Exploring virtual environments

for cognitive and physical rehabilitation

Kessler Foundation research scientist Denise Krch, PhD, is investigating how virtual reality (VR) can help treat individuals with traumatic brain injury. The findings also have important implications for older adults, many of whom cope with similar impairments, she reveals in this exclusive interview

by Marilynn Larkin, MA

The word is out: Virtual reality is emerging as a key technology for helping older adults. In a 2017 Consumer Technology Association blog post ("Seniors: the next frontier of virtual reality"),[1] Coordinator of Partnerships Marketing Michael Williams states, "Because seniors are the fastest-growing population segment in the United States—and this population will continue to grow significantly in the future—technology must cater to this demographic for both entertainment and healthcare."

Kiplinger's Retirement Report featured the article "Tech revolution benefits aging"[2] in its June 2017 issue. Author Sally Abrahms notes, "While still in its infancy, VR for seniors is gaining fans among physicians, long-term care staff,

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Kessler Foundation's Dr. Denise Krch and colleagues examine the use of virtual reality to treat balance. Photo: Joan Banks-Smith, Kessler Foundation

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Simulating 'the complexity of occupational scenarios,' the Wonderkin Wonderworks program creates cognitive tasks that train task switching and multitasking, says research scientist Dr. Denise Krch. Photo: Dr. Sebastian T. König, Katana Simulations Pty Ltd

researchers, physical therapists and family members ... For older adults with mobility issues or cabin fever, VR breaks up day-to-day monotony and loneliness, letting seniors 'travel' ... without leaving home."

As part of this "revolution," companies are beginning to offer VR programming to support the concept of aging in place. *Bett>r with Age* is a series of VR films aimed at allowing homebound older adults to revisit favorite sites that they can no longer access physically—Russell Square in London, England, and Broadway in New York, for example.

Boston-based Rendever is an "armchair travel system" targeted to assisted living. The VR start-up won a USD$25,000 Massachusetts Institute of Technology (MIT) Healthcare Innovations prize, and took second place in the 2016–2017 Stanford Center on Longevity Design Challenge. The program is being tested under the supervision of MIT AgeLab Director Dr. Joseph Coughlin and Research Scientist Dr. Chaiwoo Lee.

On a related front, One Caring Team in San Carlos, California, has produced the Aloha VR program. This relaxation program seeks to improve quality of life for assisted-living residents who feel anxious or depressed, and who may be living with dementia. **[Ed.** Marilynn Larkin will look at VR programming in a future installment of her new "TechTalk" column for the *Journal on Active Aging® (JAA).*]

The emergence of such programs does not surprise Denise Krch, PhD, a research scientist in Traumatic Brain Injury Research at Kessler Foundation in East Hanover, New Jersey. In 2013, Krch received a three-year, USD$600,000 grant from the National Institute on Disability and Rehabilitation Research (now the National Institute on Disability, Independent Living and Rehabilitation Research, part of the United States Department of Health and Human Services' Administration for Community Living) to develop a VR-based program to treat executive-function impairments such as distractibility, poor task-persistence and difficulty multitasking.

The funding enabled Krch, who is also an assistant professor in the Department of Physical Medicine and Rehabilitation at the Rutgers New Jersey Medical School, in Newark, and a licensed psychologist in New York State, to extend the collaboration between Kessler Foundation, Katana Simulations Pty Ltd., and the University of Southern California (USC) Institute for Creative Technologies. The research team has completed the development of the VR-based program, which is now undergoing evaluation for preliminary efficacy.

Krch tells the *JAA* that although her work has focused on traumatic brain injury, "most of what we've been learning is applicable to aging populations as well—particularly those with cognitive impairment and balance issues." Such studies are needed, she says, because there is still a dearth of published research on VR therapy.

"In the rehabilitation area, we mainly have assessment programs such as the Virtual Reality Functional Capacity Assessment Tool (VRFCAT)," Krch explains. This computer-based test simulates instrumental activities of daily living in a realistic and interactive virtual environment. It is used primarily to assess functional capacity in clinical trials of schizophrenia treatments.[3]

VR programs aimed at actually improving function are scarce, however, according to Krch's research for a review chapter on the subject. "When it comes to treatment, there's our program, which is not commercially available yet," she states. "The Laboratory of Computational Psychology at Lufósona University in Lisbon, Portugal, offers a portfolio of behavior modification and rehabilitation games online, but they're in Portuguese. A French product, AGATHE, was also in development as of a few years ago, but it's not clear what its status is now."

