Using tendinous vibration to explore posture, spatial orientation and gait in post-stroke population

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INVITED SEMINAR

UJM SAINT-ETIENNE, LABORATOIRE INTERUNIVERSITAIRE DE BIOLOGIE DE LA MOTRICITÉ

October 15th 2020

Noémie Duclos

2006 - 2010

B.Sc. **Science and Technique of Physical and Sports Activities**
Adapted Physical Activities and Health

Physical Therapy State Diploma

2010 - 2014

M.Sc. **Human Movement Sciences**

Ph.D. **Human Movement Sciences**

2015 - 2018

Postdoctoral fellowship **Rehabilitation Sciences**

2018 …

Associate professor

Current affiliation:

Univ. Bordeaux, College of Health Sciences

Institut universitaire des sciences de la réadaptation

Univ. Bordeaux, INSERM, BPH, U1219,

"Handicap, Activity, Cognition & Health" Team

Activities and participation

Non-pharmacological interventions and new technology

Rehabilitation

Psychology

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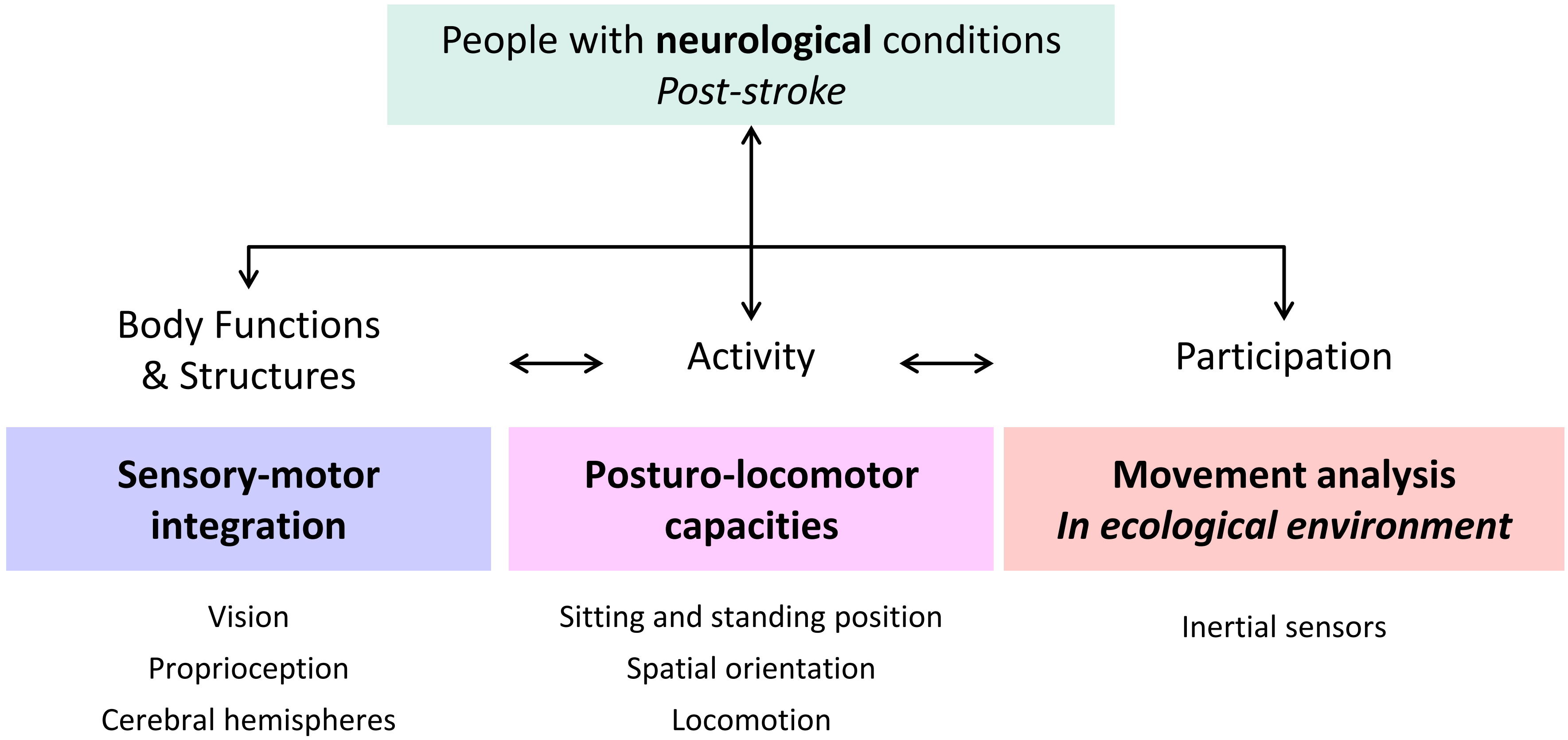
Fields of research

International Classification of Functioning, Disability and Health



Postural control in post-stroke population

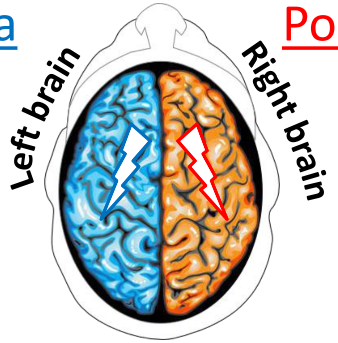
Stroke → Brain damage → Contralesional deficits

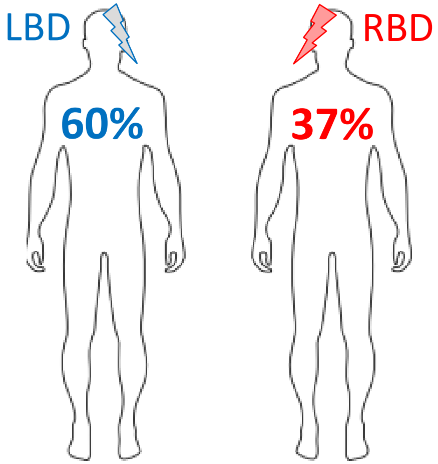
- → *Sensory* deficits
- → *Motor* deficits

Side of lesion → Typical clinical picture:

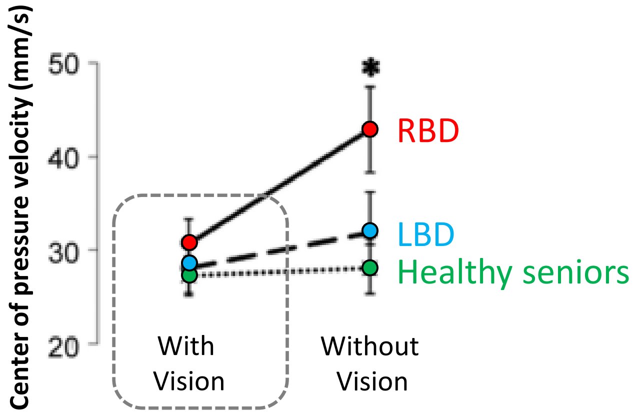
Aphasia

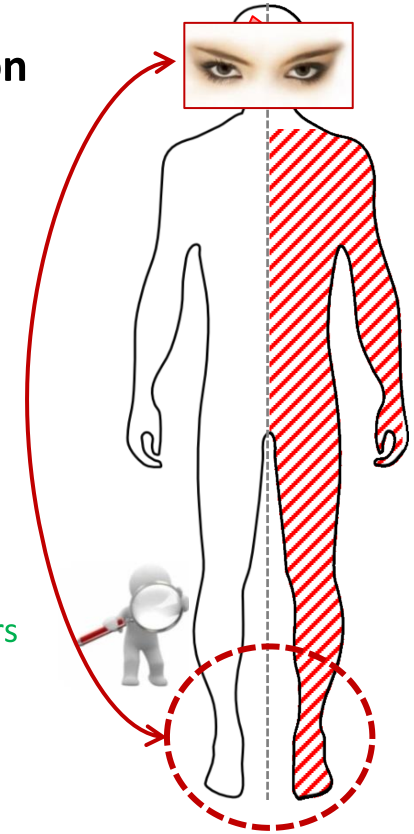
Postural instability





Hemispheric specificity
for visual proprioceptive information integration
& postural control?



