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

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INTRODUCTION | VR-based balance rehab. relevance ?

- Automatic sensory and motor compensations (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) virtual visual flows
- Standardized optokinetic stimulus
- 8 Optic. flows STEMS: 3D scrolls (Up, Down) + 3D Rotations (Clockwise, Counterclockwise) + 3D Radial expansion.
- 6 flows SPEED (speed ratio from 0.3 to 2.8 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
  - Ment - Flow - Rest = 23 sec.
- 1 Serie = 8 stim. (8 trials)
  - 5 different 10/20-30 visual flows
- 1 Session = 6 Speed
  - Stims x 6 speed = 48 trials
- 2 Gaze Anchorage cond.
  - Secs. 1-4: With GA
  - Secs. 5-8: Without GA
  - 14 trials x 8 = 112 trials (in 15sec.)
- Total trial duration: 25.5 min.
- [2 phases: (1) Visual stimulation (virtual trial)
  - 2D & 3D optical flows
  - (2) Visual correction (virtual trial)

RESULTS | VR immersion → Visual perturbation → Balance restoration

- Automatic sensory and motor compensations during a short rehabilitation period.

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 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 (unordered 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).