Hindawi Publishing Corporation
Advances in Human-Computer Interaction
Volume 2012, Article ID 213143, 6 pages
doi:10.1155/2012/213143

Research Article

A Game-Based Virtualized Reality Approach for Simultaneous Rehabilitation of Motor Skill and Confidence

Alasdair G. Thin

School of Life Sciences, Heriot-Watt University, Edinburgh EH14 4AS, UK

Correspondence should be addressed to Alasdair G. Thin, a.g.thin@hw.ac.uk

Received 18 May 2012; Revised 24 September 2012; Accepted 8 October 2012

Academic Editor: Francesco Bellotti

Virtualized reality games offer highly interactive and engaging user experience and therefore game-based approaches (GBVR) may have significant potential to enhance clinical rehabilitation practice as traditional therapeutic exercises are often repetitive and boring, reducing patient compliance. The aim of this study was to investigate if a rehabilitation training programme using GBVR could simultaneously improve both motor skill (MS) and confidence (CON), as they are both important determinants of daily living and physical and social functioning. The study was performed using a nondominant hand motor deficit model in nonambidextrous healthy young adults, whereby dominant and nondominant arms acted as control and intervention conditions, respectively. GBVR training was performed using a commercially available tennis-based game. CON and MS were assessed by having each subject perform a comparable real-world motor task (RWMT) before and after training. Baseline CON and MS for performing the RWMT were significantly lower for the nondominant hand and improved after GBVR training, whereas there were no changes in the dominant (control) arm. These results demonstrate that by using a GBVR approach to address a MS deficit in a real-world task, improvements in both MS and CON can be facilitated and such approaches may help increase patient compliance.

1. Introduction

Functional impairment of human motor function can arise due to a number of different causes including a variety of disease processes, physical trauma, and aging. The best treatment outcomes are seen when rehabilitation exercises are instituted early and in an intensive and repetitive manner in order to promote neural plasticity and muscle hypertrophy [1]. Given the often long and arduous nature of treatment programs requiring many thousands of exercise repetitions over many months, if not years, it is hardly surprising that patients commonly complain that the therapeutic exercises are repetitive and boring and this leads to poor compliance with the prescribed exercises and results in suboptimal optimal treatment outcomes. Not only is this scenario likely to impact on a patient's quality of life, but also it may ultimately result in a loss of their ability to live independently and necessitate long-term provision of care. Treatment programs are also very often resource intensive in terms of the time a physical therapist needs to devote to an individual patient and also the time spent traveling in connection with treatment. A range of technology-based solutions are therefore currently being actively investigated in terms of their potential for improving the efficiency and effectiveness of rehabilitation programs and to also increase the independence of patients and empower them to take control of their own treatment [2].

Virtual rehabilitation has been defined as "the combination of computers, special interfaces, and simulation exercises used to train patients in an engaging and motivating way." [3]. A range of different systems developed so far include remote monitoring of therapeutic exercises enhanced by virtual reality (VR) [4, 5], finger strengthening and hand-eye coordination exercises and games using VR combined with a haptic glove [6, 7]. For the purposes of this paper the term "Game-based Virtualized Reality" (GBVR) is considered to include all forms of games that involve players physically interacting with virtual objects that only exist as a digital representation on a screen.

The potential for game-based approaches in rehabilitation practice to provide a more engaging and motivating experience and that large numbers of game-based rehabilitation scenarios could be developed to provide greater realism and to correspond more closely to a wide range of everyday activities is now being more fully recognised [8–12]. Furthermore, there is now a growing evidence base to support their use in a variety of different rehabilitation applications including mobility and aerobic fitness [13–15], post-stroke rehabilitation of hand-arm function [16–18], balance [14, 19–21], pain distraction while undergoing treatment/therapy [22], and treatment of amblyopia ("lazy eye") [23].

There is a long standing call to have rehabilitation programs focus simultaneously on improving both physical motor skill and confidence (i.e., self-efficacy) [24] as the importance of a person's perception of their ability has long been recognized as an important determinant of physical performance [25]. Video games are a highly interactive and engaging form of entertainment [26] and incorporate clear goals, immediate feedback and rich visual and aural information [27]. It would therefore seem plausible that GBVR training could rise to this challenge and go a long way to meeting these dual treatment goals. This study was therefore undertaken to investigate if a rehabilitation training programme using a GBVR approach could simultaneously improve both motor skill and confidence. In order provide a stable and reliable experimental setting for both this study and future basic research into the development and refinement of GBVR, a nondominant hand motor deficit model was devised and will be described in subsequent sections.