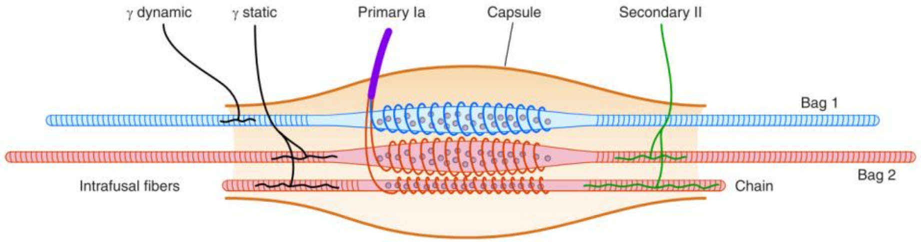


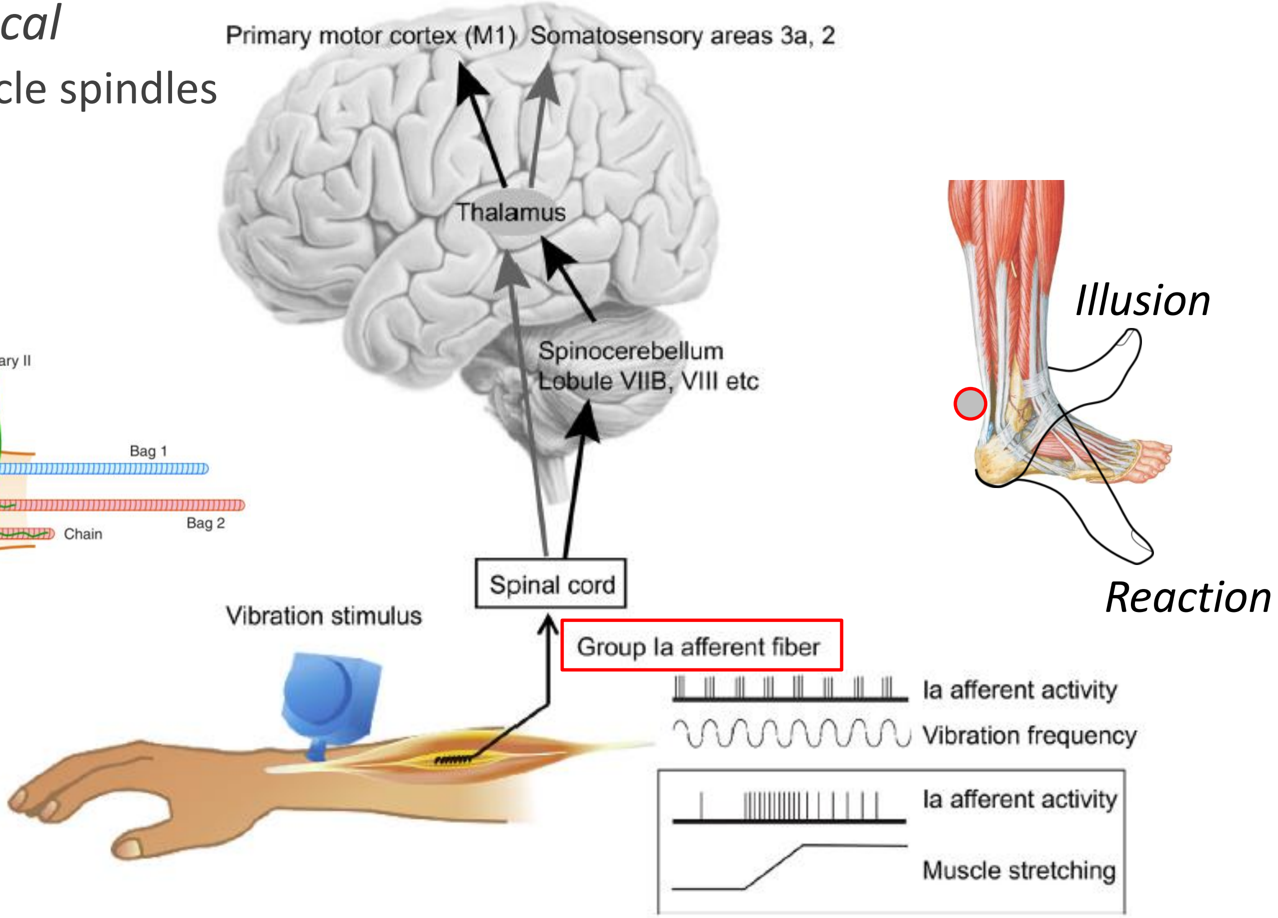
Bohannon RW, Smith MB, Larkin PA. Relationship between independent sitting balance and side of hemiparesis. *Phys Ther* 1986; 66: 944–5.
Laufer Y, Sivan D, Schwarzmann R, et al. Standing balance and functional recovery of patients with right and left hemiparesis in the early stages of rehabilitation. *Neurorehabil Neural Repair* 2003; 17: 207–13.
Manor B, Hu K, Zhao P, et al. Altered control of postural sway following cerebral infarction: a cross-sectional analysis. *Neurology* 2010; 74: 458–64.

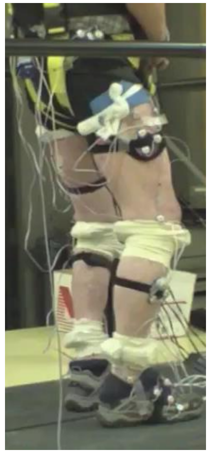
Manipulating proprioceptive information

Vibration: *muscles / focal*

- Activation of the muscle spindles
  - Primary (Ia) afferents







Proske U, Gandevia SC. The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. *Physiol Rev* 2012;92:1651–97.
Naito E, Morita T, Amemiya K. Body representations in the human brain revealed by kinesthetic illusions and their essential contributions to motor control and corporeal awareness. *Neurosci Res* 2016; 104: 16–30.

Vibration and postural control
Methodology

<u>Hypothesis:</u> The different effects of vibration on the paretic and non-paretic limbs would help to define the main cause of ill-adapted postural behavior after stroke

