Virtual Reality

The Next Step in Rehab for People with Balance Disorders

Losing one's balance and falling is so commonplace that it's almost hard to believe it is a serious health problem. But for the elderly, a fall can be fatal. And for others, poor balance and the constant fear of falling can lead to a life of social isolation and debilitation. Falling carries with it societal expense, too. Because of the rapid aging of the population, hip fractures alone result in several billion dollars in medical costs every year.

Falling can be caused by everything from a simple momentary lack of concentration to a serious deficiency in the way the brain, ears, eyes, and body work together to maintain balance.

Sue Whitney

It's this very complexity that makes it exceptionally difficult to help people prevent falls. Some people fall because they have what are defined as vestibular disorders. Yet it is hard to work with these people because what causes them to fall – vestibular "confusion" due to sensory input that is too complex – is nearly impossible to duplicate in the laboratory. On top of that, there are a plethora of factors that can have an impact; some known, some unknown, some interlocking. So it's very challenging to test people to see what kinds of events and actions lead to falls. And, of course, it's very difficult to develop ways to offer them treatment in a therapeutic setting that replicates the situations that lead to the vestibular symptoms.

That's why researchers at the University of Pittsburgh are leading an effort that uses virtual reality (VR) to address these problems. Dr. Sue Whitney and Dr. Patrick Sparto of the Departments of Physical Therapy and Otolaryngology are working with specialists in the fields of bioengineering, physical therapy, neurology, and clinical psychology, as well as VR experts from the Georgia Institute of Technology. Other valuable members of their team include Dr. Mark Redfern and Dr. Joseph Furman. Working with grants from the National Institutes of Health (NIH), they have developed a testing booth that lets them simulate and manipulate many different variables to determine what affects people's balance negatively, why they fall, and how they compensate for a previous injury to keep themselves from falling.

Patrick Sparto

Inside the Booth

According to Whitney, it was imperative that the test booth and the experience be very safe. "That was our first priority," Whitney explains. "We had to create a test environment where people knew they were both physically safe and psychologically secure." To prevent falls, the test subject stands in the test booth securely fastened into a harness.

"Our facility is more properly called the BNAVE," explains Sparto. "That stands for 'Balance Nave Automatic Virtual Environment.' "

When you're inside the booth, you literally feel like you're standing inside a box. Projected on three walls (left, center, and right) and the floor is an abstract geometric image, similar to a checkerboard pattern. The image takes up all of your horizontal field of view and most of the vertical. Equipped with a headpiece and goggles, you're asked to look straight ahead and stand as steady as you can. The headpiece shows the researchers exactly where on the projected image you are looking. Both the patterns you see and the overall sensation remind one of a box, hence the nickname "Box World."

The image can be adjusted for width, length, brightness, complexity, and speed with which it moves "past" the subject. The speed of movement is a vital component of the experience. As Whitney explains, "Testing by others to date has shown that motion past the retina is a powerful signal that can induce adaptation of visual responses."

The motion is called "retinal slip." Retinal slip is an error signal that the brain tries to minimize. This can ultimately cause the balance system to improve. How? How much? When? "That's exactly what we're trying to figure out," says Whitney.

In addition, during exposure to changes in the visual environment, the patient can be monitored closely for the entire gamut of physical and psychological responses. The researchers can watch their blood pressure, heart rate, and muscle tension. "You can look into their faces and see how they're responding," Whitney says. "We ask, 'How do you feel?' 'How hard is this for you?' Are you getting sick?' "

Virtual reality is already being used in medical research in some amazing ways. Systems not unlike the BNAVE have been used to help people who suffer from fear of heights or fear of flying. People who have had a stroke, head trauma, or spinal cord injury also have been helped with VR. A research team has worked with Vietnam veterans suffering from Post-Traumatic Stress Disorders, using a "Virtual Vietnam."

