Pol. Ann. Med., 2010; 17(1): 101–111.
OVERVIEW PAPER

VIRTUAL ENVIRONMENTS FOR REAL TREATMENTS

Arie Burstin, Riki Brown

Beit Rivka Geriatric Rehabilitation Center, Israel

ABSTRACT

Introduction. In the era of evidence-based practice, more evidence of the beneficial impact of physical therapy and rehabilitation interventions have emerged. Kwakkel and Wagenaar's meta-analysis, Carr and Shepherd's work relating to the motor learning concept, and Fiatarone's research of strength training, emphasize the influence of rehabilitation in outcome gains by demonstrating that in conjunction with the therapist's expertise, the most influencing factors are therapy frequency and intensity.
Aim. To show the problem which is the gap between this knowledge and reality.
Discusion. Recently published observational studies revealed that patients in rehabilitation facilities receive a very small amount of therapy time during rehabilitation. Virtual reality (VR) technology offers assistance, as it enables patients who have difficulties coping in the "real world" to gradually deal with their problems via the "virtual world". It provides the user with a real time interactive experience, through visual, audible, tactile or any other kind of feedback. Individuals find themselves in a pleasant, challenging, motivating and "inviting" functional environment, thus tending to forget their limitations or disability. In addition, VR encourages them to reach their goals which are difficult to achieve in any other treatment setting.
Conclusions. VR is a new, innovative technology utilizing virtual and adaptable worlds, created by sophisticated computer systems with improved graphic capability (hardware) and interactive software allowing one to interact "naturally" with the virtual environment, without the risk and cost of moving the patient into the "real world". The interactive experience is perceived by both, therapist and patient, as very positive, enabling treatment to continue over time without feelings fatigue or boredom. VR can be created through a variety of tools, simple to complex, cheap to expensive. Basic computer systems with different input and output devices, such as different

Corresponding address: Arie Burstin, Beit Rivka Geriatric Rehabilitation Center Day Hospital, 4 Hachamisha St., Petach Tikva 49245, Israel; phone: 972-3-9373974, fax: 972-3-9332344, e-mail: ariebur@clalit.org.il

Received 26.04.2010, accepted 28.06.2010

types of monitors or expensive and sophisticated systems using helmets with small video screens head mounted display have been used.

Recently, cheap "on the shelf" video game consoles were adopted by clinicians as valuable tools in treating patients suffering from various pathologies and disabilities. Therefore, therapists are required to manoeuvre and plan treatments in systems where the delineation between therapy and fun is not always clear or controlled. The common practice has to be, as always, somewhere in between the most expensive and sophisticated systems and the "non adaptable" video game consoles. We estimate that in the near future, VR technology will be widely used. Meanwhile, today's technology allows us to take more of the VR advantages to the clinical world.

Key words: Virtual Reality, rehabilitation, physical therapy, occupational therapy.

INTRODUCTION

Virtual reality (VR) technology, a big disappointment during the late 1980s, made a big "come back" during the late 1990s, and was consequently discovered as a powerful instrument to be used in rehabilitation. This technology enables the patient to cope in the "real world" and to gradually deal with his problems via the virtual world. It provides the user with a real time interactive experience through visual, audible, tactile or any other kind of feedback. The individual finds himself in a pleasant and "inviting" functional environment, tending to forget his limitations or disability. In addition, VR encourages him to reach his goals which are difficult to achieve in any other treatment settings.

What is VR?

VR is a new, innovative technology utilizing virtual and adaptable worlds, created by sophisticated computer systems with improved graphic capability (hardware) and interactive software allowing one to interact "naturally" with the virtual environment (VE). A virtual story is constructed in the VE, which can be adjusted under laboratory conditions. VR technology creates a virtual simulation of real-time interactive environments. When using different senses and motor strategies, the patient can practice three-dimensional (depth, width, height) or two-dimensional virtual tasks. The VR experience is achieved by the user's immersion into the VE, thus facilitating the user's feelings of presence.