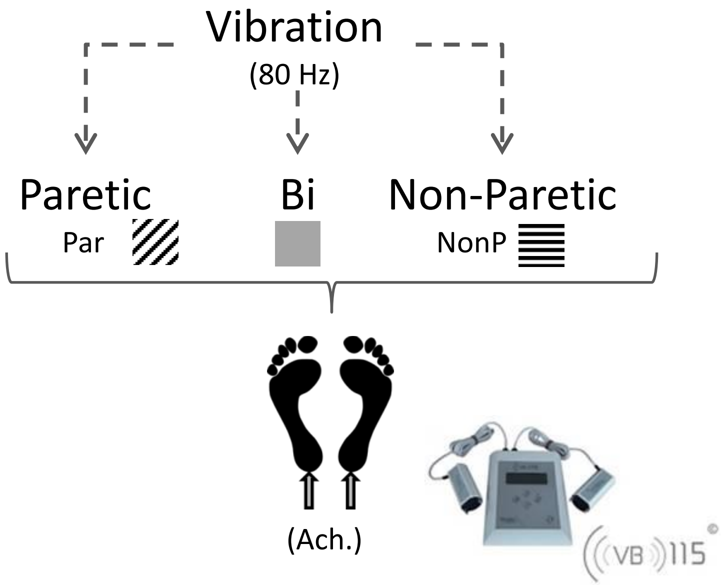
Upright – 48 seconds – without vision

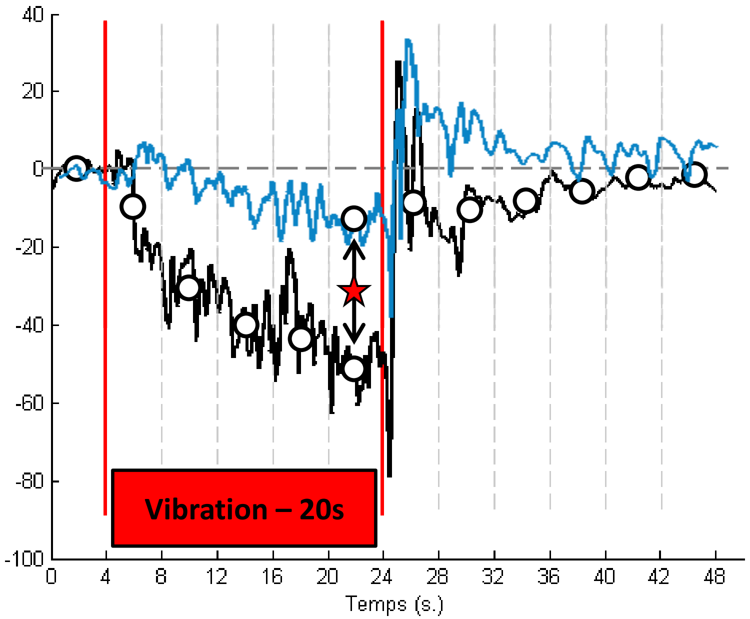
- Force platform → Center of pressure (CoP)
  - Data analysis: periods of 4 s
    - Mean antero-posterior position, and standard deviation
    - Velocity of the displacement

S < G$_2$ > C$_3$ (* 2)

LBD: n = 14 / 66 *(±11)* years
Time since stroke: 10 *(±12)* months
FIM score: 110 *(±12)* /126 pts

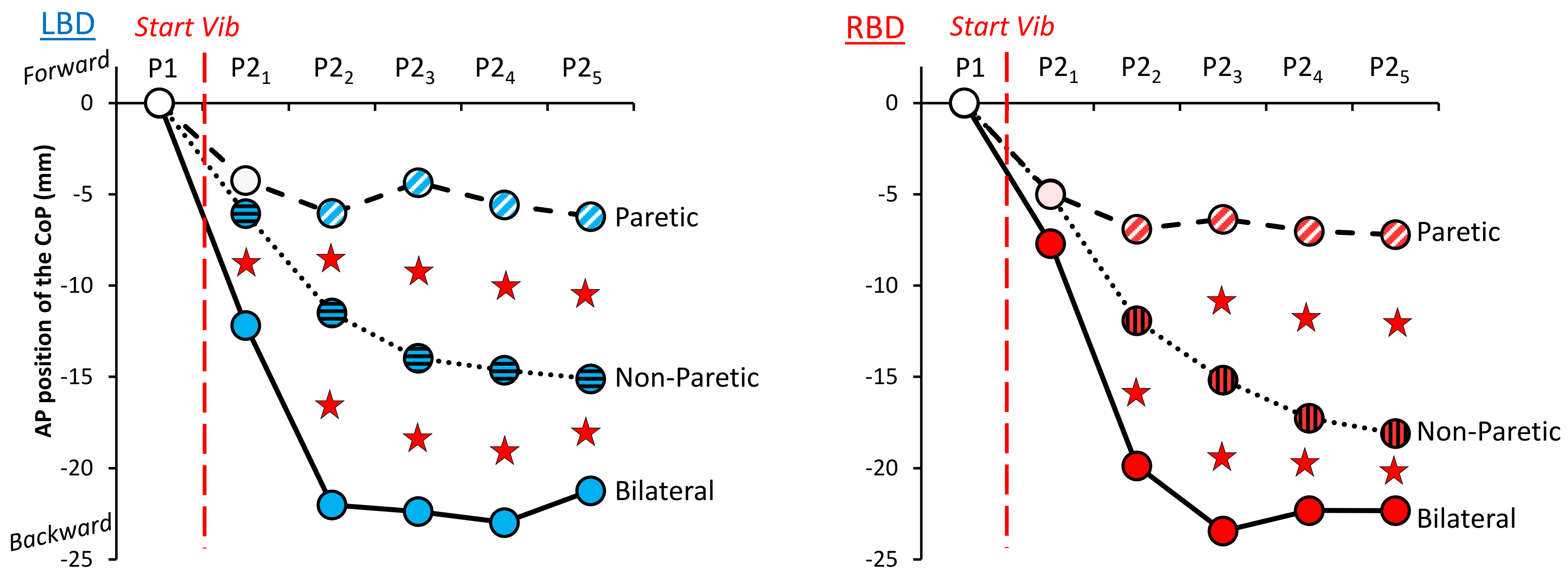
RBD: n = 12 / 69 *(±13)* years
Time since stroke: 10 *(±14)* months
FIM score: 106 *(±11)* /126 pts





Duclos NC, Maynard L, Abbas D, et al. Hemispheric specificity for proprioception: Postural control of standing following right or left hemisphere damage during ankle tendon vibration. *Brain Res* 2015; 1625: 159–170.

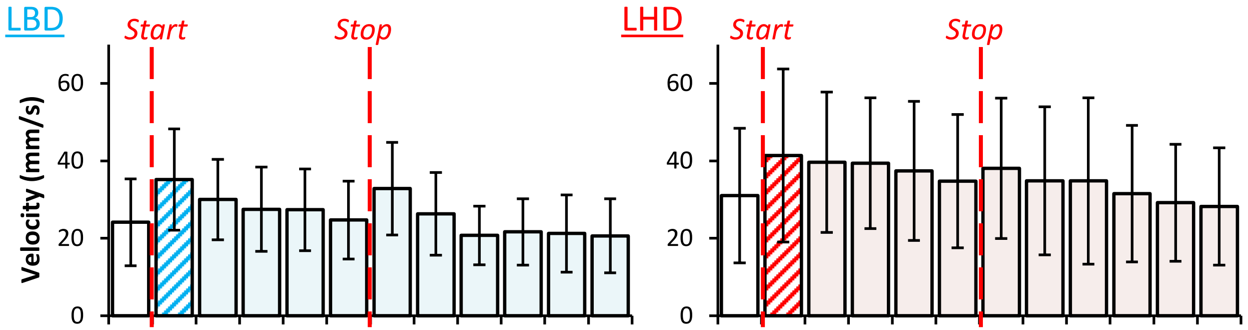
Effects of Achilles vibration:
Backward displacement of the CoP



Backward displacement : Paretic **<** Non-Paretic → **similar** for both LBD & RBD groups

Duclos NC, Maynard L, Abbas D, et al. Hemispheric specificity for proprioception: Postural control of standing following right or left hemisphere damage during ankle tendon vibration. *Brain Res* 2015; 1625: 159–170.

