Rehabilitating walking through virtual environments

by Judith E. Deutsch

Many stroke victims never fully regain their walking ability. In particular, they may not be able to walk as far or as fast as is required to function in a community setting. To improve walking, we have developed virtual reality devices that allow an individual to train at the intensity and duration necessary to achieve improvements in strength, coordination and endurance. We have shown that providing leg movement training in a virtual environment achieves increased walking speed outside the virtual environment. We are now in the process of testing a walking simulator, where one can stay in the clinic setting but practice in a variety of virtual worlds. We are also working on the remote delivery of rehabilitation and the transfer of technology from the laboratory to the clinic. Our work is an excellent example of interdisciplinary collaboration.

Figure 1. Airplane simulation: Users navigate through the targets while therapists monitor patients' performance. Target speed, pattern lighting, sound and turbulence can be modified.

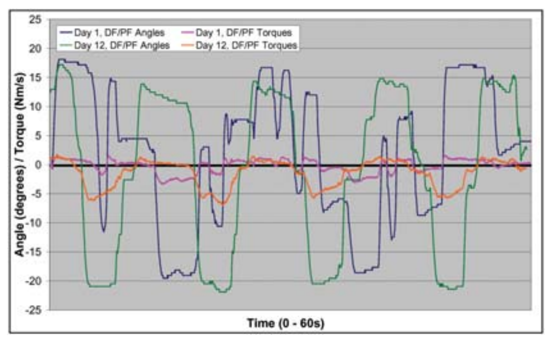

Figure 2. Ankle coordination before and after training. The patient's ability to generate torque (pink and orange) and displacement (blue and green) not only increase after training but become more synchronized (orange and green).

In our lab, a major focus is the rehabilitation of individuals post-stroke, as they strive to recover function, and in particular to improve their walking ability. We are pursuing several lines of inquiry to address the question of how to improve walking ability in individuals who are recovering from a stroke. These interventions include the use of motor imagery, awareness through movement training and virtual reality. This article will focus on the virtual reality work.

The clinical application of virtual reality to rehabilitation of walking is grounded in several areas of basic science. Animal studies have shown that training in enriched environments produces improvements in motor behavior. Furthermore, animals trained with specific goal-directed activities, in contrast to endurance and strength training, develop both behavioral improvements and neural plasticity. We have also learned from animal studies that a high degree of repetition and intensity is required for motor learning and brain plasticity. These principles form the foundation for pursuing virtual environments as an avenue to rehabilitation.

Virtual environments can be used to engage the patient in the intensive repetitive practice required to produce behavioral changes. Furthermore, the environments can be customized to address specific deficits of the individual patient. It is this promise of virtual rehabilitation (VR) that we are investigating in our lab.

In collaboration with Greg Burdea, PhD, and Rares Boian, PhD, at Rutgers University, we have developed and refined virtual reality technology for rehabilitation. In particular, we have been interested in creating systems to rehabilitate individuals post-stroke. These systems use a combination of hardware as inputs into the virtual environments that are displayed using software on a desktop computer. We use a combination of vision, sound and touch (haptics) to engage users in the virtual environments.

Our first system, the Rutgers Ankle Rehabilitation System, has a device that allows patients to use their foot to navigate in two virtual worlds. We have created an airscape and a seascape (for airscape see Figure 1) with targets and obstacles to be navigated. As patients are occupied with moving in the virtual environment, they perform hundreds of repetitive foot movements without realizing it. We make the tasks more interesting by creating weather disturbances such as a thunderstorm. For example, one scenario is based on a virtual airplane that will shake in the storm when it encounters turbulence. Using this system, we have shown that individuals post-stroke who trained three times a week for four weeks improved their walking speed, endurance and stair climbing speed. We confirmed that these gains were in part achieved through better control, coordination and strength of foot movements (see Figure 2).

Figure 3. Street crossing simulation: users cross the street before the flashing light turns red. Therapists can change the speed necessary to cross the street, curb height, scene lighting and vehicle behavior.

Our second system (see Figure 3) is designed for walking in different virtual environments. This system has two platforms on which the person stands with a weight reducing device (the amount of weight the person bears on his feet is reduced by 40% of the person's body weight) to maintain balance. Our street crossing simulation has a flashing light signaling when it is time to stop and go. Cars encroach on the crosswalk and honk their horns. The length and surface of the street can be changed, making it slick or sticky to simulate ice or mud. We can also change the season. Currently, we are in the process of characterizing the gait of healthy individuals in these virtual environments. We are using motion analysis tools to

continued on page 20

JUDITH E. DEUTSCH, PHD, PT, ASSOCIATE PROFESSOR AND DIRECTOR, RESEARCH IN VIRTUAL ENVIRONMENTS AND REHABILITATION SCIENCES LAB, UMDNJ-SCHOOL OF HEALTH RELATED PROFESSIONS, AND JEFFREY LEWIS, RESEARCH ENGINEER, SHOWN IN THE LAB. PATIENT WORKING WITH MOBILITY SIMULATOR IN BACKGROUND.

continued from page 19

describe the kinetics and kinematics of gait in different environments and are comparing it to regular walking. We will then begin to analyze the gait of individuals post-stroke.

The virtual reality systems are integrated with software that allows for remote delivery of rehabilitation, also called tele-rehabilitation. We have shown that individuals can train at a rehab site while being monitored by a physical therapist at a remote location.

Finally, to facilitate the transfer of our technologies to the clinic, we involve both therapists and patients in the development and refinement of the technology through an interactive process called a usability study. Users are trained in the technology and then practice with it to provide feedback on its ease of use. Ultimately, we hope to develop and validate the use of these technologies to augment rehabilitation. Our work is funded by the National Science Foundation.

Judith E. Deutsch, PhD, PT, is an associate professor of physical therapy and director of the Research in Virtual Environments and Rehabilitation Sciences Lab at UMDNJ-School of Health Related Professions. She received her BA in human biology from Stanford University, her MS in physical therapy from the University of Southern California and her PhD in pathokinesiology from New York University. She was a NIDRR post-doctoral fellow in rehabilitation research at Kessler Institute of Rehabilitation. She is the editor in chief of the Journal of Neurologic Physical Therapy (JNPT)*, which was recently indexed in Medline. Dr. Deutsch is also a member of the UMDNJ Master Educators Guild.*

FOR FURTHER INFORMATION, PLEASE VISIT OUR WEBSITE AT WWW.UMDNJ.EDU

UMDNJ
UNIVERSITY OF MEDICINE & DENTISTRY OF NEW JERSEY

65 Bergen Street
P.O. Box 1709
University Heights
Newark, NJ 07101-1709

Non-profit Organization
U.S. Postage
PAID
Newark, New Jersey
Permit No. 5287