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TITLE: PTSD in Limb Trauma and Recovery

PRINCIPAL INVESTIGATOR: Dr. Susan E. D'Andrea
                                  Dr. Tracie Shea

CONTRACTING ORGANIZATION:  Brown University in Providence in State
                                          Providence, RI  02912

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Abstract on next page.

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## 14. ABSTRACT

This grant consists of three projects, each with its own investigative team, as described below. **Program 1**: "Establishing the Parameters of Virtual Reality Environments in the Treatment of PTSD" (Tracie Shea, Ph.D. lead investigator). This project has obtained local IRB approval and pre-approval from the DoD. Hardware has been tested and validated and subject recruitment will begin with DoD HRPO approval. **Program 2**: "Framework for Comparison of Display Technologies as Routes of VR Exposure" (Samuel Fulcomer, Lead Investigator). This project is studying the usage of the Virtual Iraq scenario to run on advanced multi-panel displays and the development of new display technology. These studies are concentrating on the technical adaptation of the current scenarios designed for head mounted displays to more high fidelity advanced display techniques. Solution of these technical difficulties will make this display technology suitable for a variety of VA, DoD, and civilian environments. **Program 3A:** "Identifying Clinically Meaningful Improvement in Rehabilitation of Lower-Limb Amputees" (Linda Resnik, Ph.D., P.T., O.C.T, Lead Investigator). These studies have the goal of generating data to guide selection and interpretation of outcome instruments for lower limb amputees. Results showed that self-report measures have reliability coefficients comparable to those reported by instrument developers and that the 0-7 point numerical scoring system for the PEQ combined mobility scale will have good to excellent reliability. A manuscript has been submitted for publication. **Program 3B**: "Analysis of Gait Mechanics of Amputees Using a New Lower Limb Prosthesis" (Susan D'Andrea, Ph.D.). The gait lab has been established in a new facility and is being used to quantify human motion in a variety of research projects. **Program 4:** "Virtual reality and Motion Analysis to Characterize Disabilities in Lower Limb Injury" (Christopher Rhea, Ph.D., lead investigator). This project focuses on the use of virtual reality as a tool to assess physical function. The project will utilize information gather using VR with an emulated injury and apply similar procedures to assess patients with ACL injury to document functional mobility from injury onset through rehabilitation. Currently, local IRB approval is being sought for this project.

**15. SUBJECT TERMS**

# Table of Contents

ANNUAL REPORT 10/16/2011
VIRTUAL REALITY AND MOTION ANALYSIS TO CHARACTERIZE DISABILITIES IN
LOWER LIMB INJURY
PI: SUSAN E.D'ANDREA, Ph.D.

**Page**

## PROGRAM 1
## "ESTABLISHING THE PARAMETERS OF VIRTUAL REALITY ENVIRONMENTS IN THE TREATMENT OF PTSD"
## M. Tracie Shea, Ph.D.

### INTRODUCTION

Severity of trauma during deployment has consistently been shown to be among the strongest, if not the strongest, predictor of PTSD. Many if not most individuals experience some symptoms of PTSD after serious trauma exposure, but only some will develop PTSD. The ability to identify those at higher risk, particularly for chronic PTSD, is critical to targeting treatment and other preventive interventions. Moreover, early identification may play a significant role in reducing the need to provide intensive programs for all combat veterans. The primary objective of the current project is to evaluate the utility of a Full Spectrum Warrior, a PC software application for use with Virtual Reality (VR) technology, in the early identification of individuals at risk for PTSD and as a diagnostic tool for objective assessment of PTSD in military service personnel returning from OIF/OEF. The overall goal is to establish a dose response curve and determination of a standard combat VR challenge in 52 OEF/OIF combat veterans. Increasing doses are defined as VR exposures with more stimulus elements included. Skin conductance (SC) and heart rate variability (HRV) in response to the VR challenge in combat-exposed OIF/OEF veterans with a PTSD diagnosis will be compared to SC and HRV in combat-exposed veterans who do not have a diagnosis of PTSD on neutral, and combat-standardized VR challenges to determine the specificity of the VR challenge to PTSD. The purpose of this work derives directly from congressional mandates to improve the care and outcome for veterans with limb trauma and the common presentation of PTSD.

