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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?

- Balance processes use visual, vestibular and proprioceptive sensory inputs to maintain a symmetrical way of movement.
- Vestibular deficit increases in a time-dependent way due to the vestibular compensation syndrome.
- Therapeutic effects of virtual reality (VR) based sensory training are not well understood, in particular virtual vestibular training during a short rehabilitation period.
- Automatic sensory and motor compensation (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.a.; 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.: 3D scrolls (Up, Down) + 3D Rotations (Clockwise, Counterclockwise) + 3D Radial expansion.
- 6 flows SPEED (speed ratio from 0.03 to 828 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
- Trial 1 = Visual stimulation
- Series B: 8 stim. (8 trials)
  - 5 different 10/20-30 visual flows
- Session 6 Speed
  - Flow. & Flow. speed = 64 trials
- 2 Gaze Ancehorage cond.
  - With GA: 4 sessions
  - Without GA: 4 sessions
- 2 Phases + Compar./Valid.
  - A VR-based (PIVVIT)
    - VR = “Proof of concept” +
    - 2 standard OGS slots

DATA RECORDING AND ANALYSIS
- Balance control: Center-of-Pressure (Wright board, 100 Hz); CoP Trajectory length; Disequilibrium indicators (lost of balance control, falls)
- Gaze behaviour (Eye-Head-body) stability; BlueGain EOG, 100Hz; EOG trajectory (preliminary results)
- (Questions Responses: subjective estimation of the “balance comfort” in everyday life tasks)


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RESULTS | VR immersion → Visual perturbation → Balance restoration

INTER SESSIONS effect (representative patient)
- Increase the CoP Trajectory length
- Reduced the postural reaction
- Encouraged the balance perturbation
- Improved the balance interactions

INDIVIDUAL effect (all patients)
- Increase the CoP Trajectory length
- Reduced the visual dependency
- Stimulate the compensatory postural adjustments.

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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 synergetic 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 balance in plastic 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).