2. Materials and Methods

2.1. Design. In order to be able to attribute any increase in motor skill and/or confidence to the GBVR rehabilitation training, a nondominant hand motor skill deficit model was conceived whereby each subject acted as their own control with their dominant and nondominant arms act as the control and intervention conditions, respectively.

2.2. Subjects. Nonambidextrous, young adults with no reported health issues were recruited from the student population at Heriot-Watt University. Potential subjects were asked if they had experience of playing racket sports and any reporting regular recreational participation or any competitive matches were excluded. The study was subject to local ethical committee approval and all subjects gave written, informed consent and underwent health screening. A total of 20 subjects were recruited although three subjects withdrew at various stages from the study. The 17 subjects (8 male) who completed the study ranged in age from 18 to 21 years with a mean (±SD) height 1.74 ± 0.09 m, weight 71.2 ± 10.4 kg, and a body mass index of 23.5 ± 2.6 kg/m^2. The study comprised a total of six sessions comprising an initial familiarisation session and then five sessions on consecutive days (Monday through to Friday). In order to minimise any effect of bias on the results, the subjects were unaware of the potential rehabilitation applications of the outcome of the study. Furthermore, the subjects were not given any feedback on their performance by the experimenters.

2.3. Familiarisation Session. In the familiarisation session subjects' height and weight were measured using a portable stadiometer (model 225, Seca Ltd, Birmingham, UK), and weighing scales (model 770, Seca Ltd) respectively. Subjects then completed the Edinburgh Handedness Inventory [28] which comprises a series of questions relating to hand preferences (left or right) for a range of everyday activities. Scoring of the inventory gives a Laterality Quotient (LQ) ranging from −100 for total left-hand dominance to +100 for total right-hand dominance. The LQ obtained for each individual subject was used to designate his or her dominant and nondominant arms. Subjects were then shown a short video clip illustrating how the tennis real-world motor task (RWMT) skill assessment would be conducted. Finally, the subjects performed a basic target shooting game on the game console used in the study (Wii Play, Nintendo of Europe GmbH, Grossostheim, Germany) using the hand-held motion sensitive controller in a point-and-shoot manner.

2.4. Baseline Assessment Session. The RWMT skill assessment session took place in indoors on a squash court in order to ensure consistent conditions. The RWMT involved using a tennis racket (Slazenger Smash 2", Dunlop Slazenger Int. Ltd, Shirebrook, UK) to strike a tennis ball served by a machine (Tennis Twist, Sports Tutor Inc., Burbank, US) over the net and to try and hit a 1.4 m^2 target on the back wall of the squash court. The tennis RWMT assessment set-up is illustrated in Figure 1. The tennis balls were served to the subjects in a consistent arc trajectory by the serving machine with an interval of 5 seconds between balls. The subjects then had to strike the ball back over the net and aim so as to hit the square target marked out on the back wall. As layed out in Figure 1, with the subject having right-hand dominance, dominant forearm, and nondominant backhand strokes were performed in this configuration. For the other two strokes (nondominant forearm and dominant backhand), the serving machine and the subject were placed at the opposite mirror positions on the court.

Self-efficacy is the term used to refer to task-specific confidence (i.e., the conviction that the behaviour required to achieve a particular outcome can be performed successfully) [25]. Prior to commencement of the RWMT skill assessment, the self-efficacy ratings of the subjects were assessed using a questionnaire designed using published guidelines [29]. Subjects were asked to indicate the number of shots on target they thought they would be able to achieve for each of the four separate tennis strokes.

Subjects had a practice run through the four different stokes (forehand and backhand for both dominant and nondominant arms) comprising 10 trials of each stroke with a short break between strokes allow for adjusting of the position of the tennis serving machine. Performance of RWMT was then assessed with a further 10 trials in turn for each of four strokes with an observer recording the position of each ball that struck the back wall of the squash court and whether or not it was on target.