### BODY

Full Spectrum Warrior (FSW) is a PC software application that simulates the experience of commanding a light infantry company. It was developed through collaboration between the Institute for Creative Technologies (ICT); entertainment software companies; the U.S. Army Training and Doctrine Command (TRADOC); and the Research, Development, and Engineering Command, Simulation Technology Center (RDECOM STC). The Army's Infantry School also contributed to its design. FSW can be run on a head-mounted display (HMD) unit to create a virtual reality (VR) environment that simulates deployment scenarios.

A project coordinator (clinical psychologist) has been hired for the study and has received training in the use of the VR and psychophysiological equipment. He has also completed training in the Clinician Administered PTSD Scale, the primary outcome measure in the study. Preliminary testing of the Biopac MP 100 data acquisition system has been conducted, and programmed settings for psychophysiology data capture (i.e., heart rate and galvanic skin response parameters) have been obtained. A standardized progressive presentation of VR scene stimuli has been developed and refined, reflecting increasing doses (VR exposures with more stimulus elements included). Programming of the Full Spectrum Warrior software to automate scene presentation during administration of VR task, to ensure standardization of delivery and timing of scene presentations has been completed.

Piloting of the VR protocol for the study has been completed, with results indicating the need for equipment (i.e., retrofitting the HMD) and protocol modifications to maximize the immersive experience, increase feasibility, and reduce participant burden. In January 2011, the existing protocol for the study was revised with the current protocol including only Aim 1. This revision has received final human subjects approval from the DoD HRPO and relevant local IRBs. The previous protocol involved four separate combat scenarios administered over the course of two back-to-back days. Furthermore, the previous protocol required a 1-year post-assessment of symptoms to meet the goal of Aim 2. Results from piloting indicated that this procedure was

unnecessary to achieve the revised goals of the study. Instead, the revised protocol indicates that study participants will undergo a VR task involving only a 1-day administration lasting approximately 1.5 hours. The task now involves a series of combat scenes and a series of classroom scenes delivered consecutively and counterbalanced to account for order effects. This streamlined administration of the VR task will improve the feasibility of the study by reducing participant burden and potential participant dropout.

Recruitment efforts have commenced and are currently ongoing, with the first participant completing the finalized VR protocol on 9/21/2011. Data entry is currently in process for this initial participant.

**KEY RESEARCH ACCOMPLISHMENTS**
- Protocol modifications were conducted in January 2011 to streamline administration of the VR task and alter the scope of the study by removing Aim 2. Modifications were made to increase feasibility, reduce participant burden, and reduce potential participant dropout.
- The revised protocol for Program 1 has received full approval from the DoD and local IRBs (Brown and the Providence VA Medical Center).
- Piloting of the protocol has been completed with the administration of the Virtual Reality task to two consented OEF/OIF veterans.
- Revisions and modifications to VR and psychophysiological equipment have been completed in accordance with information obtained during piloting of VR protocol.
  o Modifications include retrofitting current Head Mounted Display (HMD) to increase immersion and sense of presence in VR environment.
  o Development of timed protocol for presentation of stimuli and data capture
- Recruitment efforts are currently in progress.
  o Study staff have presented information and distributed recruitment material at Providence VAMC clinics (i.e., Primary Care clinics, Returning Veterans clinic, etc.) and at local community OEF/OIF Task Force meetings.
  o Recruitment materials have been posted in targeted high traffic locations throughout Providence VAMC.
  o Five potential participants have indicated interest in participation and will be scheduled for assessment.
- First participant has completed protocol as of 9/21/2011. Data entry in process.

**REPORTABLE OUTCOMES**
Data entry is currently in process. We expect to complete the following remaining accomplishments:
- Complete recruitment and assessment of 52 combat-exposed OEF/OIF veterans (i.e., 26 veterans with a PTSD diagnosis and 26 veterans without a PTSD diagnosis)
- Complete implementation of VR protocol with all 52 study participants.
- Complete processing of psychophysiological and assessment data.
- Conduct data analyses to test hypotheses regarding differential responding to VR stimuli based on absence or presence of PTSD diagnosis.
- An optimal level of arousal to the VR task, or dose response curve, will be identified so as to maximize our ability to find differences between PTSD+ and PTSD- groups.

