A Virtual Reality Environment to Assist Disabled Individuals[1]

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ABSTRACT

The potential of virtual reality (VR) technologies to assist and improve rehabilitation techniques and procedures is unlimited. VR is an emerging application of both sensory and computational technology which has the capability to incorporate the individual's senses and use proprioception to allow for participatory rehabilitation. We formatted our approach toward developing a virtual reality rehabilitation (VRR) system to help to increase the functionality of disabled individuals and improve their activities of daily living (ADLs) through the incorporation of an environment consisting of functional real world demands and employing chronic and repetitive exercises. Using real-time feedback and performance metrics, user progress will be objectively tracked and programs will be modified based on feedback inputs. This work focuses on the Human Activity Virtual Reality Rehabilitation (HAVRR) model, incorporating the total life cycle of training with the human, environment and assistive aids including virtual reality, haptics and cognitive assist devices.

KEYWORDS

Virtual Reality Rehabilitation, Human Activity Rehabilitation, Traumatic Brain Injury, Disabled Individual, Virtual Reality, Disability, Haptics

BACKGROUND

Recently, the Academy of Neurology released data regarding neurological disease and injury research over the last fifteen years. The January 2007 issue of Neurology states that every 1/1000 Americans suffer from Multiple Sclerosis, 67/1000 elderly Americans have Alzheimer's Disease, 101/100,000 Americans suffer from a traumatic brain injury each year, 183/100,000 Americans suffer a stroke each year, and 10/1000 elderly Americans have Parkinson's disease (Hirtz, 2007). Some of these statistics have decreased since the previous fifteen year study and some have increased; regardless, individuals suffering from disabilities deserve the best

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rehabilitation treatment in order to deal with or overcome the struggles of their diseases and/or injuries. Virtual reality (VR) holds great promise to assist and improve rehabilitation techniques and procedures. VR is an emerging application of both sensory and computational technology which has the capability to incorporate the individual's senses and use proprioception to allow for participatory rehabilitation. Findings using VR environments to help rehabilitate disabled individuals are becoming a popular publication topic; however, VR technologies have yet to be successfully integrated as a whole to create a fully immersive, haptic feedback, virtual reality rehabilitation (VRR) system (Feintach, 2006).

Virtual reality has been successfully implemented in training and assessment environments (Moire, 2005). Current interfaces for virtual environments include monitors (flat and CAVE), head mounted displays (HMDs), sensors, force feedback mechanisms (haptics), and real time tracking devices (Sviestrup, 2004). These devices allow the user the capability to interact with his/her virtual environment and provide feedback recordings in real time. This coordinated action of sensors and user inputs defines the virtual world (Carrozzo, 1998). The feedback recordings are taken through multiple sensory modalities such as motion (visual) and force (touch) feedback. Virtual environments have the ability to track body movements, provide kinematic data, and adapt the user's environment based on individual feedback and therapist input (Gourlay, 2001).

These virtual environments can be specifically designed to aid in the rehabilitation of a large number of disabilities resulting from disease and injury. Virtual reality systems can be created so that they are adaptable to different functions and interfaces and incorporate flexible training programs. These rehabilitation systems need to be created with each individual in mind, yet they must be adaptable to the needs of a broad range of disabled individuals if they are to become economically viable. Through the understanding of the changing needs of disabled individuals and the path or progression of a person's rehabilitation process, as it reaches maturation, the ultimate VRR system will be created. This initial VRR system will be created as a high end, multidimensional system suitable for comprehensive laboratories or research studies. It will eventually be scaled down after the necessary factors for immersion are determined and only those factors that optimize the immersive properties are included in order to develop a canonical system.

PROBLEM AREA

Traumatic Brain Injury (TBI), a major neurological disorder and disabling disability, is considered a worldwide epidemic and is becoming a growing public health problem (Gentleman, 2001). Rehabilitation targeted to improve the recovery of TBI individuals requires a multidisciplinary approach and diverse team of experts. The main goal of rehabilitation is to restore as much function as possible to the individual and ultimately, restore independence and social integration (Gentleman, 2001). TBI results in physical, psychological and social trauma that needs to be addressed in a rehabilitation program. In order for this program, and other programs that involve related disabilities, to be optimized, a partnership must be created between the patient, medical and rehabilitation team, and family involving tolerance, trust and understanding.

