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Virtual Reality Provides Real Therapy

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You are in a kitchen when suddenly a large spider appears just inches from your hand, crawling right toward you—welcome to SpiderWorld! You are terrified of spiders, especially huge hairy ones, and want nothing more than to flee. But you hold your ground, and your therapist reassures you that the spider won't harm you. Go ahead, pick it up. See what it feels like. You reach out, grasp the plump body, and hold it as long as you can before the anxiety takes over. That's okay, the therapist intones; you can try again later. Spiders take time to get used to.

SpiderWorld is one of a growing number of virtual environments that psychologists and VR researchers have begun to use to treat phobias and other anxiety disorders. Created by researchers at the University of Washington's Human Interface Technology Laboratory (HITLab), SpiderWorld immerses the patient in a routine environment—like a home kitchen—and introduces realistic-looking spiders that the patient can observe, manipulate, or even squash as part of exposure therapy. Therapists who treat phobic patients often try to reduce anxiety by exposing a patient to the stimuli or situations that provoke the phobic reaction. Generating these as part of a virtual environment promises a new approach to treatment—not to mention sparing some spiders their exoskeletons.

Image courtesy of H. Hoffman, HITLab, Univ. of Washington

A frame from SpiderWorld. The user's hand appears in the scene (right edge) as she lifts and moves the spider around, even examining it up close as her phobia abates. (Image generated by Hunter Hoffman.)

Integrating perception and experience

VR lets people act within and upon computer-generated environments, making it ideal for exposure therapy and some other forms of mental health treatment. In addition to representing stimuli with some degree of realism, a virtual environment (VE) lets users look at and interact with these things much as they would in the real world, using primarily their eyes and hands. This gives users a sense of physical as well as mental control over the things around them in the VE.

Flight simulators and other VR training systems have shown that a user interacting with a carefully designed environment can gain new skills and knowledge quite effectively compared to traditional methods. As the user interacts with the environment, the environment acts upon the user in ways we are just beginning to understand. Therapeutic applications can harness this transformative potential to help therapists cognitively "retrain" patients whose anxiety over certain situations or things has become disabling.

A growing number of research studies reported in both graphics and psychological publications document how VR can, to some extent, replicate and replace traditional exposure therapy for phobias. Patients who are afraid of heights, for example, can spend time in a VE that simulates such situations as being in an elevator, on a bridge, or looking out an upper-floor window. Fear of flying (aerophobia), typically treated by walking the patient progressively through the steps of taking an airline flight, can be much more easily—and cheaply—treated in a VE that replicates the airplane compartment and some of the noises, movements, and other sensations of taking off and landing.

The first controlled studies of VR's effectiveness in treating psychological disorders began in late 1992. Max North, Sarah North, and

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Joseph Coble, researchers at Clark Atlanta University's VR Technology Laboratory, claim credit for conceiving the idea to apply VR technology to mental health treatment. They worked with psychologist Barbara Rothbaum and VR expert Larry Hodges and his team at Georgia Institute of Technology to develop and report on the aerophobia and acrophobia treatments mentioned above. The Norths and Coble have also applied virtual environment desensitization (VED) to agoraphobia treatment and recently announced a partnership with the Speech Improvement Company to develop VR-based treatment for fear of public speaking.

Image courtesy of GVU, Georgia Institute of Technology

A view from a virtual elevator developed to treat acrophobia. (Image by Rob Kooper, Tom Meyer, and Larry F. Hodges.)

What makes VR real (sort of)

Like all computer graphics, VR begins with representation. A virtual environment or virtual world contains 3D objects situated in a context; while these may be represented with much or little visual detail, objects' "behavior" must be realistic enough that users believe the experience is the same as "being there." Though subjective and thus difficult to measure, as T.B. Sheridan pointed out, this sense of presence is key to VR, especially to the "reality" part—the VE must closely replicate spatial and temporal as well as visual characteristics of objects and their movement.

Computationally, this can become quite expensive, often requiring a trade-off between visual realism and temporal performance. A fairly simple environment, however, does not require a great amount of visual detail, making it easier to provide the real-time or near-real-time performance required for the user to adapt easily to the system. Bolter and his colleagues noted that even if each individual frame of a VE appears cartoonish, systems that let the user control point of view using normal head movements compensate to some degree for low visual quality.

The power of VR thus lies in this control and multisensory engagement, not just in compelling graphics. A virtual spider must look something like a real spider, of course, but it must also scurry or crawl like a spider and is more believable if it does so in response to user movements. Better yet, it should feel like a spider. New haptic interfaces add the sense of touch to VEs, which not only makes such physical manipulations as pushing and pulling seem more realistic but also engages a sensory interaction besides vision and hearing and thus adds to the sense of immersion. The Japanese VR community has taken a particularly active interest in this approach. VE designers can add "heft" to objects using force-feedback technology or tactile augmentation. The latter, used in SpiderWorld, matches position-tracked real objects with computer-generated virtual objects. As the user reaches out to explore the virtual object, her hand encounters a physical "stand-in"—in SpiderWorld, this is a furry toy spider attached to a Polhemus position sensor.