**CONCLUSIONS**
N/A. Data analysis has not yet begun.

**REFERENCES**
N/A

## PROGRAM 2:
## "FRAMEWORK FOR COMPARISON OF DISPLAY TECHNOLOGIES AS ROUTES OF VR EXPOSURE"

### INTRODUCTION

Under the original scope of work for this thrust we investigated the adaptation and implementation of the Virtual Iraq application for a large Virtual Reality (VR) display, the Cave at Brown University. While relatively uncommon, Caves (large, partially or fully enclosed VR display screen systems) are the epitome of visual VR environments, offering full visual/spatial immersion in the virtual world presented by the application. Caves also present complex display system characteristics which must be supported by a successful software application and its supporting middleware, including (typically) distributed execution on multiple host platforms, multiple synchronized display channels on non-coplanar screens, and head and gesture tracking for input to rendering and animation controls.

Two potential approaches were explored. The first involved the use of Virtual Iraq on its native Microsoft Windows and Gamebryo game engine. While this approach would require little modification to the Virtual Iraq application, it would require significant work to adapt Windows and Gamebyo to allow synchronization of the display channels. In addition, the Brown Cave is normally used with the Linux operating system, in a mode which permits disparate application development use by several research groups. Our use of Windows/Gamebryo would require reserved, dedicated time, and incur the Cave usage charges originally included in the contract budget.

The second possible approach involved the use of the Linux operating system and a rendering/animation system suitable for the Virtual Iraq environment. Unlike Windows, for Linux there is readily available low-level software for multi-channel display synchronization; however, a different rendering/animation system would have to be found which could both support the multi-channel VR display and also import the Virtual Iraq models and animation descriptions.

Ultimately, we chose the Linux platform and the XVR (eXtreme Virtual Reality) system developed by VRMedia of Italy. This eliminated the requirement for dedicated Cave time, freeing the associated funds.

Our primary scope was to investigate the adaptation of the Virtual Iraq application to advanced display technologies. In the course of our work we learned of a particularly exciting line of new consumer display technology developed to support stereographic entertainment content (e.g., 3D movies). These display products are essentially large screen televisions, and are targeted at the home theater market. Initially available as DLP projection televisions, there have been subsequent short-lived plasma-based products, and there soon will be LED-based products.

### BODY

For clinical application of Virtual Iraq these displays have significant advantages over HMDs (Head-Mounted Displays). They have higher brightness, contrast and acutance, present a wider field of view, are less confining, require no fit adjustment, and present little difficulty in sanitizing the required shutter glasses. In addition, they are relatively inexpensive and widely available.

In order to facilitate the use of these displays by the PTSD research and treatment community, we re-budgeted our remaining funds in FY10 to purchase displays and rendering computers to be configured in two settings: 1) as a vehicle simulator and mini-Cave in the Brown VR lab; 2) as a treadmill display in the Center for Restorative and Regenerative Medicine's Gait Lab. The display in the Brown VR lab also requires a motion capture system. The gait lab display will use the gait lab's existing motion capture system.

Our schedule for much of this work has been constrained by the availability of suitable technology in the consumer market. Our early work with the Mitsubishi LaserVue projection TV showed that the design features used to reduce laser speckle (in particular, a moving image-plane diffuser) made it unsuitable for mounting in any but a plumb, normal TV orientation. We were able to obtain, in the spring of 2010, low-cost stereographic projectors from Dell, and these are the basis for the new display at Brown. These projectors cost $700 each, have 1:1 short-throw lenses, and provide 120Hz field-sequential stereographic projection at 720p HDTV resolution.

