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Overview of CAREN Research

State of the Science Symposium: Virtual Reality and Its Role in Wounded Warrior and Veteran Care

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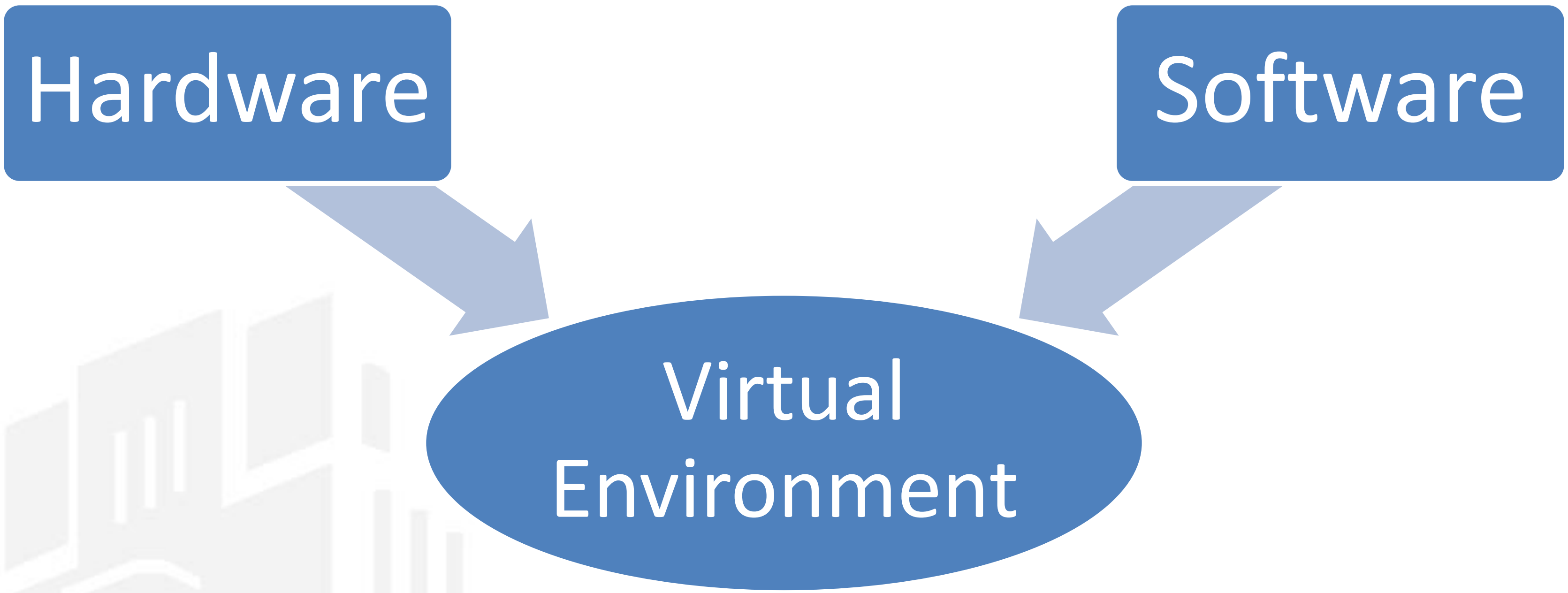
What is CAREN

- **C**omputer **A**ssisted **R**ehabilitation **En**vironment



- Rehabilitation Modality
- Research

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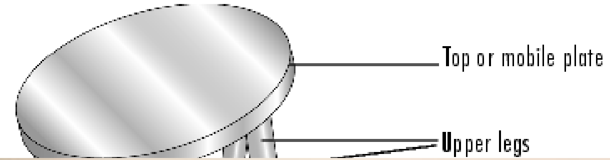
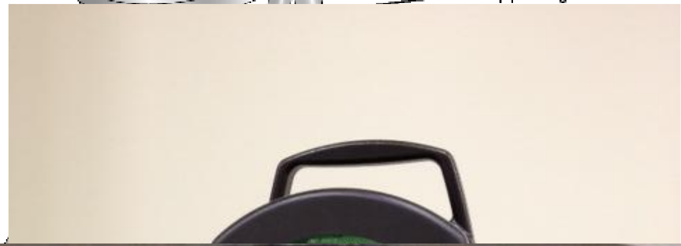
What is CAREN

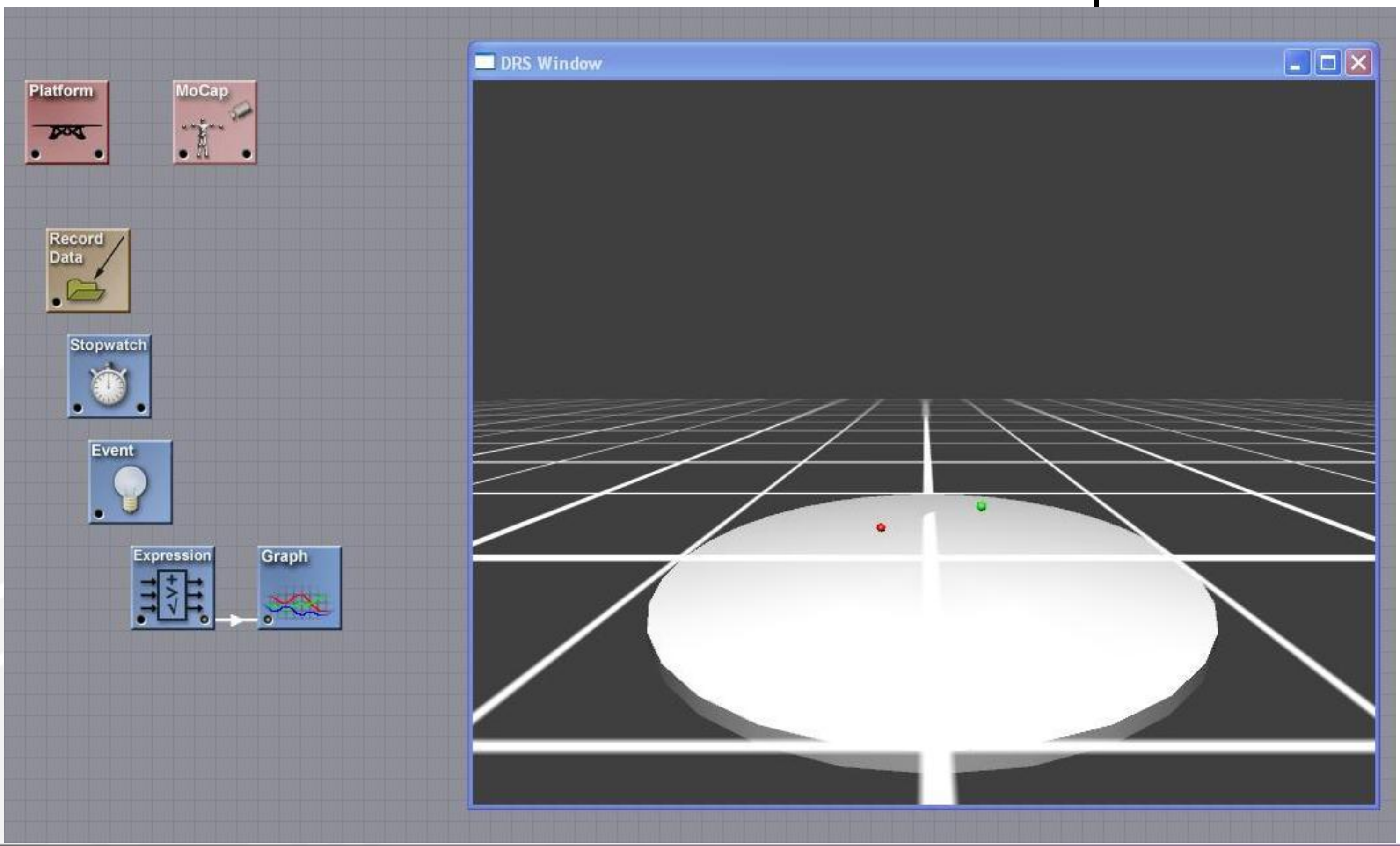
- Hardware
  - Motion Base – Stewart Platform
    - 6 Degrees of Freedom
    - X, Y, and Z translation
    - Roll, Pitch, and Yaw Rotation
  - Motion Capture System
  - Instrumented Treadmill
  - Projection System
  - Safety Harness





