Expanding the Rehabilitation of Injured Service Members Using Immersive, Large-Scale Virtual Environments

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Human subjects participated in this study after giving their free and informed consent. This research has been conducted in compliance with all applicable federal regulations governing the protection of human subjects in research (Protocols NHRC.2011.0017, NHRC.2013.0022, and NMCSD.2011.0003).
Disclosures

• No personal disclosures

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• All persons presented within have given their expressed written consent to be filmed and/or photographed.
Today’s Presentation

• **Who we are**
  - Naval Health Research Center (NHRC)
  - Walter Reed National Military Medical Center (WRNMMC)
  - Brooke Army Medical Center, Center for the Intrepid (CFI)
  - National Intrepid Center of Excellence (NICoE)

• **What we do**
  - Who we serve
  - Clinical and research priorities
DoD VR Sites for Rehabilitation
How Are Large-Scale Virtual Environments (VEs) Used in DoD Rehab?

**Assessment and Treatment**

- **Patient-specific** (Collins et al 2015)
  - Orthopaedics, extremity trauma, and amputation
    - (Kruger, 2011; Darter & Wilken, 2011; Gates, Darter, Dingwell, & Wilken, 2012; Kaufman, Wyatt, Sessoms, & Grabiner, 2014; Sheehan, Rábago, Rylander, Dingwell, & Wilken, 2016)
  - Traumatic brain injury (TBI)
    - (Rábago & Wilken, 2011; Sessoms et al., 2015; Onakomaiya et al., 2017)
  - Vestibular dysfunction
    - (Gottshall, Sessoms, & Bartlett, 2012; Gottshall & Sessoms, 2015)

**Goal:** To optimize wounded warrior rehabilitation using physical and cognitive tasking in challenging but safe environments
NHRC’s Computer Assisted Rehabilitation Environment (CAREN)

- Optical motion capture system
- 3D video projectors (3)
- 180° curved screen
- 6-DoF motion platform
- Instrumented split-belt treadmill (high performance)
- Surround sound

(Photo courtesy of NHRC)
Goal Oriented: Patient-Specific Flexibility of Applications

(PHotos and Videos courtesy of WRNMMC)
WRNMMC: Return/Learn to Ski Program

- Objective: To return patients to civilian life/sport, specifically skiing
- Virtual environment allows:
  - Simulate complex tasks prior to real-world
  - Practice/training with adaptive equipment
- Patients completed questionnaires pre-training sessions, when on ski trip, and post-training
  - 2/3 felt ski application prepared them for the ski trip
  - All but one felt application utilized musculature that was used during actual activity
  - All stated would recommend trialing equipment and practicing on CAREN to future patients
• Tasking static and dynamic stability with novel and engaging exercises relevant to patient’s life.

• Patient with knee-ankle-foot orthosis with IDEO base (kIDEO).
Objective Measures Using Virtual Reality (VR) Componentry

- Systems can be used to record data for clinical research and outcomes
  - Stimulus response
    - Task performance (e.g. reaction time), physiologic, metabolic
  - Biomechanics
    - Joint powers, moments, kinematics
    - Balance, stability

(Photo courtesy of CFI-MPL)
Online Monitoring of Brain Activities With Mobile Electroencephalography Systems

- Application for objective, real-time assessments of how an individual experiences the environment (e.g., cognition, fatigue)

(Video courtesy of NHRC)
Multisensory Assessments

Assessing the Impact of mTBI on Multisensory Integration While Maneuvering on Foot (PI: Douglas Brungart)

(Photos courtesy of NICOE)
Novel Applications of Traditional Cognitive Tests

(Video courtesy of WRNMMC)
NICoE: Acclimation to the CAREN

Three Preliminary VEs

CAREN Performance Measures:
- Balance Balls and Balance Cubes = time spent (s)
- Continuous Road = self-selected speed (m/s)

Photos courtesy of NICoE
NICoE: Diminished Performance With Comorbidities

**Balance Balls**
- **Diagnosis**
  - TBI Only
  - Comorbid PH
- **Time (s)**
  - $n = 63$
  - $n = 147$
- **$p = 0.001$**

**Continuous Road**
- **Diagnosis**
  - TBI Only
  - Comorbid PH
- **Speed (m/s)**
  - $n = 53$
  - $n = 121$
- **$p = 0.018$**

**Balance Cubes - Static**
- **Diagnosis**
  - TBI Only
  - Comorbid PH
- **Time (s)**
  - $n = 62$
  - $n = 147$
- **$p = 0.002$**

**Balance Cubes - With Platform Motion**
- **Diagnosis**
  - TBI Only
  - Comorbid PH
- **Time (s)**
  - $n = 57$
  - $n = 120$
- **$p < 0.001$**
WRNMMC: Real-Time Biofeedback

Gait Retraining for Asymmetrical Limb Loading

Traditional Direct

Direct “Game”

Indirect “Game”

(Photos and video courtesy of WRNMMC)
Purpose: To determine the effectiveness of vestibular physical therapy using large-scale VR compared with traditional therapy for patients with mild TBI (mTBI)

3 Subject Groups: 13 in each group
- VR based therapy, twice weekly
- Traditional vestibular physical therapy, twice weekly
- Hybrid therapy (one session VR, one session traditional weekly)

6 weeks of therapy, 12 visits total
NHRC: Effectiveness of VPT Using Large-Scale VR

(Video courtesy of NHRC)
NHRC: Effectiveness of VPT Using Large-Scale VR

Compare clinical outcomes of the 3 different groups
• Sensory Organization Test (SOT)
• Activities-specific Balance Confidence Scale
• Dizziness Handicap Inventory
• Functional Gait Assessment (FGA)
• Measures were taken at 3 time points, pre- (T1), mid- (T2), and post-therapy (T3)
NHRC: Vestibular Therapy
Computerized Dynamic Posturography Sensory Organization Test (SOT) Scores

(Photo courtesy of NHRC)
NHRC: Vestibular Therapy

Self-Selected Walking Speed on CAREN

(Sessoms et al., 2015)
CFI: Clinical Application for Return to Duty

CASE STUDIES

Application of a Mild Traumatic Brain Injury Rehabilitation Program in a Virtual Reality Environment: A Case Study

Christopher A. Rabago, PT, PhD, and Jason M. Wilken, PT, PhD

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• Active duty Army driver/gunner
• Unit was to deploy
• Persistent postconcussive symptoms (so patient was non-deployable)
• Unresolved with time, medications, or conventional rehabilitation
Assessment (Pre-Tx)  Re-assessment (Post-Tx)

Ecological Validity

Methods, materials, tasks, and settings of VR applications best approximate the real-world – integration to return to duty

(Video courtesy of NHRC)
Ecological Validity

Methods, materials, tasks, and settings of VR applications best approximate the real-world – integration back into the community

(Video courtesy of WRNMMC)
Ecological Validity

Methods, materials, tasks, and settings of VR applications best approximate the real-world – integration back into the community.
Current/Future Research

Psychological health dual treatment program (PI: Pinata Sessoms)

Dual treatment incorporating:
- Motion-Assisted, Multi-Modal Memory Desensitization and Reconsolidation (3MDR)
- Cognitive behavioral therapy for insomnia (CBT-I)

(Video courtesy of NHRC)
When Do We Use Immersive VR Environments?

• As a BRIDGE between the clinic and returning a patient to real-world activities
• To provide a TREATMENT environment that expands from traditional clinic capabilities
• To ASSESS: Allows for a controlled, measurable, repeatable environment to address all aspects of engaging in the complexity of daily activities and activities that can not be replicated in conventional clinical settings
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