## KEY RESEARCH ACCOMPLISHMENTS

Our 2011 work has focused on three areas:
- Configuration and testing of the single-panel display for the Providence VA/CRRM Gait Lab - We have acquired and configured a computer system and single panel Mitsubishi projection television for installation in the Gait Lab. This computer system will also be capable of driving the Gait Lab's multipanel immersive stereo display due to be installed in the Fall of 2011.
- - We have identified and worked with an immersive display vendor to design a display suitable for use with the Gait Lab's prototype realtime-actuated treadmill. This treadmill is suitable for use as a haptic interface device in virtual environments.
- Display technology tracking - we have continued to track available technology for consideration in virtual environments designed for CRRM applications. The wide available of consumer stereo display technology has proved something of a disappointment, as the majority of current products based on the HDMI 1.4a stereo signalling standard introduce too much latency for use in virtual environments and also cannot be synchronized in systems using multiple displays. Still, there are some current products which can be suitably adapted for our applications, and we expect that many more will appear in 2012, when projectors televisions will become widely available with a much higher bandwidth HDMI hardware video interface (340MHz vs. today's 167MHz).

## REPORTABLE OUTCOMES

Because of the extended schedule for design and acquisition of the new Gait Lab virtual reality display, we have further delayed travel for working meetings with Dr. Rizzo's group, to formalize the Virtual Iraq Linux framework, and to Stanford, for working meetings with Dr. Andriacchi's biomotion research group. Dr. Andriacchi's group has developed innovative markerless motion capture techniques which we would like to use in a real time implementation on the Graphics Processing Unit (GPU). This could allow us to eliminate the need for a marker-based motion capture system and greatly simplify the deployment of a multi-channel Virtual Iraq system.

## CONCLUSIONS
N/A.

## REFERENCES
N/A

# PROGRAM 3A:
## "IDENTIFYING CLINICALLY MEANINGFUL IMPROVEMENT IN REHABILITATION OF LOWER-LIMB AMPUTEES"
### Linda Resnik, Ph.D.

## THIS PROGRAM HAS BEEN CLOSED

**Susan D'Andrea <susan.dandrea@gmail.com>**

## Re: A-14397.2a and A-14397.2b, Protocol Closure Memorandum (Proposal Log Number 07347002, Award Number W81XWH-07-1-0689)

**Aaron, Roy <roy_aaron@brown.edu>**                                    **Tue, Sep 13, 2011 at 7:53 PM**
To: "Duchesneau, Caryn L Ms CIV USA MEDCOM USAMRMC" <Caryn.Duchesneau@us.army.mil>
Cc: Susan_D'Andrea <susan.dandrea@gmail.com>

The PI on this grant is Susan D'Andrea at Providence VA Medical Center

On Tue, Sep 13, 2011 at 5:53 PM, Duchesneau, Caryn L Ms CIV USA MEDCOM USAMRMC <Caryn.Duchesneau@us.army.mil> wrote:

SUBJECT: Project Completion for the Protocol, "Identifying Clinically Meaningful Improvement in Rehabilitation of Lower Limb Amputees," Submitted by Linda Resnik, PhD, Brown University, Providence, Rhode Island, in Support of the Proposal, "PTSD in Limb Trauma and Recovery," Submitted by Roy K. Aaron, MD, Brown University, Providence, Rhode Island, Proposal Log Number 07347002, Award Number W81XWH-07-1-0689, HRPO Log Numbers A-14397.2a (Providence Veterans Affairs Medical Center Site) and A-14397.2b (VA Boston Healthcare System Site)

1.  A request to close the protocols was received by the U.S. Army Medical Research and Materiel Command (USAMRMC), Office of Research Protections, Human Research Protection Office (HRPO) on 10 January 2011 and 6 July 2011.  These no greater than minimal risk studies were initially approved by the USAMRMC HRPO on 6 February 2008.

2.  The Brown University documentation acknowledging closure of these protocols (A-14397.2a and A-14397.2b), dated 22 August 2011, was received by the USAMRMC HRPO on 25 August 2011; the Providence Veterans Affairs Medical Center documentation acknowledging closure of the protocol (A-14397.2a), dated 9 February 2011, was received by the USAMRMC HRPO on 14 March 2011; and the VA Boston Healthcare System documentation acknowledging closure of the protocol (A-14397.2b), dated 13 June 2011, was received by the USAMRMC HRPO on 7 July 2011.  The final report and supporting documents were reviewed and found to be acceptable.