Technologies which create artificial worlds

VR can be created through a variety of tools, simple to complex, cheap to expensive. Basic computer systems with different input and output devices, such as different types of monitors or helmets with small video screens head-mounted display (HMD) have been used. In the HMD, video screen images are updated, using motion trackers, in accordance with the patient's head movements (Fig. 1).

Fig. 1. Head-mounted display and haptic glove

The image can also be projected on two or three walls of a room (cave). Adding sounds makes the VE much more realistic. The patient controls the VE by computer input devices, such as keyboards, joysticks, mouse, or more sophisticated devices such as speed motion detection trackers, various input–output accessories that enhance the sense of position by vibration or resistance to movement (haptic devices) and motion platforms.

Other systems use video caption technology to embed the participant's image into virtual stories, using complicated algorithms to allow the patient to control the story by body and limbs movements.

Researchers believe that the greater the immersion and sense of presence, the better the treatment results.

Clinical applications of VR systems

Hundreds of experimental and commercial systems have been used to diagnose and treat different illnesses and disabilities in almost all fields of medicine.

Many of the first VR applications were developed to treat phobias. A phobia is defined as an unrealistic fear of a situation and/or a specific object. The individual experiences irrational fear, unaware that it is not life threatening. This is the most common mental disorder, with one out of 10 individuals suffering at least one phobia during his lifetime.

Common phobias treated using VR software are: claustrophobia (fear of closed places), acrophobia (fear of heights), agoraphobia (fear of being in a public place), arachnophobia (fear of spiders), fear of flying, and more. The most common approach used in assisting phobia sufferers is through a controlled treatment situation, with gradual exposure to the phobia "generator" (desensitization). Gradual exposure is accomplished by accessing a virtual controlled world, with the patient feeling that he controls the situation. The VR software helps reduce stress and anxiety. Success rates are similar to those achieved by exposure to the real source of fear. In most cases, this treatment is more economical, safer and preferable to the patients [12, 16]. Rizzo developed a virtual classroom to help discover ADHD problems in children and to subsequently treat them [17]. The system "immersed" the child wearing an HMD into a virtual class. The child listens to the teacher conducting the class, however, simultaneously various distractions are heard, such as a car passing outside, noise of a paper aircraft flying through the room, etc. The system tracks the child's eye movements at any given moment. Therapists monitored the information to ascertain how the various events distracted the child, approximately how long it took for the child to reach a reasonable level of concentration, and then to determine if he suffered from attention deficit disorders [17].

Another VR system helped diagnose driving skills of stroke patients and determine whether they were capable of driving again. In the VR environment, the patient wore special 3D eyeglasses, an HMD or actually sat in a car and experienced a "road trip", taken with a special video camera creating a realistic scenario at 360°. When the patient "drove" on the road, the therapist evaluated the patient's decision making processes, i.e. how he reacted when a child suddenly crossed the road, if he was pressing the accelerator instead of the brakes, how he reacted in different weather situations (snow, rain), etc. [24].

VR is also used to treat post traumatic stress disorders (PTSD). The first therapeutic meaningful trial, with good results, related to soldiers returning from Vietnam suffering from PTSD [18, 19]. Weiss et al. from the University of Haifa, developed a new scenario to treat victims of terrorist attacks in Israel. The technique allowed a controlled exposure to the cause of the stress and helped the patient return to a normal life (Fig. 2).

Fig. 2. Virtual Vietnam

Hoffman et al. found that during physiotherapy treatment of patients with extensive burns, VR helped reduce pain by distraction [6]. It has also been applied in dental treatments and chemotherapy.

Applications in the rehabilitation world

During the mid to late 1990s, VR systems were developed for use in various areas of rehabilitation. In 1998, Ring suggested a potential use for VR in neurological rehabilitation [14].

One of the main goals in rehabilitation is to improve the quality and the quantitative performance of daily tasks and achieve independence in daily life [21, 22]. There are three guiding principles in rehabilitation therapy: early intervention, specific task training and multiple repetitions [10]. Rehabilitation therapy tasks are repetitive, can be "boring", distract the patient and reduce motivation [1, 15]. Treatment programs utilizing VR combine relevant experience with multi-sensory stimulation and an ecological valid environment, which is challenging, thus raising the motivation level of the patient. In recent years, technology has improved, thus facilitating the use of VR in research and clinical settings.