Making VR therapeutic

VR systems vary widely, typically depending on their task or purpose. Certain technical and design considerations, however, make for better therapeutic applications. Real-time performance is essential for both a sense of control and prevention or minimization of simulator sickness. It costs quite a bit, computationally, to render a detailed scene in real time—especially if you want to present a stereoscopic view to enhance 3D effects. Furthermore, many head-mounted displays (HMDs)—the primary visual interface for most VR systems—can present only small images and do not support fine resolution.

Hodges' team, in designing a VE to treat acrophobia, started with a bottom-line measure for real-time performance: at least 10 frames per second. They then had to figure out how much detail they could put into each frame, which forced a choice between low-detail stereoscopic images and detailed, texture-mapped monoscopic images. To some extent, hardware limitations forced the choice, but analyzing the task's visual requirements also revealed that most of the visual stimuli representing height situations did not require stereoscopic representation, which is necessary for close-up work but not for distance viewing.

Some VR systems provide physical components in addition to the computer-generated stimuli; such "props" as guard rails and chairs both enhance the sense of presence in a physical space and provide physical anchors for the virtual images and actions. Depending on the environment and desired effects, sound and animation may also be necessary. Hodges and his colleagues noted that whereas the VEs they designed for acrophobia treatment were static and provided no animation except that generated by users' head movements, the virtual airplane for aerophobia treatment required motion and sound effects. They thus had to create an environment that the plane would fly through as it took off, flew, and landed. They then coordinated the animation with corresponding sound effects.

Given these applications' therapeutic goal, they must also take the therapist into account. Carlin's team used a video monitor to watch their patient's actions in the VE (which they could also see) and verbally communicated their suggestions and encouragement to the patient. In addition to triggering preprogrammed spider behaviors such as crawling and hopping, the researchers used a position sensor and keyboard commands to control the virtual spiders' locations and movements. This let them interactively adjust the patient's level of exposure—moving a spider closer to increase the intensity of the exposure and moving it away when the patient reported extreme discomfort.

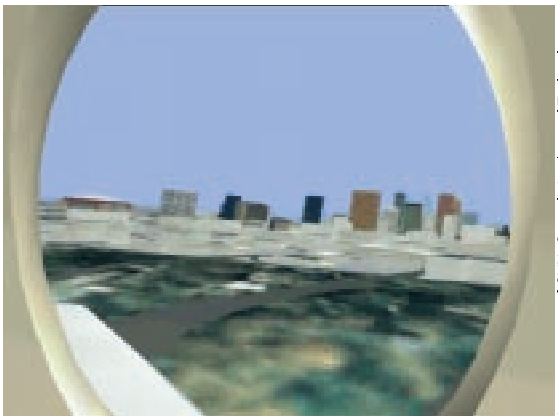

Image courtesy of GVU, Georgia Institute of Technology

The scene "outside" this virtual airplane window moves as the plane taxis, takes off, flies, and lands. (Image by Brian Wills, Kevin Hamilton, Rob Kooper, Jarrell Pair, and Larry F. Hodges.)

Perception and practice

The best VR system is not necessarily the most powerful but rather the one that most intelligently uses its rendering and display power. However, this requires understanding how humans perceive and interact. This wouldn't seem necessary if we had hardware robust enough to support any level of detail and real-time interaction—and could program fast enough to keep up with the enormous input volume required. But such brute force is not only impractical (and currently unavailable to most of us), it's unnecessary.

Mary Kaiser, a perceptual psychologist doing human factors research at NASA Ames Research Center, considers how to integrate understanding of human perception into visual display engineering. If we have a more precise understanding of how humans perceive—visually, tactilely, aurally—we can design systems optimized to a user's level of perception rather than systems that inefficiently bombard the senses at certain levels and present inadequate information at others. Modulating resolution to account for central versus peripheral vision, for example, might seem more complicated from a programming standpoint but would save computation for those areas a user focuses on and not waste resources on areas the user isn't looking at.

Kaiser and colleague Mike Montegut are also working with University of Virginia researchers on alternative rendering methods, one of which creates stereo displays that present images of different resolution to each eye. Knowing how the mind and senses work will permit further development of such "shortcuts" that save on computational costs but do not sacrifice the sense of reality essential to VR.

Sometimes virtual is better...

