

Therapeutic effects of large-field visual virtual immersion on balance control in unilateral vestibular patients

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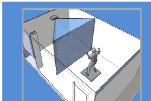
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INTRODUCTION | VR-based balance rehab. relevance ?



3. OBJECTIVES



VR REHABILITATION

- Balance processes use visual, vestibular and proprioceptive sensory signals in a synergistic way. [1]

- Vestibular deficit increases a visual dependency due to the vestibular inhibition suppression [2].

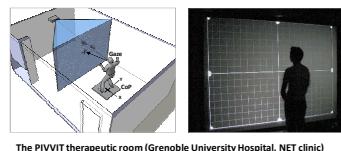
- Therapeutic effects of virtual reality (VR) based protocols (optical flows) to restore the reciprocal visual-vestibular-motor to reduce the patients' visual dependency.



METHODS | The PIVVIT project (Plateforme d'Immersion Visuelle Virtuelle Thérapeutique)

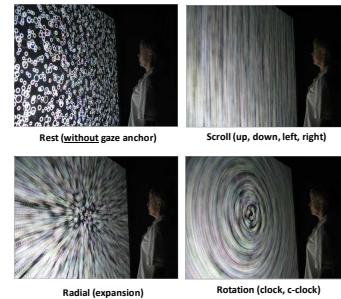
CLINICAL TRIAL - PATIENTS

- Unilateral vestibular patients (42-80 y.o.; 3 m., 4 f.)
- Visually-induced dizziness (areflexia, chronic recurrent dizziness, vestibular neuritis)
- 8 weeks rehab. period = 1 or 2 rehab. session per week included in the patients care process
- Ethics validation (CPP - voluntary informed patients)



VISUAL STIMULI

- Large-field (panoramic) visual virtual flows
- Standardized optokinetic stimulus
- 8 Optic flows STIM. : 1D scrolls (Up, Down) + 2D Rotations (Clockwise, Counterclockwise) + 3D Radial expansion.
- 6 flows SPEED (speed ratio from s03 to s28 A.U.)
- Scenarios optimized for efficiency on patient : visual-flows constraints increase throughout the therapeutic session : flows pattern (scroll, radial and rotation), stimulation speed increased, gaze anchoring on the visual reference (with/without).



GAZE ANCHORAGE (GA)

- Visuo-spatial reference
- With GA : session 1-4 ; Without GA : session 5-8
- [With : session 9 ; Without : session 10]



PROTOCOL

- 1 Trial = Visual stimulation

• Rest – Flow – Rest : 25 sec.

- 1 Serie = 8 stim. (8 trials)

• 5 different 1D/2D-3D visual flows

- 1 Session = 6 Speed

• 8 trials x 6 speed = 48 trials

- 2 Gaze Anchorage cond.

• Sess. 1-4 : With GA

• Sess. 5-8 : Without GA

• (48 trials x 8) = 384 trials (15 sec.)

➤ Total stim. duration = 96 min. (1h36)

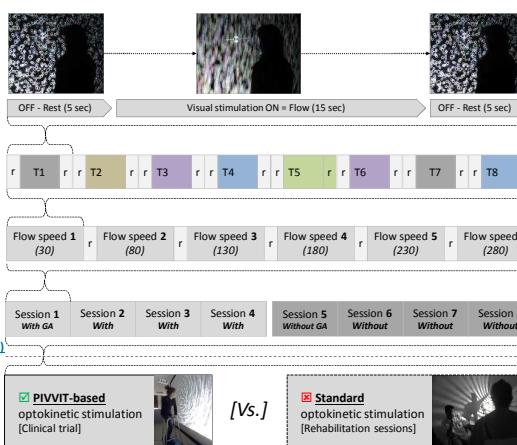
- [2 Phases = Compar./Valid.]

• 8 VR-based sess. (PIVVIT)

→ *"Proof of concept"* +++

• 8 Standard OKS sess.

→ *"Proof of non-inferiority"* +++



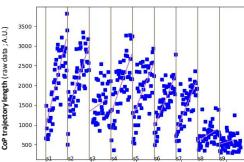
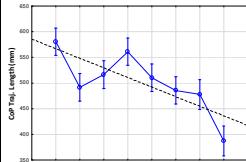
DATA RECORDING AND ANALYSIS

- Balance control : Center-of-Pressure (Wiifit board, 100 Hz) : **CoP Trajectory length** → Disequilibrium indicators (lost of balance control, falls)
- Gaze behaviour (Eye-Head(-body) stability ; BlueGain EOG, 100Hz) : **EOGxy trajectory** (preliminary results)
- [Questions-Responses (subjective estimation of the "balance comfort" in every day life tasks)]

REFERENCES. [1] Peterka, R. J. J. Neurophysiol, 2002. [2] Roberts et al., Adv. Clin. Neurosci. Rehab. 2016. [3] Voda et al., IFAC PapersOnLine 2019.