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Moving his hand to direct his avatar's movements, a man interacts with a virtual environment being used to treat balance issues as part of a study by Kessler Foundation's Dr. Denise Krch and colleagues. Photo: Joan Banks-Smith, Kessler Foundation

Krch continues, "While we are now seeing applications being deployed for older adults, we don't yet see studies demonstrating or validating their efficacy. A number are being investigated, as ours was and will continue to be. The VR treatment field is still young," she adds, "but its potential is great."

JAA talked with Krch about her work, which includes VR programs to improve balance as well as executive function, and the promise of VR for improving activities of daily living and quality of life for older adults across settings.

ML: *I understand there are different types of VR. What are the differences, and which system is best for older adults?*

DK: There are three main categories. Most people are familiar with ***immersive VR,*** which is where an individual puts on a headset and navigates through an artificial environment that convincingly replaces the real-world surroundings. Individuals can relatively easily suspend disbelief and fully engage with the created environment. Although some rehabilitation applications are being developed for head-mounted displays, those devices can cause "simulator sickness," which is essentially dizziness and nausea. We want to be careful using this technology with patient populations, who may already be dizzy or nauseated either from an injury, medications or illness, and then have the device exacerbate symptoms.

Recently, we've been exploring newer headsets, like the Oculus Rift and the HTC Vive, which have significantly improved the "lag" time in the displays that can trigger those symptoms. These may be more appropriate for patients, and we're beginning to experiment with them.

Semi-immersive VR generally involves the use of a large screen, a projection system and high-end computer graphics. This VR experience is similar to what you might see in an IMAX movie.

But most applications for rehabilitation currently are ***nonimmersive VR.*** That means the virtual environment is viewed on a desktop system or a tablet computer, using a standard high-resolution monitor. Users can interact with the environment using a keyboard, mouse, trackball, joystick or other interaction device—or they can sit passively as the software explores the environment for them.

Even within the nonimmersive category, we've seen that both patients and healthy controls have more dizziness and nausea when using a joystick or mouse. If the software navigates the environment for individuals, and they don't have to touch or click anything to move around in it, then it works well. Users can concentrate on their specific tasks while the environment takes care of itself.

Our experience with brain injury patients would likely be similar for older adults, so if organizations are considering purchasing VR systems or devices, I suggest they do a trial run first to see what works best for their specific populations.

ML: *Do you create your own software for your studies or use off-the-shelf products?*

DK: We create our own software. Off-the-shelf games or activities are not rehabilitation products, though certainly some organizations might use them for this purpose. We simply don't know if they're efficacious yet. We do know that they're not designed to target the "sweet spot" of appropriately raising the level of challenge without becoming frustrating for patients who might have limitations.

ML: *Tell us more about your work with executive function.*

DK: We know that impairments in executive functions negatively impact capacity for independent living and adversely affect quality of life. We have found that virtual environments offer a way to evaluate a person's ability to carry out tasks that depend on executive function, and potentially to improve performance.

Our three-year development study led to the completion of a virtual environment that simulates the complexity of occupational scenarios and the creation of a set of cognitive tasks that specifically train task switching and multitasking. We created and fine-tuned the program, called Wonderkin Wonderworks, during that time. This program, which has eight modules, is designed with "adaptive difficulty," meaning that if someone is really struggling, the program automatically decreases the amount of distractions that could interfere with the completion of a task. And if a person is doing well, we can make the program more difficult by adding distractions.

Each module lasts about half an hour. We start by educating the participants, explaining what we're targeting, why that task is important, and what it might look like in daily life. For example, we explain what task switching is—being able to switch from one task to another and back again. And we explain what practice means in the context of rehabilitation—that is, the more we do a task, the more the brain "wires" that connection and the stronger that connection gets, enabling us to be better able to perform a particular cognitive skill.

We also educate participants about transference, or the generalizability of what they're doing in the clinical scenario, and how that is relevant to their activities of daily living. This provides context. It explains why they should care, and how playing the game will help them.

Then we launch into some tasks in the virtual environment, which in our software is an office setting. But it's not just a typical office. The software is videogame-like in that we have a fun story line that involves animated animals.

We know the program needs to be gamelike to be motivational. The more fun it is, the less people will perceive it as a boring, traditional, repetitive rehab task, and the harder they're probably going to try. Compliance will be better. Individuals will be more invested in completing the tasks. And we hypothesize that therefore outcomes will be better. Our pilot trial will begin to sort out whether our hypothesis is upheld.