3.  No further review of the protocols will be conducted, and the HRPO protocol files will be closed.

4.  The HRPO point of contact for these studies is Karen M. Eaton, MS, Human Subjects Protection Scientist, at 301-619-9268/karen.m.eaton@us.army.mil<mailto:301-619-9268/karen.m.eaton@us.army.mil>.


CARYN L. DUCHESNEAU, CIP
Chief, Human Subjects Protection Review
Human Research Protection Office
Office of Research Protections
U.S. Army Medical Research and Materiel Command

## PROGRAM 3B:
## "ANALYSIS OF GAIT MECHANICS OF AMPUTEES USING A NEW LOWER LIMB PROSTHESIS"

### INTRODUCTION

The newest generation of limb prostheses is biomimetic in that they more closely simulate normal human movement. A novel lower limb prosthesis with a biomimetic knee has been devised by Hugh Herr, of MIT and a Center for Restorative and Regenerative Medicine (CRRM) investigator. The gait mechanics and metabolic energy expenditure of unilateral transfemoral amputees using this prosthesis will be examined and compared to age-, height- and weight-matched non-amputees to understand how closely the prosthesis approximates the biological leg during walking.

Once recent study found that approximately 31% of recent combat injuries requiring amputation resulted in a trans-femoral amputation (Stansbury, 2008). For trauma victims, conventional, standard of care prosthetics for trans-femoral amputees have metabolic costs approximately 33% higher than those of able-bodied individuals during level-ground walking (Waters and Mulroy, 1999), as well as marked gait asymmetry, which can lead to higher prevalence of hip and back pain and osteoarthritis (Edhe et al., 2001; Gailey et al., 2008). As a result, individuals using these devices walk approximately 45% slower in order to compensate for the increased physical demand. Still, they fatigue sooner and are able to walk less distance than able-bodied individuals. More advanced prosthetics (such as the C-Leg and Rheo Knee) can alleviate some, but not all, of these issues particularly at speeds above customary walking speed (Taylor et al., 1996; Johansson et al., 2005).

To address these limitations, a novel, powered transfemoral prosthesis system is being developed in the MIT Media Lab (Martinez-Villalpando & Herr, 2009) which is intended to provide a more natural gait, while also being able to supply additional motive power. The AAA Knee consists of a modular robotic knee coupled to a conventional energy storage and release carbon-fiber prosthetic foot. The knee itself (mechanism and electronics) fits within the form factor of conventional prosthetic knees (26x8x7 cm, 2.2kg) so as to not encumber or interfere with cosmesis. The knee is capable of 0-120$^{o}$ of flexion and is able to produce an output torque of 80Nm.

### BODY

The approved scope of work for this program is to 1.) Establish a gait laboratory within the CRRM in a rehabilitation research facility at the Providence VA Medical Center and 2.) Assess lower limb function for amputees with a new biomimetic prosthesis. The gait lab has been installed at the Providence VA Medical Center as reported in last year's annual report. The remainder of the work on this program is related to evaluating a powered knee prosthesis in the gait laboratory.

The overall objective of this study is to ascertain the potential metabolic and gait improvements of the AAA Knee over conventional prosthetic knee systems (standard of care knee with carbon-fiber foot). To that end, the following evaluations will be performed:
- Determine the metabolic cost of transport using the AAA Knee and a conventional standard of care knee at three speeds corresponding to slow, medium, and fast walking speeds for above-knee amputees. This will also include an assessment of subjects' self-selected walking speeds.
- Evaluate gait symmetry by analyzing the kinetic, kinematic, and muscle activity patterns (EMG) of the affected and non-affected legs.

<u>Work Proposed</u>
The study will include between five and ten unilateral trans-femoral amputees and an equivalent number of height-weight matched able-bodied individuals. Subject population sizes are based upon a priori power analysis using G*Power 3 (Faul et al., 2007) with a relatively large effect size as the significant differences in metabolic cost for walking and gait asymmetries between trans-femoral amputees and able-bodied individuals are well documented (Waters et al., 1976), (Waters & Mulroy, 1999), (Schmalz et al., 2002). Prosthetic users will be capable of ambulating at the K3 level in that they are capable of walking with variable cadence. Subjects with amputations will perform all tasks using a both a conventional standard of care prosthetic knee and foot and the AAA Knee.

