The Challenge of Using Virtual Reality in Telerehabilitation

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ABSTRACT

Continuing advances in virtual reality (VR) technology along with concomitant system cost reductions have supported the development of more useful and accessible VR systems that can uniquely target a wide range of physical, psychological, and cognitive rehabilitation concerns and research questions. VR offers the potential to deliver systematic human testing, training, and treatment environments that allow for the precise control of complex dynamic three-dimensional stimulus presentations, within which sophisticated interaction, behavioral tracking, and performance recording is possible. The next step in this evolution will allow for Internet accessibility to libraries of VR scenarios as a likely form of distribution and use. VR applications that are Internet deliverable could open up new possibilities for home-based therapy and rehabilitation. If executed thoughtfully, they could increase client involvement, enhance outcomes and reduce costs. However, before this vision can be achieved, a number of significant challenges will need to be addressed and solved. This article will first present three fictional case vignettes that illustrate the ways that VR telerehabilitation might be implemented with varying degrees of success in the future. We then describe a system that is currently being used to deliver virtual worlds over the Internet for training safety skills to children with learning disabilities. From these illustrative fictional and reality-based applications, we will then briefly discuss the technical, practical, and user-based challenges for implementing VR telerehabilitation, along with views regarding the future of this emerging clinical application.

INTRODUCTION TO VIRTUAL REALITY TELEREHABILITATION

VIRTUAL REALITY (VR) has now emerged as a pragmatically viable tool in several aspects of therapy and rehabilitation.1–4 Continuing advances in VR technology, along with concomitant system cost reductions, have supported the development of more useful and accessible VR systems that can uniquely target a wide range of physical, psychological, and cognitive rehabilitation concerns and research questions. VR represents more than a simple linear extension of existing computer technology for human use. It offers the potential to deliver systematic human testing, training, and

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treatment environments for precise control of complex dynamic three-dimensional stimulus presentations, including sophisticated interaction, behavioral tracking, and performance recording. Much like an aircraft simulator serves for training and testing pilots, virtual environments (VEs) present simulations to assess and rehabilitate human functional performance under a range of stimulus conditions that are not easily deliverable and controllable in the real world. When combining these assets within the context of functionally relevant, logically valid VEs, a fundamental advancement emerges in how human behavior can be addressed in many rehabilitation disciplines. Over the last few years, revolutionary advances in the underlying enabling technologies (i.e., computation speed and power, graphics and image rendering, display systems, interface devices, immersive audio and haptics tools, movement tracking, voice recognition, intelligent agents, and other software) have supported development resulting in more powerful, low-cost “stand alone” PC-driven VR systems. The next step in this evolution will allow Internet access to libraries of VR scenarios as a likely form of distribution and use. VR applications that are Internet deliverable could open up new possibilities for home-based therapy and rehabilitation. If executed thoughtfully, this could increase client involvement, enhance outcomes, and reduce costs. Future Internet distribution of VR applications could also be supplemented by maintaining connectivity between the remote client using the system and a primary server at a rehabilitation facility. In this manner, the client’s home-based performance within the VR application could be tracked, quantified, analyzed, and graphically represented in a intuitively understandable format for analysis by rehabilitation professionals. In addition, the ongoing continuing updating of the VR world and the actions and activities that it requires of the client during rehabilitative exercises could be implemented both by the monitoring therapist and via “intelligent” systems on the main server. This functionality would allow efficient tracking of client progress. This information could then be used to develop performance demands on the client to foster positive rehabilitative outcomes.

Before this vision can be realized, a number of significant challenges will need to be addressed. This article will first present three fictional case vignettes that illustrate the ways that VR telerehabilitation might be implemented with varying degrees of success. This will be followed by a description of a system used to deliver virtual worlds over the Internet for training safety skills to children with learning disabilities. Based on these illustrative fictional and reality-based applications, we will then briefly discuss some technical and practical challenges for implementing VR telerehabilitation, along with views regarding the future of this emerging clinical application. Throughout the article the terms rehabilitation and therapy are used interchangeably.