Once this partnership is created, the team as a whole must work together to implement the VRR system. VR is an excellent assistive rehabilitation technology to assess both motor and cognitive abilities and to help plan and execute rehabilitation training. Often, disabilities result in at least an initial reduction in environmental interaction and enrichment which is counterproductive to rehabilitation and restoration of daily living functions. VR environments present the capabilities to provide all individuals, regardless of their mobility level or cognitive capabilities, the ability to participate in rehabilitation tasks in an enriched environment. VR environments can exploit normal every day experiences and immerse the individual, helping them to focus on real life tasks. These environments have been shown to reduce the consequences of disabilities, such as TBI and Stroke (Wang, 2004).

The potential for Virtual Reality Rehabilitation (VRR) in the disability field is limitless. VR, already used for training, can be modified to aid in retraining of both cognitive and motor performance by simulating both real life and imaginary situations. The VR environment provides a consistent and repetitive rehabilitation program designed for each individual and his/her needs. Sensory presentation and task complexity can be varied and response requirements can be tailored to the capabilities of the user. VR is an ideal assistive aid for rehabilitation as it provides real time feedback and precise and accurate performance measurements. Task performance can be modified and rehabilitation programs adjusted according to the monitored real-time performance results of the individual.

Opportunities for future research using VRR to improve rehabilitation programs include expanding the currently limited opportunities for rehabilitation scenarios, enhancing primitive spatial and temporal training scenarios, addressing staff and facility limitations, creating user friendly interfaces and integrating an interactive environment.

RESEARCH FRAMEWORK

Chronic and repetitive exercises have been shown to create permanent structural changes in the brain and a reorganization of the nervous system. An environment that consists of functional real world demands and repetitive procedures can aid in the restoration and rebuilding of an individual's cognitive processes (Optale, 2001). This stepwise training process will help to improve the overall quality of life of the individual.

The proposed system will help to increase the functionality of disabled individuals and improve their activities of daily living (ADLs). It will incorporate real time feedback and performance metrics in order to objectively track user progress and help motivate the user to achieve and sustain higher levels of performance. The goal of the system is to not only reduce the restrictions resulting from individual disabilities but also to improve self esteem and allow individuals to feel as if they are actually participating in the task at hand rather than a rehabilitation program. The essential characteristic of this VRR system is that it will effectively and efficiently integrate VR into current rehabilitation programs and be accepted by both the individual and the training team. This will require an adaptable and flexible system. The initial system model will be based on healthy individuals. These individuals will be used to set parameters, establish criteria and goals, and test prototype modeling designs.

A tangible benefit of VRR is the augmentation of facility and staffing, thus allowing quality therapist or rehabilitation staff time to be allotted to more patients. Applying VR is a challenging task that requires a multidisciplinary approach. It is essential to pool together rehabilitation team knowledge to provide a comprehensive rehabilitation program for each individual. Therapists use their core rehabilitation education and experience to develop individual training techniques and processes for each patient; this provides unique training for individual needs but may lead to inconsistent training if a patient sees multiple therapists. Through the use of the VRR, knowledge can be captured and training modules built to provide the best program for each individual. Thus, the patient benefits from training designed by a rehabilitation team and a synchronized multidiscipline program and the benefits to subsequent patients are even greater. This rehabilitation program, using the assistance of VR environments, provides functional, individual, and motivational therapy. The need for such a system is immediate.

CURRENT STATUS

Cook and Hussy, through in depth research and experience, designed a framework for the design and implementation of assistive technology (Cook, 2002). The goal of modeling and designing a virtual reality rehabilitation system fits well within their framework which aids in the restoration of function and helps individuals reintegrate into ADLs. Cook and Hussy's model, the HAAT model (Human, Activity, Assistive Technology), is based on Bailey's human performance model (Bailey, 1989) and integrates the human, context, activity and assistive technology, or in this case the VRR, holistically. The original model, designed by Bailey, was broadened to include environmental and physical conditions and our proposed adapted model (Figure 1) shows the specific relationship that VRR has as part of human performance.

