19

Common Issues of Virtual Reality in Neuro-Rehabilitation

Man, D.W.K.
Department of Rehabilitation Sciences, The Hong Kong Polytechnic University
Hong Kong, PRC

1. Introduction

Use of virtual reality (VR) has been developing rapidly in the rehabilitation field. The efficacy and efficiency of VR application in either an immersive or a non-immersive type, has been demonstrated for different client groups during the last few decades. This book chapter provides a review of “what, how and why” of virtual reality application for neuro-rehabilitation, with a focus on cognitive rehabilitation. Examples of technology transfer to VR-assessment (such as retrospective and prospective memory assessment) and -intervention for persons with special needs (for examples, everyday memory, community living skills and vocational training skills) will be highlighted. The client groups include persons with stroke, traumatic brain injury, schizophrenia, older adults with mild cognitive impairment and dementia. Ecological validity of VR-test will be discussed in terms of transfer ratio from training to real-life task. Hints in better designing, structuring the content in virtual environment (VE) for navigation, interaction, presence and immersion functions will be outlined. New development including tele-VR rehabilitation, artificial intelligence (AI) application in cognitive rehabilitation in neurological patients and vocational rehabilitation for schizophrenic trainees will be introduced.

2. What is the problem?

Virtual reality has been considered as a cutting-edge technology. Its development is sporadic and can possibly be used in rehabilitation for persons with neurological conditions and those with long-hauled cognitive problems. It is clear the VR has its strengths and “room for expansion”, its limitations should not be under-estimated. We need to be cognizant of VR’s development in terms of technology advancement, as well as its working mechanism in order to develop evidence-based practice. To a certain extent, the above question has been partially answered, but a lot more to be explored. This chapter may serve as a bridge between what we knew, we know and we will know.

3. What is virtual reality (VR)?

It is a cutting-edge computer technology which has its origins in visually coupled system (Kalawksy, 1993) and formed the basis of the first flight simulator. VR is a computer generated environment. It was based on computer simulation and real-time visual, auditory and touch feedback (Katz et al., 2005). Schultheis and Rizzo (2001) defined it as a way for humans to visualize, manipulate, and interact with computers and extremely complex data. VR could also be viewed as an advanced form of human-computer interface that allowed users to "interact" with and become "immersed" in a computer-generated environment in a naturalistic fashion (Riva, 2002). Characteristics of virtual reality systems include navigation (exploring, orientating), interaction (opportunities to engage in virtual environment or VE), presence (subjective feeling of being present in a simulated environment) and immersion (objective measure –VR platform, technology-based) (Aguinis et al., 2001; Vince, 1998). VR is now being widely applied in many fields including engineering, architecture, design, medicine, education and training. The potential of virtual environments (VEs) in the field of neurological rehabilitation has been noted (Rose et al., 1998).

4. "How VR works?"

Virtual reality can be of two types, immersive and non-immersive. In its immersive form the visual and auditory aspects of the computer generated environment are delivered to the user via visual display units and speakers situated in a head mounted display while tactile sensations can be delivered via data gloves or a body suit. In the non-immersive form of VR the visual aspects of the environment are presented to the user on a PC monitor (or projected onto a large screen) and the auditory array is presented through speaker. Through VR's capacity to control dynamic 3-dimensional, ecologically valid stimulus environments within which behavioral responding can be recorded and measured, it offers clinical assessment and rehabilitation options that are not available with traditional methods (Schultheis, 2001). VR has several advantages including cost- effectiveness and a good match between the current capabilities of VR technology and generalization issues (Rizzo et al., 1997; 1998). In studying the relative advantages of immersive and non-immersive type of VR, it was commented that immersive VR (IVR) applications might cause some side-effects such as motion sickness. It is believed to occur when there is a conflict between perceptions in different sense modalities, e.g., auditory, visual, vestibular, or proprioceptive (Rizzo et al., 1997; Galimberti et al., 2001). Morganti and associates (2006) also suggested the benefits and challenges in VR neurological rehabilitation (See Figure 1).