The following case vignettes are fictional. They are presented here to illustrate many of the challenges that will need to be addressed in the creation of effective VR telerehabilitation systems over the next 10 years.

The good

Jane is a 30-year-old accountant who received a closed head traumatic brain injury due to a motor vehicle accident. After 1 month of post acute inpatient rehabilitation, she was released to her home with residual right-sided hemiparesis, deficits in selective, sustained, and divided attention, and mild depression. Her residence is 100 miles from the nearest rehabilitation facility and her impairments preclude her from driving this distance, relying instead on relatives to transport her to therapy only once a week. Her inability to return to work at this time adversely affects her emotional state, and she has “lost hope” that she would ever return to work because there is no noticeable change in her functioning on a daily basis.

The staff at her rehabilitation facility decided that since Jane had considerable familiarity with computers in her previous employment
and had a high-speed Internet 2 connection to her home, she would be a good candidate for their new VR telerehabilitation system. After becoming familiar with operating the technology via a detailed orientation meeting at the rehabilitation facility, she was given the latest high-resolution, wide field-of-view head-mounted display (HMD) and tracking system. These devices simply require her to plug them into her existing high-end computing appliance at home. The cost of this HMD and tracking system is only $200. After plugging the system into her home computer, a connection was automatically made to the rehabilitation facility’s main server that downloaded all the prescribed software to her system.

The rehabilitation software involved a gaming-like application that presented an engaging three-dimensional panoramic mountain valley backdrop with many varieties of colorful birds (Jane likes birds!) flying around within the HMD. Her task was to move her arms and hands, which were tracked and represented in the HMD using low-cost net cam technology, in a manner to catch the birds or to strategically position her hands such that the birds could land on them. In this way, the scenario could be used to provide rehabilitation exercises to promote upper body strength, range of motion, general motor dexterity, and other relevant therapeutic variables. She found the “game” compelling and fun, and she was able to perform quite well at the activity. She also liked the fact that after each trial she received a score that reflected her increasing skill at the game. Meanwhile, her performance was routed back to the facility’s database server, which monitored and recorded her activity and produced data on relevant performance metrics. The system automatically uploaded the data to her therapist in a format that presented an efficient and intuitive visualization of Jane’s performance. This allowed the therapist to make changes promptly in the “game” program based on Jane’s increasing skill level. The automated online query and analysis program also adjusted the difficulty level of the program to promote optimal success while gradually increasing the challenges needed to keep the game interesting.

As Jane’s movement parameters began to suggest that she was at a predefined performance level, the bird-catching task evolved a set of attentional tasks that required her to catch only specific birds under certain conditions. The new task addressed selective and divided attention. This level of mental challenge excited Jane, and, as she saw her scores continue to improve, her motivation also continued to increase. Over time, new “games” were uploaded to her computer from the facility server, based on her evolving motor and cognitive performance. At this point, while she still occasionally played the “bird game” for fun, she became more involved in the new simulation games that reminded her of her past employment working with numbers. The VR telerehabilitation system consistently evolved the demands of the tasks based on Jane’s improving performance, kept meticulous records of Jane’s activity, and produced intuitively understandable graphic representations of this information for her therapist. As well, Jane’s therapist was able to maintain the therapeutic relationship based on her capacity to monitor Jane’s performance data efficiently and via periodic phone, Internet teleconference, and face-to-face contact. Jane’s therapist also joined her within the VE via a shared connection that allowed them to interact in virtual real time. In 6 months, Jane had regained enough of her physical and cognitive abilities to begin returning successfully to her previous employment on a part-time basis. She stated that while she knows that her rehabilitation would be a long-term, ongoing process, she felt that she had accomplished a lot and is overjoyed to see her independence return as she embarks on the rest of her life!