ML: *Can you give an example of the kinds of scenarios participants encounter?*

DK: Sure. Participants sit at a desk in a cubicle in a virtual office environment that includes other desks in other cubicles. Their desk has a computer monitor, keyboard and mouse, a telephone and a tablet. In that setting they need to look through incoming emails to find those that contain an order placed for an animated animal. Participants also receive plenty of spam messages, so they have to pay attention to the type of email content and delete the spam. Once they find the order, they have to click on it, and then send it to a tablet on their desk. That means switching from the primary task, which is the email task, and picking up the tablet to process the order.

On the tablet, participants might see lots of animated horses and goats, cats and dogs on the screen wearing hats, flowers and scuba gear—and they're tasked with looking for and selecting only goats wearing scuba gear. There might be

The Kessler Foundation's Dr. Denise Krch investigates the use of virtual reality therapy. Photo: Christopher Wood

eight goats that aren't wearing anything scuba-related, and there are flowers and other graphical figures affixed to the animals. The user has to sift through all that and pick the relevant stimuli.

Distractions are attached to every task. In this scenario, an office coworker carrying a heavy box keeps coming by, asking if the shipment belongs to the participant. So individuals constantly have to stop the email and tablet tasks to tend to this staff person, otherwise the heavy box becomes too much and he falls.

These modules really challenge people to use and improve skills that are meaningful in real life. But they get to use those skills in an environment that's not so serious and therapy-like. Because our feasibility work showed that participants enjoyed and could navigate the program and complete the tasks, we recently embarked on a small clinical trial to gain some preliminary data on how individuals with traumatic brain injury handle these tasks compared with controls.

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ML: *What about your balance study?*

DK: The balance study emerged from a partnership between Kessler Foundation and our collaborators at the USC Institute for Creative Technologies, under the direction of Dr. Albert "Skip" Rizzo, director for Medical Virtual Reality. Dr. Rizzo, Dr. Belinda Lange and colleagues developed VR software called Jewel Mine, which runs on Microsoft Kinect. This software was designed as an upper-body mobility treatment for people with orthopedic and neurologic problems, as well as balance issues associated with aging.

In the Jewel Mine game, the user takes on the role of a miner who has to gather jewels from a mine shaft by reaching and touching each jewel individually. The scenario can be changed instantly to, for example, a meadow in which the user has to reach out and gather flowers; or to a library, where he or she has to reach for books. As with Wonderkin Wonderworks, the level of challenge can be tailored to the individual's level of ability and progress.

Several years ago, we deployed Jewel Mine with our clinical population at the Kessler Institute for Rehabilitation in New Jersey. We had a mixed sample from the neurorehabilitation unit—patients with strokes and brain tumors as well as traumatic brain injury. They were all ages, from 20 to 98, and everyone used the software. We didn't collect outcomes data at that point, but the feedback was very positive and participants felt it was challenging and fun.

Building on that experience, we refined the Jewel Mine software to be a balance-specific treatment, now called Island Quest. Island Quest also uses Microsoft Kinect technology—in other words, it uses infrared light to project the person's avatar onto the screen. The game takes place on an island. As users explore the island, they have to do different things, such as reaching for virtual fruit off a tree while performing sit-to-stand and other traditional rehab exercises.

We have a multisite clinical trial underway to look at whether our gamified treatment will be more efficacious than the standard-of-care treatment. This study, funded by the US Department of Defense, is being carried out in civilian, veteran and active duty military populations at Kessler Foundation and Fort Belvoir Community Hospital National Intrepid Center of Excellence Intrepid Spirit One in Virginia. A second treatment arm in the study involves participants doing all the reaching and other physical exercises on the island while simultaneously being challenged with cognitive tasks. For example, in cone tapping, participants must calculate the sum of two numbers in order to determine how many times to tap the cone with their foot. Our hypothesis is that if you challenge your system overall, brain and body, your balance will improve because you're forced to do more in a given moment. We've also started experimenting with the feasibility of running Island Quest in a Vive head-mounted display.

ML: *What about the fear factor? Are participants or therapists reluctant to participate in the studies because they feel uncomfortable with the technology?*

DK: The setup for both the cognitive and balance software is simple. For the cognitive software, you click the program on, you choose the session and you

VR as a therapeutic tool

Kessler Foundation research scientist Denise Krch, PhD, presented at an event, "Shades of Reality: Augmented, Virtual and Mixed Realities in Healthcare," on May 31, 2017, in New York City. In addition to talking about her own research, Krch highlighted the advantages and limitations of VR as an intervention for individuals with a range of cognitive and physical challenges.

