Virtual Reality in Rehabilitation: Applications for Wheelchair Users

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Objectives

• Understand the spectrum of real→virtual environments
• Name ≥3 factors that affect wheelchair user experience in VR
• Identify ≥3 applications of VR research for wheelchair users
• Be familiar with HERL research on VR for wheelchair users
REAL ENVIRONMENT

Tangible User Interfaces (TUI)
A TUI uses real physical objects to both represent and interact with computer-generated information (Ishii & Ullmer, 2001).

Projection Augmented models (PA model) are a type of Spatial AR display, and are closely related to TUIs

Augmented Reality (AR)

Spatial AR
Spatial AR displays project computer-generated information directly into a user’s environment (Bimber & Raskar, 2005).

‘See-through’ AR (either optical or video)
A user wears a head-mounted display, through which they can see the real world with computer-generated information superimposed on top (Cakmakci, Ha & Rolland, 2005; Billinghurst, Grasset & Looser, 2005).

Virtual Reality (VR)
VR refers to completely computer-generated environments (Ni, Schmidt, Staadt, Livingston, Ball, & May, 2006; Burdea & Coifet 2003).

Virtual Reality (VR)
Immersive VR, which uses either a head-mounted-display or a projection-based system, completely fills the user’s field-of-view.

MIXED REALITY (MR)

Augmented Virtuality (AV)
AV ‘adds’ real information to a computer-generated environment (Regenbrecht, et al. 2004).

Semi-immersive VR
A semi-immersive VR display fills a limited area of a user’s field-of-view.

Semi-immersive VR using the Barco Baron workbench (Drettakis, Roussou, Tsingos, Reche & Gallo, 2004).

Immersive VR
Projection-based immersive VR. The users are fully immersed in the ‘CAVE’ (FakeSpace, 2006; Cruz-Neira, Sandin & DeFanti, 1993).

VIRTUAL ENVIRONMENT

Using physical objects to create a virtual model (Ichida, Itoh, & Kitamura, 2004). As a user adds a physical ‘ActiveCube’ to the construction, the equivalent virtual model is automatically updated.

The ‘Bubble Cosmos’ – ‘Emerging Technology’ at SIGGRAPH’06. The paths of the smoke-filled bubbles are tracked, and an image is projected into them as they rise.

See-through AR: the butterfly is computer-generated, and everything else is real (Fischer, Bartz & Strasser, 2006; Kölsch, Bane, Höllner, & Turk, 2006).

Semi-immersive VR using the Barco Baron workbench (Drettakis, Roussou, Tsingos, Reche & Gallo, 2004).

Projection-based immersive VR. The users are fully immersed in the ‘CAVE’ (FakeSpace, 2006; Cruz-Neira, Sandin & DeFanti, 1993).
Important Design Factors

• Design affects:
  – perception
  – behavior
  – driving performance
  – sense of presence

• Visualization of your own avatar
• Display type (head-mounted display v monitor)
• Ability to freely change the field of view (FOV)

McGill Immersive Wheelchair Simulator (miWe)

- Home computer set up w/ joystick
- 6 driving activities
- N=35
- miWe vs video game
- Practice 20min/2d x 2wk
- Wheelchair skills test (WST)
- 6% increase in scores in miWE (vs 3% in control)

VR for Accessibility

- U.K. 1996 Disability Discrimination Act (DDA)
- Wheelchair VR system
- High-quality immersive graphics
- Sense of "feel": electromechanical force-feedback

Diagram 9 Effective clear width of doors
Neglect

- $N = 9$
- Right-hemisphere stroke
- VR navigation task
  - Name virtual objects encountered along path
- Real-life wheelchair navigation task
- Battery of attention and neglect tests
- VR:
  - Correlated strongly with real wheelchair task
  - Detected lateralized attention deficits

VRNChair

- Uses MWC movement to feed any VR environment
- \( N = 34 \)
- VRNChair vs joystick
  - Lower motion sickness
  - Accurate performance

Kinect-Wheelchair Interface Controlled (KWIC) Smart Wheelchair

- 8 therapists, 50 hrs, 8 kids in MWC
- Played games using various control interfaces
- 2 became PWC drivers

Ocululs Rift

- A Wheelchair Training System – oculus and joystick
- Clinicians and expert wheelchair users with SCI
- Focus groups and interviews
- A virtual rehabilitation setting?
- Nausea

Wheelchair-Rift

- Oculus Rift
- Leap Motion hand tracking device
- Face validity by a panel of experts from a local Posture and Mobility Clinic

Reality-based User Interface System (RUIS)
The Smart House Living Lab
Campus of Excellence Moncloa International (CEI Moncloa)
University Politécnica de Madrid (UPM)
Brain-Computer Interfaces

- N = 1 SCI
- EEG
- beta oscillations were used for a self-paced (asynchronous) BCI control
- single bipolar EEG recording
- Task = Talk to each avatar
- Performance 90%

Isometric Joystick in TBI

- N=20, 1 year post-TBI
  - 12 men, 8 women
  - mean age 31
- Isometric vs conventional joystick
- Measures
  - Average trial completion time, and
  - root mean squared error
  - movement offset
  - movement error
  - number of significant changes in heading
- Isometric = faster and fewer forward driving errors
- Conventional = slower and fewer reverse driving errors

Isometric Joystick in CP

- Repeated-measures design
- N = 34 participants with CP and controls - matched by age and sex
- Isometric joystick vs. conventional joystick
- CP = lower driving performance in most variables of interest compared with controls.
- Isometric = fewer performance errors but prolonged reaction time.