The bad

Billy, a 19-year-old high school graduate working as a security guard, suffered a T3 spinal cord injury (SCI) and an open head traumatic brain injury in a motorcycle accident. He did not have health insurance. After 6 months of post acute care, he was released from his rehabilitation facility, now using a wheelchair. His residual impairment included loss of motor function from the chest down below his SCI and severe visual neglect in the upper-left vi-
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sual quadrant. Without insurance, the amount of financial support from the state for his con-
tinued rehabilitation was limited and Billy dis-
continued receiving any therapy following his hospital release. At this time Billy moved into the home of his only living relative, his brother. Unable to return to his former employment and incapable of driving, Billy became despondent and spent his days drinking and watching tele-
vision. After 6 months, Billy’s brother came upon a newspaper article about a local reha-
bilitation facility that was experimenting with a new VR telehabilitation system. An ap-
pointment was arranged and it was explained to Billy and his brother that the facility had just set up this prototype system. Some of the bugs were still being worked out. However, it was agreed that Billy could try this system for home-based rehabilitation to address his visual neglect and driving training. Unfortunately, due to financial constraints, a therapist would be available to him only once a month for re-
view of progress. Because money was tight, Billy could not afford the computer with the 4-
GHz processor that was recommended by the facility. Billy’s brother agreed to let Billy use his 3-year old system and with a quick search on E-Bay, a low-quality HMD, inertial tracker, and gaming steering wheel were acquired for $300. The facility loaned Billy a set of hand con-
trols for the VR driver training and sent a tech-
nology specialist to the home to integrate the devices and run the system via an existing AOL phone connection. After much effort, the sys-
tem worked, but it had significant lag time in the program and was prone to crashes at ran-
don intervals.

One of the VR scenarios consisted of the first version of the “bird-tracking” application. In it, Billy was required to follow certain birds as they flew into his neglected visual field in the three-dimensional space and to attempt to catch them with a mouse actuated “net.” The background provided optokinetic stimulation in the form of small dots that slowly moved to-
ward the upper left in an effort to induce op-
tokinetic nystagmus or “dragging of the eye” in the direction of the neglected space.3 A sec-
ond VR scenario used the gaming steering wheel with integrated hand controls for a se-
ries of driver training exercises. The perfor-
mance tracking software at the facility server was still being written, so the therapist needed to download Billy’s performance data shortly before his monthly appointment and try to make sense of the data in order to provide feedback to Billy regarding his therapeutic gains. At the first monthly session, Billy complained that the driver training made him dizzy when-
ever he made a right turn, and consequently did not use that program very much. Further, Billy lost interest in the “bird-catching” pro-
gram after a few times claiming that he “doesn’t like birds.” Nonetheless, his brother made him try it three times a week for 20 min-
utes. Billy’s brother reported in private that Billy did use the hardware nearly obsessively to play computer games, spending many hours playing the latest version of the best selling game “Interstellar Hitman: Path of Destruc-
tion.” The therapist responded by instructing Billy that if he ever wanted to be independent again, that he would just have to “suck it up” and do his home-based telehabilitation! Un-
fortunately, Billy became more frustrated and depressed. His use of the rehabilitation system declined to a once-a-week session on Saturday night after a few beers. He missed his second monthly “therapy” session and after resched-
uling his appointment by phone, he never made contact with the facility again.

The ugly

John was a 38-year-old male with a self-re-
ported 10-year history of panic attacks and multiple phobias. His only experience in ther-
apy occurred in the 1990s when he attended three sessions following his first panic attack. This occurred shortly after John experienced an earthquake in Southern California while at-
tending a party in which several of his friends were killed or seriously injured. During his brief course of therapy, he was diagnosed as having post-traumatic stress disorder. During the following 15 years, he had numerous panic attacks and flashbacks at home, at social gath-
erings, in tall buildings, when with groups of people in long hallways, and in many other di-
verse circumstances. Due to his embarrassment over his panic attacks, he became more reclu-
sive over the years and had virtually no social
life or outside interests. However, he was able to make a living by working out of his home designing Web sites. Recently, he had met a woman online who lived in Europe and this "cyberrelationship" blossomed to the point where he decided to fly to France to meet his fiancé in person.