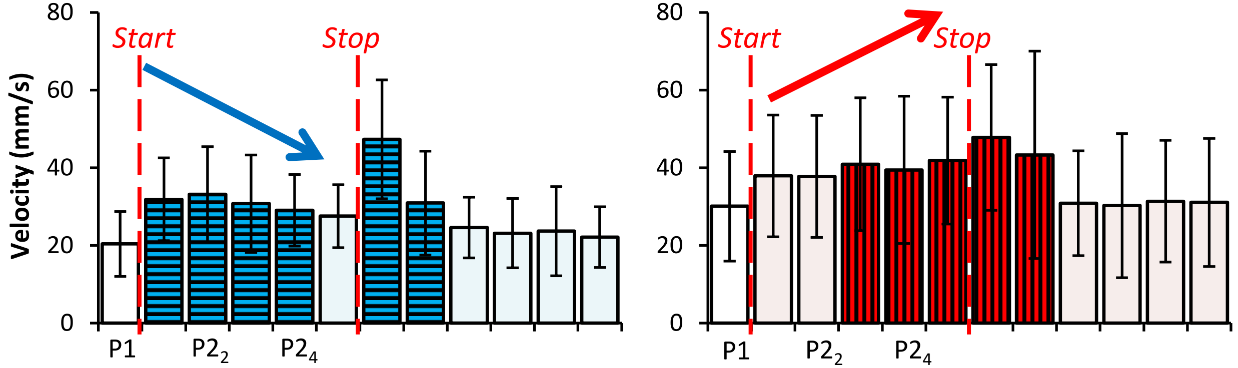
Vibration on the **paretic** limb:



Group effect : RBD > LBD

Similar behavior
for both groups

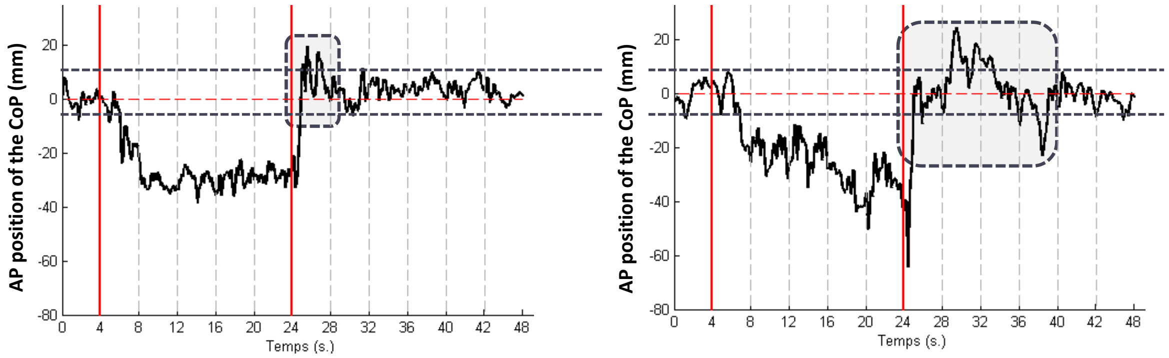
Vibration on the **non-paretic** limb:



Specific for each group

LBD : ↘ destabilization

RBD : ↗ destabilization



Patient with **LBD** (Bi)

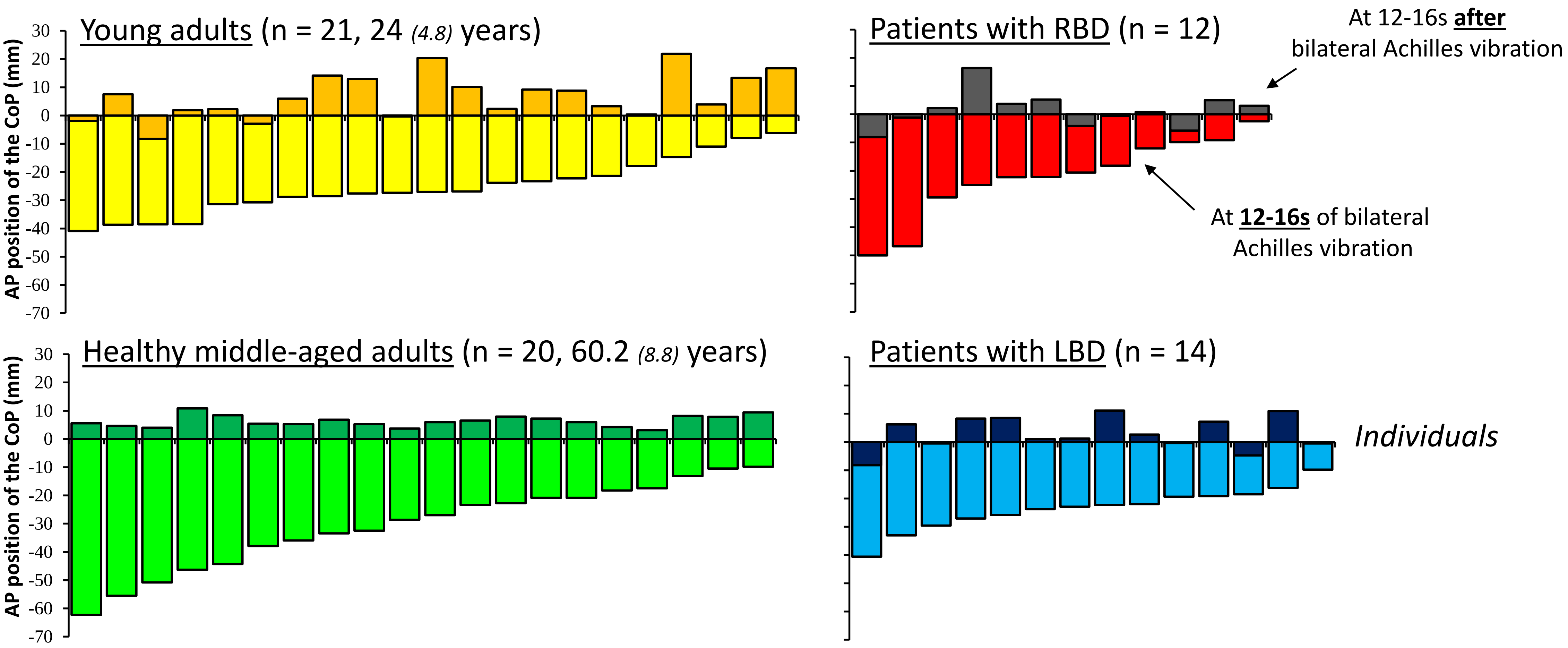
Patient with **RBD** (Bi)

Variability of the AP displacement

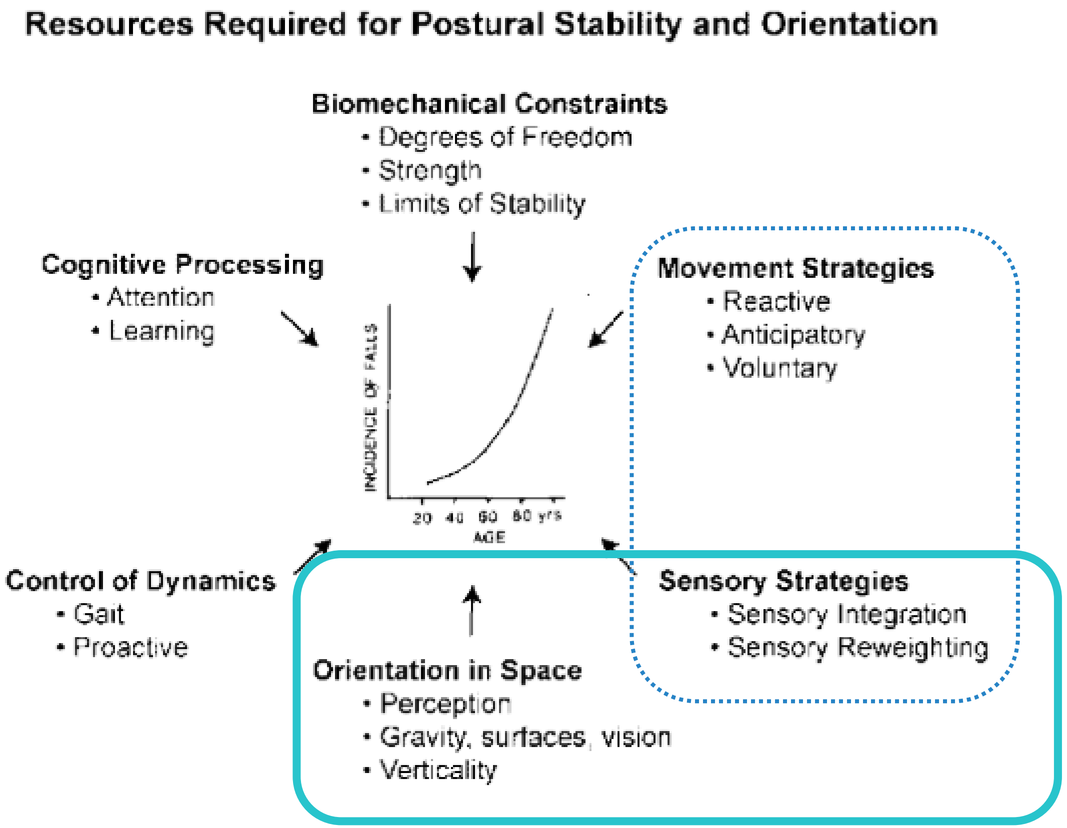
RBD → **more time** to regain stability

Duclos NC, Maynard L, Abbas D, et al. Hemispheric specificity for proprioception: Postural control of standing following right or left hemisphere damage during ankle tendon vibration. *Brain Res* 2015; 1625: 159–170.