2.5. Game-Based Virtualized Reality Training Sessions. During three days following the baseline RWMT assessment, subjects undertook three separate GBVR training sessions each of 30 minutes duration. The sessions involved working progressively through the training drills that formed part of the tennis game (Wii Sports, Nintendo of Europe GmbH, Grossostheim, Germany) and which involved developing the ability to play shots in different directions towards fixed and moving targets and also periods of match play using equally both dominant and nondominant arms. Screen shots of the drills and match play are shown in Figure 2. In order to mimic as closely as possible the RWMT, a commercially available imitation tennis racket (Play On, Toys R Us, Gateshead, UK) was attached to the motion sensitive hand-held controller used to control the game and mass was added by means of a solid plastic cylinder machine to fit inside the shaft to make the weights of the two rackets equivalent (Figure 3).

2.6. Post-Training Assessment Session. The post-training RWMT assessment session occurred the day after the last GBVR training session and was an exact repeat of the baseline assessment session.

2.7. Statistical Analysis. All data are reported as mean ± standard error of the mean (SEM) with the exception of the demographic data (±SD). The impact of the GBVR training on self-efficacy ratings and RWMT skill performance (number of shots on target) was assessed using Wilcoxon Signed Rank tests (SPSS 14.0 for Windows, SPSS Inc., Surrey, UK) due to the nonparametric nature of the data with Holm's sequential Bonferroni adjustment for multiple comparisons. Congruence between actual subjects' self rating of their ability and their actual number of shots on target was assessed using the method described by Cervone [30] and the confidence interval of the estimate determined by using Bootstrapping.

3. Results

Sixteen of the subjects reported right-hand dominance and the other remaining subject left-hand dominance. The magnitude of the LQs ranged from 50 to 100 and indicated that all subjects had a clear hand preference and that none could be classed as ambidextrous. Prior to the baseline RWMT skill assessment, the subjects' confidence in their ability to hit the target (self-efficacy ratings) was significantly lower for both nondominant arm forehand and backhand strokes versus the dominant arm (control) strokes (Table 1). As expected, there was a deficit in motor skill performance of both nondominant arm strokes (Table 1). After the GBVR training there were significant increases in the self-efficacy ratings for both nondominant arm strokes (Table 1). With regard to motor performance, there was a significant improvement in the nondominant arm backhand stroke performance

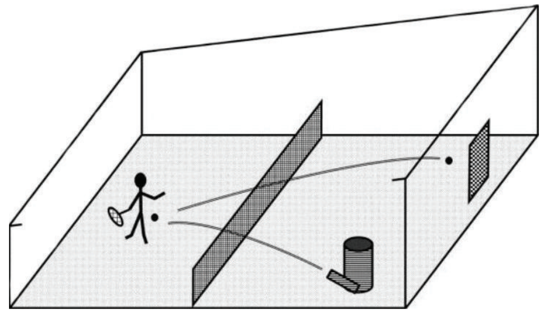

Figure 1: Illustration of the set-up of the tennis RWMT assessment performed indoors in a squash court. The tennis serving machine is denoted by the cylinder plus arm shape.

(Table 1) while the improvement in nondominant forehand stroke just failed to reach statistical significance ($P = 0.06$). In contrast there were no changes in the dominant arm strokes. Congruence between self-efficacy ratings estimates and actual performance was consistent across all conditions and the grand mean across all subjects and strokes was 81% and out-with the 95% confidence interval for random chance alone.

4. Discussion

The key findings of this study were that a performance deficit in a real-world motor task (RWMT) improved in response to a game-based virtualized reality (GBVR) training programme that closely mimicked the RWMT. Furthermore, the improvement was manifest as concomitant increases in both motor skill and self-efficacy (i.e., increased confidence in ability to perform the task).