While ordering his ticket online, he realized that he hadn’t flown since he was a child. As he contemplated the long flight, he felt a surge of anxiety that typically preceded a panic attack. When the anxiety subsided, he searched the internet for self-help information regarding fear of flying. This search produced several links. The pop-up ad that proclaimed “Cure Fear of Flying Using Virtual Reality in Your Own Home” caught his eye! Upon linking to the site, he saw that for $900 dollars, he would be sent a set of "3D Glasses" and have access to the fear of flying virtual reality treatment site for 1 month. Extra months could be assessed at a rate of $49.95 per month. The site claimed that most customers were “cured” in the first month. John ordered the service and shortly received a very flimsy low-resolution HMD along with Web access software. One of the earphones broke off as he first put on the HMD, but John assumed that sound was not all that important, and he signed on for his first session of VR flight. The images he saw of the inside of the plane were a little grainy, and the sound in the remaining earphone was not realistic. Nonetheless, he started the program. It proved to be very easy and he was not anxious at all. At one point, he drifted off to sleep. He used the “treatment” three more times and proclaimed himself cured. He even sent an e-mail testimonial to the Internet based company.

Two weeks later John went to the airport, checked in for his flight and was one of the first passengers to board the plane. As the cabin started to fill up with passengers, he began to feel some apprehension. As he heard the exit doors close and the engines fire up, he began to perspire heavily. As the plane started to taxi from the gate, he began to feel uncontrollable tremors in his legs and arms while his heart started to race. As the plane went down the runway for take off, the vibrations and rumbling brought about a flashback to his earthquake experience. He felt he had to get out of there, the whole structure was going to collapse on him, and he would be trapped! He bolted from his seat and grabbed at the emergency exit door in a state of wild-eyed frenzy. Two passengers in the exit row held him down as the plane lifted off. But his actions panicked some of the other passengers, and there were screams and crying throughout the plane. It took the pilots 30 minutes to return and make an emergency landing back at the airport, where paramedics and FAA security officials were waiting for John at the gate!

**VR TELEREHABILITATION IN THE PRESENT—ANALYSIS OF AN EXISTING WEB VIRTUAL REALITY PROGRAM**

While the three scenarios described above are fictional, they illustrate many of the general issues and challenges that must be addressed before implementing any VR telerehabilitative system in a clinically effective and ethical manner. Lessons learned from integrating virtual environments for training over the Internet were considered. For example, Do2Learn, a company that provides resources for children with autism, has developed Web-delivered virtual worlds to help teach safety skills for young children with learning disorders. Typically, children have difficulty conceptualizing abstract ideas regarding dangers without concrete examples and repeated practice. Virtual worlds provide one of the few safe methods for understanding potentially dangerous situations.

Do2Learn has developed several VR computer games for a home PC that create a virtual space and introduce dangers within that space. An animated computer character in the virtual world demonstrates how to respond safely to each danger. A child moves through the virtual world with the help of the character, who tracks and responds to the child’s motions, either rewarding safe actions or warning of dangers and demonstrating the correct steps. Because the worlds are computer controlled, they can be customized for each child with a menu, and each safety skill is divided into smaller steps to allow a child to learn at his or her own pace. For example, a child might learn...
how to cross at a crosswalk before learning to cross at a stoplight with a crosswalk, or learn to cross with no cars before learning to watch for cars when crossing.