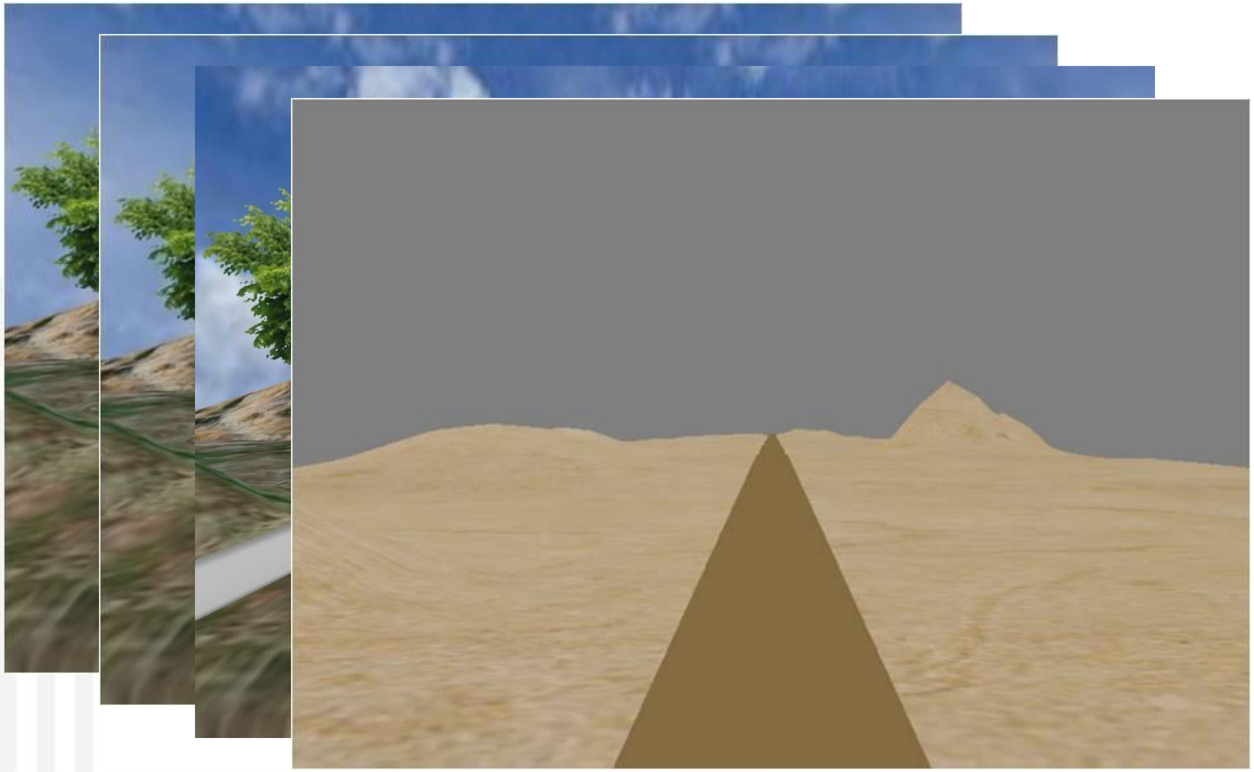
What is CAREN

- Software
  - D-Flow software links and controls components



Participant Interaction

- Safety
  - Realistic Environments in a "Clinical Setting"
- Flexibility



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MOTEK

- GRAIL (Gait Real-Time Analysis Interactive Laboratory)
  - Evaluates treadmill gait and outputs real-time kinematics and kinetics
- STABLE (Stability and Balance Learning Environment)
  - Assessment and training of balance disorders in a virtual environment
- Human Body Model
  - Uses inverse dynamics to estimate muscle forces and visualize them in a virtual environment in real-time

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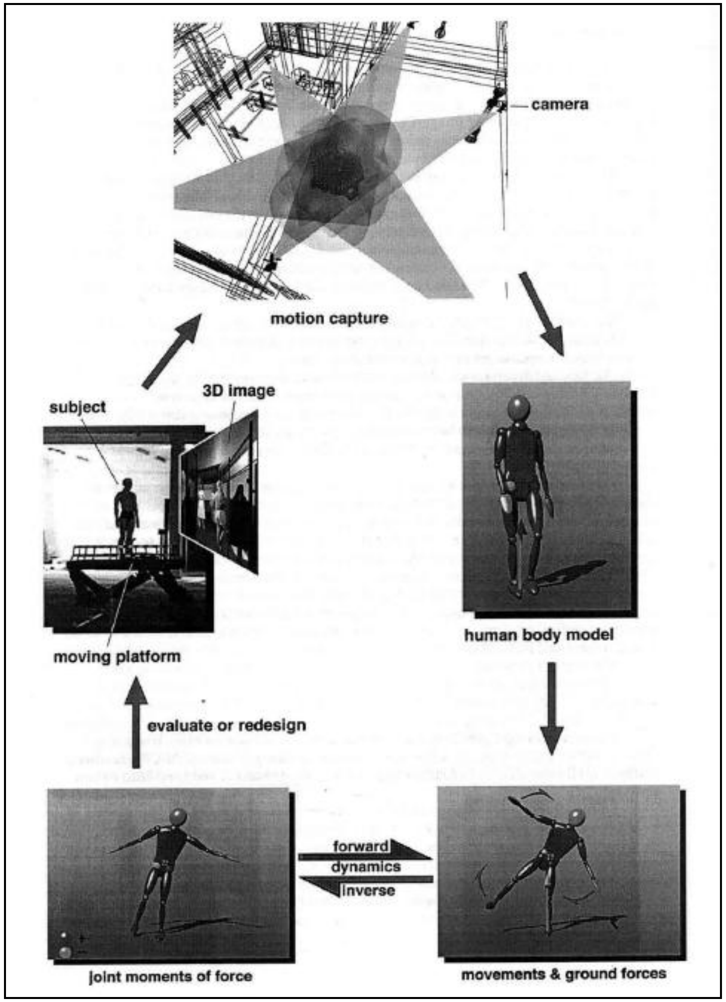
Research Populations

- Uninjured
- Lower Extremity Trauma
- Stroke
- Spinal Cord Injury
- Orthopedic Injury
- Traumatic Brain Injury
- Post Traumatic Stress Disorder
- Vestibular Injury
- Visual Impairment

CAREN Development

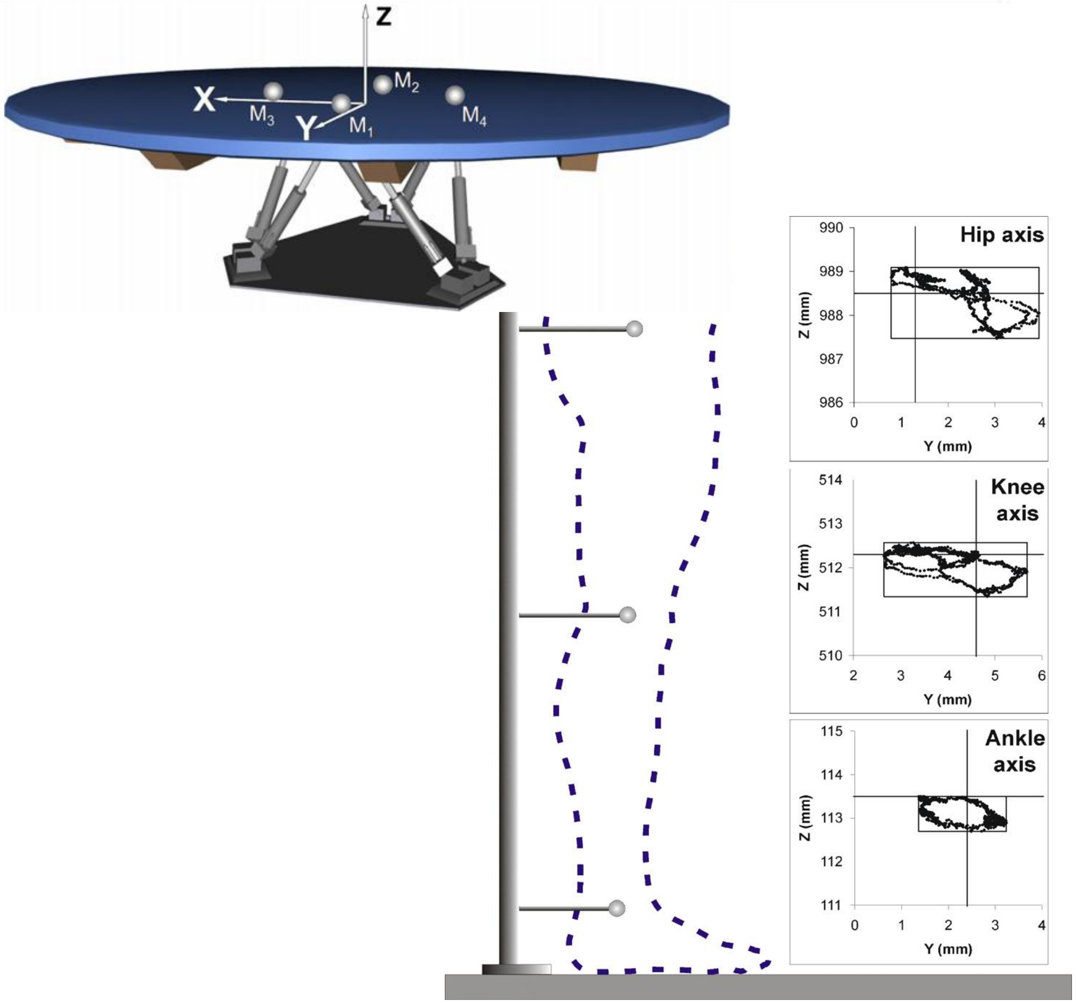
- 1999 – Paper published describing the Computer Assisted Rehabilitation Environment
  - Describes how the platform is controlled and how the patient interacts with the device



