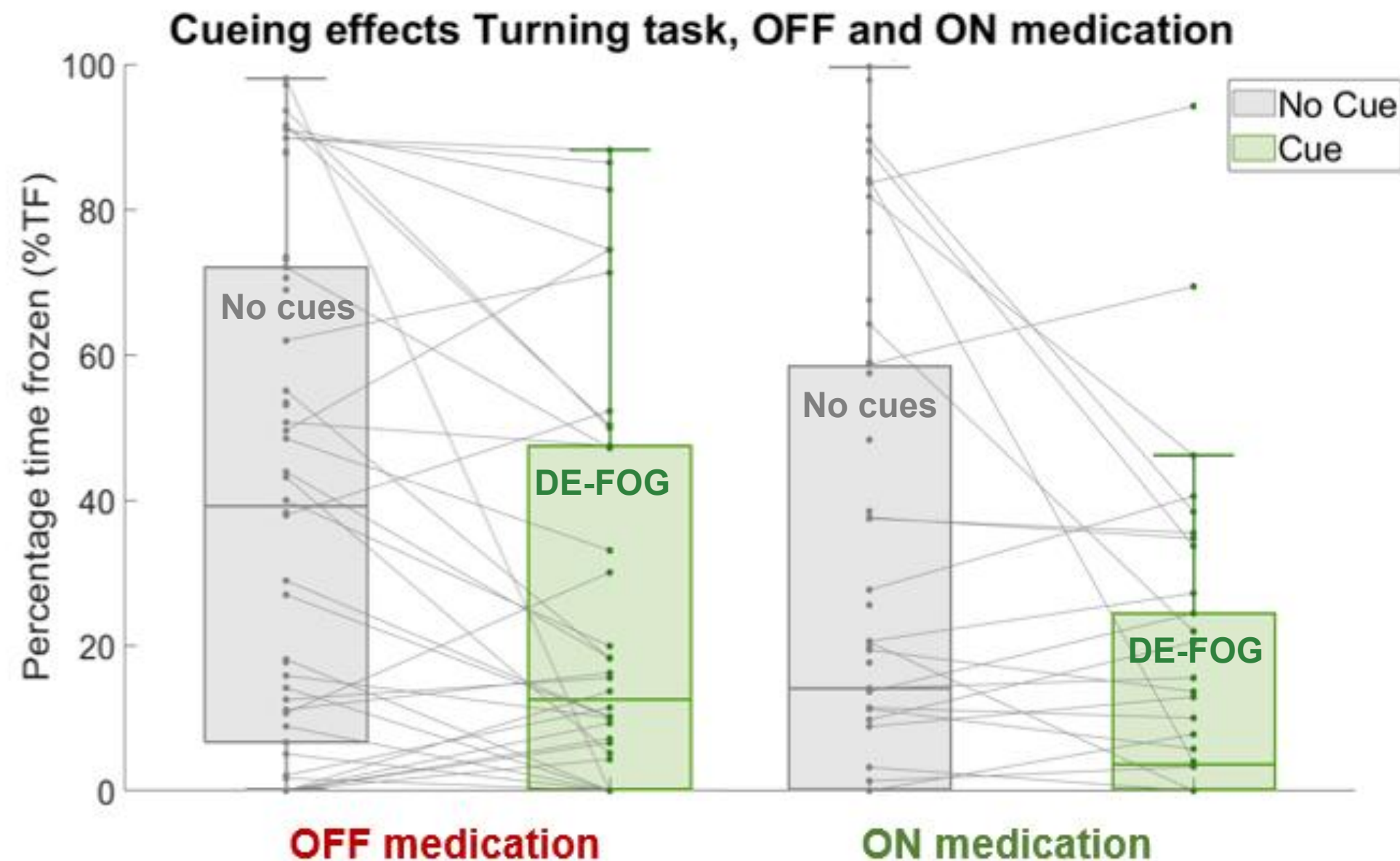


# Intelligent auditory cueing

## FOG detection sensors



# Effects on % time frozen – standardized home protocol



## FOG-provoking home protocol in ON+OFF

- Cueing effects  $d = 0.52$