Efficacy tests

In a series of different trials with children who had been previously diagnosed with either Pervasive Developmental Disorder or Fetal Alcohol Syndrome, 19 children between the ages of 3 and 7 were tested to see if they could learn previously unknown recommended home fire safety actions from practicing in a virtual world (see Figs. 1–4). Sixteen of the children learned to: (1) recognize a fire, (2) take the shortest safe route outside, and (3) wait at a predetermined meeting place until someone comes to find you. This game plus a street-crossing game are available at http://www.do2learn.org for free play. Current users of these VR safety games are from Europe, North and South America, Asia, Africa, New Zealand, and Australia.

Despite the obvious advantages of combining VR safety practice with Web delivery, the major technical challenges encountered in this application are as follows:

1. The Web infrastructure was not originally designed to handle a high volume of traffic. Hence, it is not easy to keep the connections fast and clean, particularly with problems of mass spam, denial-of-use attacks, and viruses. Do2Learn has to modify code continually while monitoring the flow of data on their server.

2. Any Web delivery requires interaction with a variety of products from other outside companies. All Web programs must run in someone else’s browser and operating system on a range of different hardware configurations. Often the details of how these outside products are implemented are hidden, thereby limiting their interoperability.

3. The correct programming language for the VR code is difficult to project in today’s changing market. Java was used for Do2Learn games and was until recently the accepted Web standard. Microsoft, however, threw that into turmoil by announcing it would not longer support Java in the future. The virtual machine to support Microsoft Java is different and incompatible in many ways from the original SUN Java virtual machine. The long-term existence of Java without Microsoft support makes programming a VR engine to support any Web-delivered application problematic.

4. Most service providers tend to protect their own remote servers through special features, such as time-out triggers if trans-
fers take too long. This can make getting virtual three-dimensional worlds to the user difficult. While response and transfer rate are highly dependent on the part of the world where the users live and how they are connected to the network, transfer time during peak hours for AOL in the United States can be 2K baud, as opposed to the 56K baud rate most users think they are getting over their modem. This can keep some users from being able to access VR games or require a high-speed connection, which can be expensive or unavailable.

FIG. 2. Different fire locations in virtual house.

FIG. 3. Selectable meeting places.
5. VR programs require a fast three-dimensional graphics platform and often a three-dimensional graphics card. Substantial funding is required to develop and update an interoperable platform for a virtual world. Fortunately, there are presently several VR platforms being developed by a variety of sources, such as Atmosphere at Adobe and Wild Tangent, which allow low-cost virtual worlds using sophisticated graphics platforms.

6. Headsets were not an option for the Do2Learn virtual world because of high cost and limited availability. This might change in the future. However, it is important to address these issues because of the potential value of this type of treatment. While creating bottlenecks, the mass use of the Web has also created opportunities for trying new ideas such as remote VR treatment programs.

CHALLENGES OF REMOTE VR TREATMENT PROGRAMS

The traditional problems in implementing telemedicine/telehealth have been addressed in the literature, along with other important issues, such as the lack of physical touch (e.g., shaking hands or holding the patient’s arm during an exercise). But many challenges are specific to VR rehabilitation. Some of these challenges are related to the level of technological sophistication required to produce a specific application. Others are more practical in nature and still others involve essentially the patients themselves.

**Technological challenges**

Implementing rehabilitation in VR already involves important technological advances and resources. Delivering VR over the Internet or with any other telecommunication system, significantly adds to the challenge. The needed progress in this area is mostly in the hands of computer scientists and other developers of VR systems and environments. Key challenges include:

- **Developing affordable high-quality hardware.** VR requires fast computers, efficient graphic cards, precise tracking systems, high-resolution displays, and highly specialized peripherals. While the first two components are evolving rapidly, the others are lagging behind, especially HMDs and haptic feedback devices.
- **Producing robust hardware.** Given the significant cost of VR hardware, lending the equipment to patients for the duration of rehabilitation treatment could become an attractive solution rather than asking them to buy it. However, VR equipment is still relatively fragile, and it is likely that few researchers and clinicians would allow patients to take these systems into their homes. Perhaps the expanding market of the gaming industry would drive future develop-
ments leading to the availability of low cost, robust hardware.