"The truly exciting thing from a therapeutic point of view," Whitney goes on to explain, "is that we can make fine adjustments to the program – discrete levels, quantifiable changes – on the spot. Whereas a typical physical therapy process might involve increasing the exercises' complexity in broad steps, we can do it in real time, making everything more difficult in the 'here and now' to see how the patient responds. Because they are safe and secure, we can push the envelope, but do it incrementally. We can manipulate shapes, sizes, colors, and the intensity of the light. We can make the floor move."

What We're Learning

"There are two levels to our initial research here," Sparto explains. "First is what we call the 'basic science.' The second is an effort to address the pre-clinical issues, so we can move to the next dimension – actual rehabilitation."

The "basic science" level consists of efforts to determine how different visual environments influence people's balance. These efforts have already begun, both with healthy subjects and with people who have had surgery on one ear and have found it affected their balance.

The complexity of the process of maintaining balance increases the difficulty of studying why people fall. It is the interaction between three different information generators that tells your brain where you are.

First, your vestibular system lets you know where your body is in space, with shifts in the fluid of your inner ear telling you how gravity is affecting you. Are you leaning or standing straight? Are you spinning or standing still? Next, vision provides further information. Third, sensors in your joints and muscles help you find out the position of your body. Is your arm straight or bent? Are you leaning forward or back?

Says Sparto, "We know that it is possible to improve the balance of people who have had ear injuries or strokes. Although we don't understand how, we know that certain kinds of eye exercises can, in effect,

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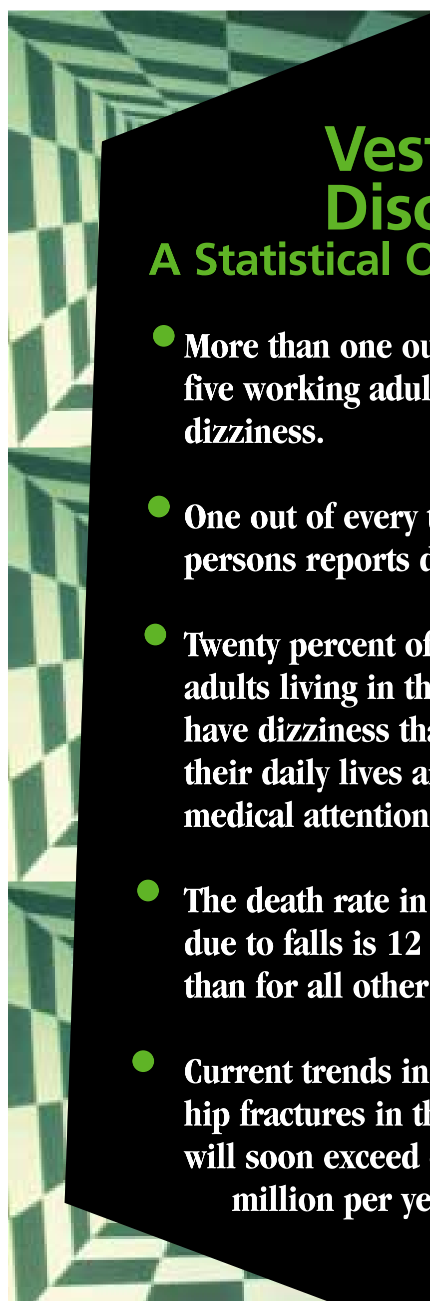

Vestibular Disorders

A Statistical Overview

- **More than one out of five working adults reports dizziness.**
- **One out of every three elderly persons reports dizziness.**
- **Twenty percent of older adults living in the community have dizziness that impairs their daily lives and requires medical attention.**
- **The death rate in the elderly due to falls is 12 times greater than for all other ages combined.**
- **Current trends indicate that hip fractures in the elderly will soon exceed one half million per year.**