- Combined with Meds  $d = 0.67$

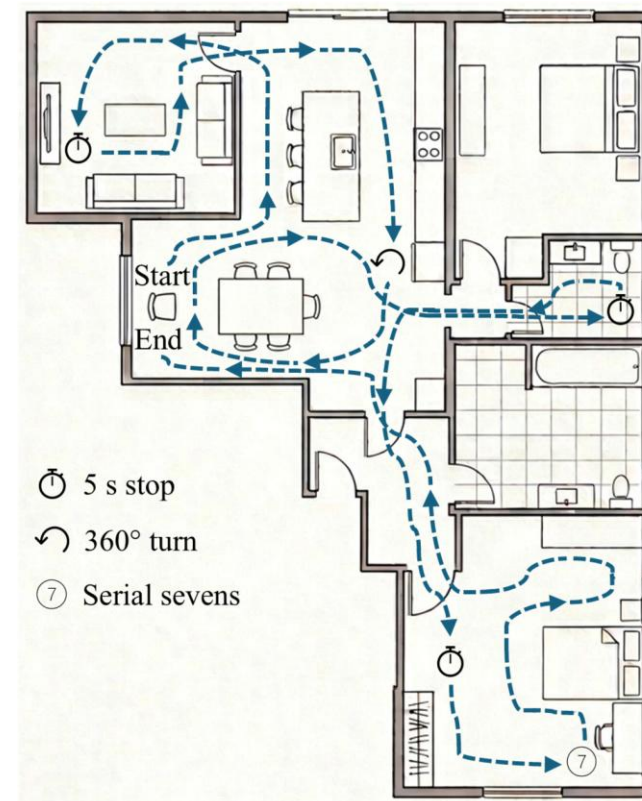
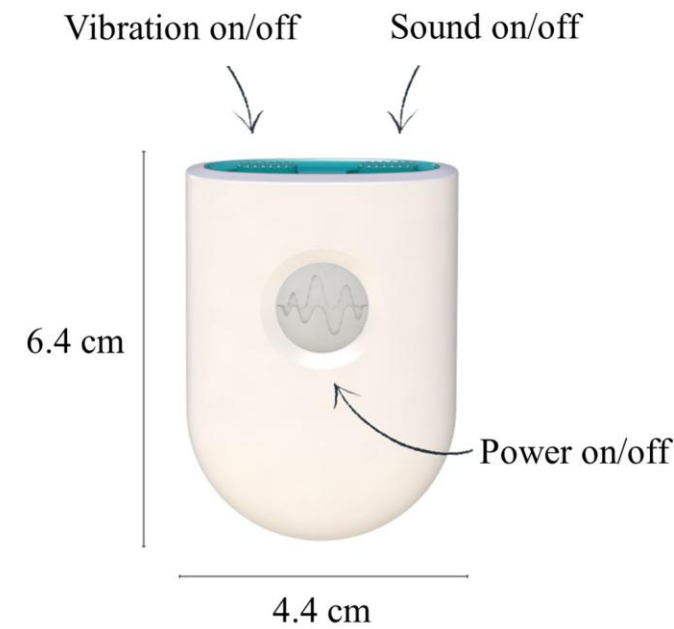
## Detection problems

Many false positives

Just 50% of episodes correctly detected

Delay was on average 1.76 s.