• Reducing side effects due to VR usage. Cyber-sickness and perceptuomotor aftereffects are reported to be potential side effects from the use of VR, particularly with HMD-delivered applications. Similar to motion sickness, cybersickness (i.e., dizziness, nausea, disorientation, etc.) is related to conflicts between various sensory systems. While cybersickness may never be entirely eliminated for certain users, it may be substantially reduced as advances occur in the quality of hardware. Perceptionmotor after effects (i.e., eye-hand coordination, postural instability, etc.) due to a lag in the sensorimotor system’s readaptation to the “real” world following VR use may also be a concern. Patients must be warned of this potential problem and of behaviors not recommended for a period of time following use of HMD VR (e.g., driving). Perhaps, some type of flatscreen post-VR activity should be mandated to monitor patients immediately following VR use.

• Creating new visual displays. It will soon be possible for people to “meet” in a shared virtual environment and communicate in real-time. This could provide options for shared virtual experiences between patients and therapists. Much like a videoconference system, each interlocutor would be immersed in a virtual room where they could see and interact with representations of each other. However, when wearing an HMD, it becomes impossible to see the eyes and much of the face of the interlocutors. The lack of such nonverbal cues could diminish clinical utility for certain therapeutic targets.

• Facilitating installation and operation of user-friendly programs. When telerehabilitation involves using VR at a patient’s home, the installation and operation of the software must be as an efficient, seamless “plug-and-play” process. This involves attention to programming needed to eliminate conflicts among programs, missing driver files, and cumbersome installing and calibrating procedures for using motion trackers. The installation and operation of complex VR software may be especially challenging for people with significant physical and mental impairments.

• Making the exercises enticing. Patients must be motivated to perform repetitive tasks, which are often involved in the use of VR. Hence, gaming features must be incorporated into rehabilitation and training exercises including a variety of VR scenarios to fit various tastes.

Practical challenges

Clinicians, researchers, health-care providers, and VR developers must also face certain practical challenges, as follows:

• Avoiding false claims. Technological advances should not be introduced for public use before people have the skill to use them effectively, and not before empirical validation and practice guidelines are established. Often new psychotherapies are widely disseminated long before their efficacy is established. Patients must be informed of the experimental nature of treatment when indicated. Existing guidelines and criteria for defining a treatment as “empirically supported” exist and should be consulted before claims are made to this effect.

• Establishing practice guidelines. Before VR tele-rehabilitation becomes common practice, guidelines must be established that specify how, where, and for whom this technology is appropriate, as in the development of other mental health approaches. The unique psychological, cognitive, physical, and functional characteristics that are commonly seen in different types of clinical conditions must be considered, along with an informed sensitivity to vulnerabilities of specific patients including, apprehensiveness to use a HMD, reality testing, capacity to learn to operate in a VE, susceptibility to side effects, and verbal reporting ability. These issues must be addressed for ethical reasons as well as for treatment efficacy.

• Establishing safety parameters. Rehabilitation exercises conducted at or outside the home without direct “in-person” therapist supervision may pose certain risks. Under such
situations, safety parameters and guidelines should be established to ensure the safe use of VR telerehabilitation (e.g., use accompanied by a relative or in a quite nondisturbing environment). A system for automated monitoring patient performance that is embedded in the VR software could recognize problematic activity. It could supplement therapist observations and serve to inform the patient when a problem occurs and when to discontinue using the system (i.e., acute pain, maladaptive tension in a specific muscle, movement outside the range of advised action, etc.). Ideally, an avatar would appear to inform the patient to stop and perhaps guide the patient in a relaxation exercise.

• Professionally based diagnosis and treatment. Like any other form of treatment, VR telerehabilitation must be used only when based on an adequate clinical assessment and diagnosis conducted by a professional. Self-help VR telerehabilitation services could expose patients to significant risks.