VR can only work well according to good guidelines in development (Castelnuovo et al., 2003; Munro et al., 2002; Tarr & Warren, 2002). Fidelity, target client characteristics and purpose of assessment or treatment are closely considered. Observers must be able to move freely, and the VR system can respond to his/her actions on close to real time. They will be provided with significant portion of visual view for a sense of "embeddedness", viewing multiple 3D objects with realistically shaded and textured surfaces. Thus accurate representation of the real world (physical fidelity) should be provided. Factors contributing to the users' sense of presence has also been proposed (Weiss et al., 2005). Apart from users' characteristics (age, gender, immersive tendencies, prior experience, and disability), the VR system characteristics (e.g. dimensionality, representation, multimodality, and encumbrance) and VR task characteristics (meaningfulness, realism, and interaction) also contribute to presence (also see Figure 2).

5. Why VR works?

May be it is more important to provide answers to the key question on "Why VR works?" In recent years, several papers on VR efficacy have been published in which the effects of exposure to VR on the activity of the nervous system have been discussed (Pugnetti et al,

VR Application	Benefits	Challenges
Neuro-muscular	• Improve compliance • Fine time resolution • Rehabilitation at home • On-line data gathering	• Equipment cost • Technical expertise • Safety at home • Network bandwidth
Post-stroke	• Engaging/motivation • Repetitive intensive • Adaptable to patient education • Usable in chronic phase • Activities of daily living	• Clinical acceptance • Technical expertise • Abnormal limb configuration • Upper functional population applicability • Cognitive load
Cognitive functions	• More realistic assessment • Reduced therapy cost • Increased safety • Learning transfer	• Equipment cost • Safety at home • Psychological factor

Fig. 1. Benefit/challenges in VR neurological rehabilitation (Adapted from Morganti, 2006)

Key questions	**Possible answers**
1. Are virtual environments (VEs) useful, effective and efficient in clinical applications?	Evaluations of possible advantages and limits , cost-benefit analysis
2. Do VEs reproduce the physical and perceptual characteristics of real environments?	Attentions to graphics and technical characteristics. Focus on realism and technical issues
3. Do VEs allow users to function in an ecologically valid way?	Attention on cultural and social aspects. Focus on interaction, importance of relationships and context

(Adapted from Castelnuovo et al., 2003)

Fig. 2. Possible issues to consider in designing virtual environments (VEs) (Adapted from Castelnuovo et al., 2003)

1998). Positive effects in functional outcome, transfer of skills and *f*MRI studies have been shown (Bertella et al., 2001; Mcgeorge et al., 2001; Rose et al., 1998; Zhang et al., 2003). One possible explanation would be brain plasticity resulted from environmental stimuli and essential for therapeutic strategies development and for many cerebral disorders. For examples, virtual-reality training environment was suggested to induce cortical organization and associated locomotor recovery in chronic stroke (Sung et al., 2005). VR-based program was used to conduct motor training of affected upper limb in people with hemiparetic stroke. Functional improvements in affected limb were showed in VR group, but not in control group. Cortical reorganization was found in the primary sensorimotor cortex under *f*MRI examination. These findings supported that the effect of VR exposure was not limited to functional gains, but also in the activities in nervous system.

The high training effectiveness of VR in neurological (e.g. Burke et al., 2009; Grealy & Heffernan, 2001) and cognitive rehabilitation (e.g. Dou et al., 2006; Pascoe, 2010; Yip & Man, 2009) had been explained by "environmental enrichment" (EE; Kolb, 1999) that environmental effect was very important to patients' recovery from brain injury. From animal studies, enriched VR environments might stimulate neuroplastic change in the cerebral cortex, enhance learning and problem-solving, and reduce cognitive impairment caused by brain-damage (Rose et al., 1998).This was further evidenced by neuro-imaging studies and psychophysiological studies (McComas & Jayne, 1998). Relatively complex and stimulating environment had better training effect than impoverished environment (Johansson, 2004; Kolb, 1999). Virtual environment thus could offer rich and vivid visual and auditory stimulations. Better training effects were expected as compared to other training strategies on which the application of visual and auditory stimulation was not focused. In addition, the "naturalistic" training environment created by VR matched the principle of learning such as contextual learning (Gordon et al., 2006). The focus on training in real life situation and day-to-day problem had been found to be more effective than training isolated cognitive skills. While real life training may impose potential hazard to both patients and therapists, virtual environment was a good substitution. This is supported by studies that training in virtual environment yielded equivalent training effect as training in real environment (Brooks et al., 1999). Moreover, modern functional imaging technology indicated the activation of hippocampus under functional imaging during virtual navigation (Astur et al., 2005). It means that virtual environment or tasks may produce a similar stimulation to corresponding neural structure just like the real environment does. On the same "learning theory" vein, constructivist therapy for theory of VR learning also suggested that people could learn through first-person, non-symbolic experience. VR allows them to construct knowledge from direct experience by the "perceptual illusion of non mediation" between themselves and the computer. People assimilate knowledge more effectively when they have the freedom to move and engage in self-directed activities within their learning context. VR facilitates the active process of making sense of new information, by creating their own version of reality instead of simply receiving others' view (Mantovani, 2001).