Individual proprioceptive sensitivity for postural control



Spatial orientation in post-stroke patients



Stroke → Brain damage → Contralesional deficits

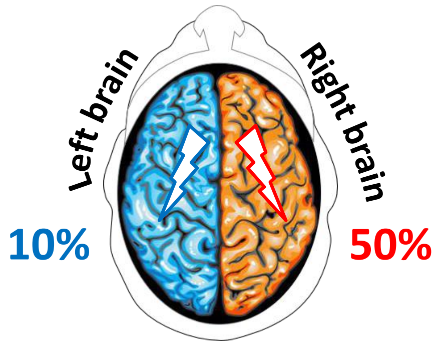
→ *Sensory* deficits

→ *Motor* deficits

→ ***Perceptual*** deficits

Side of lesion → Typical clinical picture:

Unilateral spatial neglect



"Difficulty
in attending and responding to stimuli
on the side of *space* or the *body*
opposite to the lesion"

→ *Not caused by an specific sensory or motor deficit*

Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? Age Ageing 2006;35 Suppl 2:ii7–11. Figure 1
Heilman KM, Valenstein E. Mechanisms underlying hemispatial neglect. Ann Neurol 1979; 5: 166–70.

Unilateral spatial neglect (USN)

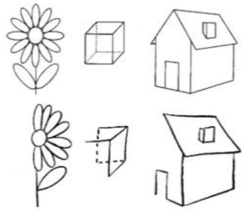
Associated with poor motor recovery, higher disability, and poor response to rehabilitation

Negative prognostic factor of functional recovery

Diagnosis

Treatment

Complex and heterogenous syndrome

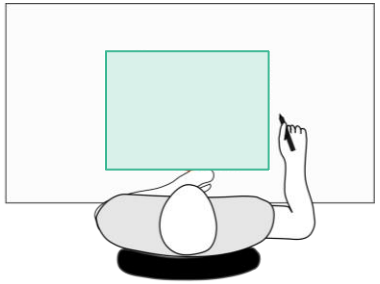


Allocentric reference *(object-based)*

Egocentric reference *(body centered)*

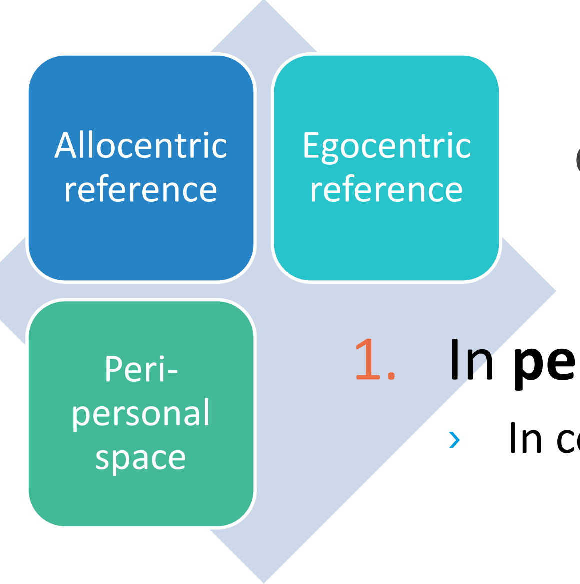
Peri-personal space *(near)*

Extra-personal space *(far)*



Buxbaum LJ, Ferraro MK, Veramonti T, et al. Hemispatial neglect: Subtypes, neuroanatomy, and disability. *Neurology* 2004; 62: 749–56.

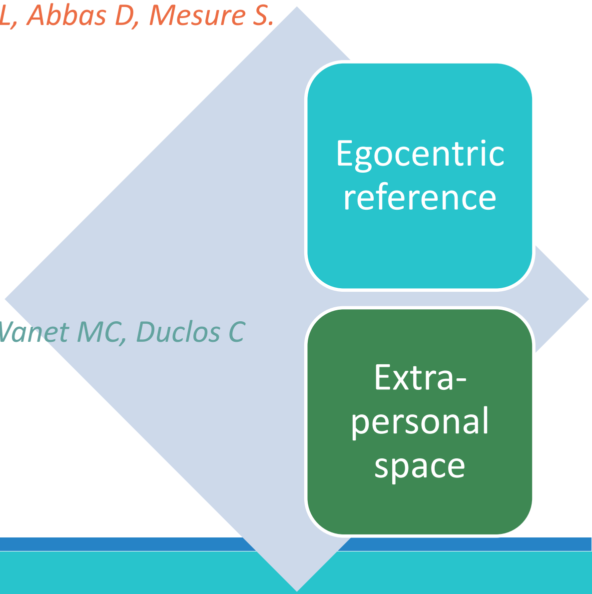
Vibration and orientation
Research questions



Influence of posterior neck muscles vibrations (NMV) on the performance in a visuo-spatial exploration test in post-stroke patients with NSU?

1. In **peri**-personal space?
   - In comparison with visual manipulation

Duclos NC, Maynard L, Abbas D, Mesure S.



2. In **far** space, during a mobility task (moving along a corridor)?

Poncet F, Duclos NC, Azouvi P, Cybis W, Wanet MC, Duclos C

Vibration and NSU in peri-personal space
Methodology

Population :

- Patients with RBD and LBD
  - Able to understand instructions
  - All signed an informed consent form

Experimental set-up:

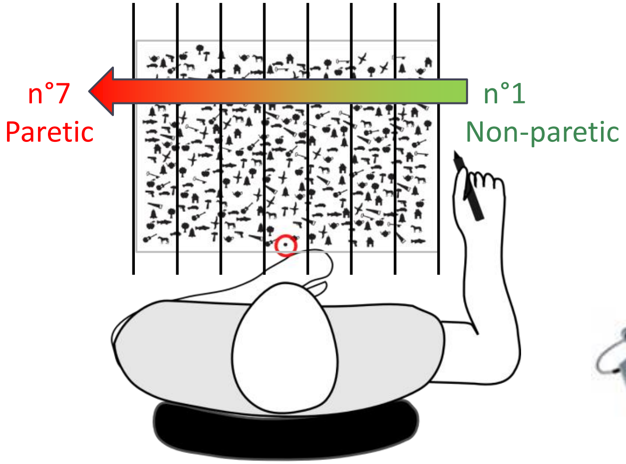
- Bells test (cancellation task)

