The Use of Virtual Reality in Assisting Rehabilitation

Madeleine A. Grealy

Bilal Nasser

School of Psychological Sciences and Health, University of Strathclyde, Glasgow, UK

Department of Biomedical Engineering, University of Strathclyde, Glasgow, UK

Using virtual reality (VR) to assist with rehabilitation is an attractive option for many reasons. With the desire to increase the intensity and frequency of therapy sessions whilst maintaining or cutting costs, the use of VR provides a feasible and efficient method of delivering therapy. VR systems are based on three dimensional computer generated simulations of the real world. Interacting with these simulations creates compelling perceptual illusions which allow the user to behave in the virtual world in a similar way to how they behave in the real world. The capability that this type of interaction affords means that VR systems have many advantages in rehabilitation settings; they can provide safe environments which can be tailored to meet the individual's needs, they can mimic real situations, they can make boring repetitive tasks more engaging and interesting, they enable detailed monitoring of performance to be taken and they allow specific and measureable goals to be set. VR also offers a variety of mechanisms for therapeutic gain including the repetitive practice of movements, engaging in problem solving, memory and attention tasks and exposure to anxiety provoking stimuli or events. Until recently though the use of VR in rehabilitation has been described as 'more virtual than real'[1], but with rapid developments in affordable software and hardware this is changing rapidly. Today the number and nature of computer-based interactive tasks that can be used for rehabilitation is growing, and their use is becoming more commonplace. However, in reviewing the current state of play it is clear that whilst the potential for VR-based therapies is significant we still have some way to go before they are embedded in everyday clinical practice or the home.

VR-based therapies have been used for a variety of conditions including movement disorders, pain management[2], cognitive deficits[3] and anxiety disorders[4] but the most commonly reported and assessed neurorehabilitation applications have been in postural control[5,6] and stroke rehabilitation. Assessing the efficacy and effectiveness of VR-based therapies is not straightforward though as the literature on the use of VR in stroke rehabilitation exemplifies. A Cochrane review[7] carried out in 2011 that evaluated the effects of virtual reality and interactive video gaming on upper limb, lower limb and global motor function after stroke, revealed only 19 randomised control trials that met the inclusion criteria and 12 of these had sample sizes of less than 25 participants. Whilst the conclusions of this review were favourable for the use of VR and interactive video gaming in improving arm function and activities of daily living in stroke rehabilitation, there was insufficient data to draw more conclusions. This lack of empirical evidence also extends to which aspects of VR-based therapies will be the most important for different groups of patients, and whether the benefits of VR-based therapies are maintained in the long term.

Similarly, a meta-analysis to determine whether VR-based therapies provide additional benefits for arm motor recovery after stroke published in 2011[8] included 12 studies of which only five were randomised control trials. When pooled the data showed that the patients who were randomised to the VR-based therapy were 4.9 times more likely to improve their motor strength compared to patients in the control conditions. However, there were no large studies which compared conventional therapy to VR-based therapy, and a large and varied number of outcome measures were used in the different trials included in this review.

This poor evidence base for the efficacy of VR-based therapies reflects a number of difficulties. The cost of equipment and the need for skilled programmers to create bespoke virtual environments has restricted research programmes in the past, although this is improving. Greater difficulties lie in the designing of informed games-based tasks and in understanding the nature of how the intervention could or should be delivered. Lange et al.[9] described seven core elements that a VR-based intervention should address, including specifying the precise tasks to be targeted for rehabilitation and adjusting the levels of difficulty as the person progresses. This indicates that clinicians and therapists have critical roles to play in designing and implementing VR interventions, and the importance of this was raised by Levac et al.[10] who pointed out that VR systems are tools whereas VR-based therapies involve making decisions about the appropriateness of the VR system in terms of the person's ability to interact with it, the types of VR tasks to be used, frequency of use, rates of progression etc. The role of the therapist in ensuring the clarity of instructions and objectives, and helping with the initial interactions with the virtual world has been documented in a qualitative study of stroke patient's experiences of VR-based therapy[11], but unfortunately within the current quantitative literature the processes and procedures surrounding how interventions were delivered are generally not well described.