Another possible explanation would be the "transfer of skills to real world". It was suggested that training established association between physical aspects of the task and cognitive organization learnt during task performance resulting in a learnt cognitive response to the task. Thus visual picture may result in more autonomic real world performance, due to possible freeing up cognitive capacity to deal with interfering tasks (Rose et al., 2000). In addition, training skill transfer should be best when training mimics performance as closely as possible virtual reality fulfills the principles for generalization (Lathan et al., 2002). During the design phase, generalization is already a key issue of programming: identification of naturalistic reinforcement, selection of appropriate transfer measurement, use of sufficient examples and repetitions, stimuli common to both the training environment and the example of repetition (Rizzo & Buckwalter, 1997).

When applying VR to cognitive rehabilitation, VR was proposed to be able to reduce the required attentional resource and prevent overload by simplifying the tasks (Grealy et al., 1999). In the learning process, the virtual environment can reduce brain's work load by easier recognition of objects, spatial ordering, large-size environment (Seidel & Chatelier, 1997). Using VR in training may reduce cognitive load by eliminating the need for a trainee to convert two-dimensional training materials into three-dimensional representation, thus enable them to utilize more cognitive resources on learning the task (Johnson & Hyde, 1997).

Last but not the least, use of VR may serve as a motivational factor. Usability and motivational factors seem to be an important reason for the success of computer-based rehabilitation. VR is considered as the more advanced evolution of the relationship between man and computers. VR designers typically aim to create a convincing, engaging, environment in which sense of presence has to be recreated (Priore et al., 2003)

6. VR for assessment and treatment

Presence of an "e-supervisor" through VR may provide a more valid, reliable and less-threatening assessment situation, and may better reinforce/ structure the disabled individual's residual self-management skills in a somewhat familiar, simulated environment. For instance, executive function deficits are revealed only when the individual is alone, or fails to maintain awareness when left unsupervised, but being observed by the VR program. In VR training, responsibility for the activities will be transferred to the patient, including the generalization to the environment of daily life and sustain training efforts and bringing about behavioral changes (Trepagnier, 1999). In the context of cognitive rehabilitation, virtual environment may be valuable when assessment and training in "real-life" situations is made difficult. For instance, brain injured patients' sensory, motor and cognitive disabilities may not allow them to threatening real-life situation, or cause danger by "pre-mature" exposure. It is also suggested that VR-based tests overcome several limitations of traditional paper-and pencil tests, and are at least as sensitive to target cognitive impairments, while providing a richer range of opportunities for measuring behavior (Pugnetti et al., 1998). VR can thus be a useful tool for assessment and treatment in neurological and cognitive rehabilitation. Moreover, different cognitive rehabilitation approaches rest upon the assumption that what is learnt in training transfers to the equivalent real world task. There have been preliminary findings that a clear positive transfer effect from virtual and real training suggests that the cognitive strategy elements and cognitive loads of the training is broadly equivalent (Rose et al., 2000). Moreover, VR has been used in conjunction with traditional therapeutic techniques to promote cognitive and visual perceptual functioning (Cunningham & Krishack, 1999). Virtual reality has proven useful in enhancing human perceptions and thus resulting behaviors, psychological health and well being (Thomas et al., 1996).