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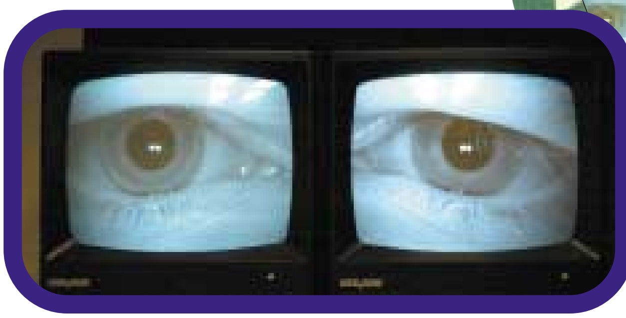
"re-calibrate" the ear to decrease dizziness. But it takes weeks or even months. The power of VR-based rehab would be to test many possibilities safely and very quickly. Simply being able to rapidly rule out problems that aren't there could greatly shorten the time between diagnosis and full recovery."

There are a host of issues that must be addressed before any clinical work can begin; such as what types of visual scenes and motions can be tolerated; what types of head and eye movements can be performed accurately while watching the visual environment; what are the best measures of a patient's response; what is the optimal length of time for a treatment session; are there potential side effects of this treatment and if so, what are they; are there age-specific issues; and, what should the therapist be doing in terms of control and interaction during the session.



The Exciting Future

Getting the patient back to work, to gainful employment and a full life, is a very important goal in the treatment of vestibular disorders. It is a vexing irony that the patient who suffers from these disorders may be too ill to perform many of the most basic functions of life, yet he or she "looks fine." Most employers, and even usually sympathetic family members, don't understand the suffering involved. And like many physical dysfunctions, vestibular disorders carry a psychological and emotional price as well. People who are afraid of dizziness and falling may become afraid even to move. They don't know if, or when, they are likely to have a dizzy spell that could lead to a fall. The fear of falling itself becomes incapacitating. The results can be devastating to a happy life. And as always, the elderly are the most susceptible.

Many people with vestibular disorders complain of what has been called "space and motion discomfort." Patients describe this as a feeling that occurs when there is a lot going on around them. Typically, this occurs in environments such as large grocery stores and "big box" retail outlets. The layout of such stores – aisles with boxes stacked on either side – is visually not unlike "Box World."

This fact led the University of Pittsburgh researchers to begin the next phase of their efforts: actual rehabilitation in a new VR environment they've dubbed, "Grocery World." In this VR setting, patients will interact with a complex visual environment that looks like a grocery store – even down to the reflection of the overhead lights on the floor. Naturally, the variables of the environment will be much greater than "Box World." In addition to movement through the image, the size and complexity of the scene, even its brightness, will have to be adjustable. It will be necessary to "shift" the scene up, down, left, and right. The height of the focus of vision will have to be variable as well. A wider palette of colors will be required.

"Grocery World" will build on the therapeutic efforts of "Box World," moving the patient from an abstract setting to a very real-looking one. Patients can be instructed to locate a particular box of cereal on a shelf. How long they take, other physical parameters, and the psychological impact will be noted and quantified.

In the future, the information learned from the BNAVE settings may be incorporated in a head-mounted display, which will make its use more available to a wider number of patients. There are head-mounted units in use now, but studies have shown they often cause nausea and other discomforts. By working from the downsized BNAVE booth, researchers will more easily be able to determine which elements of the program can lead to distress, and make choices to minimize them.

With falls being a major health concern, especially for the elderly, studying balance and vestibular disorders is vital. However, the success of some techniques in balance rehabilitation has only more clearly pointed out the very deficits of those techniques, particularly in quantifying the therapy and deciding when to advance a patient's regimen. Virtual Reality has demonstrated it can help people with some other disorders. Now it's time to see how much it can keep people upright – and happy.

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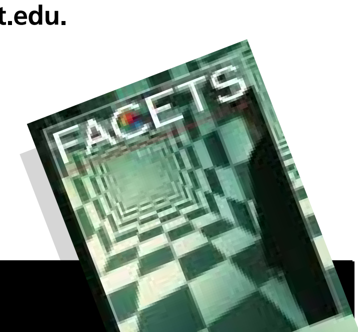

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