WJ van der Eerden et al, CAREN-Computer Assisted Rehabilitation Environment, Student Health Technology Information, Vol. 62, pgs 373-378, 1999

CAREN Development

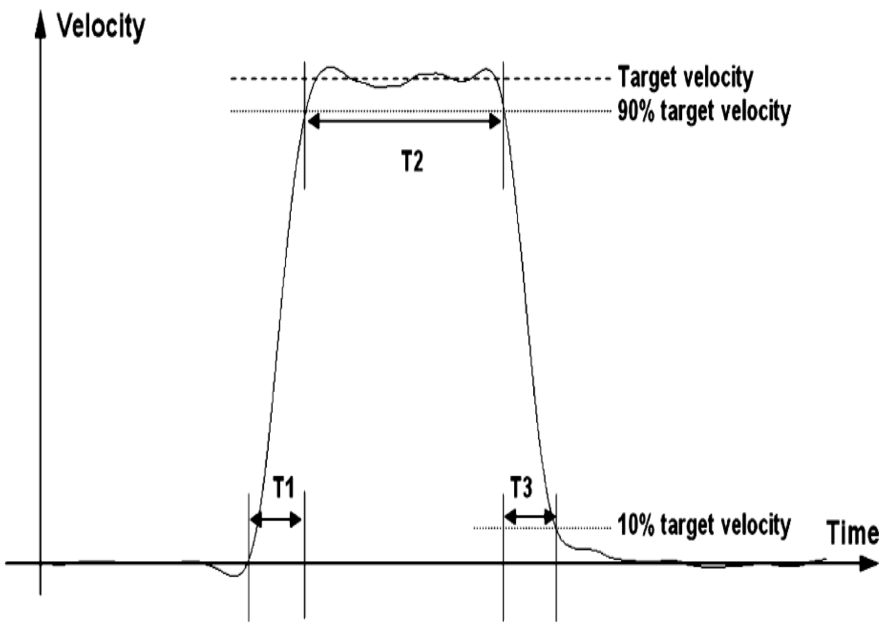
- Barton et al (2006) evaluated device control with respect to other similar platforms
  - Manipulated the axes of rotation of the device
  - Flexible system with regard to creating rotations around various axes



G Barton et al, A Method for Manipulating a Movable Platform's Axes of Rotation: A Novel Use of the CAREN System, Gait & Posture, Vol. 24, pgs. 510-514, 2006

CAREN Development

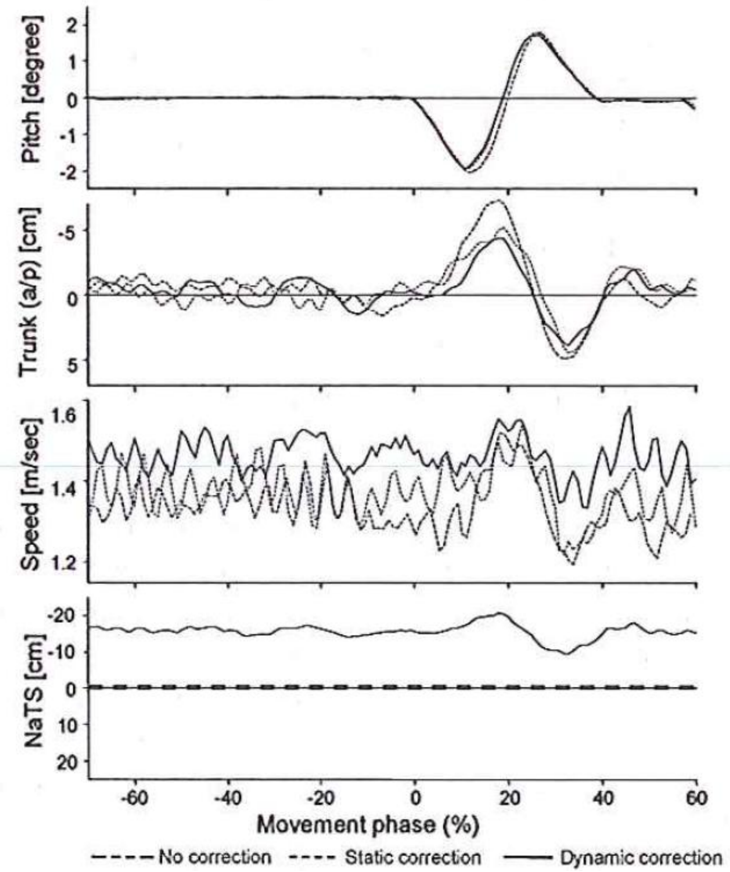
- Lees et al (2007) continued to explore the kinematic characteristics of the device
  - Created technical specifications for use with research or clinical protocols
  - Showed that the device was exceptionally well suited for multiple degree-of-freedom perturbations



A Lees et al, Kinematic Response Characteristics of the CAREN Moving Platform System for Use in Posture and Balance Research, Medical Engineering and Physics, Vol. 29, pgs 629-635, 2007

CAREN Development

- Makssoud et al (2009) explored the patient interaction with the virtual environment a
  - Created and implemented dynamic rotation corrections
  - Single subject testing showed improved trunk dynamics and less variable speed



H Makssoud, Dynamic Control of a Moving Platform using the CAREN System to Optimize Walking in Virtual Reality Environments, 31st Annual International Conference of the IEEE Engineering in Medicine & Biology Society, Minneapolis, MN, September 2-6, 2009

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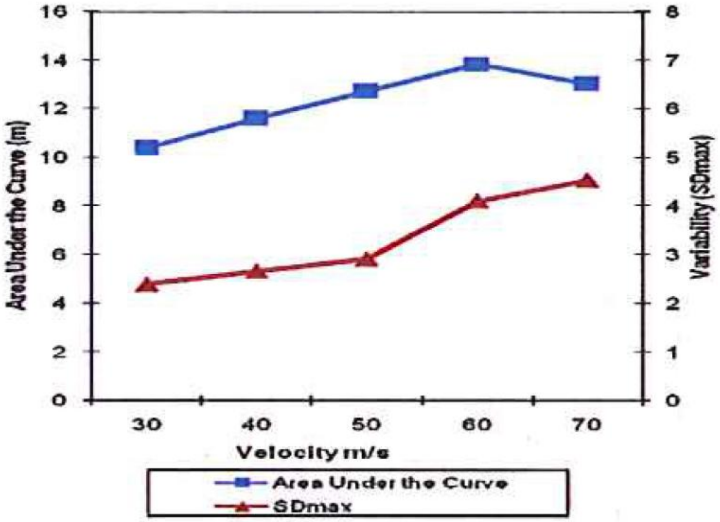
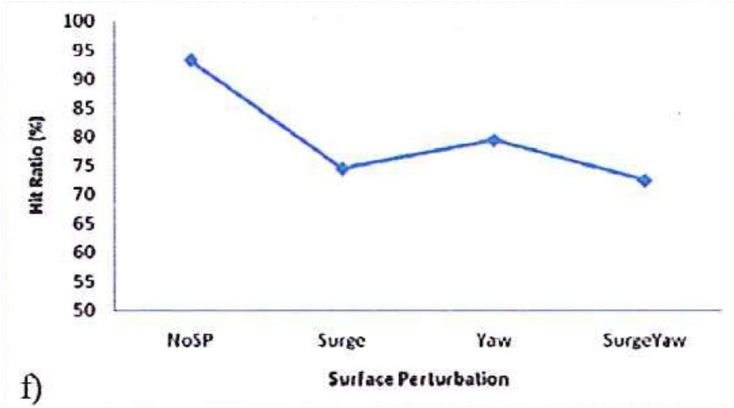
Uninjured Testing