6.1 More examples to illustrate

The potential for VR applicable in neuro-rehabilitation and cognitive rehabilitation has been found to be great. For instances, VR has been used in unilateral neglect and hemineglect in stroke (Myers & Bierig, 2000; Tsirlin, et al., 2009), brain injury assessment and rehabilitation (Pugnetti et al., 1998; Rizzo et al., 2000; Rose et al., 2005), physical rehabilitation in stroke (Saposnik, et al., 2010) and spinal cord injury (Kizony et al., 2003), functional evaluation and training (Lee et al., 2003), as well as tele-rehabilitation (Tam et al., 2003; Rizzo, et al., 2004).

There are also precedents for use of VR in memory rehabilitation (Brooks & Rose, 2003), executive dysfunction (Mendozzi et al., 1998), perceptual disorders and learning difficulties (Wann et al., 1997). VR has also been proposed for the relearning of community living skills (Christiansen et al., 1998; Gourlay et al., 2000), as VR environments are precisely controlled, entirely safe environments within which patients' learning outcome and behaviours can be minutely monitored.

More specific examples include the assessment of children with attentional deficits through a virtual classroom (Rizzo, et al, 2002), spatial and episodic memory of brain damaged patients through a virtual town (Spier et al, 2001), prospective memory assessment of stroke through a virtual four-room bungalow (Brooks, et al, 2004), and acquired brain injury through a virtual shopping mall (Man et al., 2010a, under review), evaluating brain injured patients' daily living skills through a simulated kitchen (Zhang et al., 2003).
Recently, there has been memory training in older adults with mild cognitive impairment (MCI) using a virtual model home and a convenience shop (Man et al., 2010b, under review), community living skill training (room crossing, bus-taking, shopping, use of bank services and meeting friends) through a virtual city and a supermarket (da Costa et al., 2000; Tam et al., 2005; Yip & Man, 2009), motivation of stroke survivors through VR leisure program (Reid & Hirji, 2003), virtual play in children with cerebral palsy (Reid, 2004), driving skills training for persons with brain injury (Schultheis & Peterson, 2000). Application to persons with schizophrenia for vocational training using a virtual boutique has also been noted (Tsang & Man, in preparation).

6.2 Artificial intelligence-based virtual reality program

The innovative use of artificial intelligence (AI) techniques such as Case-Based Reasoning has been proposed (Yip & Man, 2010, under review) to develop the VR system allows some flexibility to facilitate individual learning. The main advantage in integrating VR systems with embedded AI software can be the ability of providing instant analysis of the user's behavior. Therefore, immediate feedbacks and assistance can be given to the users in the forms of additional clues and objects in the virtual world. This will allow for individual styles of learning and their relative stages of recovery. A recent development would be an AI based VR system for prospective memory training for shopping skills (Yip & Man, 2010, under review). By altering three parameters, namely number of items in a shopping list (S), number of prospective memory task (P) and level of assistance (A). After gathering the training performance of each trial/session, AI system can plan the level of difficulty in the next session.

7. Conclusion

It is optimistic that application of VR is wide-spreading and feasible for neurological and cognitive rehabilitation. VR can be especially valuable when training in real life situations will be impractical, dangerous, logistically difficult, unduly expensive, and too difficult to control (Rose et al., 2000). VR has the capacity, and greater flexibility, to simulate a greater range of situations and environments as compared to other simulation-based techniques (Aguinis et al., 2001). VR holds people's attention for a longer period of time than other methods because it is immersive, interactive, imaginable and interesting (Albani et al., 2002). Limitations of VR might result in a decreased sense of presence due to heavy and cumbersome headsets, low spatial resolution, narrow field of view that may presently be available in the headsets, primitive methods of force and tactile feedback, inappropriate time lags in tracking performance, induction of stimulator/motion sickness/cyber sickness (Gaggioli, 2001; Priore et al., 2003). Further development depends how we resolve these problematic issues and reduce the technological and financial demand. The initial demonstration of VR using commercial games such as Wii game technology in stroke rehabilitation (Sapnosnik et al., 2010) might be an alternative way to provide VR rehabilitation in motor recovery and possibly more in rehabilitation arena.