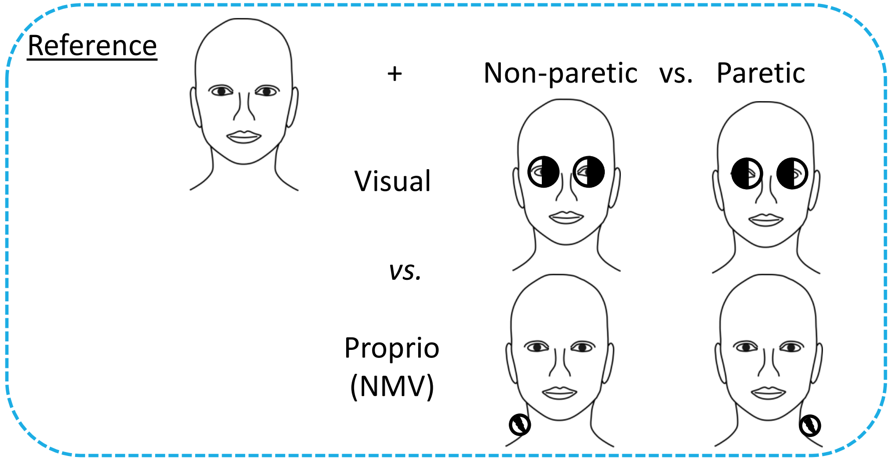
« Circle all the bells dispersed on the sheet »

  - A3 printed sheet
  - 3 minutes
- 5 conditions:
  - Reference (without perturbation) → baseline performance → N+
  - 4 sensory conditions (visual/proprio)

Data analysis:

- Measure of interest: circled bells
- Variables:
  - Total number of circled bells
  - Rate of occurrence of each sensory condition in minimal and maximal individual performances





Gauthier L, Dehaut F, Joanette Y. The Bells Test: a Quantitative and Qualitative Test For Visual Neglect. *Int J Clin Neuropsychol* 1989; XI: 49–54.

Vibration and NSU in extra-personal space
Methodology

Population:

- Patients RBDN+ and LBDN+
  - Able to understand instructions
  - All signed an informed consent form

Experimental set-up:

- Moving along a corridor and detecting targets on the corridor walls
  - 9 magazine covers / wall
    - At 3 height levels *(Poncet et al.)*
  - Corridor: 2.30 meters wide, 20 meters long
- Conditions:
  - Without / with vibration
    - On **left** posterior neck muscles

Data analysis:

- Measures:
  - Eye movements *(Tobii® Eye tracking system)*
  - Pointed magazine covers
- Variables:
  - Exploration time of each wall
  - Number of pointed covers on each wall

Poncet F, Duclos N, Cybis W, Azouvi P, Duclos C, Wannet MC. Reliability properties of the UN-moving-task, an ecological assessment of Unilateral Neglect in patients with acquired brain injuries. Preliminary results. *12th International Conference by the International Society for Low Vision Research and Rehabilitation*, June, La Hague (Netherland), 2017.

Vibration and NSU in peri-personal space
Results

Population: n = 35

- RBD: n = 10; LBD: n = 14; RBDN+: n = 9
  - *LBDN+ : n = 2, excluded from the analysis*

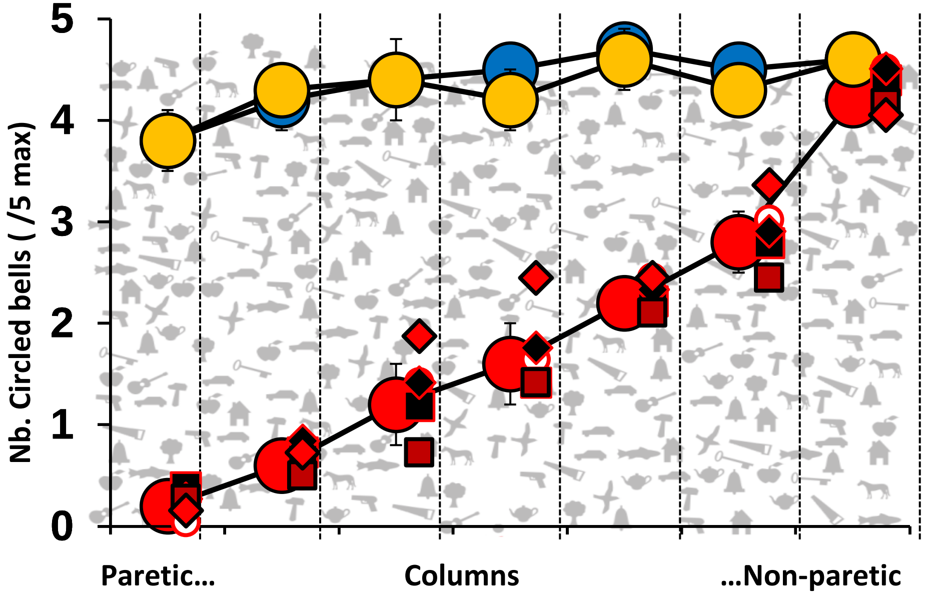
Total number of circled bells:

- Main effect of Group: mean *(SD)*

RBD and LBD * RBDN+

30 *(4)* 30 *(5)* 13 *(8)* bells

  - Circled bells dispersed over fewer columns for RHDN+
- No difference between sensory conditions



Duclos NC, Maynard L, Abbas D, et al. Neglect following stroke: The role of sensory sensitivity in visuo-spatial performance. *Neurosci Lett* 2014; 584: 98–102.

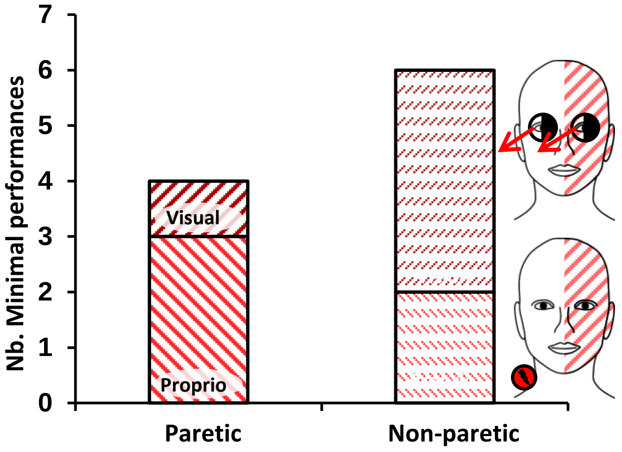
Vibration and NSU in peri-personal space
Results - at the individual level

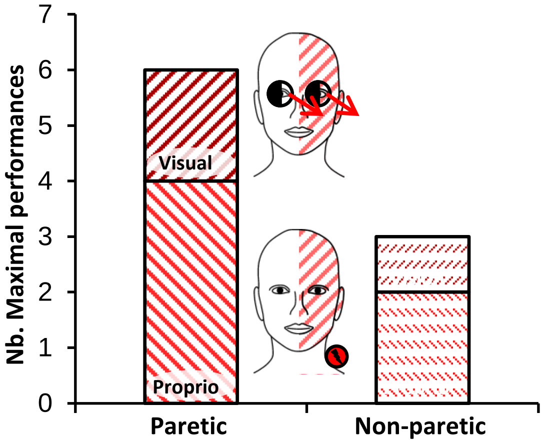
Sensory effects: individual-dependent

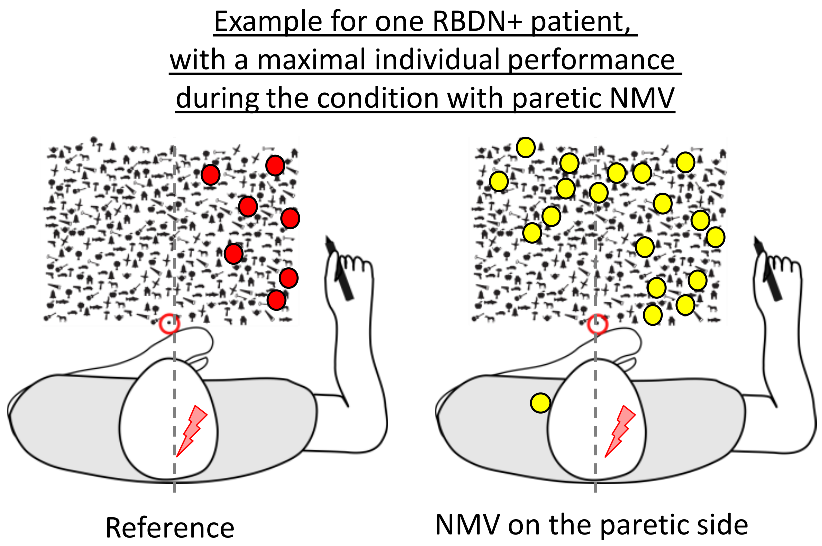
RBDN+ :