As the subjects completed the self-efficacy ratings prior to the RWMT performance assessments, the post-training ratings given by the subjects (Table 1) predicted a differential improvement in their nondominant strokes compared with no change in the performance of their dominant hand strokes. The most likely explanation for the subjects' change in their perception of their ability to perform the nondominant strokes were due to an improvement as a result of the GBVR training. While care was taken by the experimenters not to give any explicit feedback during training, the subjects would have seen the consequences of their actions in displayed on the screen and through the game scoring mechanisms. Given that the baseline RWMT assessment comprised a total of only 20 shots of each stroke (10 familiarisation and 10 assessment), it seems unlikely that the baseline assessment session could have provided an adequate training stimulus to explain the observed effects. However, were the RWMT to be used for training, it is likely that performance improvements similar to those in the current study would be observed.

The experimental model designed for this study was based on the fact that in non-ambidextrous subjects, the nondominant arm has less well developed motor skill than that of the dominant arm, which by definition has much better developed motor skill due its preferential use in daily

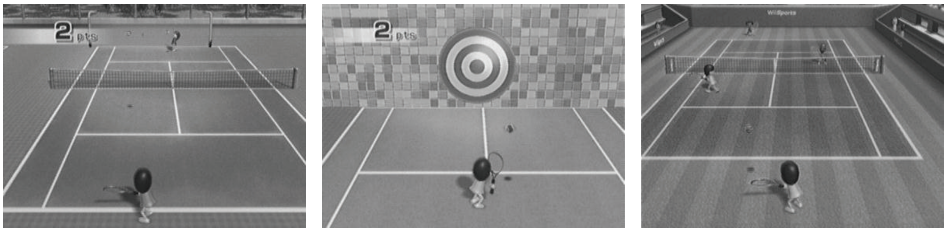

Figure 2: Screen shots from the GBVR training drills and match play.

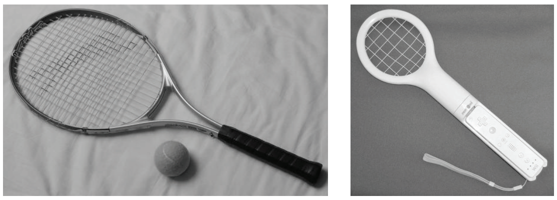

Figure 3: Conventional tennis racket for the tennis RWMT assessment and the tennis game controller.

life and therefore has much less potential for improvement in motor performance. In contrast, the relative under-use of subjects' nondominant arms (again by definition) means that they have a lower baseline level of motor skill and therefore much greater scope for improvement in response to training.

There is a growing interest in the use of GBVR approaches to rehabilitation practice [8–10] and in particular its potential for reducing the need for patient travel and reaching out to rural communities [2, 19]. However, the focus of attention has predominantly been on developing new forms of treatment modalities with a view to improving physical outcomes. The results of this study indicate that there is also the potential for significant positive psychological outcomes. The game used in this study provided the subjects with a number of different forms of feedback on their performance. When the user makes "contact" with the virtual tennis ball, a sound is played through a small speaker in the handheld controller. In addition, the trajectory of the ball in the on screen game play reflects the angle, speed, and timing at which the virtual ball is "struck". The game play environment also provides additional visual (in terms of game score) and aural (cheers of spectators) feedback on performance. The impact of the GBVR training was such that the relative deficit in the RWMT performance in the subjects' nondominant arms was rehabilitated closer to that of the corresponding dominant arm stroke. Furthermore, it would appear that the subjects were able to sense this motor skill improvement as a result of the GBVR training and that it was reflected in an increase in the self-efficacy ratings for the nondominant arm strokes prior to the post-training RWMT skill assessment. Thus, while the GBVR training did not fully replicate the sensation of striking a physical ball, nor did it directly replicate the geometry of the tennis RWMT, it did provide a training stimulus that was adequate enough to elicit an effect.

As described in the Introduction, rehabilitation treatment programs are usually long and arduous and therefore supporting and sustaining patient motivation is a major challenge. Game-based approaches are of particular interest in this regard due to the motivational appeal of video games [26]. Developing GBVR approaches to rehabilitation therefore require a degree of trade-off to be made, whereby the training stimulus may not quite match the real world equivalent, but that this is more than compensated for by appropriately designed selections of games that promote and maintain patient motivation and long-term adherence to a treatment program by providing immediate feedback on performance, in-game achievements and rewards, and a sense of accomplishment as they progress through the game. Also, there is evidence to indicate that both the challenge and the immersive potential offered by games controlled by body movement can result in a greater flow experience compared to traditional forms of exercise [31].