8. References

Aguinis, H., Henle, C.A. & Beaty, J.C. (2001). Virtual Reality Technology: A New Tool for Personnel Selection, *International Journal of Selection and Assessment* 9(1/2): 70-83.

Albani, G., Pignatti, R., Bertella, L., Priano, L., Semenza, C. & Molinari, E. (2000). Common daily activities in the virtual environment: a preliminary study in parkinsonian patients, *Neurological Sciences* 23: S49-S50.

Astur, R.S.,Germain, S.A., Baker, E.K., Calhoun,V., Pearlson G.D. & Constable, R.T. (2005). fMRI hippocampal activity during a virtualradial arm maze. *Applied Psychophysiology and Biofeedback*: 30(3), 307-316.

Bertella, L., Marchi, S. & Riva, G. (2001). Virtual environment for topographical orientation (VETO): Clinical rationale and technical characteristics, *Presence, 10*: 440 – 449.

Brooks, B. M., McNeil, J. E., Rose, F. D., Greenwood, R. J., Attree, E. A. & Leadbetter, A. G. (1999). Route learning in a case of amnesia: A preliminary investigation into the efficacy of training in a virtual environment, *Neuropsychological Rehabilitation* 9(1): 63-76.

Brooks, B.M. & Rose, F.D. (2003). The use of virtual reality in memory rehabilitation: current findings and future direction, *Neurorehabilitation* 18: 147-157.

Brooks, B.M., Ross, F,D,Potter, J. Jayawardena, S. & Morling, A. (2004). Assessing stroke patients's prospective memory using virtual reality, *Brain Injury*: 18(4), 391-401.

Burke, J.W., McNeill, M.D.J., Charles, D.K., Morrow, P.J., Crosbie, J.H. & McDonough, S.M. (2009). Optimising engagement for stroke rehabilitation using serious games, *Visual Computer* 25: 1085-1099.

Castelnuovo, G., Priore, Liccione C. L. & Cioffi, G. (2003). Virtual reality based tools for the rehabilitation of cognitive and executive functions: the V-store, *PsychNology Journal* 1(3): 310-325.

Christiansen, C., Abreu, B., Ottenbacher, K., Huffman, K., Masel, B. & Culpepper, R. (1998). Task performance in virtual environments used for cognitive rehabilitation after traumatic brain injury, *Archives of Physical and Medical Rehabilitation* 79: 888-892.

Cunningham, D. & Krishack, M. (1999). Virtual reality promotes visual and cognitive function in rehabilitation, *CyberPsychology and Behavior* 2(1): 19-23.

da Costa, R., de Carvalho, L. & de Aragon, D.F. (2000). Virtual reality in cognitive training, Proceedings of 3rd International Conference on Disability, Virtual Reality & Associated Technology, Alghero, Italy, pp. 221-224.

Dou, Z.L., Ou, N.H., Zheng, J.L., Man, D.W.K. & Tam, S.F. (2006). Computerized errorless learning-based memory rehabilitation for Chinese patients with brain injury: a preliminary quasi-experimental clinical design, *Brain Injury* 20(3): 219-225.

Gaggioli, A. (2001). Using virtual reality in experimental psychology. *In* Riva, R. & Galimberti, C. (ed.), *Towards cyberpsychology: mind, cognition and society in an internet age*, IOS Press, The Netherlands, pp.157-174.

Galimberti, C., Ignazi, S., Vercesi, P. & Riva, G. (2001). Characteristics of interaction and cooperation in immersive and non-immersive virtual environments. *In* Giuseppe, R. & Galimberti, C. (ed.), *Towards cyberpsychology: Mind, cognition and society in the internet age*, IOS Press, The Netherlands, pp. 129-155.

Gordon,W.A., Cantor, J., Ashman, T. & Brown, M. (2006). Treatment of post-TBI executive dysfunction: application of theory to clinical practice, *Journal of Head Trauma Rehabilitation* 21(2): 156-167.

Gourlay. D, Lun, K.C., Lee, Y.N. & Tay, J. (2000). Virtual reality for relearning daily living skills, *International Journal of Medical Informatics* 60(3): 255-261.

Grealy, M. A., & Heffernan, D. (2001). The rehabilitation of brain injured children: the case for including physical exercise and virtual reality, *Pediatric Rehabilitation* 4(2): 41-49.