- Hawkins et al (2008) examined the effects of game speed and surface perturbation
  - Increased game speed and perturbation led to decreased performance
  - Concluded that adaptability of the CAREN would make it a good rehabilitation tool





P Hawkins et al, Effect of Game Speed and Surface Perturbations on Postural Control in a Virtual Environment, Proceedings of the 7th ICDVRAT, Maia, Portugal, 2008

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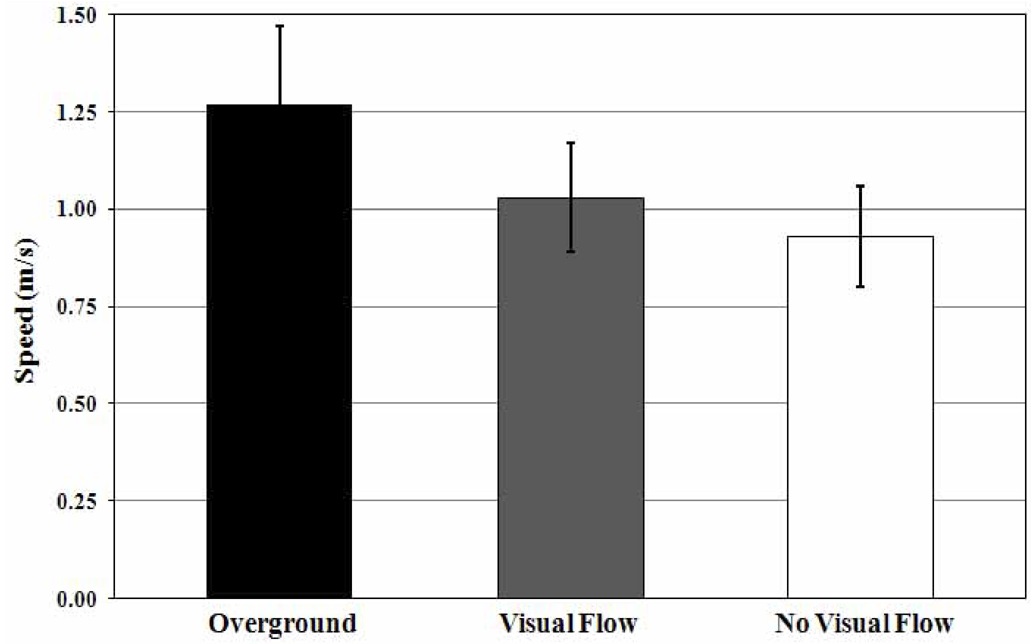
Uninjured Testing

- Bartlett and Sessoms (2012) showed that optic flow contributed to walking speeds closer to that of overground



J Bartlett and P Sessoms, Preferred Walking Speed in a Virtual Environment, 36th Annual American Society of Biomechanics, Gainesville, Florida, August 15-18, 2012

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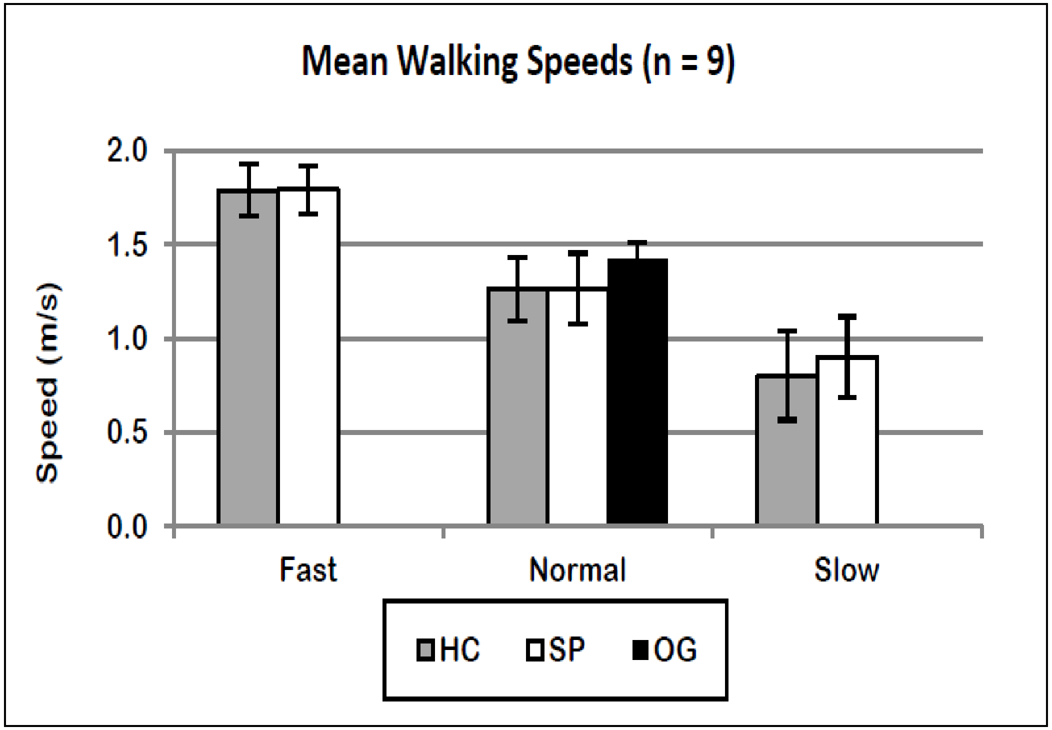
Uninjured Testing

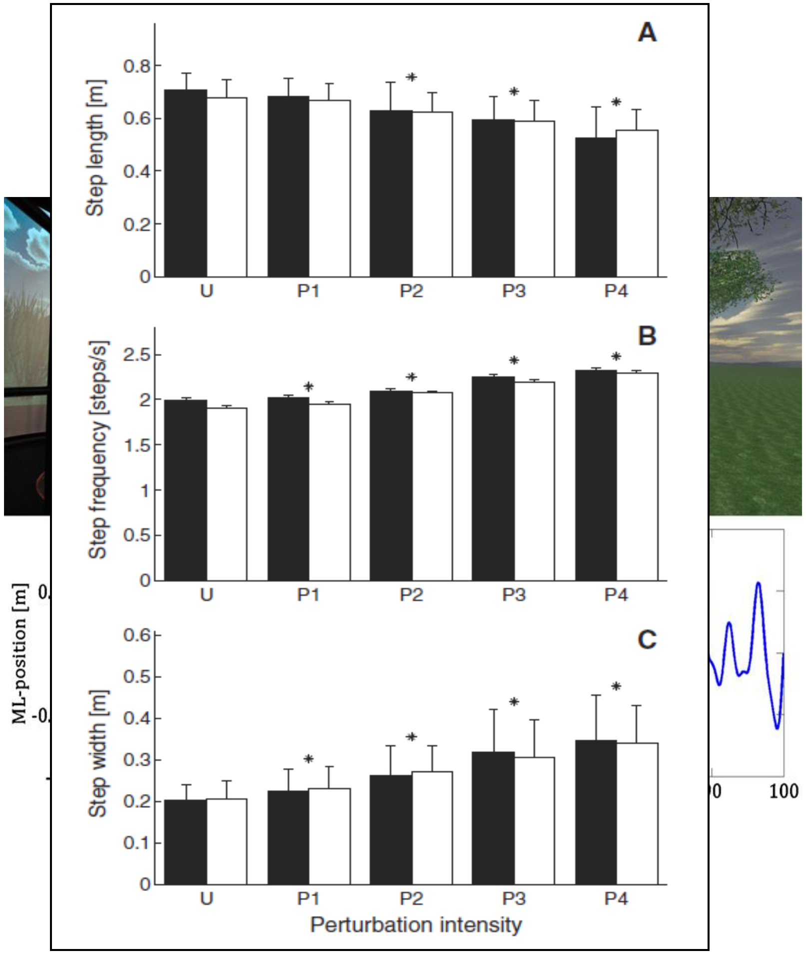
- Collins et al (2012) showed that patient controlled treadmill speed was no different than feedback controlled speed



