Balance Rehabilitation Through Virtual Environments

Dr. Emily A. Keshner
Professor and Chair, Department of Physical Therapy
Director, VEPO Lab
Temple University
<table>
<thead>
<tr>
<th>Motivating Activities that can be graded to be demanding but feasible</th>
<th>Task-specific practice</th>
<th>High intensity, repetitive exercise</th>
<th>Knowledge of performance &amp; results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varied, meaningful &amp; purposeful environmental contexts</td>
<td>Motivating</td>
<td>Increased client participation</td>
<td>Client’s performance documented</td>
</tr>
</tbody>
</table>
Application of Virtual Reality to rehabilitation is becoming more common

Nintendo Wii is being used to work on weight bearing and increasing coordination, increasing strength and stability, increasing fine and gross motor skills.

Limitations: the parameters of the interaction are not well controlled:
- how much force is produced?
- is the whole limb or one joint being used?
- can the game be tricked - are they really moving as we expect?
- are the children learning anything beyond how to win the game?
Caution: “Active" video games don't necessarily boost physical activity

39 children chose from 5 active fitness-focused games and the other half from inactive games.

All received needed accessories including balance boards, remote controllers and resistance bands.

Accelerometer logs showed active games didn't promote any more exercise than inactive video games.


https://www.youtube.com/watch?v=HkMJJIOzCTUE#!
What do we need in Clinical Interventions to Challenge Sensorimotor Integration?

- Matching experiences to patient deficits
- Grading complexity of sensory experiences
- Creating rich sensory environments for practice

Properties of Virtual Reality Environments
• Trained for a 2 week period

• In the dark

• Increased sensitivity of platform each day up to 2 times COM motion

• Patient instructed to focus on position of hips and knees.

Haran and Keshner 2011
Postural Sway Decreases with Practice

- 73 yo female who falls
- 10 years post-onset of bilateral vestibular deficit
- an active, community dweller
- no other significant health problems
Effect of Balance Training on Patients Post-Stroke

SUBJECTS

- Four adults with right hemiparesis (39-67 years old)
- At least 1-2 months post-stroke
- Berg Balance Scale scores from 39-56
- 5-20 deg reduction in ankle range of motion in the paretic limb
- Lower limb vibration sense was intact

- Used visual motion and platform motion to produce instability
- Trained with plantar vibration in the dark to enhance stabilization
Thus, sensory integration training with VR can be used as a tool for modifying postural behavior.
VR is not meant to replace real world action but to enhance it in order to encourage CNS reorganization.

Physiological Impact of Virtual Reality can be seen through psychophysical phenomena:

1. Immersion
2. Presence
3. Vection
4. Cybersickness
VR Immersion Promotes Verbal and Gestural Communication in Individuals with Aphasia

Table 2. Proportions of Utterances with Symbolic, Interactional, Referential Pointing Gestures and Facial Expressions

<table>
<thead>
<tr>
<th>Story</th>
<th>Gesture Priming Condition and Dialogue Scenario</th>
<th>Low</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
<td>Hot Wok</td>
<td>Capital Grille</td>
<td>Owl Diner</td>
<td></td>
</tr>
<tr>
<td>XH46</td>
<td>.60 (n=45)</td>
<td>.61 (n=67)</td>
<td>.51 (n=41)</td>
<td></td>
</tr>
<tr>
<td>KC3</td>
<td>.38 (n=26)</td>
<td>.36 (n=39)</td>
<td>.27 (n=26)</td>
<td></td>
</tr>
<tr>
<td>CN39</td>
<td>.72 (n=25)</td>
<td>.72 (n=32)</td>
<td>.40 (n=25)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task</th>
<th>Low</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
<td>Florida</td>
<td>Las Vegas</td>
<td>Washington DC</td>
</tr>
<tr>
<td>XH46</td>
<td>.45 (n=65)</td>
<td>.60 (n=72)</td>
<td>.62 (n=50)</td>
</tr>
<tr>
<td>KC3</td>
<td>.33 (n=49)</td>
<td>.43 (n=42)</td>
<td>.43 (n=70)</td>
</tr>
<tr>
<td>CN39</td>
<td>.41 (n=41)</td>
<td>.51 (n=35)</td>
<td>.50 (n=32)</td>
</tr>
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</table>
Presence: To become unaware of your real surroundings and focus on your existence in the environment

Presence Modifies Motor Planning

Immersion: the feeling of being inside and part of the virtual world

Immersion NeuroPlasticity

Random Dot Pattern

Great Hall of Vection
Immersion + Presence Promotes Adaptation to a Moving World

Participants:
- 5 adults with unresolved dizziness (25-60 yrs)
- chronic symptoms of dizziness and nausea
- stood on dense foam while wearing an Oculus Rift
- 1-2x/week for 4 weeks
- visual field was sinusoidally rotated at 0.25 Hz for 60 sec, 3 times in each direction
Pre- and Post-training COP Footprints and Magnitudes