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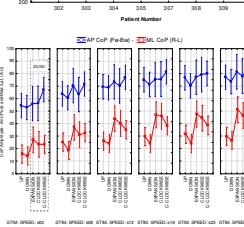
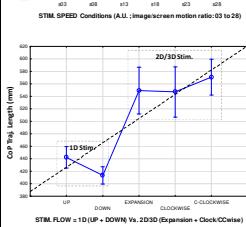
RESULTS | VR immersion → Visual perturbation → Balance restoration



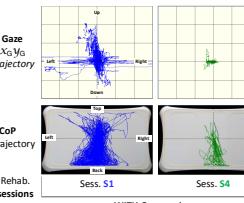
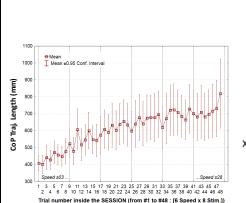
- INTER-SESSIONS effect (representative patient)**
- Decreases the CoP Trajectory length
 - Reduces the postural reaction
 - Decrease the balance perturbation
 - Improve the Gaze-Balance interactions



- Flows SPEED effect (all patients)**
- Increase the CoP Trajectory length
 - Increase the balance perturbations
 - Stimulate the compensatory postural adjust.



- ISPEED x STM.1 effect on AP-ML adjustments (all patients)**
- [Speed max. + 2/3D stim.] > [Speed min. + 1D stim.]
 - High [Speed x Stim.] increase the CoP Trajectory length → related to the augmented complexity of the virtual stim.
 - Increase the balance perturbations
 - Multiple visual flows parameters "co-stimulate" the compensatory postural strategies



- STM. SPEED x STM.1 effect on AP-ML adjustments (all patients)**
- [Speed max. + 2/3D stim.] > [Speed min. + 1D stim.]
 - High [Speed x Stim.] increase the CoP Trajectory length → related to the augmented complexity of the virtual stim.
 - Increase the balance perturbations
 - Multiple visual flows parameters "co-stimulate" the compensatory postural strategies

INTRASESSIONS effect (all patients)

- Increase the CoP Trajectory length
- Increase of the postural reaction
- *"Positive fatigue effect"* ? → Optimal Difficulty Level ?

GAZE XG YG trajectory

CoP XY trajectory

Rehab. sessions

GAZE-BALANCE INTERACTION (representative patient)

- Functionally (neuro-mechanically) coupled and synchronized
- Synergistic improvement and interactive stabilisation
- Gaze Balance enhancement ... ocular OR vestibular efficiency thanks to the visual-retinal flows ... Which sub-system drives the improvement ?

DISCUSSION – CONCLUSION | Rapid VR-based rehab. benefits

At a Clinical/Rehab. level : Positive effects of the "large visual field" immersion on balance restoration

➤ **METH.** Patient-related sessions repetition + **difficulty-dependent** tuneable scenarios + patient follow-up + **methodical practice** through short period (**two months**)

➤ **BENEFITS.** Rapid functional restoration of efficient synergistic control between balance and gaze process.

➤ **PSYCHOL.** Patients' motivation and self-confidence !

At a Neuro-functional level : "visual-vestibular-motor" adaptation occurs despite the vestibular deficits

➤ **PROCESS.** Reweighting of the visual-vestibular sensory inputs → reciprocal inhibition restoration

➤ **ADAPTATION.** Reduction of the visual dependence by visual-vestibular reverse compensations

➤ Questions about the neural basis of the "visual-vestibular plasticity"

➤ Sensory adaptive threshold/gain of the VOR and/or OKN ?

➤ Dual sensorimotor plasticity in balance restoration : Interaction MT visual area - vestibular nuclei → visual-vestibular integration for motor command tuning/adjustment.

CONCLUSION

➤ Optimized rehabilitation strategies based on simple virtual visual immersions Vs. standardized rehabilitation protocols (uncontrolled OKS) for unilateral vestibular patient

➤ Limit: No long-term effects

(reported by patients after a six months period) requiring periodic booster sessions

➤ Our study corroborate the proof of concept of interactive VR-rehabilitation based on a large visual field stimulation device (experimental and clinical validation).