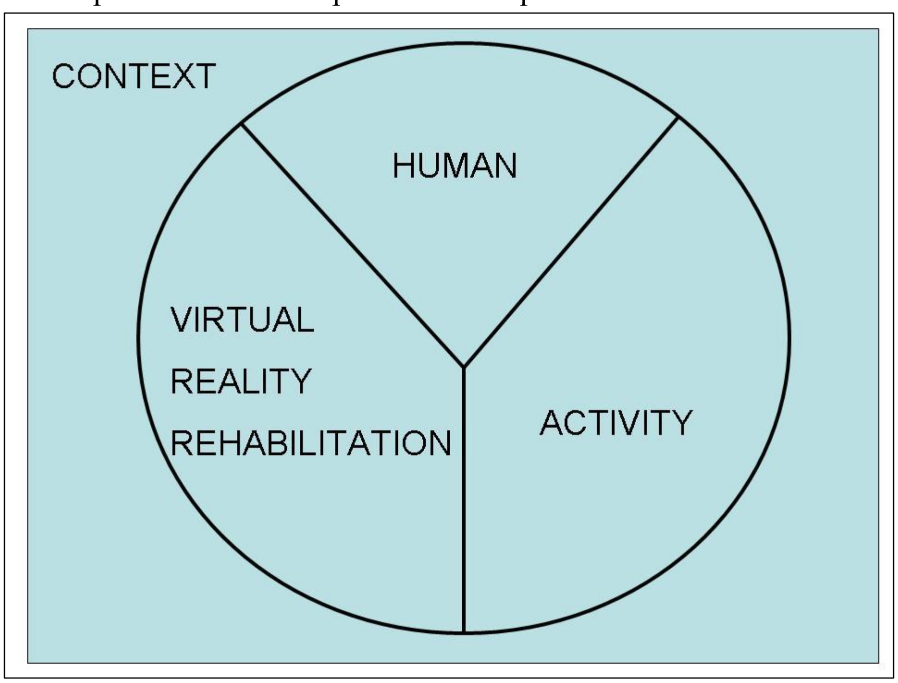

Figure 1: HAVRR – Human Activity Virtual Reality Rehabilitation Model

The model begins with the need or desire of an individual to perform or achieve a task or activity. This task or activity is the disabled individual's specifically designed rehabilitation program and is incorporated through the use of VRR. These activities are accomplished within a context, also presented as part of VRR. Through the combination of activity and context, the human can use and build upon his/her skills necessary for achieving his/her goals. The VRR system approaches the total life cycle of training, providing assistive aids, if required, early in the training to build skills and knowledge of how to accomplish a task (skill learning), through a development period where VRR reinforces progress and moves the individual toward a predetermined goal (skill mastering), to the final stages of training where increased forced feedback and challenging scenarios push the individual to higher levels of accomplishment (exceeding expectations). A representation of this life cycle is illustrated in the Figure 2.