<u>A. Metabolic Evaluation</u>
Each subject's customary walking speed (CWS) will be determined. Subjects will then have their rate of oxygen consumption and carbon-dioxide production measured while standing still and while walking on a level track at 0.75, 1, and 1.25m/s – speeds that correspond to slow, medium, and fast gait for above-knee amputees.

The metabolic cost of transport (COT) for each subject (using each knee system in the case of amputees) will be computed from the oxygen consumption and $CO_2$ production rates normalized by subject mass. The metabolic costs and CWS for each knee system will be compared to both each other and the CWS and costs computed for the matched able-bodied subject.

<u>B. Gait Symmetry Evaluation</u>
Each subject's gait symmetry will be evaluated by comparing the performance of each leg to the other. For subjects with amputations, of critical investigation is the similarity in performance between the amputated leg using each prosthetic knee and the non-affected leg. Gait performance will be assessed based on gait kinematics, kinetics, and the activity of the major hip muscles.

Gait will be measured using an IR-based multi-camera motion capture system to record subjects' gait kinematics and two force-plates in the walkway will capture ground reaction forces. Surface EMG signals will be collected as subjects walk. Specific gait performance measures for each leg will include hip, knee, and ankle moments and powers, maximum ground reaction forces, stand and swing times, stride frequency, and mean rectified EMG. These will be compared as the ratio between the non-affected and affected sides (right to left in the case of able-bodied subjects).

**KEY RESEARCH ACCOMPLISHMENTS**
- The research protocol has been approved at the DoD and local IRBs (Providence VA Medical Center and Brown University).
- Training has been completed on the use of the metabolic measurement and motion capture and analysis systems.
- Custom software routines have been developed for rapid analysis of collected data.
- Amputee and able-bodied subjects have been identified, formal recruitment in progress.

**REPORTABLE OUTCOMES**

N/A – Data collection to commence imminently

**CONCLUSIONS**

N/A – Data collection to commence imminently

**REFERENCES**

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**SUPPORTING DATA**      N/A

# PROGRAM 4
## VIRTUAL REALITY AND MOTION ANALYSIS TO CHARACTERIZE
## DISABILITIES IN LOWER LIMB INJURY

### INTRODUCTION

Following a locomotor impairment, assessment of the extent of the impairment often focuses on the ability to make gross motor movements. However, navigating complex environments filled with obstacles such as other pedestrians, stairs, and moving cars require a person to adapt their locomotor pattern to accommodate the constraints of the environment; this is often termed functional mobility. Quantitative assessments of functional mobility are lacking the literature.

Since virtual reality (VR) offers the flexibility to create a variety of challenging environments to probe the nature of the locomotor impairment, VR was explored in this study as a potential locomotor assessment tool. An obstacle course was developed in Brown University's Virtual Environment Navigation Laboratory (VENLab) and required subjects to maneuver around two obstacles set six meters apart in a figure-eight fashion. First, subjects with an emulated lowerlimb disability were tested to examine the efficacy of the locomotor task in VR. Following the successful demonstration of the task, patients with a torn anterior cruciate ligament (ACL) are now being recruited for assessment. This longitudinal study will track progress by testing each patient three times: 1) prior to ACL-reconstruction, 2) three months post surgery, and 3) 12 month post surgery. Data from the functional mobility assessment will be compared to their standard clinical evaluations and quality of life questionnaires assessed over the same time frame. Additionally, interoperative surgical data (location/laxity of the reconstructed ligament precise to the mm) for each patient will be compared to their functional mobility task performance to determine if patients with a particular type of reconstruction are better able to adhere to obstacles in the environment, thus creating a more adaptive, effective locomotor pattern.