In order for GBVR approaches to be incorporated into routine clinical rehabilitation practice, it will require the development of game systems that are fit for purpose [19]. They will need to have sufficient fidelity in their detection of motion that the can keep the patient within the desired movement envelope. The physical exercises that the game play requires will need to correspond the prescribed therapeutic exercises and scenarios and will also need to be capable of providing sufficient stimulus to promote the desired restoration of function. There is also a requirement for the therapist to be able to tailor the game to match the precise rehabilitation requirements of each individual patient and to be able to regularly monitor a patient's progress and have the ability to adjust the specific game demands over time [8]. The game will also need to appeal to patient and be capable of sustaining their interest. However, not only is there a scope for a wide range of genres of games to appeal to different users, but more fundamentally, if appropriately programmed, a game could adapt and respond to any improvements in a given user's performance. This would help ensure that the game presents a challenge at an appropriate level for each individual and as the rehabilitation treatment program progressed, the game scenarios would become increasingly demanding. Other features which could be incorporated into games for rehabilitation include offering helpful tips and coaching, rewarding, and praising the user when they make progress, monitoring game use time, and providing some form of progress chart. It is not necessary and indeed may not be

Table 1: Baseline and post-training self-efficacy ratings and motor task performance.

Real-world motor task	Baseline		Post-training change	
Tennis stroke	Self-efficacy rating	Motor task performance	Self-efficacy rating	Motor task performance
Dominant forearm	7.2 ± 0.4	7.1 ± 0.6	+0.1 ± 0.4	+0.4 ± 0.6
Dominant backhand	5.4 ± 0.5	6.4 ± 0.6	+0.4 ± 0.4	+0.8 ± 0.5
Nondominant forearm	4.1 ± 0.3*	4.7 ± 0.5*	+1.2 ± 0.4†	+1.2 ± 0.6‡
Nondominant backhand	3.4 ± 0.3*	4.1 ± 0.4*	+1.2 ± 0.3†	+1.7 ± 0.5†

Baseline data are shown as mean ± SEM shots on target. Post-training data are shown as mean change (delta values) ± SEM shots on target. *indicates significantly lower baseline for nondominant stroke compared to corresponding stroke for dominant arm ($P < 0.05$). †indicates significant increase for nondominant stroke post-training ($P < 0.05$). ‡indicates increase for nondominant stroke post-training just failed to reach statistical significance ($P = 0.06$).

desirable that these functions are performed by a virtual representation of a human, but rather they can be subtlety incorporated into the game play experience [32].

4.1. Clinical Rehabilitation Impact. GBVR approaches to rehabilitation have the potential to facilitate simultaneous improvements in motor skill and confidence and may also help increase patient compliance. The availability of low-cost motion sensors and increasingly sophisticated games development tools means significant progress is to be expected in this field over the next few years. The nondominant hand motor deficit model outlined in this study is intended as far as possible to mimic the impact of trauma or disease process on arm motor function, whereby the reduced motor performance in the nondominant arm mimics the functional loss due to trauma or disease process and which therefore is in need of rehabilitation as part of the treatment programme. However, the model does not incorporate the complex nature of different clinical scenarios nor does it reflect the fact that even with specific conditions there is significant variability between patients. While this might potentially be seen as a limitation, there are in fact significant advantages to having a stable and reliable experimental setting in order to undertake basic research into the development and refinement of GBVR approaches including hardware, software, game design, clinical interfaces, and data logging [19]. Furthermore, the convenience of being able to use healthy human subjects and having each subject act as there own control will further reduce potential sources of variability and therefore make experimental testing even more efficient.

With regard to clinical interfaces, it is an essential requirement that therapists are able to precisely control the parameters of the rehabilitation exercises (e.g., specific movements, range of motion, number of repetitions, and frequency of exercise) and also get detailed information via data logging and summary reports on patient performance in order to track rehabilitation progress and adjust their programme when required. It should be noted that existing commercial off-the-shelf interactive games (including the game used in this study) have little or no functionality in this regard. Once solutions that address these issues are developed, it will then be a much more realistic proposition to transition to clinical settings in order to tailor approaches to specific clinical needs and to undertake comprehensive clinical evaluations. Finally, there are also a number of infrastructure issues that will need to be addressed before routine clinical adoption of GBVR rehabilitation is possible including accessibility issues [33], licensing and reimbursement [10], and issues of resource allocation and treatment policies [11].