Rothbaum, a clinical psychologist who specializes in treating anxiety disorders, stressed that in addition to adequately replicating a stress-inducing situation and key stimuli, a VE provides a level of interactivity and control not always available in the real world. For example, a patient trying to conquer the fear of flying must at some point in treatment take an actual airline flight. A VE not only saves that cost and inconvenience but lets the patient and therapist home in on specific cues that cause the anxiety and repeat a certain sequence as many times as needed—for example, lifting off the runway or approaching it. Rothbaum also said that patients gain a sense of control in the VE that transfers to the real world. One patient told her that when she was on a real flight, she found it comforting to visualize specific cues from the virtual situation and recall how she mastered her anxiety over them.

Kaiser echoed this belief that VR gives both therapist and patient a new degree of control over the therapeutic experience. The therapist can control the parameters by varying the amount of detail presented and the length of immersion; at her or the patient's discretion, sequences can be repeated or skipped, and if the therapist also has a view of the VE, she can discuss the patient's reaction to certain details as both observer and semi-participant. This extends the work that some therapists have done for years with videotapes. Rather than placing the patient in a passive observer position, however, VR elicits both emotional reaction and—as mentioned, a crucial element of therapy—direct action.

While phobias and other anxiety disorders seem natural candidates for virtual exposure therapy, researchers have begun to explore ways to apply VR to other disorders as well. Riva reported preliminary results from a study on how to use VR to treat distorted body image, a major factor in such diseases as anorexia nervosa and bulimia. He sought to integrate the two main therapeutic methods: cognitive-behavioral therapy, which addresses a patient's dissatisfaction with bodily appearance, and visual-motor therapy geared to shifting the patient's conceptions and awareness of his or her body from negative to positive. While this research is in its early stages, VR appears to provide another useful means for addressing cognitive disorders.

Pain is both a physical and an emotional health issue—burn patients often suffer extreme pain, and while VR can't take it away, a project at the University of Washington's Harborview Burn Center is showing how it might help patients cope a bit better, especially during particularly painful burn dressing changes. Dave Patterson, associate professor of rehabilitative medicine, asked HITLab researchers Hunter Hoffman, Tom Furness, and Suzanne Weghorst to help him design an immersive VE that would grab patients' attention and engage them both mentally and physically. Two initial case studies yielded promising results, one child reporting that he had "forgotten" his pain while manipulating objects and traveling in the VE. Hoffman suggests that research and development should focus further on how the patient's sense of presence in the VE correlates with the level of pain distraction. Patterson and Hoffman plan to conduct a National Institutes of Health-supported, large-scale controlled experiment starting this summer to verify their preliminary results and find additional ways, such as tactile augmentation, to further reduce patients' awareness of their pain.

Patients with neurological disorders can also benefit from VR and related technology. Augmented reality (AR) merges natural and computer-generated stimuli; Suzanne Weghorst sees it as a potentially useful therapeutic tool and has begun to study its application as a "perceptual prosthesis" for people with Parkinson's Disease. She explained that this disorder sometimes causes akinesia, a sudden inability to walk that stems from a dopamine deficiency. Akinesia paradoxa, a well-known clinical phenomenon, refers to triggering the walking response by putting something in front of the person's feet. Weghorst proposed capitalizing on this response by presenting artificial cues such as 3D images of stairs or large block-tile patterns. The electronics for generating and presenting the visual cues can be hidden in a pair of sunglasses along with a tilt sensor. Triggered upon looking down, the system presents a stationary object that appears to be located on the ground in front of the patient's feet; as the patient looks ahead, the object starts scrolling and others appear in sequence. The technology still needs work—current HMDs don't support AR very well—but Weghorst mentioned that other techniques such as virtual retinal display show much promise for presenting objects visually.

VR can help disabled patients understand and better cope with their condition. It also blurs the line between ability and disability by providing new ways for them to act and interact. Blind or sight-impaired people can navigate or find and manipulate objects using audio or tactile cues, and paraplegic and quadriplegic people can learn how to use a wheelchair in simulated real-world situations or fly through a fantasy VE using little more than head movements. Researchers are working on brain-body-actuated control technology that uses electroencephalographic (EEG) and electromyographic (EMG) signals as navigation control inputs. Recent work on electrical vestibular stimulation shows that it is possible to produce the sensation of tilting and swaying by applying a low-level electrical current to the eighth cranial nerve using an electrode behind the user's ear. While still experimental, these and other techniques will make it possible to navigate through VEs in many different ways and to adapt a system to a particular user's needs, both physical and emotional.