J Collins et al, Walking Speed Overground and on a Feedback-Controlled Treadmill, 36th Annual American Society of Biomechanics, Gainesville, Florida, August 15-18, 2012

Uninjured Testing

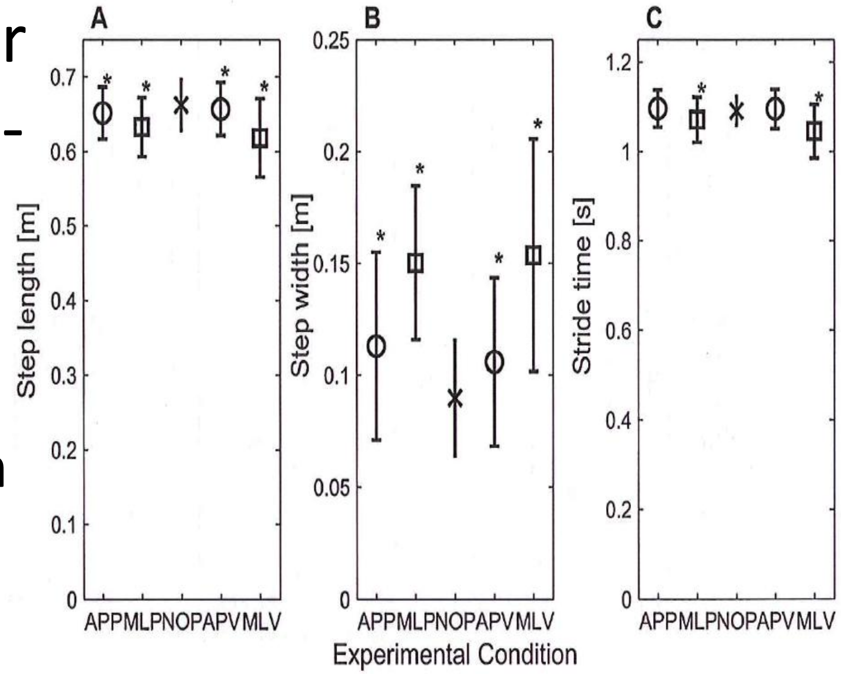
- Hak et al (2012) disturbed participants with quasi-random perturbations in the medio-lateral direction
  - No change in speed
  - Decreased step length
  - Increased step frequency and step width



L Hak et al, Speeding Up or Slowing Down? Gait Adaptations to Preserve Gait Stability in Response to Balance Perturbations, Gait & Posture, Vol. 36, pgs 260-264, 2012

Uninjured Testing

- McAndrew et al (2010) applied continuous oscillations of either the walking surface or the visual field in the medio-lateral (ML) and antero-posterior (AP) directions
  - Decreased step length and increased step width for both directions
  - Decreased step length and increased step width for both ML versus AP



P McAndrew et al, Walking Variability during Continuous Pseudorandom Oscillations of the Support Surface and Visual Field, Journal of Biomechanics, Vol. 43(8), pgs 1470-1475, 2010

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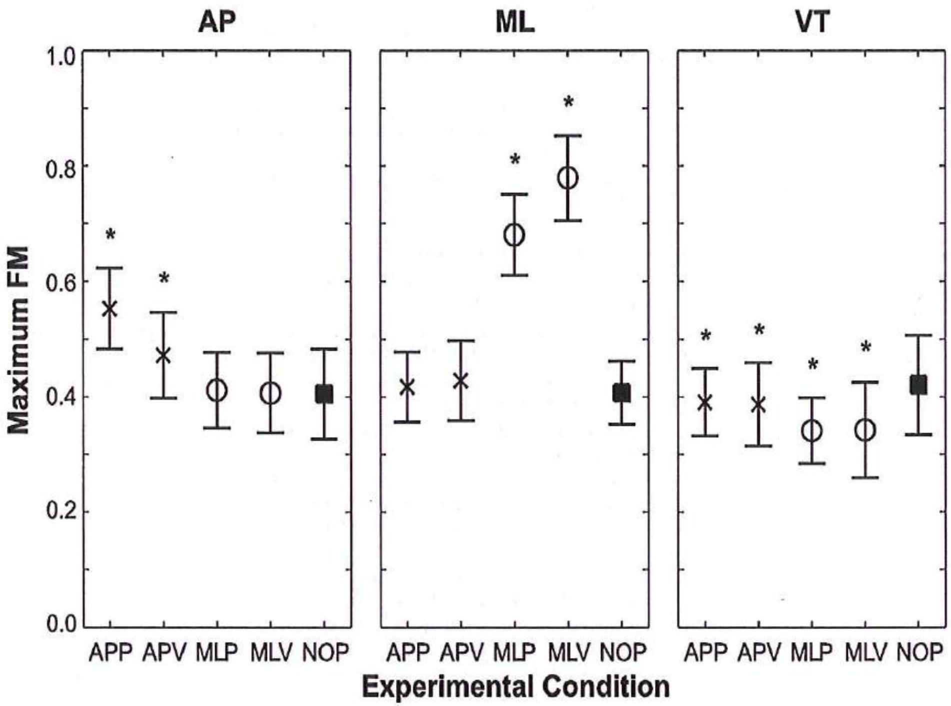
Uninjured Testing

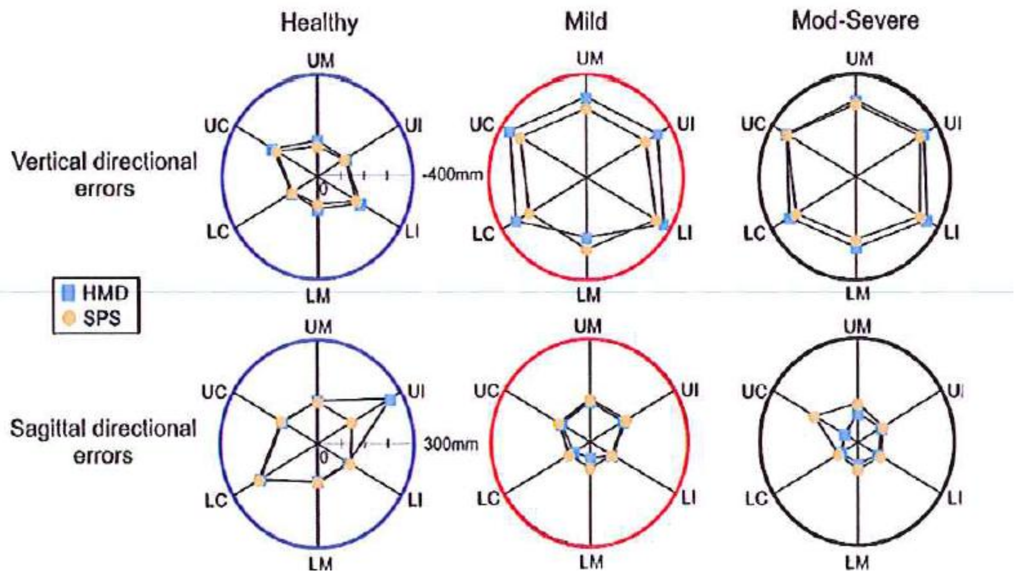
- McAndrew et al (2011) used the same methodology to evaluate stability using Floquet Multipliers
  - AP direction displayed greater instability from platform motion
  - ML direction displayed greater instability from visual field motion



P McAndrew et al, Dynamic Stability of Human Walking in Visually and Mechanically Destabilizing Environments, Journal of Biomechanics, Vol. 44(4), pgs 644-649, 2011