5. Conclusion

GBVR training has significant potential in the development of rehabilitation practice. However, significant hardware and software design issues still need to be addressed and the nondominant hand motor deficit model described in this study provides useful paradigm for conducting basic research and development. The results of this study indicate that improvements in confidence, which is an important determinant of treatment outcome in terms of daily living and physical and social functioning, should be added to the list of potential benefits of GBVR training in rehabilitation practice.

Conflict of Interests

The author declares that there are no conflict of interests associated with this work.

Acknowledgments

Liam Baird and Graham McCraw who undertook data collection and Annemarie Crozier who provided technical support. This work has been funded in part by the EU under the FP7, in the Games and Learning Alliance (GALA—http://www.galanoe.eu) Network of Excellence, Grant Agreement no. 258169.

References

[1] S. H. Jang, S. H. You, Y. H. Kwon, M. Hallett, M. Y. Lee, and S. H. Ahn, "Cortical reorganization associated lower extremity motor recovery as evidenced by functional MRI and diffusion tensor tractography in a stroke patient," *Restorative Neurology and Neuroscience*, vol. 23, no. 5-6, pp. 325–329, 2005.

[2] T. G. Russell, "Physical rehabilitation using telemedicine," *Journal of Telemedicine and Telecare*, vol. 13, no. 5, pp. 217–220, 2007.

[3] G. C. Burdea, P. L. T. Weiss, and D. Thalmann, "Guest editorial special theme on virtual rehabilitation," *IEEE Transactions on*

Neural Systems and Rehabilitation Engineering, vol. 15, no. 1, p. 1, 2007.

[4] J. E. Deutsch, J. A. Lewis, and G. Burdea, "Technical and patient performance using a virtual reality-integrated telerehabilitation system: preliminary finding," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 15, no. 1, pp. 30–35, 2007.

[5] M. K. Holden, T. A. Dyar, and L. Dayan-Cimadoro, "Telerehabilitation using a virtual environment improves upper extremity function in patients with stroke," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 15, no. 1, pp. 36–42, 2007.

[6] A. Heuser, H. Kourtev, S. Winter et al., "Telerehabilitation using the Rutgers Master II glove following carpal tunnel release surgery: proof-of-concept," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 15, no. 1, pp. 43–49, 2007.

[7] V. G. Popescu, G. C. Burdea, M. Bouzit, and V. R. Hentz, "A virtual-reality-based telerehabilitation system with force feedback," *IEEE Transactions on Information Technology in Biomedicine*, vol. 4, no. 1, pp. 45–51, 2000.

[8] B. Lange, S. M. Flynn, and A. A. Rizzo, "Game-based telerehabilitation," *European Journal of Physical and Rehabilitation Medicine*, vol. 45, no. 1, pp. 143–151, 2009.

[9] H. Sveistrup, "Motor rehabilitation using virtual reality," *Journal of NeuroEngineering and Rehabilitation*, vol. 1, no. 1, article 10, 2004.

[10] D. Theodoros and T. Russell, "Telerehabilitation: current perspectives," *Studies in Health Technology and Informatics*, vol. 131, pp. 191–209, 2008.

[11] D. Kairy, P. Lehoux, C. Vincent, and M. Visintin, "A systematic review of clinical outcomes, clinical process, healthcare utilization and costs associated with telerehabilitation," *Disability and Rehabilitation*, vol. 31, no. 6, pp. 427–447, 2009.

[12] A. Rizzo and G. J. Kim, "A SWOT analysis of the field of virtual reality rehabilitation and therapy," *Presence*, vol. 14, no. 2, pp. 119–146, 2005.

[13] H. L. Hurkmans, G. M. Ribbers, M. F. Streur-Kranenburg, H. J. Stam, and R. J. van den Berg-Emons, "Energy expenditure in chronic stroke patients playing Wii Sports: a pilot study," *Journal of NeuroEngineering and Rehabilitation*, vol. 8, article 38, 2011.