# Intelligent vibration cueing for home use

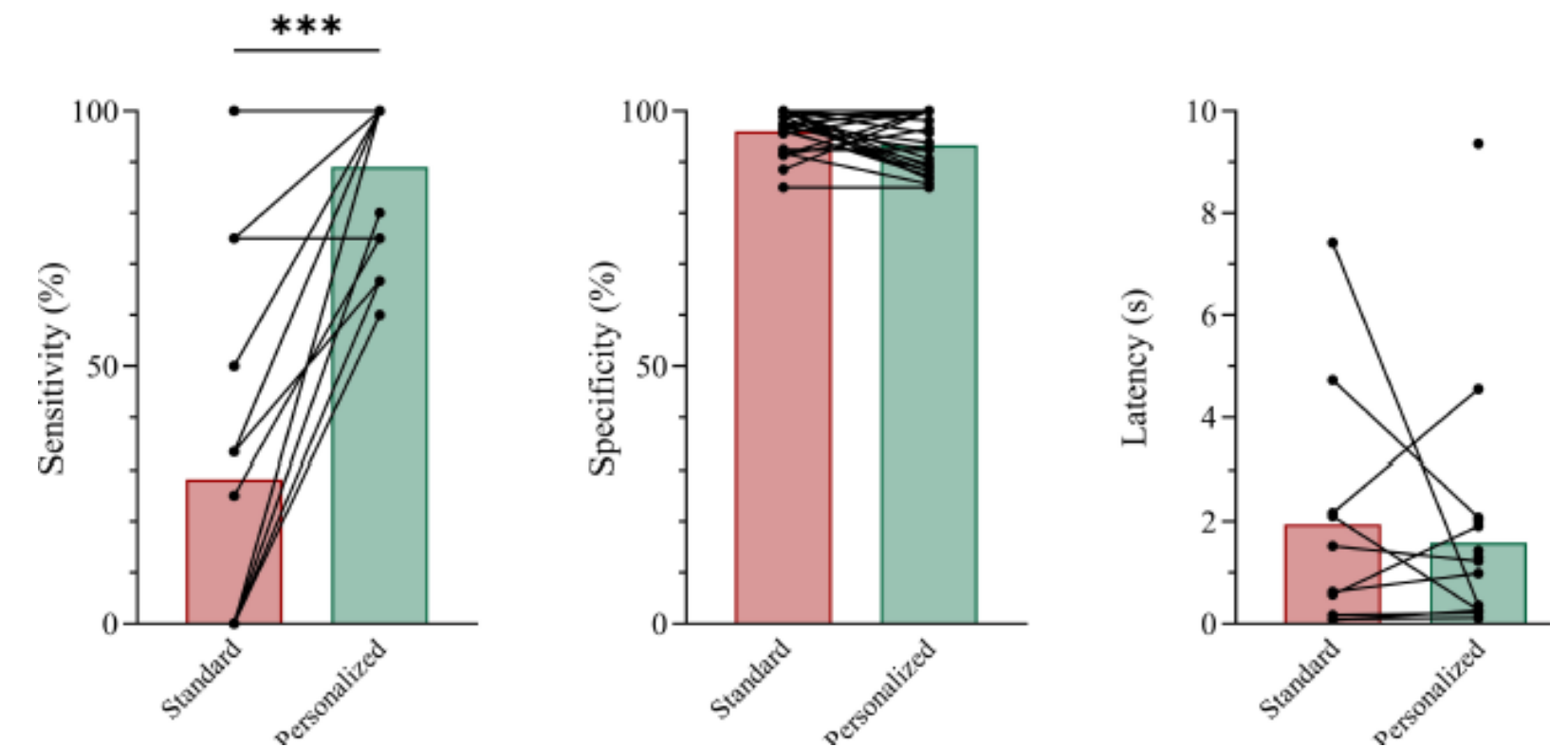


Cue2walk device

Tested in 24 people with FOG

Semi-standardized home setting

Performance on the test set after model training



Personalized (manual threshold settings) have potential

## Future directions



**Determinants of compensatory potential→ adaptive responses?**



**Efficacy of training strategies based on compensatory potential?**



**Closed-loop cueing for FOG plus explicit FOG prevention training?**

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