### BODY

Our group has previously demonstrated that subjects deviate from their healthy pattern by adopting one of two mechanisms when walking with an emulated injury – either walking speed was preserved and pathway geometry was manipulated (i.e. wider turns around the obstacles) or vice versa (Gérin-Lajoie *et al*., 2010). Additionally, Rhea *et al*. (2010) reexamined the data from Gérin-Lajoie et al. (2010) using a nonlinear analysis called Recurrence Quantification Analysis (RQA). The next goal of the project was to extend this research to patients who have ruptured their anterior cruciate ligament (ACL). ACL tears are common in military personnel, with a rate of incidence 10 times that of the general population due to the physical demands of their job (Owens et al., 2007). Assessment and rehabilitation of a torn ACL is costly, as is the patient's time away from work. Proper examination of when a patient is ready to return to their normal daily activities is crucial not only to maintain a stable workforce, but to the patient's health as well. If, through the lack of quantitative functional mobility assessments, a patient is improperly designated as ready to return to activity and tears their ACL for a second time, their risk for developing osteoarthritis dramatically increases.

We achieved three critical accomplishments. First, we equipped the VENLab with a Qualisys motion capture system for the recording and analysis of gait. Camera placement has been optimized and the data can be processed and analyzed with standard software. With this system we can now assess the joint motion as subjects navigate the figure-of-eight, and specifically can examine joint angles, as well as tibial rotation and translation. Second, we optimized the design and procedures of our Virtual Reality environment to achieve the best motion capture. This included (i) updating the figure-of-eight virtual environment on several aspects, as well as (ii) establishing electronic communication between the VR and Qualisys systems. Our final, and most important, accomplishment is that we successfully ran four pilot

participants, using the new motion capture and updated VR systems. Based on the data collected from these participants, we have developed and standardize a method of processing and analyzing the kinematics of the joint data as well as the path data. In summary, we are fully prepared to run patients in the lab and analyze their data.

**KEY RESEARCH ACCOMPLISHMENTS:**
- The protocol has been approved by three local IRBs as well as the DoD IRB.
- Pilot data has been captured VR walking task using healthy subjects
- Recruitment of subjects is scheduled to begin at the end of October 2011.
- Research staff has been added to include Elizabeth Drewniak, a postdoctoral fellow with a biomedical engineering background and Hugo Bruggeman, a Brown University faculty in clinical psychology. Both individuals have backgrounds which are well suited to the project.

**REPORTABLE OUTCOMES:**
*Conference Presentations*
- Christopher K. Rhea, University of North Carolina at Greensboro, Adam W. Kiefer, William H. Warren, Susan E. D'Andrea, & Roy K. Aaron, Brown University. Synchronizing to a noisy metronome induces corresponding shifts in fractal gait dynamics. *North American Society for the Psychology of Sport and Physical Activity*, Burlington, Vermont, June 9–11, 2011.
- Christopher K. Rhea1, Adam W. Kiefer, Susan E. D'Andrea, William H. Warren and Roy K. Aaron. Dynamic Structure Of Postural Variability Following An ACL Injury. *Gait & Clinical Movement Analysis Society*, Bethesda, MD, April 26-29, 2011.

**CONCLUSION**
This project uses VR and gait analysis to investigate the maladaptive nature of the locomotor pattern following an anterior cruciate ligament. Over the course of the past year, many advances have been made in order to extend this project beyond testing able-bodied subjects with locomotor impairment devices, to subjects with ACL tears, of which there is a high rate of incidence in the military. As described above, a great deal of time and effort was put forth to incorporate the use of motion tracking cameras and technology, so that subject kinematics can be analyzed in conjunction with the VR data. Additionally, the VR programs have been optimized. The next step for this project is to test subjects with ACL ruptures. The outcomes of this work <u>HAVE</u> the potential to provide quantitative assessments of functional mobility following ACL injury.

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**SUPPORTING DATA:**
Exemplar pilot data of a participant walking the figure-of-eight course for three conditions: (i) baseline, at a fixed and higher speed and following a fixed path. Conclusions are consistent with Martin Gérin-Lajoie et al. (2010). First, speed varies on the figure-of-eight, with a reduced speed on the turns. Second, a more reduce speed when forced to walk a sharper turn (left loop of the green path). Third, no wider turns when forced to walk faster (loops of the blue and red paths have an equal area of 4.0m2).