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

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INTRODUCTION | VR-based balance rehab. relevance?

CLINICAL TRIAL - PATIENTS

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

METHODS | The PIVVIT project (Plateforme d’Imagerie Visuelle Virtuelle Thérapeutique)

VISUAL STIMULI

- Large-field (panoramic) visual virtual flows
- Standardized optokinetic stimulus
- 8 Optic flows STIM. : 3D scrolls (Up, Down) + 2D Rotations (Clockwise, Counterclockwise) + 3D radial expansion.
- 6 flows SPEED (speed ratio from 0.3 to s8 A.U.)
- Scenario 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
  - Nest = Flow - Nest = 23 sec.
- 1 Series = 8 stim. (8 trials)
  - 8 different 10°/20°/30° visual flows
- 1 Session = 6 Speed
  - 8x stimulus speed = 64 trials
- 2 Gaze Anchorage cond.
  - Secs. 1-4: With GA
  - Secs. 5-8: Without GA
- 12 phases: a) Comparator/Validation
  - 3 VR-based tests (PIVVIT): "Proof of concept" +++
  - 3 Standard OGS tests: "Proof of non-inferiority" +++

RESTING COUNIT: Radial (expansion)
Lateral (black, red+)
UP DOWN EXPANSION CLOCKWISE-CLOCKWISE

PIVVIT-based standard stimulation

[VR]

S8 = (48 trials x 8) = 384 trials (x 15sec.)
Total stim. duration = 96 min. (1h36)

MORE PHASES: Comparator/Validation
- 8x stimulus speed = 64 trials

RESULTS | VR immersion → Visual perturbation → Balance restoration

INTER SESSIONS effect (representative patient)
- Increase the CoP Trajectory length
- Increase the postural reaction
- Improve the balance perturbations

INTRA SESSIONS effect (representative patient)
- Reduce the CoP Trajectory length
- Reduce the postural reaction
- Improve the gaze-balance interactions

VISTA PLUS
- Increase the CoP Trajectory length
- Increase the postural reaction
- Improve the balance perturbations
- Multiple visual flows parameters to "obstruit" the compensatory postural strategies

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 tunable 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 OCN?
- Dual sensorimotor balance in plastic restoration: Interaction MT visual area - vestibular nuclei
- vestibulo-visual integration for motor control tuning/adjustment

CONCLUSION

- Optimized rehabilitation strategies based on simple virtual visual immersive strategies.
- Dual stimulation prototypes (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 paradigm (experimental and clinical validation).


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