The rapid evolution of the technology in this field has seen different forms of VR systems come on the market ranging from fully immersive room sized systems to the more common non-immersive experience of using a games console or a computer and monitor. The range of ways in which individuals can interact with virtual environments has also expanded with the invention of haptic and force feedback devices which provide tactile sensations and allow the user to grasp and feel objects in the virtual world. Recent advances in augmented reality (where the user wears a head mounted display and views the real world, but with the addition of computer generated information overlaid onto the scene) may also prove to be useful in rehabilitation settings. Alongside these developments the games industry is also making an impact on rehabilitation with products such as the Nintendo Wii being incorporated into therapies. However, viable concerns are being raised about games that have been designed for entertainment being used in therapeutic settings[12]. Studies that have classified the content of games[13] will certainly help clinicians decide the appropriateness of the game, but knowing whether playing the game will generate the most appropriate movement pattern or behaviour is more challenging. For example, the mapping of a patient's movement amplitude and direction to the movements of an avatar in the game may not be sufficiently sensitive to provide adequate feedback[13], and when patients have been asked about how they played the games some have admitted to 'cheating' by making proscribed rather than prescribed movement patterns in order to gain more points in the game[11]. Overall, there is good evidence for the feasibility of using VR-based therapies in neurorehabilitation, although consideration needs to be given to the kinds of devices used since some have the potential to cause cybersickness (nausea, eyestrain, blurred vision etc.)[14]. However, robust evidence for the effectiveness and efficacy of this type of therapy is yet to emerge although the signs are promising. Clearly much more work needs to be done and future studies will need to explore not only the functional outcomes of VR-based therapies but also the extent to which they influence cortical reorganization. Some progress has already been made on this, for example, a preliminary report using fMRI to assess changes in five patients with hemiparetic stroke who had received VR training daily for five weeks indicated that following VR training there was a decrease in the ipsilateral activation and an increase in contralateral activation of the sensorimotor cortex when moving the affected limb[15]. Future work also needs to consider the extent to which there is transfer from the virtual to the real world, and a greater understanding of the mechanisms that promote change in VR-based rehabilitation settings will aid this. These challenges are likely to be met soon since this rapidly developing field has seen the creation of numerous research laboratories and companies in recent years and the formation of an International Society for Virtual Rehabilitation (www.isvr.org/).

References

1. Crosbie JH, Lennon S, Basford JR, McDonough SM. Virtual reality in stroke rehabilitation: Still more virtual than real. *Disability and Rehabilitation* 2007;29(14):1139-46. DOI: 10.1080/09638280600960909
2. Mahrer NE, Gold JI. The use of virtual reality for pain control: A review. *Current Pain and Headache Reports* 2009;13(2):100-09. DOI: 10.1007/s11916-009-0019-8
3. Cherniack EP. Not just fun and games: applications of virtual reality in the identification and rehabilitation of cognitive disorders of the elderly. *Disability and rehabilitation. Assistive technology* 2011;6(4):283-9. DOI: 10.3109/17483107.2010.542570
4. Opris D, Pintea S, Garcia-Palacios A, Botella C, Szamoskozi S, David D. Virtual reality exposure therapy in anxiety disorders: a quantitative meta-analysis. *Depress. Anxiety* 2012;29(2):85-93. DOI: 10.1002/da.20910

5. Duque G, Boersma D, Loza-Diaz G, Hassan S, Suarez H, Geisinger D, et al. Effects of balance training using a virtual-reality system in older fallers. *Clinical Interventions in Aging* 2013;8:257-63. DOI: 10.2147/cia.s41453
6. Meldrum D, Glennon A, Herdman S, Murray D, McConn-Walsh R. Virtual reality rehabilitation of balance: assessment of the usability of the Nintendo Wii() Fit Plus. *Disability and rehabilitation. Assistive technology* 2012;7(3):205-10. DOI: 10.3109/17483107.2011.616922
7. Laver KE, George S, Thomas S, Deutsch JE, Crotty M. Virtual reality for stroke rehabilitation. *Cochrane database of systematic reviews (Online)* 2011(9):CD008349-CD49. DOI: 10.1002/14651858.CD008349.pub2
8. Saposnik G, Levin M, Stroke Outcome Res Canada S. Virtual Reality in Stroke Rehabilitation A Meta-Analysis and Implications for Clinicians. *Stroke* 2011;42(5):1380-86. DOI: 10.1161/strokeaha.110.605451
9. Lange B, Koenig S, Chang C-Y, McConnell E, Suma E, Bolas M, et al. Designing informed game-based rehabilitation tasks leveraging advances in virtual reality. *Disability and Rehabilitation* 2012;34(22):1863-70. DOI: 10.3109/09638288.2012.670029
10. Levac DE, Galvin J. When is virtual reality "therapy"? *Archives of physical medicine and rehabilitation* 2013;94(4):795-8. DOI: 10.1016/j.apmr.2012.10.021
11. Lewis GN, Woods C, Rosie JA, McPherson KM. Virtual reality games for rehabilitation of people with stroke: perspectives from the users. *Disability and rehabilitation. Assistive technology* 2011;6(5):453-63. DOI: 10.3109/17483107.2011.574310
12. Bavelier D, Green CS, Han DH, Renshaw PF, Merzenich MM, Gentile DA. Brains on video games. *Nature Reviews Neuroscience* 2011;12(12):763-68. DOI: 10.1038/nrn3135
13. Deutsch JE, Brettler A, Smith C, Welsh J, John R, Guarrera-Bowlby P, et al. Nintendo Wii Sports and Wii Fit Game Analysis, Validation, and Application to Stroke Rehabilitation. *Topics in Stroke Rehabilitation* 2011;18(6):701-19. DOI: 10.1310/tsr1806-701
14. Bruck S, Watters PA. Accessible virtual reality therapy using portable media devices. *Studies in health technology and informatics* 2010;154:87-91.
15. Jang SH, You SH, Hallett M, Cho YW, Park C-M, Cho S-H, et al. Cortical reorganization and associated functional motor recovery after virtual reality in patients with chronic stroke: an experimenter-blind preliminary study. *Archives of Physical Medicine and Rehabilitation* 2005;86(11):2218-23. DOI: 10.1016/j.apmr.2005.04.015.