Grealy, M. A., Johnson, D. A. & Rushton, S. K. (1999). Improving cognitive function after brain injury: the use of exercise and virtual reality, *Archives of physical medicine and rehabilitation* 80: 661-666.

Johnson, S. & Hyde, B.G. (1997). *Training for a rapidly changing workplace: applications of psychological research*, American Psychological Association, Washington.

Kalawksy, R.S. (1993). *The science of virtual reality and virtual environments*. AddisonWesley Publishing Co,UK.

Katz, N., Ring, H., Naveh, Y., Kizony, R., Feintych, U. & Weiss, P. L. (2005). Interactive virtual environment training for safe street crossing of right hemisphere stroke patients with Unilateral Spatial Neglect, *Disability and Rehabilitation 27:* 1235-1243.

Kizony, R., Katz, N., Weiss, P.L. (2003). Adapting an immersive virtual reality system for rehabilitation,*The Journal of Visualization and Computer Animation* 14: 261-268.

Kolb, A. & Kolb D. A. (2001). *Experiential Learning Theory Bibliography 1971-2001*, McBer and Co, Boston.

Lathan, C.E., Tracey, M. R., Sebrechts, M. M., Clawson, D. M. & Higgins, G. A. (2002). Using virtual environments as training simulators: Measuring transfer. *In* Stanney, K. M. (ed.), *Handbook of virtual environments: Design, implementation, and applications,* Erlbaum, Mahwah, NJ, pp. 403-414.

Lee, J.H., Ku, J., Cho, W., Hahn, W.Y., Kim, I.Y., Lee, S.M., Kang, Y., Kim. D, Y., Y. T., Wiederhold, B.K., Wierderhold, M.D. & Kim S.I. (2003). A virtual reality system for the assessment and rehabilitation of the activities of daily living, *CyberPsychology & Behavior* 6(4): 383-388.

Man, D.W.K., Shum, D. & Fleming, J. (2010a, under review). Development and validation of a prospective memory test – a shopping mall.

Man, D.W.K., Chung, J.C.C. & Lee. G.Y.Y. (2010b, under review). Evaluation of a virtual reality-based memory training programme for Hong Kong Chinese older adults with Mild Cognitive Impairment (MCI).

Mantovani, F. (2001). VR learning: potential and challenges for the use of 3D environments in education and training. *In* Riva, R. & Galimberti, C. (ed.), *Towards cyberpsychology: mind, cognition and society in an internet age*, IOS Press, The Netherlands, pp: 207-223.

McComas, J.P. & Jayne, L.M. (1998). Children's transfer of spatial learning from virtual reality to real environments, *CyberPsychology and Behavior* 1(2): 121-128.

McGeorge, P., Phillips, L.H., Crawford, J.R., Garden, S.E., Sala, S.D. & Mine, A.B. et al. (2001). Using virtual environment in the assessment of executive dysfunction, *Presence* 10: 375 – 383.

Mendozzi, L., Motta, A., Barbieri,E., Alpini, D. & Pugnetti, L. (1998). The application of virtual reality to document coping deficits after a stroke: report of a case study, *Cyberpsychology and Behavior* 1:79-91.

Meyer, R.L. & Teresa, A.B. (2000). Virtual reality and left hemineglect: a technology for assessment and therapy, *CyberPsychology & Behavior* 3(3): 465-468.

Morganti, F., Goulene, Gaggioli, A., StrambaBadiale, M. & Giuseppe, R. (2006). Grasping virtual objects: a feasibility study for an enactive interface application in stroke, PsychNology 4(2):181-197.

Munro, A., Breaux, R. & Patrey, J. (2002). Cognitive aspects of virtual environments design. *In* Stanney, K. M. (ed.), *Handbook of virtual environments: design, implementation, and applications*, Erlbaum, Mahwah, NJ, pp. 415-434.

Pascoe, J. (2010). The effect of an enriched environmental language-accessing programme on the reacquisition of language in a person with traumatic brain, *Social Care and Neurodisability* 1(2): 4-15.