AIM

To show the problem which is the gap between this knowledge and reality.

DISCUSSION

Representative examples in the area of rehabilitation:

In 1998, Riva published a case report documenting a spinal cord injury patient walking on a treadmill embedded in a VR environment using a HMD [15]. Girolamo et al (1999) demonstrated that adding VR therapy is useful for treatment and assessment of vestibular problems [4]. Merians et al. showed improvement in strength, speed and movement components in the hands of three hemiparetic patients treated with the Rutgers University Cyberglove [11].

The Department of Occupational Therapy, Haifa University, tested the ability to safely cross the road. People suffering from unilateral spatial neglect after a stroke were treated using a relatively simple computer application. These results indicate the feasibility of using the system [7, 25] (Fig. 3).

Fig. 3. Safe street crossing

Weiss et al. also tested the connection between cognitive, motor ability and performance in VR in stroke patients and found that improved cognition lead to improved performance in VE. Other studies have examined hand reaching in real and VE. Viau et al. found that performance in the VE was equal or even better than in the real environment [23]. Nyberg et al. developed a system designed to evaluate the impact of attention level and unexpected obstacles on the ability of a person to control his posture and movements in VR [13]. Keshner et al. used VE to study posture and stability mechanisms by examining the impact of multiple system stimulations on balance reactions in populations with different pathologies [8].

In 1996, Vivid Group introduced an interactive video projection system called Gesture Xtreme (GX) with applications in the entertainment and education fields. The system includes a video camera recording the patient's movements in real time. The figure is digitally removed from a monochromatic background and "embedded" in real time in the VE. The system's potential for rehabilitation was identified in 1999. Cunningham et al. used this system to treat elderly people in danger of falling [3] (Fig. 4).

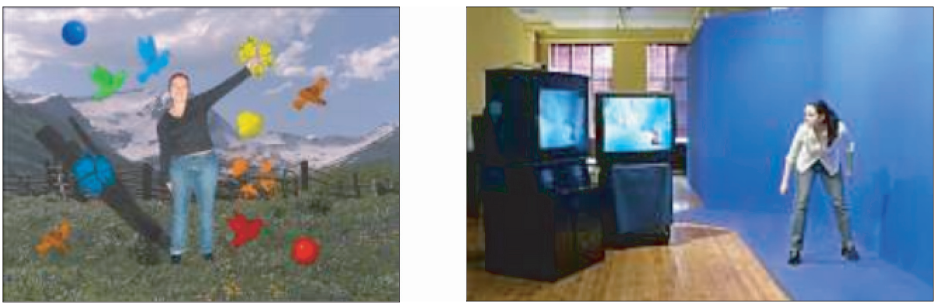


Fig. 4. Balls and birds (IREX System)

In recent years, GX has been adapted for use in rehabilitation and is now capable of changing levels of difficulty, recording a patient's performance and generating reports. The clinical application of GX is called "IREX" (Interactive Rehabilitation Exercise System) and is a product of GestureTek. Weiss et al. published clinical research papers proving the feasibility of IREX system in treating various pathologies [26].

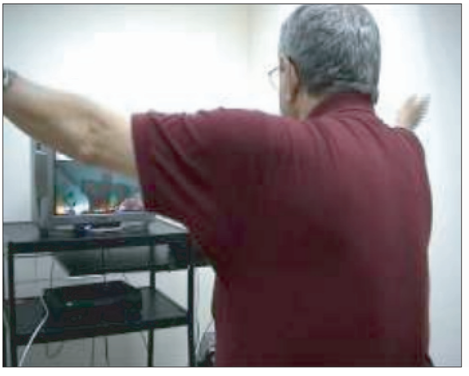
Motek, an Israeli-Dutch Company, created a revolutionary system called CAREN (Computer Assisted Rehabilitation Environment), enhancing video projection by adding a force platform and video motion analysis working in real time, thus enabling a variety of scenarios for challenging and fully controlled experiences (Fig. 5).