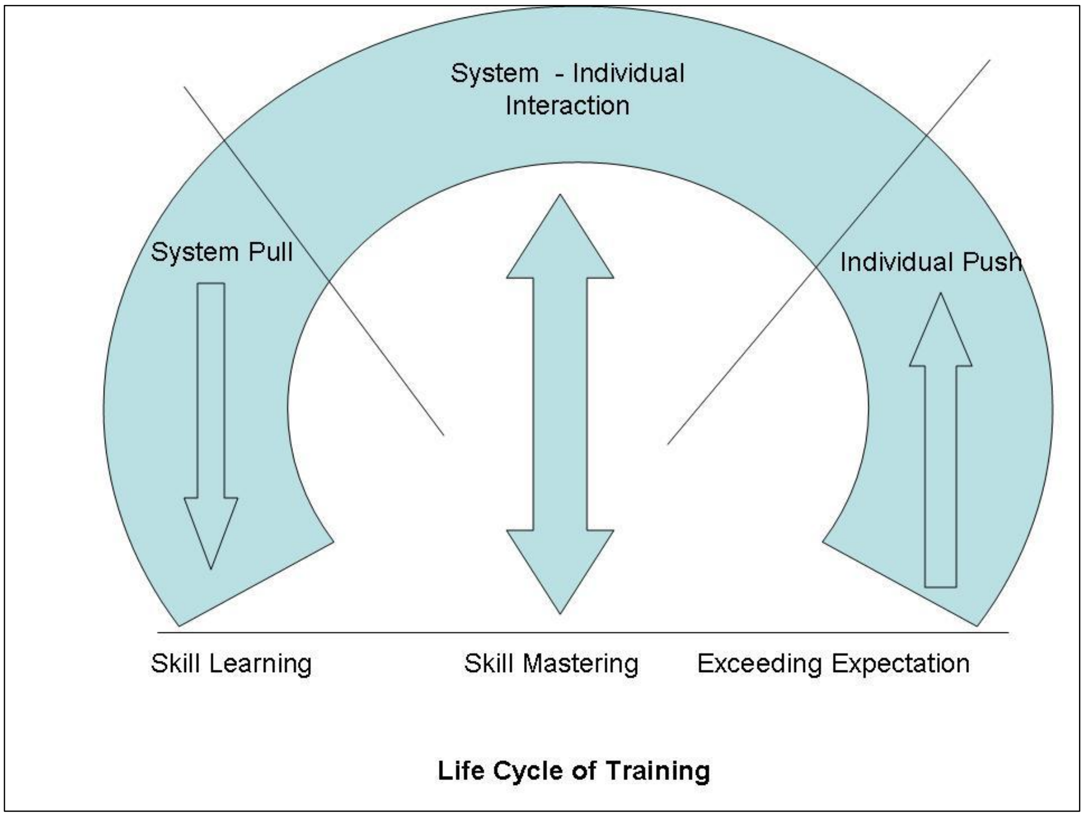

Figure 2: VRR Total Life Cycle of Training

The facilities available for this research are located on the Wright State University (WSU) campus. WSU currently operates a state-of-the-art virtual reality system within The Ohio Wright Center for Data. daytaOhio, a nonprofit organization, with offices located at the university, oversees the operation of the VR facility and works with the Ohio Supercomputing Center to make continuous improvements and enhancements to the capabilities of the VR environment. The VR facility has two systems. The first is a large flat wall space with 2D/3D passive/active stereo capabilities. The second is a four wall immersive CAVE with active stereo and infrared based active tracking. This system also includes ceiling tracking. These two systems are linked in order to share experiences between the systems. The idea of this facility is to have the capability to cascade down from a high end 3D immersive environment to a laptop with a low end HMD and haptic device that is effective for rehabilitation purposes. The advantage to this facility is the capability of performing research with high tech computing talent, man-machine interface and human interaction in a VR environment.

Wright State University campus is a campus that is community friendly toward individuals with disabilities and plans to further specialize in disability rehabilitation using VRR. WSU works closely with rehabilitation facilities in the area. The goal of this research is to target both adults and children in the area of cognitive and motor rehabilitation. Potential subjects have been identified and design for the VRR program is underway. A conceptual design for the VRR, VR sensor and control feedback is in the process of being developed. It incorporates sensory stimulation in a closed loop adaptive system.

DISCUSSION

Studies have shown that individuals suffering from Parkinson's disease have benefited from virtual rehabilitation therapy through repetitive therapy of scrolling cues that aid their walking and help them work with the debilitating effects of akinesia (Reiss, 1995). Individuals who suffer hemiplegia as a result of a stroke are able to use virtual environments to improve their walking speed and muscle strength by increasing the symmetry of their walking, therefore improving their overall quality of life (Sviestrup, 2004). As well, stroke patients have used virtual reality in order to improve upper extremity function and motor processes (Kuttuva, 2006). Even spinal cord injured patients have benefited from virtual reality technology. Using virtual reality during rehabilitation of spinal cord injured patients has helped to increase self confidence and motivation, therefore allowing the individual to rehabilitate in a more relaxed setting and increase the time he/she participates in activities. Spinal cord injured patients have learned to strengthen the muscles that they are able to control and maintain this strength in order to participate in everyday activities (Riva, 1998). Virtual rehabilitation helps the individual concentrate on activities other than rehabilitation (such as the task they are engaged in), therefore distracting the individual from strict therapy and decreasing anxiety, fear and self reported pain.

In summary, virtual reality rehabilitation systems are emerging as valuable tools in the reestablishment of functionality and quality of life for individuals suffering from disabilities due neurological disease and injury. An immersive virtual rehabilitation system can be used to better understand the effect of visualization on rehabilitation by incorporating user friendly interfaces, motion and position trackers, and force feedback loops to enhance virtual manipulation. A multi-disciplined collaborative effort can bridge technology gaps and create a closed loop virtual reality rehabilitation system.

This paper outlined the overall research and presented some of the challenges in designing a VR system for rehabilitation. Future work will focus on a specific disability and describe the findings from implementation and evaluation of this system.

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