Stroke

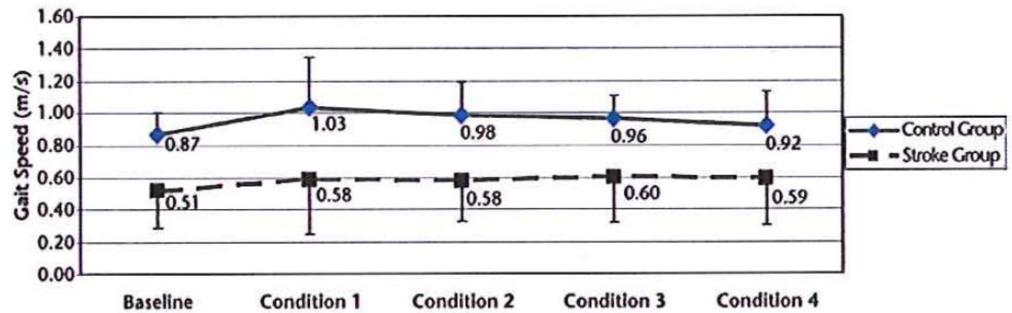
- Subramanian and Levin (2011) compared a reaching task in patients with stroke
  - Head mounted display (HMD) versus CAREN
  - No difference in trajectory straightness or shoulder kinematics

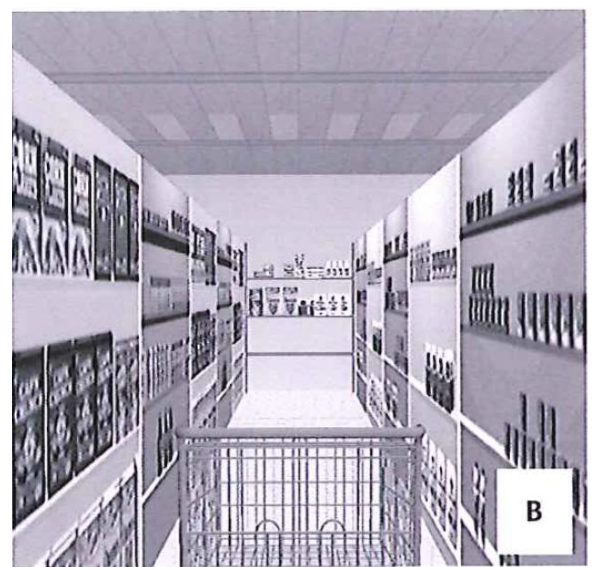


S Subramanian and M Levin, Viewing Medium Affects Arm Motor Performance in 3D Virtual Environments, Journal of Neuroengineering and Rehabilitation, Vol. 8, pgs 36-44, 2011

Stroke

- Kizony et al (2010) looked at self paced walking while performing a shopping task
  - Stroke group increased walking speed, uninjured decreased
  - Coping strategies were variable but participants were able to complete tasks with minimal mistakes





Kizony et al, Cognitive Load and Dual-Task Performance During Locomotion Post-Stroke: A Feasibility Study Using a Functional Virtual Environment, Physical Therapy, Vol. 90(2), pgs 252-260, 2010

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Traumatic Brain Injury

- Gottshall et al (2012) utilized CAREN in lieu of standard therapy for patients with mild TBI
  - Patients showed improvements in balance, gait, and visual measures after 6 weeks of training

K Gottshall et al, Vestibular Physical Therapy Intervention: Utilizing a Computer Assisted Rehabilitation Environment in lieu of Traditional Physical Therapy, 34th Annual International Conference of the IEEE Engineering in Medicine & Biology Society, San Diego, CA August 28 – September 1, 2012

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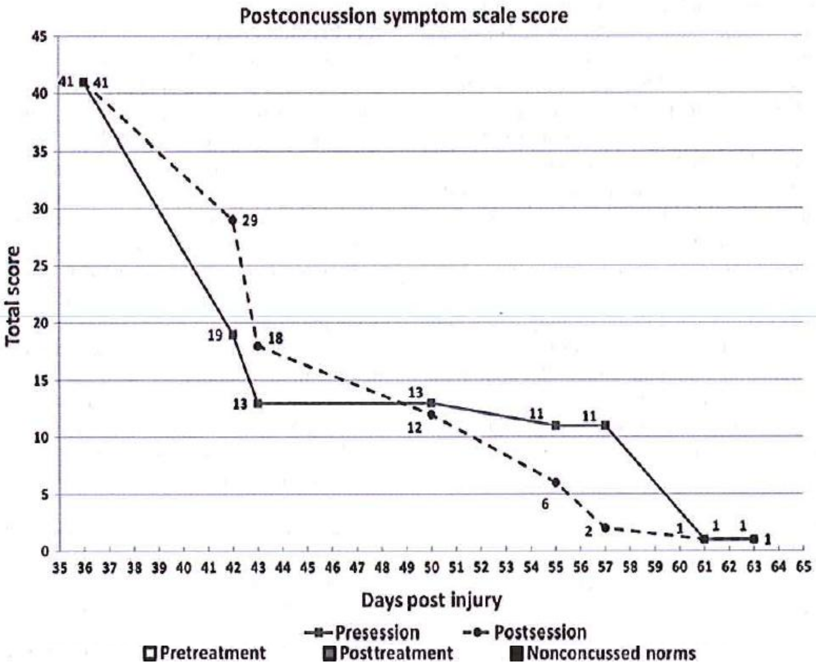
Traumatic Brain Injury

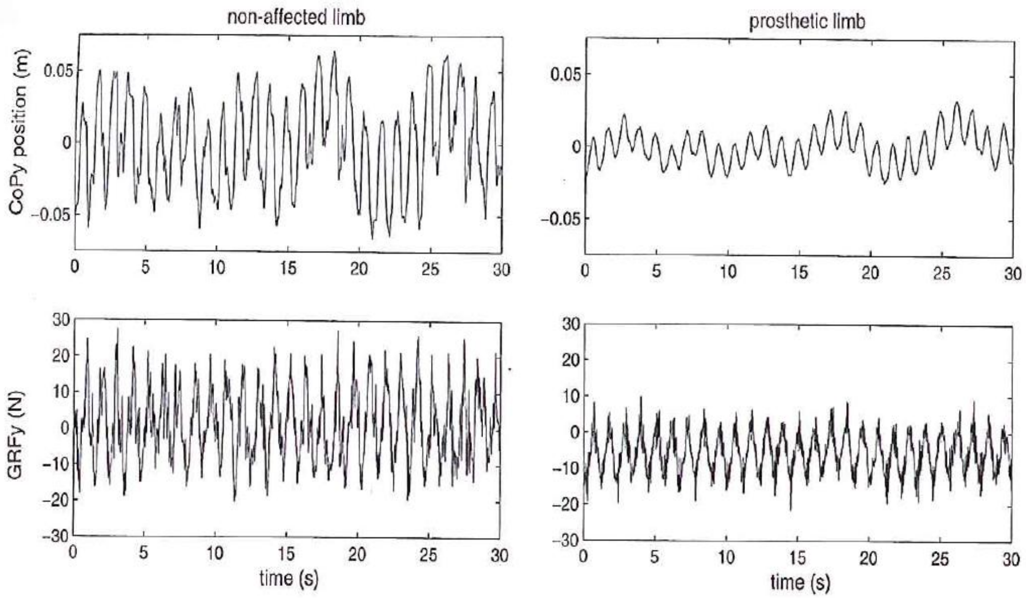
- Rabago and Wilken (2011) conducted a case study of a patient with mild TBI
  - Immersion therapy within the CAREN showed improvement in gait and balance



C Rabago and J Wilken, Application of a Mild Traumatic Brain Injury Rehabilitation Program in a Virtual Reality Environment: A Case Study, Journal of Neurologic Physical Therapy, Vol. 35, pgs 185-193, 2011