Priore, C.L., Castelnuovo, G., Liccione, D. & Liccione, D. (2003). Experience with V-STORE: considerations on presence in virtual environments for effective neuropsychological rehabilitation of executive functions, *CyberPsychology & Behavior* 6(3): 281-287.

Pugnetti, L., Mendozzi, L., Attree, E., Barbieri, E., Brooks, B. BM., Cazzullo, C.L., Motta, A. & Rose, F. D. (1998). Probing memory and executive functions with virtual reality: Past and present studies, *CyberPsychology and Behavior* 1(2):151-161.

Reid, D. (2004). The influence of virtual reality play in children with cerebral palsy, *Occupational Therapy International* 11: 131-144.

Reid, D. & Hirji, T. (2003). The influence of a virtual reality leisure intervention program on the motivation of older adult stroke survivors: a pilot study, *Physical and Occupational Therapy in Geriatrics* 21(4): 1-19.

Riva, G. (2002). Virtual reality for health care: the status of research, *CyberPsychology & Behavior* 5(3): 219-225.

Rizzo, A. A. Buckwalter, J. G. & Neumann, U. (1997). Virtual reality and cognitive rehabilitation: a brief review of the future, *Journal of Head Trauma Rehabilitation* 12(6): 1-15.

Rizzo, A. A., Buckwalter, J.G., Neumann, U., Kesselman, C. & Thiebaux, M. (1998). Basic issues in the application of virtual reality for the assessment and rehabilitation of cognitive impairment and functional disabilities, *CyberPsychology and Behavio*r 1(1): 59-78.

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. (2000), The virtual classroom: a virtual reality environment for the assessment and rehabilitation of attention deficits, *CyberPsychology & Behavior* 3(3): 483-499.

Rizzo, A.A., Strickland, D.M. & Bouchard, S. (2004). The challenge of using virtual reality in telerehabilitation, *Telemedicine Journal and e-Health* 10(2): 184-195.

Rose, F. D., Attree, E. A., Brooks, B. M. & Johnson, D. A. (1998). Virtual environments in brain damage rehabilitation: A rationale from basic neuroscience. In Riva, G., Wiederhold, B. K. (eds.), Virtual environments in clinical psychology and neuroscience: Methods and techniques in advanced patient-therapist interaction. *Studies in health technology and informatics, Vol. 58*, IOS Press, Amsterdam, Netherlands Antilles, pp. 233-242.

Rose, F. D., Attree, E. A., Brooks, B. M., Parslow, D. M., Penn, P. R. & Ambihipahan, N. (2000).Training in virtual environments: transfer to real world tasks and equivalence to real task training, *Ergonomics* 43 (4): 494-511.

Rose, F.D., Brooks, B.M, Rizzo, A. (2005). Virtual reality in brain damage rehabilitation: review, *CyberPsychology & Behavior* 8(3): 241-262.

Saposnik, G., Mamdani, M., Baytley, M., Thorpe, K.E., Hall, J., Cohen, L.G. & Teasell, R. (2010). Effectiveness of virtual reality exercises in stroke rehabilitation (EVREST): rationale, design, and protocol of a pilot randomized clinical trial assessing the Wii gaming system. *International Journal of Stroke* 5: 47-51.

Schultheis, M. T. & Rizzo, A.A. (2001). The application of virtual reality technology in rehabilitation, *Rehabilitation Psychology* 46(3): 296-311.

Schultheis, M. & Peterson, W. (2000). *The use of virtual reality technology for assessment of driving skills following acquired brain injury,* RehabWire, 2(8) (http://www.naric.com/RehabWire/000901.html)

Seidel, R. J. & Chatelier, P. R. (1997). Virtual reality, training's future. Plenum Press, New York.

Spier, H.J., Burgess, N., Maguire, E.A., Baxendale, S.A., Harley, T., Thompson, P.J. & O'Keefe, J. (2001). Unilateral temporal lobectomy patients show lateralized topographic and episodic memory deficits in a virtual town, *Brain* 124 (12):2476-2489.

Sung, H. Y., Jang, S.H., Kum, Y.H., Hallet, M., Ahn, S.H., Kwon, Y.H., Kim, J.H. & Lee, M.Y. (2005). Virtual-reality training environment was suggested to induce cortical organization and associated locomotor recovery in chronic stroke, Stroke 36:1166-1171.