Fig. 5. CAREN system

The patient stands on a computerized force platform (2.5 m in diameter) with the virtual story projected on a wide screen or in a HMD. The patient is actually immersed in the virtual scenario. Three-dimensional cameras read the markers on the patient's body and respond to his movements. The computer processes the data and moves the platform to different levels of difficulty, depending on the patient's ability. This system can treat patients in various stages of rehabilitation in addition to treating elite athlete after injuries, thus improving their skills.

The CAREN system is very expensive and requires skilled therapists, technicians, time and financial resources to operate. For these reasons, the system is used mainly for research and is less available for clinical use.

Sony has developed an interactive children's game called EyeToy on the PlayStation II platform. The EyeToy uses a video camera to capture the user's image, identifies his movement and embeds him in a virtual story in real time. The child actively controls the VE by using his body movements. The system is cheap, simple, available and does not require special rooms, monochromatic screens or external aids (Fig. 6).



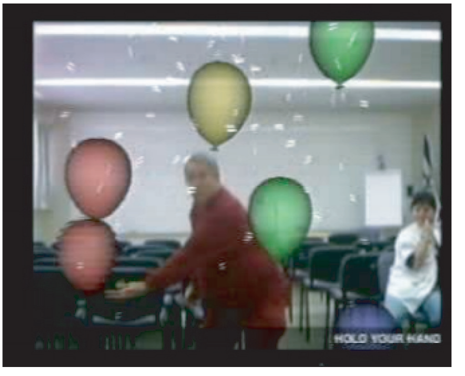


Fig. 6. Sony PlayStation II with EyeToy

Sony does not develop special software for rehabilitation, but the wide range of existing applications enables clinical use, depending on the creativity of the therapists. Weiss et al. found that the IREX and the EyeToy systems obtained almost identical results in every measured variable [26].

Nintendo Company developed a new gaming console, called Wii. The user can play different sport games like bowling, golf or tennis using a wireless movement tracker, the "Wiimote" simulating a golf stick, a tennis racket, etc. Deutsch et al. reported beneficial effects of a treatment planned and executed using this system, in cases of cerebral palsy in children [4]. Sugarman et al. reported balance improvement in a geriatric stroke patient treated with a new Wii peripheral, the WiiFit [20]. The WiiFit is a wireless force plate; the subject controls the game by shifting his weight, usually without moving his feet, or stepping, while standing on the special platform. The platform detects shifts in weight bearing in the antero-posterior and lateral directions. Increasing the range of weight shifting works on limits of stability, and seems to improve balance reactions.

At present, many systems are suitable for academic research. Those designed for clinical research are very complex and demand technical expertise, expensive equipment and special physical conditions [26].

Game consoles like Sony PlayStation II with EyeToy and Nintendo's Wii are partial solutions to therapeutic needs, by allowing challenging motor and cognitive tasks. However, it is impossible to change the difficulty level to match the patient's true ability and therefore adapt the game to his therapeutic needs. Another problem is the lack of records and reports of patients performances [26]. Therefore, therapists are required to maneuver and plan treatments in systems where the delineation between therapy and fun is not always clear or controlled [4].

Recently, a new virtual reality system, SeeMe, claimed to solve this dilemma. SeeMe uses a standard PC plus a web camera, in a double display setting with a large television screen (Fig. 7).