Extreme performances

- Minimal individual performances
  - 2/3 during « non paretic » conditions
- Maximal individual performances
  - 2/3 during « paretic » conditions
    - 44% during NMV applied on the paretic side





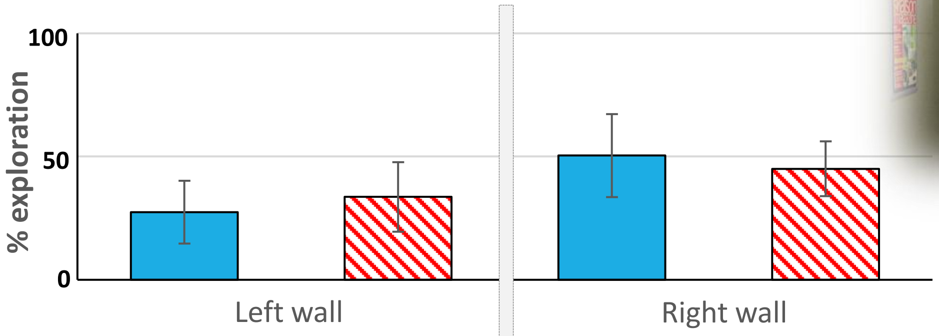


Duclos NC, Maynard L, Abbas D, et al. Neglect following stroke: The role of sensory sensitivity in visuo-spatial performance. *Neurosci Lett* 2014; 584: 98–102.

Vibration and NSU in extra-personal space
Results

Population: n = 15

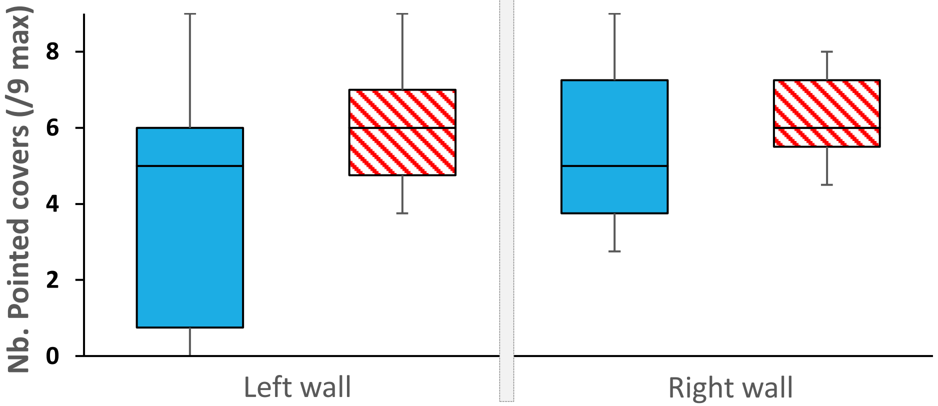
- RBDN+: n = 12
  - *LBDN+: n = 3, excluded from the analysis*



Time spend looking at each wall *(% total time of visual exploration)*:

Mean (SD)

- Without vibration
- With vibration



Number of pointed covers on each wall:

Mediane (Q1,Q3)

- Without vibration
- With vibration

Poncet F, Duclos NC, Azouvi P, Cybis W, Wanet-Defalque M-C, Duclos C. Effectiveness of a vibration of the neck on visual detection for persons with acquired brain injury and unilateral neglect. *WOFT Congress 2018*, May, Cape Town (South Africa), 2018.

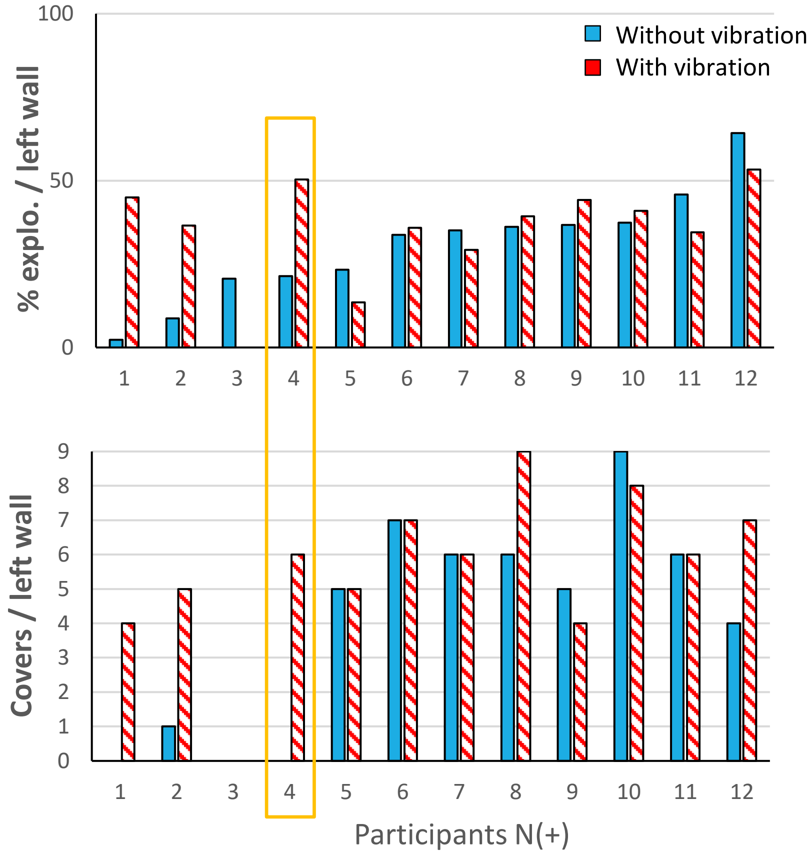
Vibration and NSU in extra-personal space
Results - at the individual level

Time spent looking at the **left** wall

- With vibration:
  - ↗ for 7 participants RBDN+
  - ≥ +30% for 3 participants RBDN+

Number of pointed covers on the left wall:

- With vibration:
  - ↗ for 5 participants RBDN+
  - For 3 participants RBDN+: from 0 to ≥4 covers



Example of *eye-tracking recordings* for one participant RBDN+

Poncet F, Duclos NC, Azouvi P, Cybis W, Wanet-Defalque M-C, Duclos C. Effectiveness of a vibration of the neck on visual detection for persons with acquired brain injury and unilateral neglect. *WOFT Congress 2018*, Mai, Cape Town (Afrique du Sud), 2018.

Gait in post-stroke population

Stroke → Brain damage → Contralesional deficits

- → *Sensory* deficits
- → *Motor* deficits
- → *Balance* deficits

Typical clinical picture:

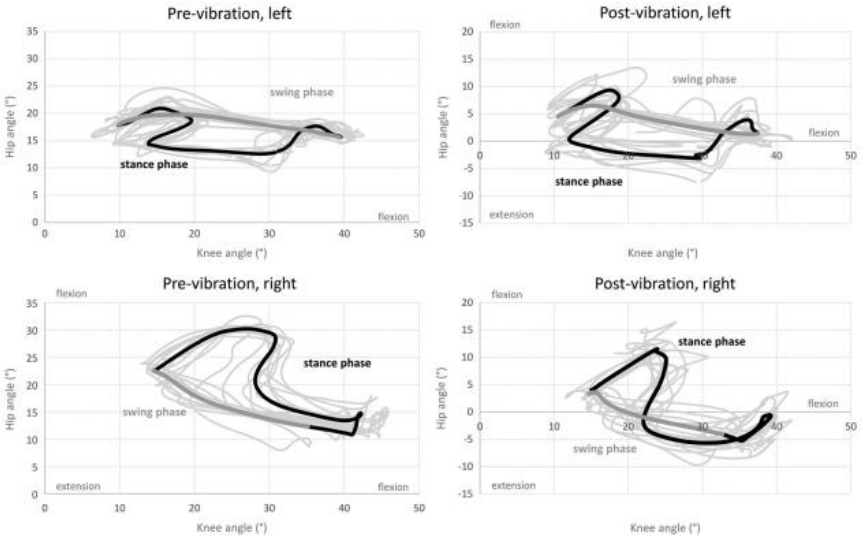
Slow walking speed

Locomotor asymmetry

Are gait-like vibrations an appropriate sensory stimulation for gait training?