Lower Extremity Injury

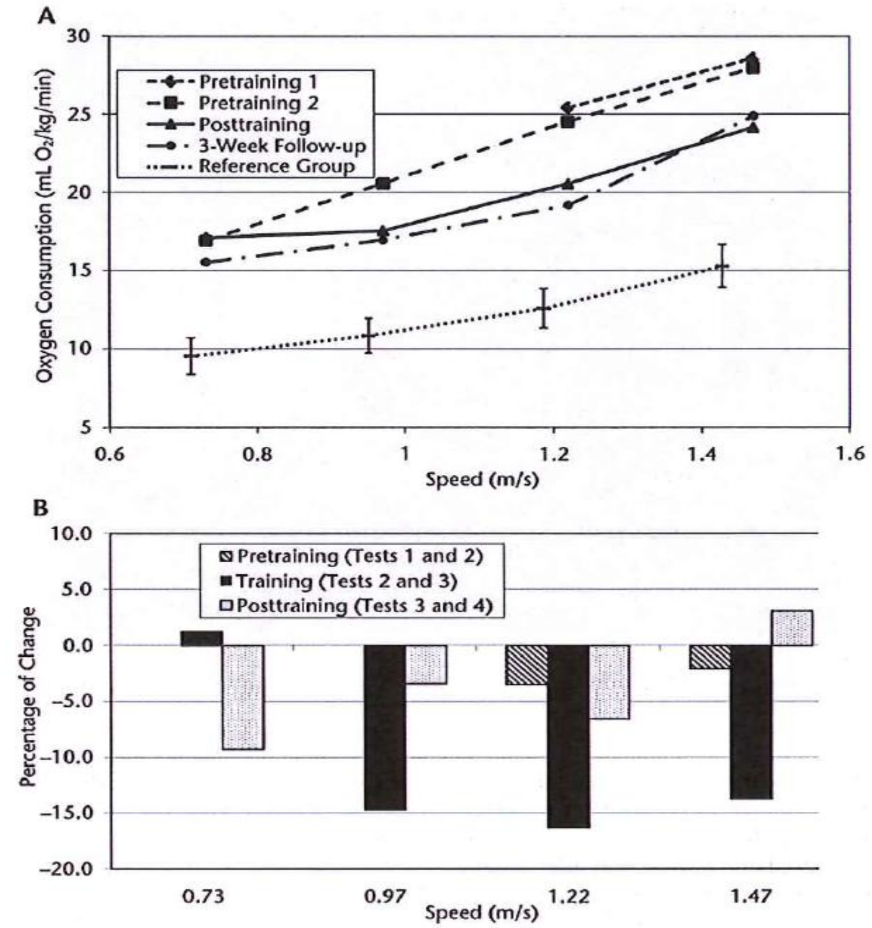
- Vrieling et al (2008) examined standing balance on subjects with unilateral transtibial amputation
  - Adjustments in response to AP oscillations occurred in the intact limb



A Vrieling et al, Balance Control on a Moving Platform in Unilateral Lower Limb Amputees, Gait & Posture, Vol. 28, pgs. 222-228, 2008

Lower Extremity Injury

- Darter and Wilken (2011) conducted a case study on a patient with unilateral transfemoral amputation
  - 12 CAREN sessions with real-time visual feedback
  - Decreased pelvic and trunk motion
  - Decreased oxygen consumption by 23%



B Darter and J Wilken, Gait Training with Virtual Reality-Based Real-Time Feedback: Improving Gait Performance Following Transfemoral Amputation, Physical Therapy, Vol. 91, pgs 1385-1394, 2011

Lower Extremity Injury

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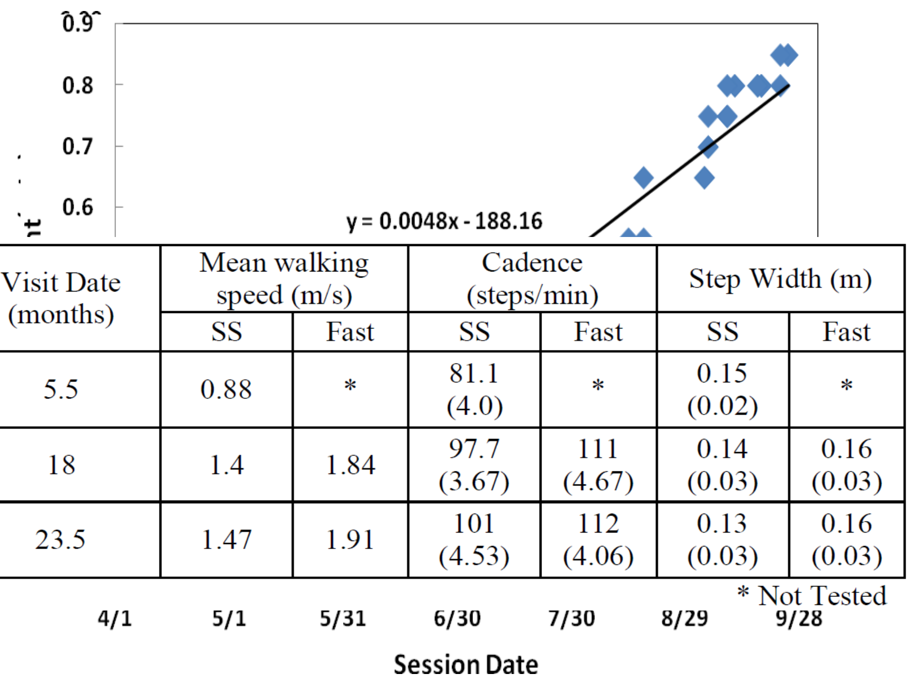
- Kruger et al (2009) looked at a single patient with bilateral amputation
  - Participated in CAREN for 6 months
  - Performance improved even with increased difficulty
  - Walking speed and cadence increased
  - Step width decreased



Visit Date (months)	Mean walking speed (m/s)		Cadence (steps/min)		Step Width (m)	
	SS	Fast	SS	Fast	SS	Fast
5.5	0.88	*	81.1 (4.0)	*	0.15 (0.02)	*
18	1.4	1.84	97.7 (3.67)	111 (4.67)	0.14 (0.03)	0.16 (0.03)
23.5	1.47	1.91	101 (4.53)	112 (4.06)	0.13 (0.03)	0.16 (0.03)

* Not Tested

S Kruger et al, Virtual reality enhanced rehabilitation for a service member with bilateral lower extremity amputations: A case study, International Conference Virtual Rehabilitation, Haifa, Israel, 2009

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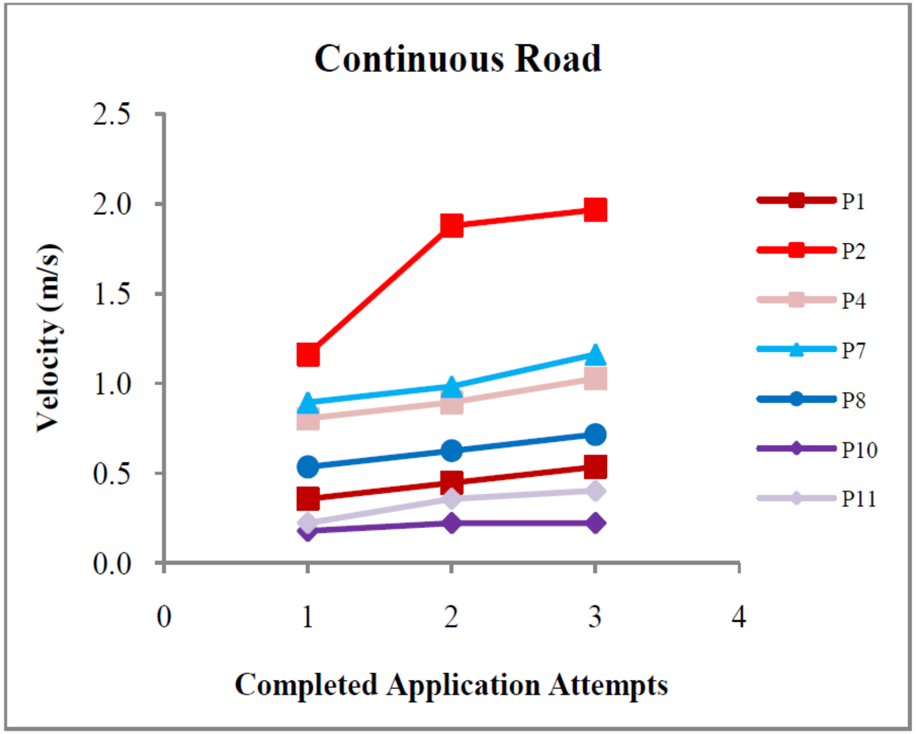
Lower Extremity Injury