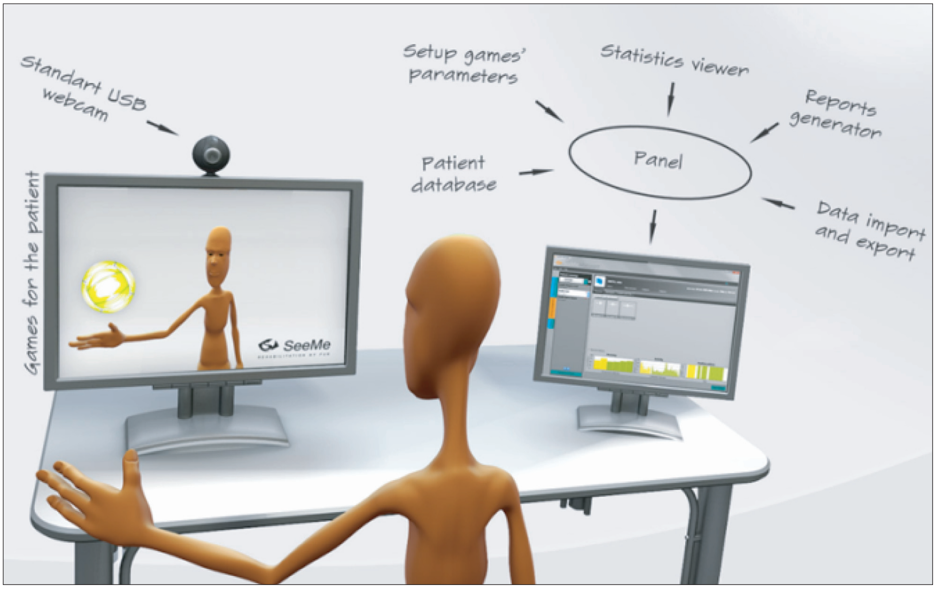


Fig. 7. SeeMe system

The therapist can make on-line changes and adaptations of the patient's ability on the PC screen. The patient sees himself on the wide screen, interacting normally, using body and limb movements within the virtual story in real time. There is no need for markers, wires or a monochromatic background. SeeMe uses novel algorithms for movement, position recognition and analysis. The system includes three "warm up" games and six challenging programs with various difficulty levels, intended to improve motor skills of patients with different cognitive and perceptual pathologies. SeeMe displays high-quality graphics (simulating three dimensional environments) for natural and interactive training. The system was successfully tested on healthy elderly individuals, who reported a high level of motivation, immersion and presence in the virtual story. In a case study describing a stroke patient with severe neglect, the system was effective in diagnosing and treating the patient [2].

The system is user friendly, intuitive, and easily tailored to the different treatment needs of patients. Demographic information and performance reports can be saved and printed, and patient progress can be monitored.

CONCLUSIONS

The interactive experience is perceived by both therapist and patient as very positive, enabling treatment to continue overtime without feeling fatigued or bored. The therapeutic intervention exists in a functional and challenging environment without the risk and cost of moving the patient into the "real world".

We estimate that in the near future, VR technology complemented by telerehabilitation will be widely used. Meanwhile, today's technology allows us to take more of the VR advantages to the clinical world.

REFERENCES

1. Burdea G. C.: *Virtual rehabilitation – benefits and challenges*. Methods Inf. Med., 2003; 42 (5): 519–523.
2. Burstin A., Brown R.: *Use of a novel virtual reality system to assess and treat stroke patients with neglect – A feasibility study*. Int. J. Rehabil. Res., 2009; 32 (1): 77–78.
3. Cunningham D., Krishack M.: *Virtual reality: a holistic approach to rehabilitation.* Stud. Health. Technol. Inform., 1999; 62: 90–93.
4. Erren-Wolters, C. V., van Dijk H.: *Virtual reality for mobility devices: training applications and clinical results: a review.* Int. J. Rehabil. Res., 2007; 30 (2): 91–96.
5. Girolamo S., Nardo P., Picciotti P., Paludetti G., Ottaviani F., Chiavola O.: *Virtual reality in vestibular assesstment and rehabilitation*. Virtual Reality, 1999; 4 (3): 169–183.
6. Hoffman H. G., Patterson D. R., Carrougher G. J., Sharar S. R.: *Effectiveness of virtual reality-based pain control with multiple treatments*. Clin. J. Pain., 2001; 17 (3): 229–235.
7. Katz N., Ring H., Naveh Y., Kizony R., Feintuch U., Weiss P. L.: *Interactive virtual environment training for safe street crossing of right hemisphere stroke patients with unilateral spatial neglect.* Disabil. Rehabil., 2005; 27 (20): 1235–1244.
8. Keshner E. A., Kenyon R. V.: *Using immersive technology for postural research and rehabilitation*. Assistive Technology, 2004; 16 (1): 27–35.
9. Lott A., Bisson E., Lajoie Y., McComas J., Sveistrup H.: *The effect of two types of virtual reality on voluntary center of pressure displacement*. Cyberpsychol. Behav., 2003; 6 (5): 477–485.
10. Malouin F., Richards C. L., McFadyen B., Doyon J.: *New perspectives of locomotor rehabilitation after stroke*. Med. Sci. (Paris), 2003; 19 (10): 994–998.
11. Merians A. S., Jack D., Boian R., Tremaine M., Burdea G. C., Adamovich S. V.: *Virtual reality-augmented rehabilitation for patients following stroke*. Phys. Ther. 2002; 82 (9): 898–915.
12. Moore K., Wiederhold B. K., Wiederhold M. D., Riva G.: *Panic and agoraphobia in a virtual world*. Cyberpsychol. Behav., 2002; 5 (3): 197–202.
13. Nyberg L., Lundin-Olsson L., Sondell B., Backman A., Holmlund K., Eriksson S.: *Development of a virtual reality system to study tendency of falling among older people*. The 5th International Conference on Disability, Virtual Reality and Associated Technologies Proceedings.
14. Ring H.: *Neurological rehabilitation is ready for 'immersion' in the world of virtual reality?* Disabil. Rehabil., 1998; 20 (3): 98–101.
15. Riva G.: *Virtual reality in paraplegia: a VR-enhanced orthopaedic appliance for walking and rehabilitation*. Stud. Health. Technol. Inform., 1998; 58: 209–218.