Advantages of VR

- Potential to simulate real-life situations
- Enhanced ecological validity—that is, skills gained during VR game play are generalizable to real-life settings
- Ability to control stimuli consistently, providing opportunities for repetition/practice for a specific sensory mode
- Ability to provide real-time feedback to participants, and exact replays of behavior
- Program can be tailored to level of impairment (complexity)
- Safe environment
- Enhanced motivation with fun interface

Limitations of VR

- Cost
- Clinician needs knowledge of the technology
- Novel, emerging approach, so few established protocols/best practices
- Complexity in data extraction and interpretation
- Potential side effects

Krch's presentation, along with those of the other speakers, is available on YouTube at http://bit.ly/2vazNHk (Krch's talk begins about an hour into the video).

click run. Yes, there's a lot of high-tech stuff that happens in the background, so the more savvy person can, for example, send a large amount of data to a printer that can then be looked at and analyzed. But, for the most part, it's a very simple user interface—just like going into an email program.

The balance software is only slightly more complicated because you can change a task's level of difficulty on the fly using a toggle button on the treatment screen. Other than that, the software is similar to the cognitive program: You see a main menu, you pick your desired module and you pick the task you want. Trained physical therapists do this every day, so there's nothing confusing about it. As noted earlier, we've seen patients of all ages and ability levels enjoy the games and navigate them, albeit with varying degrees of difficulty.

Overall, I think that something positioned as a game is less likely to provoke fear than something more "serious." Though again, all of what we do is really accessible.

ML: *What do you envision for VR with rehab going forward?*

DK: The field is wide open. VR is a hot area of study and development globally, although the treatment field, in particular, is still young. But again, the potential is so great.

For example, within my domain as a neuropsychologist, there's really little out there to rehabilitate such complex executive functions as organizing and planning. Those functions can't easily be broken down into simple enough tasks to deliver by paper and pencil; the tasks simply won't mimic real world. The only way to really help rehabilitate these functions, which are used in all kinds of daily activities, is to expose individuals to similar situations. And there are only two ways to do that: Take them out into the real world, which is not always feasible or cost- or time-effective—or use a virtual environment.

We can mimic any environment virtually in the safety of a clinic, or an outpatient or inpatient facility, and have complete control over the amount of stimulation someone receives. So we're able to target cognitive areas that we previously could not, and we can tailor the treatment to the individual.

I envision that this capability will only get stronger over time. With the right equipment and validated programs, VR therapy will make a difference in people's lives—and not only in cognition and balance, but in a whole array of domains that can be modified through practice.

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References

1. Williams, R. (2017, May 30). Seniors: the next frontier of virtual reality. Consumer Technology Association Blog. Retrieved on August 24, 2017, from http://bit.ly/2w1Rl7D.

2. Abrahms, S. (2017). Tech revolution benefits the aging. *Kiplinger Retirement Reports,* June 2017 issue. Retrieved on August 24, 2017, from http://bit.ly/2xg4N6j.

3. Ruse, S. A., Harvey, P. D., Davis, V. G., et al. (2014). Virtual reality functional capacity assessment in schizophrenia: Preliminary data regarding feasibility and correlations with cognitive and functional capacity performance. *Schizophrenia Research: Cognition, 1*(1), e21–e26; doi: 10.1016/j.scog.2014.01.004.

Resources

Internet

Bett>r with Age
http://bettvrwithage.com

COPELABS, University of Lusófona: Systemic Lisbon Battery
http://bit.ly/2g8HUgQ

Kessler Foundation
https://kesslerfoundation.org

One Caring Team: Aloha VR
https://onecaringteam.com

Rendever
http://rendever.com

University of Southern California (USC) Institute for Creative Technologies: Jewel Mine
http://ict.usc.edu/prototypes/jewel-mine

USC Institute for Creative Technologies: Medical VR
http://medvr.ict.usc.edu

Multimedia

"AGATHE: a tool for personalized rehabilitation of cognitive functions"
http://bit.ly/2wJT6Hl

"Bett>r with Age"
https://vimeo.com/215876073

Virtual Healthcare 2017: "Shades of Reality: Augmented, Virtual and Mixed Realities in Healthcare"
http://bit.ly/2vazNHk