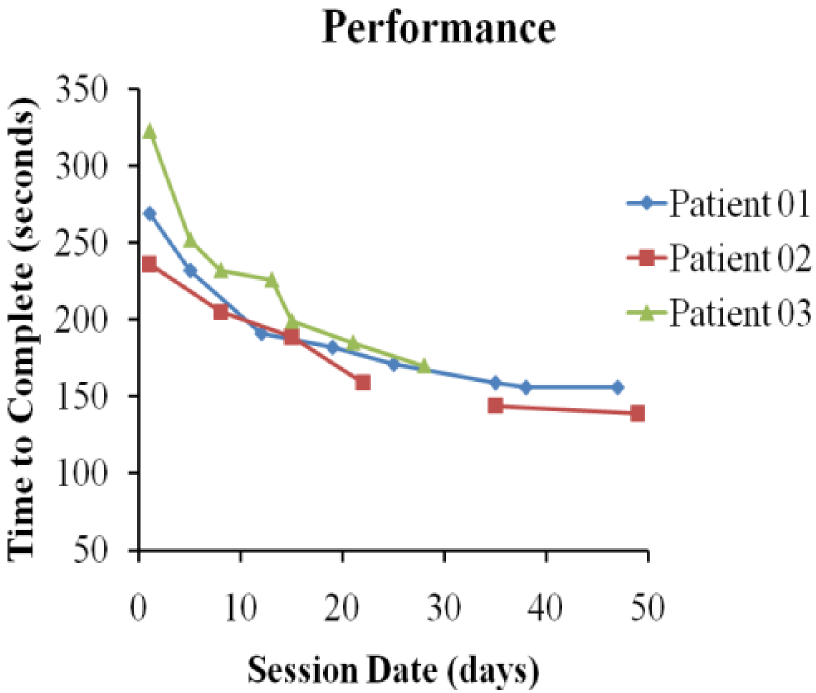
- Kruger (2010) examined patients with varying injury levels
  - Ranged from unilateral transtibial to bilateral transfemoral
  - 7/11 performed 3 consecutive attempts of a walking application in their first session
  - All patients improved in walking speed over 3 attempts



S Kruger, Virtual reality approach to gait training in service members with lower extremity amputations, Proceedings of the 8th International Conference on Disability, Virtual Reality and Associated Technologies, Viña del Mar/Valparaíso, Chile, August 31 – September 2, 2010

Lower Extremity Injury

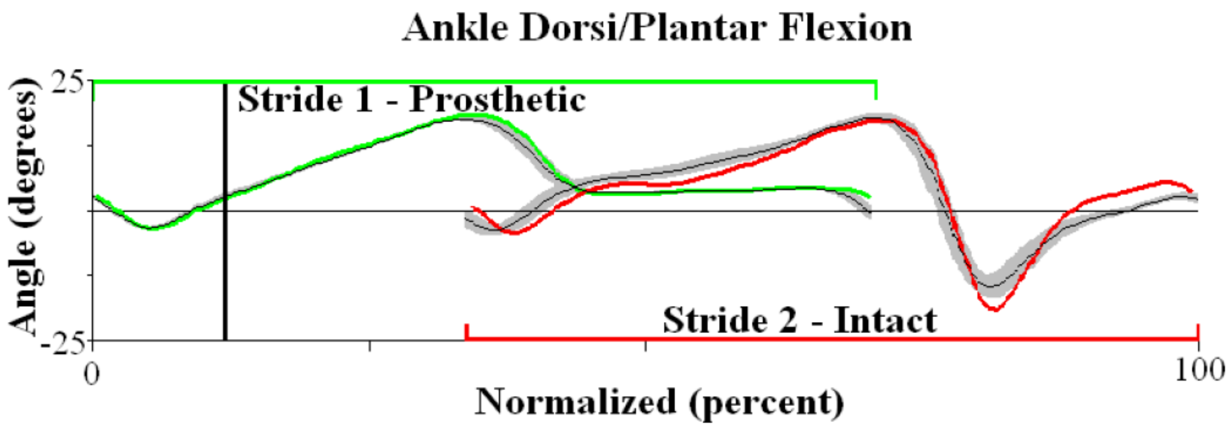
- Everding and Kruger (2011) explored improvement over time for patients with varying injury levels
  - All 3 patients improved their times on a dynamic balance application over time



V Everding and S Kruger. Virtual reality enhanced balance training for Service Members with amputations. International Conference on Virtual Rehabilitation, Zurich, Switzerland, 2011

Lower Extremity Injury

- Werner et al (2012) applied lateral perturbations to subjects with unilateral transfemoral (TFA) amputation during gait
  - Control participants made minor adjustments to recover
  - TFA made very little adjustment with the prosthetic limb and relied on their intact limb to recover



K Werner et al, Balance Recovery Kinematics after a Lateral Perturbation in Patients with Transfemoral Amputations. Platform Presentation, 36th Annual American Society of Biomechanics, Gainesville, Florida, August 15-18, 2012

Lower Extremity Injury

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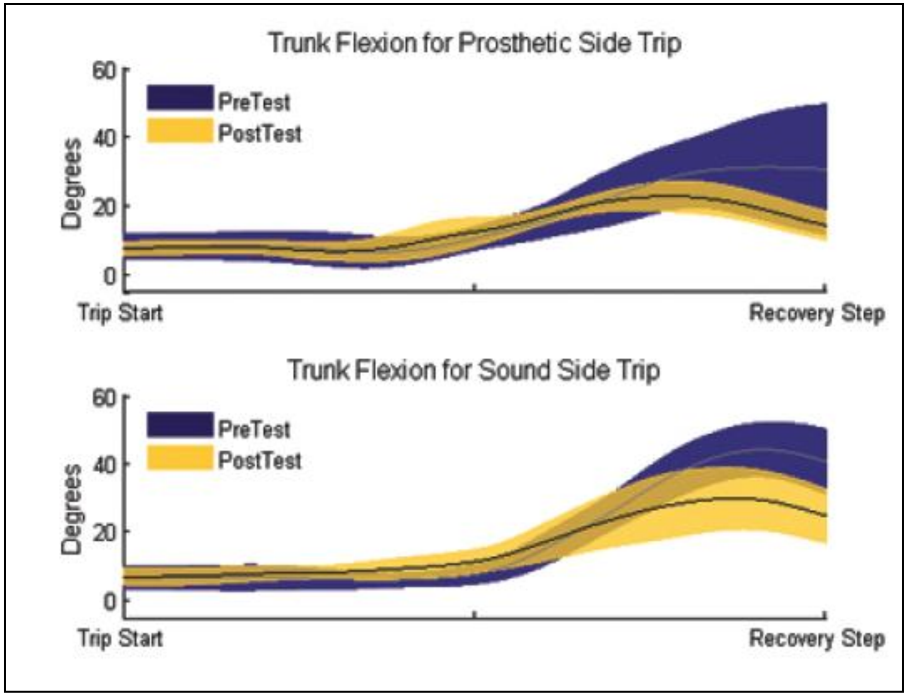
- Wyatt et al (2012) implemented a training intervention to reduce falls
  - Used CAREN to evaluate biomechanical response to trip
  - Decreased trunk flexion angles and velocities indicating improved ability to recover from a trip



M Wyatt et al, Effectiveness of a Fall-Prevention Training Program for Persons with Lower Extremity Amputations: Initial Results, 21st Meeting of the European Society of Movement Analysis for Adults and Children, Stockholm Sweden, September 10-15, 2012

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Limitations of CAREN Research

- Consistency between systems
- Translation and implementation of research findings to the clinical setting
  - Wii
  - Kinect
  - Neurocom
  - vGait
- Has CAREN been validated as a research tool?

Future Research

- More realistic environments
  - 3 dimensional worlds
- 2 dimensional treadmill
  - Would allow for complete freedom of movement in a virtual environment
- Integration of other technology
  - Brain interface
  - Olfactory sensation
- ????

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References

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2. G Barton et al, A Method for Manipulating a Movable Platform's Axes of Rotation: A Novel Use of the CAREN System, Gait & Posture, Vol. 24, pgs. 510-514, 2006
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Acknowledgements

- WRNMMC
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- NHRC

- Questions???