...but it's still not real

VR has clearly begun to make its way into the mental health field, with some clinicians as excited about its possibilities as the VR engineers. But like many VR systems, virtual reality therapy hasn't yet made much of a dent on the commercial marketplace. This is a goal of current research and development, however, with several researchers mentioning that "turn-key" systems should eventually emerge from their and others' efforts—once they can figure out how to simplify the technology. MIT's Nat Durlach noted that while it's "obvious" that virtual exposure therapy and other VR therapeutic systems can be of some help, there have been no serious evaluations of exactly what features work, and why. Therefore, according to Durlach, the real question is not so much whether such VR systems are helpful compared to real-world exposure or other therapies, but how cost-effective we can make them. Do we really need realism and immersion, he asked, and if so, how much? What features of a therapeutic system have real payoffs? How can we discern these so that we can further develop them?

Cost-effective treatment is not, of course, the only concern researchers have about VR systems. Although VR appears to provide not only an adequate substitute for but even some advantages over in vivo treatment, we have to consider how an alternate version of reality will affect a person's sense of reality. Richard Bloom, a psychologist at Embry Riddle Aeronautical University,

On the Web

The University of Washington Human Interface Technology Laboratory's Web site has information about SpiderWorld and other virtual reality desensitization therapy projects at www.hitl.washington.edu/projects/therapeutic/exposure.html. Their Parkinson's Project site is at www.hitl.washington.edu/projects/medicine/parkinson's.html. To find out more about VR therapy for burn patients, go to www.washington.edu/alumni/columns/dec96/fires5/html.

Find out more about virtual reality exposure therapy projects at Georgia Tech's Graphics Visualization and Usability (GVU) Center at www.cc.gatech.edu/gvu/virtual/Phobia/phobia.html.

The Center for the Use of Virtual Reality Technology in the Treatment of Psychological Disorders has a Web site at www.csswebs.com/maxnorth/.

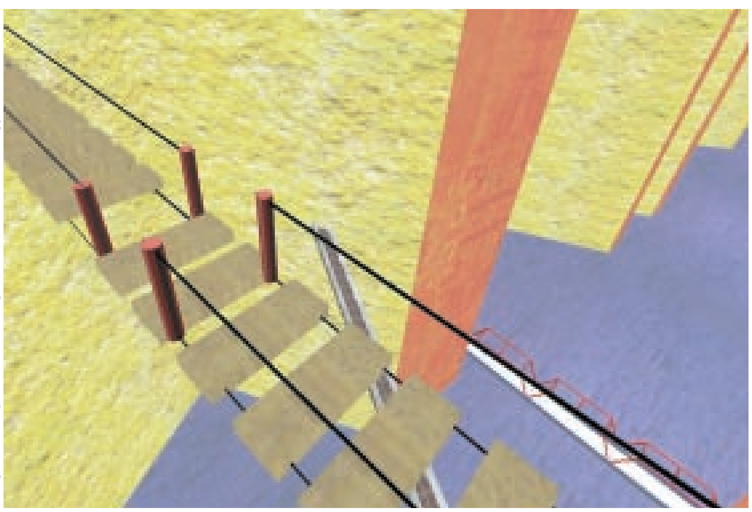

Image courtesy of GVU, Georgia Institute of Technology.

A view of a virtual bridge and the canyon below. (Image generated by Rob Kooper, Tom Meyer, and Larry F. Hodges.)

raised this issue and commented that research to date has not considered unintended negative effects of VR exposure therapy. What psychological effects—immediate and long-term—might result from immersing people in an environment that differs in both content and interactive control from what they experience in "real" reality? Bloom posed this question not to detract from the clearly apparent positive effects of such immersion but to raise some ethical issues for further consideration. Experience with virtual flight simulators and other immersive systems has shown that physical symptoms such as nausea and disorientation result from extended exposure. Paying attention to these and sorting out what specific factors cause them has led to technical adjustments and thus improved system performance.

Beyond physical system performance, however, lie the important issues of how a therapeutic VE may impact the therapist's role in treatment and thereby affect established psychological and psychiatric practices. Glantz, Durlach, Barnett, and Aviles recently suggested using VR and such constructs as virtual personae (VPs) to enhance simulation of a social as well as a physical environment. Under the therapist's direct control, a VP or several VPs can help the patient relive significant experiences to bring up repressed memories, or rehearse social situations to gain better mastery over them. This might, in some therapeutic contexts, change a therapist's stance from neutral to active or directive—which some therapists (such as psychoanalysts) might find quite undesirable.

Of course, psychologists and psychiatrists have been involved in therapeutic VR research and development since its inception. They are likely to be even more so as the technology branches out and ethical issues become part of research agendas. Hoffman cautions that false memories and memory distortion, already a problem in psychology, may also result from VR treatment. He plans to research this further with Itsukushima of the University of Japan. Such efforts will ensure that patients' welfare remains the primary consideration in system development and design. ■

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Further Reading

Studies on therapeutic VR systems have appeared in both computer graphics and psychological journals, including

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