**ROLL VISUAL SCENE**

Pre-test

Post-test

**PITCH VISUAL SCENE**

Pre-test

Post-test
Improved Sensorimotor Integration Improves Functional Balance

During pre-testing, participants fell on 75% of the trials with visual scene motion - only one fall occurred during post-testing!
IS IMPAIRED SENSORIMOTOR INTEGRATION LINKED TO FUNCTIONAL MOBILITY

- 90% individuals with CP have sensory impairments that alter sensorimotor integration

- Increased fatigue and pain
- Decreased locomotor function
- Decreased balance confidence
- Decreased quality of life

## PARTICIPANTS

<table>
<thead>
<tr>
<th>23 Cerebral Palsy (CP)</th>
<th>23 Typical Development (TY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.3 ± 11.4 years</td>
<td>29.6 ± 11.0 years</td>
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</table>

**SPASTIC CP**
- DIPLEGIC (n=16)
- QUADRIPLEGIC (n=6)
- HEMIPLEGIC (n=1)
GMFCS: level I (n=15) & level II (n=16)

**STAND INDEPENDENTLY**
- at least 2 minutes at a time without assistance
- CORRECTED VISION 20/40 and better; no visual field deficits
- No botox injection in the past 3 months at the time of participation

**No known neurological disease**
Visual Dependence with CP (Rod and Frame Test)

Cerebral Palsy (CP) n=23

CP + Visual Dependence (CPVD) n=13

CP + Visual Independence (CPVI) n=10

Typical Development (TY) n=23

TY + Visual Independence (TYVI) n=23
POSTURAL TASK in a Virtual Environment

Visual scene driven as:
1) Stationary
2) Eyes Closed
3) Pitch Up 15°/s
4) Pitch Up 30°/s
5) Pitch Down 15°/s
6) Pitch Down 30°/s

No vestibular stimulation

<table>
<thead>
<tr>
<th>Time</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 s</td>
<td>Quiet Stance</td>
</tr>
<tr>
<td>30 s</td>
<td>Sustained tilt at 3 degree</td>
</tr>
<tr>
<td>30 s</td>
<td>Returning to 0 degree at 0.1 deg/sec</td>
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</tbody>
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COM with Fixed Base of Support

- RMS of COM in the AP direction (cm)
- TY, CPVI, CPVD
Balance is Sensitive to Visual Flow and Reflects Visual Sensitivity

Significant differences in COM to changes in visual flow by CPVD group suggests differences in stabilization of the head and upper trunk.
Differences in COM are reflected in upper body response to visual field motion

\[ \theta_T \quad \text{(Head – Thorax)} \\
\theta_H \quad \text{(Thorax – Hip)} \\
\theta_I \quad \text{(Hip – Ankle)} \]

Stabilized to space

Stabilized to inferior segment


Anchoring Index (Shoulder-Hip)

Stabilized more to global space
Head and Upper Trunk Response to Tilt (0-10 sec)

**Typical** Young Adult head and trunk stable

Eyes Open (EO)
Eyes Closed (EC)
Pitch up Scene (PU)
Pitch Down Scene (PD)

**Typical hold head and trunk stable in space**

CP Visually Independent Trunk Motion

CP Visually Dependent head motion
Head and Upper Trunk During Return from Tilt (30-60 sec)

Typical Young Adult head motion

With diminished vestibular FB, Typical reorient with head motion; CPVD use the trunk more; CPVI lock head and trunk.

CP Visually Independent

CP Visually Dependent

Eyes Open (EO)
Eyes Closed (EC)
Pitch up Scene (PU)
Pitch Down Scene (PD)
Summary

• Specific sensory testing, spasticity, and strength did not differ between the CP groups.

• Adults with CP and visual dependence exhibited greater sway in the direction of visual field motion particularly when somatosensory information was unreliable.

• Restricted mechanics with spastic CP requires a sensory reweighting that will modify stabilizing behaviors.

• VR is a more sensitive diagnostic tool than current measures of balance.
What is the Clinical Value of VR?

- Intensity of effects can be modified to challenge the patients - e.g., direction and frequency of a visual field can be used to manipulate the size and timing of automatic motor responses.
- Training engages users to allow for the repetitive intensive practice required for behavioral motor plasticity.
- Visual field motion adds cognitive demands to a task.
- Can tailor interventions to address the particular needs of each patient.
- Encourages motor learning through practice and repetition.
- Provides environments to assess dynamic tasks that are performed everyday under controlled circumstances.
- Adds sensitivity to functional clinical measures of disability.
COLLABORATORS

Richard T. Lauer
PhD

Carole A. Tucker
PT, PhD, PCS

Nadine Martin
PhD

Yawen Yu
OT, PhD

Elizabeth D. Thompson
PT, DPT, NCS

Sara Snell
BS

Irina Chudnovskaya
BS

• All authors have NO reported conflict of interest.