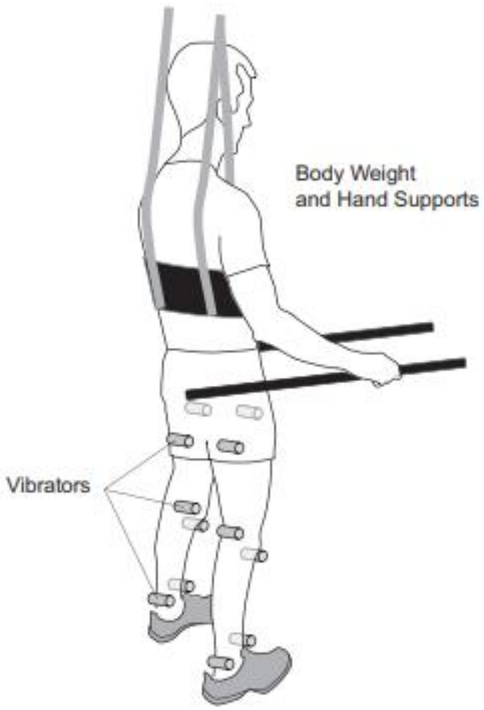
Research leader: Duclos C.

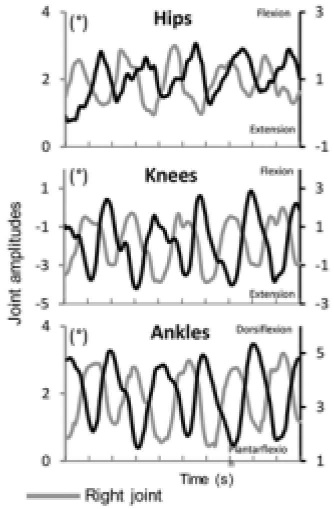
Preliminary evidence of a positive effect of patterned vibration training on gait abilities after spinal cord injury *(case report)*

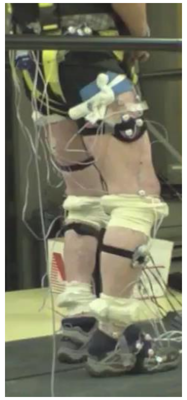


Barthélémy A, Gagnon DH, Duclos C. Gait-like vibration training improves gait abilities: a case report of a 62-year-old person with a chronic incomplete spinal cord injury. *Spinal Cord Ser Cases* 2016;2:16012.

Complex muscle vibration to induce gait-like movements







2-second pattern:

- Small amplitude cyclical movements
  - Frequency corresponding to the cycle duration of the vibration patterns
- Alternated movements between the right and left lower limbs
  - Hip flexion + knee flexion + ankle dorsiflexion
    - Then reverse pattern

Objectives:

1. To quantify the **perception of gait motion** during multiple gait-like vibrations in healthy participants
2. To determine how number of vibrated joints affect this perception

Duclos C, Kemlin C, Lazert D, Gagnon D, Dyer J-O, Forget R. Complex muscle vibration patterns to induce gait-like lower-limb movements: Proof of concept. JRRD 2014;51:245–52.

Perception of gait motion
Results

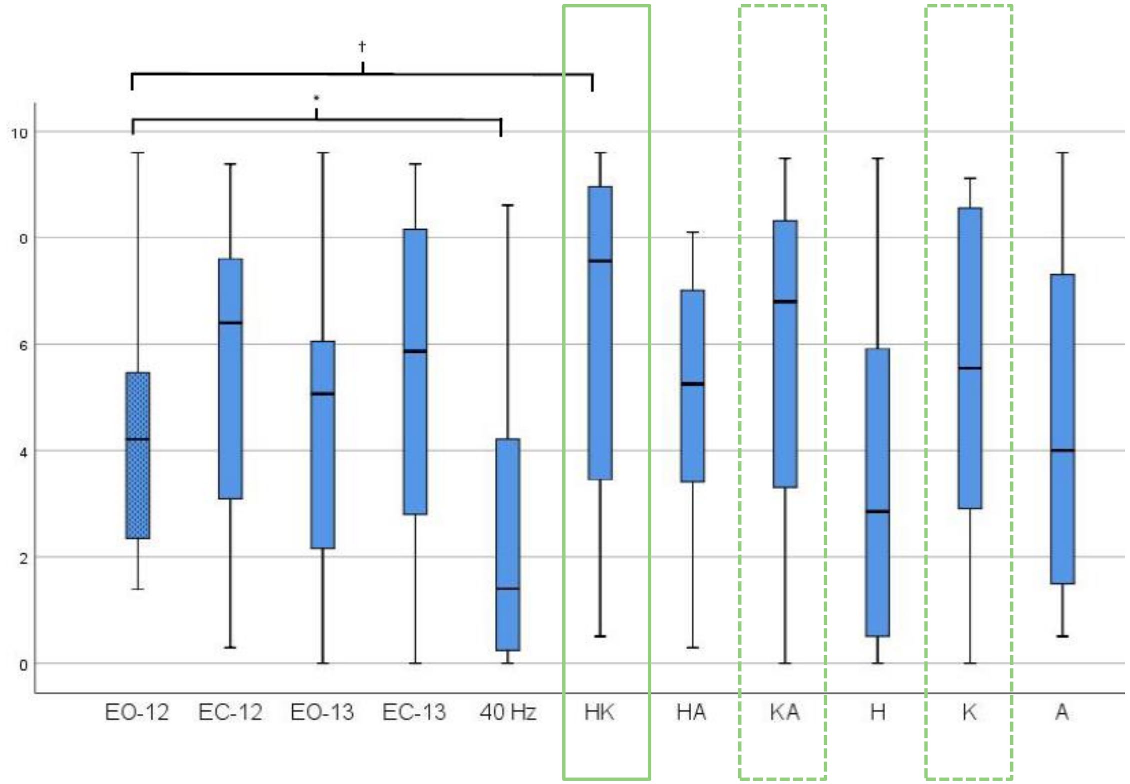
Gait motion perception:

- Score VAS higher than 5/10
  for at least one vibration condition
  - For all participants (n = 20) – except one participant

Conditions:

- Knee stimulation: positive influence on gait motion perception
  - Associated with or without other joint stimulations
- High inter-individual variability +++

→Should be considered to give participants the best perception of gait motion



Tapin A, Duclos NC, Jamal K, Duclos C. Perception of gait motion during multiple lower limb vibrations in young healthy individuals. *In preparation*

Conclusion and perspectives

Tendon vibration used to explore 3 different sensory-motor activities

- Focal stimulation: placed on the side and on the muscles of interest
  - Depending on the population and the activity
- Non-invasive and « controllable » tool

Effects during other activities?

- More ecological tasks: shopping, cooking…
  - In virtual reality and/or real life
- Prosthetic use of the vibration in real life

Equipment?

- Control, capacity to quickly change frequency
- Wearable

Generability of the results ←→ Individual sensitivity?

Thanks for your attention!

NOÉMIE DUCLOS noemie.duclos@u-bordeaux.fr

USING TENDINOUS VIBRATION
TO EXPLORE POSTURE, SPATIAL ORIENTATION AND GAIT
IN POST-STROKE POPULATION