16. Riva G.: *Virtual reality in psychotherapy: review*. Cyberpsychol. Behav., 2005; 8 (3): 220–230; discussion 231–240.
17. Rizzo A. A., Buckwalter J. G., Bowerly T., van der Zaag C., Humphrey L., Neumann U., Chua C., Kyriakakis C., van Rooyen A., Sisemore D.: *The virtual classroom: a virtual reality environment for the assessment and rehabilitation of attention deficits*. Cyberpsychol. Behav., 2000; 3 (3): 483–499.
18. Rothbaum B. O., Hodges L., Alarcon R., Ready D., Shahar F., Graap K.: *Virtual reality exposure therapy for PTSD Vietnam veterans: a case study*. J. Trauma. Stress, 1999; 12 (2): 263–271.
19. Rothbaum B. O., Hodges L. F., Ready D., Graap K., Alarcon R. D.: *Virtual reality exposure therapy for Vietnam veterans with posttraumatic stress disorder*. J. Clin. Psychiatry. 2001; 62 (8): 617–622.
20. Sugarman H., Weisel-Eichler A., Burstin A., Brown R.: *Use of the Wii Fit system for the treatment of balance problems in the elderly: A feasibility study*. Virtual Rehabilitation International Conference Proceedings. 2009; 111–116
21. Sveistrup H., McComas J., Thornton M., Marshall S., Finestone H., McCormick A., Babulic K., Mayhew A.: *Experimental studies of virtual reality-delivered compared to conventional exercise programs for rehabilitation*. Cyberpsychol. Behav. 2003; 6 (3): 245–249.
22. Sveistrup H.: *Motor rehabilitation using virtual reality*. J. Neuroeng. Rehabil., 2004; 1 (1): 10.
23. Viau A., Feldman A. G., McFadyen B. J., Levin M. F.: *Reaching in reality and virtual reality: a comparison of movement kinematics in healthy subjects and in adults with hemiparesis.* J. Neuroeng. Rehabil., 2004; 1 (1): 11.
24. Wald J., Liu L., Reil S.: *Concurrent validity of a virtual reality driving assessment for persons with brain injury.* Cyberpsychol. Behav., 2000; 3 (4): 643–654.
25. Weiss P. L., Naveh Y., Katz N.: *Design and testing of a virtual environment to train stroke patients with unilateral spatial neglect to cross a street safely.* Occup. Ther. Int., 2003; 10 (1): 39–55.
26. Weiss P. L., Rand D., Katz N., Kizony R.: *Video capture virtual reality as a flexible and effective rehabilitation tool.* J. Neuroeng. Rehabil., 2004; 1 (1): 12.