• Preparing the patient. Although VR may provide treatment that successfully incorporates gaming features that may be viewed as exotic and fun, this may not be the best approach. The therapist must acknowledge while VR-based rehabilitation may be more engaging than traditional methods, the therapy is serious and must be practiced in a rational frame of mind.

• Offering in-person clinical support. Offering VR rehabilitation from a distant site rather than on site could be motivated by problems of accessibility (e.g., patients live in an isolated rural area) or financial reasons (e.g., it may be less expensive than keeping them hospitalized for the length of the treatment). In both instances appropriate clinical monitoring and periodic in-person support at the remote site would be essential.

User challenges

Significant human factors issues exist for both VR, and, to a lesser extent, telemedicine. In this regard, patients who use VR telerehabilitation in the future will face new challenges. These challenges may be mitigated by clinical support and those who prescribe them. These include:

• Sense of presence. Presence, or the sense of being in the virtual environment rather than in an artificially created media experience, is a key “moderator” variable that influences the experience of and outcome of VR. Presence enables people immersed in a virtual environment to experience emotional reactions and behave as if the environment were real. But not everyone experiences this situation in the same way (c.f., ref. 17). Certain personal factors (i.e., concentration, emotional state, etc.) as well as environmental factors (i.e., reducing external distraction) may be under the control of the patient at home. Patients who are depressed or poorly motivated to participate in treatment may have difficulty in this area. Early orientation to these issues and periodic monitoring would be helpful.

• Reducing cybersickness. Certain user behaviors may exacerbate cybersickness during the use of VR. These include looking around rapidly while using an HMD and prior or concurrent use of alcohol and medications. Because individual users vary in their experience of such side effects, the therapist should investigate reports of cybersickness to determine user susceptibility and provide suggestions to minimize their occurrence.

• Signs of addiction. For now, there is no evidence of VR being addictive. However, sensitivity to highly immersive and enticing experiences has been reported in the popular media for certain interactive digital games such as Everquest.18 We need to be aware of signs of addictions. These include excessive use of VR; giving up important social, occupational, or recreational activities to get immersed; persistence of unsuccessful efforts to cut down immersions, etc. The line between being an “avid” participant in rehabilitation in VR and becoming “addicted” deserves some attention when the technology to deliver truly compelling VR scenarios becomes a reality.

• Selective use of VR. If VR equipment is lent
and installed on patients’ personal computers, these systems could easily be used for other purposes, such as violent games or sexual fantasies. Patients should be informed about the potential implications of using rehabilitation equipment for other purposes in order to assist them in making their own informed decisions, and how others in their home might use their system.

- **Being open to scrutiny.** The continuous monitoring of treatment progress may be viewed as useful for most patients and therapists, but certain patients may not want their low adherence to treatment to be so documented when it occurs. Indeed, these patients may be more reluctant to use this technology.

- **Positive attitude toward computers.** Not all patients like computers and technology. Some may be reluctant to use computers on their own at home. This issue needs to be conducted prior to the onset of treatment.

## CONCLUSIONS

The application of VR within a telerehabilitation format is the next logical step in considering ways to improve access to this technology by a wider group of potential beneficiaries. Successful implementation may also serve to leverage unique VR therapeutic assets and potentially reduce costs in this area of health care. However, the possible benefits that may be accrued here are equally matched by challenges that must be faced. It would be unfortunate to become enamored with the potential benefits of immersive VR technology and lose sight of the sheer technical, practical, clinical, and ethical complexities involved in using synthetic realities. A range of potential outcomes could occur when VR telerehabilitation is executed under both optimal and suboptimal conditions. It is now possible to deliver basic flatscreen VR for clinical purposes from a remote server via the Internet. Other innovations in the future would create therapeutic VR telerehabilitation applications that have ever-increasing sophistication and functionality. Optimal use of future systems in this area will likely make patients’ success more probable, but only when guided by thoughtful and empathetic clinical care.

## REFERENCES


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