Tam, S.F., Man, D.W.K., Chan, Y. P., Sze, P.C. & Wong, C.M. (2005). Evaluation of a computer-assisted, 2-D virtual reality system for training people with intellectual disabilities on how to shop, *Rehabilitation Psychology* 50(3): 285-291.

Tam, S.F., Man, W.K., Hui-Chan, C. W.Y., Lau, A., Yip, B. & Cheung,W. (2003). Evaluating efficacy of tele-cognitive rehabilitation for functional performance, *Occupational Therapy International* 10(1): 20-38.

Tarr, M. J. & Warren, W. H. (2002). Virtual reality in behavioral neuroscience and beyond, *Nature Neuroscience* 5: S1089-S1092.

Thomas, G. P., Fraizer, S., Tittle, A., Babula, M., Ferlic E. & Riggs, E. (1996). Does virtual reality enhance the psychological benefits of exercise? *Proceeding of 1st European Conference on Disability, Virtual Reality & Associated Techology*, Maidenhead, UK, p.5.

Trepagnier, C.G. (1999). Virtual environments for the investigation and rehabilitation of cognitive and perceptual impairments, *Neurorehabilitation* 12(1): 63-72.

Tsang, M., Man, D.W.K. (in preparation). A virtual reality-based vocational training system (VRVTS) for people with schizophrenia in vocational rehabilitation.

Tsirlin, Dupierrix, E., Chokron, S., Coquillart, S. & Ohlmann, T. (2009). Uses of virtual reality for diagnosis, rehabilitation and study of unilateral spatial neglect: review and analysis, *CyberPsychology & Behavior* 12(2): 175-181.

Vince, J. (1998). Essential Virtual Reality Fast: How to Understand the Techniques and Potential of Virtual Reality, Springer-Verlag, New York.

Wann, J.P., Rushton, S.K., Smyth, M. & Jones, D. (1997). Rehabilitative environments for attention and movement disorders. *Communcations of the ACM*, 40, 49-52.

Weiss, P.L., Kizony, R., Feintuch, U. & Kazt, N. (2005). Virtual reality in neurorehabilitation, *Selzer* 2-13: 182-197.

Yip, B. C.B. & Man, D. W.K. (2009). Virtual reality (VR)-based community living skills training for people with acquired brain injury: a pilot study, *Brain Injury 23(13-14: 10107-1026.*

Yip, B. C.B, Man, D. W.K. (2010, under review). Intelligent virtual reality (IVR) cognitive rehabilitation programme for everyday prospective memory training.

Zhang, L., Abreu, B., Seale, G., Masel, B., Christiansen, C. & Ottenbacher, K. (2003). A virtual environment for evaluation of a daily living skill in brain injury rehabilitation: reliability and validity, *Archives of Physical Medicine and Rehabilitation* 84: 1118-1124.

Virtual Reality

Edited by Prof. Jae-Jin Kim

ISBN 978-953-307-518-1

Hard cover, 684 pages

Publisher InTech

Published online 08, December, 2010

Published in print edition December, 2010

Technological advancement in graphics and other human motion tracking hardware has promoted pushing "virtual reality" closer to "reality" and thus usage of virtual reality has been extended to various fields. The most typical fields for the application of virtual reality are medicine and engineering. The reviews in this book describe the latest virtual reality-related knowledge in these two fields such as: advanced human-computer interaction and virtual reality technologies, evaluation tools for cognition and behavior, medical and surgical treatment, neuroscience and neuro-rehabilitation, assistant tools for overcoming mental illnesses, educational and industrial uses In addition, the considerations for virtual worlds in human society are discussed. This book will serve as a state-of-the-art resource for researchers who are interested in developing a beneficial technology for human society.

InTech Europe

University Campus STeP Ri

Slavka Krautzeka 83/A

51000 Rijeka, Croatia

Phone: +385 (51) 770 447

Fax: +385 (51) 686 166

www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai

No.65, Yan An Road (West), Shanghai, 200040, China

中国上海市延安西路65号上海国际贵都大饭店办公楼405单元

Phone: +86-21-62489820

Fax: +86-21-62489821