Variable Compliance Joystick in Multiple Sclerosis

- Variable compliance joystick (VCJ) vs conventional joystick
- Fatigue algorithms applied
- N = 11 MS
- VCJ with fatigue algorithms = better performance
GAMECycle™

- An upper-body exercise machine for wheelchair users that incorporates handcycling with video game play

- Compatible with Nintendo GameCube™ games controlled with speed and steering

- Useful for exercise testing in SCI

Gamecycle in Spina Bifida

- N = 19 Spina Bifida
  - Most sedentary at baseline
- GameCycle vs standard ergometer
- 16 week exercise program
- No differences
  - Time spent exercising
  - # sessions attended
- Significant differences
  - Miles traveled
    - 15 miles w Gamecycle
    - 1 mile w Ergometer

Virtual Reality Simulator (VRSIM)

Real HERL

Virtual HERL
VRSIM Studies

- 2 trials, within-subjects repeated measures design
- N = 10 and N = 21 wheelchair users

- Course = Power Mobility Road Test (PMRT)
- NASA-TLX and Task Load Index

- Computer screen vs VR screens vs real driving
- Instrumented rollers vs conventional joystick

- Quantitative metrics from the simulator
- Observation scores from two experienced clinicians
Psychometrics

• Virtual vs observed PMRT scores –
  • high inter-rater reliability (78-90%)
  • high intra-rater reliability (71-90%)
• Moderate stability (ICC = .50 - .75)
  – PMRT scores (P<.001)
  – self-reported performance scores (P<.001)
• Computer screen and “roller off” mode easiest for participants
• VR and “roller off” perceived as somewhat different than real driving
  – mental demand (P=.007)
  – frustration (P=.007)
Motion Capture
Quantifying Driving

- Time
- Velocity
- Acceleration
- Jerk
- Collisions
- Time in periphery
- RMSE
**Power Mobility Clinical Driving Assessment (PMCDA)**

<table>
<thead>
<tr>
<th>Indoor</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drives forward (15 ft) in a straight line in 36” hallway</td>
<td>1–3</td>
</tr>
<tr>
<td>Drives backward 10 ft in a straight line in 36” hallway</td>
<td>1–3</td>
</tr>
<tr>
<td>Passes through 36” doorway</td>
<td>1–3</td>
</tr>
<tr>
<td>Avoids therapy balls approaching from left and right</td>
<td>1–3</td>
</tr>
<tr>
<td>Turns 90° while moving forward</td>
<td>1–3</td>
</tr>
<tr>
<td>Turns 90° and enters a doorway</td>
<td>1–3</td>
</tr>
<tr>
<td>Turns 90° while moving backward</td>
<td>1–3</td>
</tr>
<tr>
<td>Turns 180° in place to the left</td>
<td>1–3</td>
</tr>
<tr>
<td>Can safely maneuver in-between 2 chairs 32 in apart</td>
<td>1–3</td>
</tr>
<tr>
<td>Approaches an accessible sink</td>
<td>1–3</td>
</tr>
<tr>
<td>Approaches a transfer surface (bed or chair)</td>
<td>1–3</td>
</tr>
<tr>
<td>Negotiates over 1 in door/mock threshold (piece of wood)</td>
<td>1–3</td>
</tr>
<tr>
<td>Stops on command (emergency stop)</td>
<td>1–3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outdoor</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drives forward 30 ft in 30 s</td>
<td>1–3</td>
</tr>
<tr>
<td>Drives over an unpaved surface</td>
<td>1–3</td>
</tr>
<tr>
<td>Ascends 5° incline</td>
<td>1–3</td>
</tr>
<tr>
<td>Descends 5° incline</td>
<td>1–3</td>
</tr>
<tr>
<td>Ascends 10° incline</td>
<td>1–3</td>
</tr>
<tr>
<td>Descends 10° incline</td>
<td>1–3</td>
</tr>
<tr>
<td>Crosses a street</td>
<td>1–3</td>
</tr>
<tr>
<td>Rolls 10 ft across 5° side-slope</td>
<td>1–3</td>
</tr>
<tr>
<td>Ascends an ADA curb cut</td>
<td>1–3</td>
</tr>
<tr>
<td>Descends an ADA curb cut</td>
<td>1–3</td>
</tr>
</tbody>
</table>

**Total** 23–69
Mtech Games and HERL
Wheelchair Trainer Course
Computer Assisted Rehabilitation Environment (CAREN)
MANUAL WHEELCHAIR PROPULSION STUDIES
Brain Computer Interfaces
Questions?
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