[14] M. Brien and H. Sveistrup, "An intensive virtual reality program improves functional balance and mobility of adolescents with cerebral palsy," *Pediatric Physical Therapy*, vol. 23, no. 3, pp. 258–266, 2011.

[15] C. Bryanton, J. Bossé, M. Brien, J. McLean, A. McCormick, and H. Sveistrup, "Feasibility, motivation, and selective motor control: virtual reality compared to conventional home exercise in children with cerebral palsy," *Cyberpsychology and Behavior*, vol. 9, no. 2, pp. 123–128, 2006.

[16] A. S. Merians, E. Tunik, G. G. Fluet, Q. Qiu, and S. V. Adamovich, "Innovative approaches to the rehabilitation of upper extremity hemiparesis using virtual environments," *European Journal of Physical and Rehabilitation Medicine*, vol. 45, no. 1, pp. 123–133, 2009.

[17] G. Saposnik and M. Levin, "Virtual reality in stroke rehabilitation: a meta-analysis and implications for clinicians," *Stroke*, vol. 42, no. 5, pp. 1380–1386, 2011.

[18] L. Zollo, E. Gallotta, E. Guglielmelli, and S. Sterzi, "Robotic technologies and rehabilitation: new tools for upper-limb therapy and assessment in chronic stroke," *European Journal of Physical and Rehabilitation Medicine*, vol. 47, no. 2, pp. 223–236, 2011.

[19] B. Lange, S. Flynn, R. Proffitt, C. Y. Chang, and A. S. Rizzo, "Development of an interactive game-based rehabilitation tool for dynamic balance training," *Topics in Stroke Rehabilitation*, vol. 17, no. 5, pp. 345–352, 2010.

[20] T. Szturm, A. L. Betker, Z. Moussavi, A. Desai, and V. Goodman, "Effects of an interactive computer game exercise regimen on balance impairment in frail community-dwelling older adults: a randomized controlled trial," *Physical Therapy*, vol. 91, no. 10, pp. 1449–1462, 2011.

[21] M. Thornthon, S. Marshall, J. McComas, H. Finestone, A. McCormick, and H. Sveistrup, "Benefits of activity and virtual reality based balance exercise programmes for adults with traumatic brain injury: perceptions of participants and their caregivers," *Brain Injury*, vol. 19, no. 12, pp. 989–1000, 2005.

[22] G. J. Carrougher, H. G. Hoffman, D. Nakamura et al., "The effect of virtual reality on pain and range of motion in adults with burn injuries," *Journal of Burn Care and Research*, vol. 30, no. 5, pp. 785–791, 2009.

[23] P. Waddingham, R. Eastgate, and S. Cobb, "Design and development of a virtual-reality based system for improving vision in children with amblyopia," *Studies in Computational Intelligence*, vol. 337, pp. 229–252, 2011.

[24] M. E. Tinetti, C. F. Mendes de Leon, J. T. Doucette, and D. I. Baker, "Fear of falling and fall-related efficacy in relationship to functioning among community-living elders," *Journals of Gerontology*, vol. 49, no. 3, pp. M140–M147, 1994.

[25] A. Bandura, N. E. Adams, and J. Beyer, "Cognitive processes mediating behavioral change," *Journal of Personality and Social Psychology*, vol. 35, no. 3, pp. 125–139, 1977.

[26] R. M. Ryan, C. S. Rigby, and A. Przybylski, "The motivational pull of video games: a self-determination theory approach," *Motivation and Emotion*, vol. 30, no. 4, pp. 347–363, 2006.

[27] J. L. Sherry, "Flow and media enjoyment," *Communication Theory*, vol. 14, no. 4, pp. 328–347, 2004.

[28] R. C. Oldfield, "The assessment and analysis of handedness: the Edinburgh inventory," *Neuropsychologia*, vol. 9, no. 1, pp. 97–113, 1971.

[29] D. L. Feltz and M. A. Chase, "The measurement of self-efficacy and confidence in sport," in *Advances in Sport and Exercise Psychology Measurement*, J. L. Duda, Ed., pp. 65–80, Fitness Information Technology, Morgantown, WVa, USA, 1998.

[30] D. Cervone, "Randomization tests to determine significance levels for microanalytic congruences between self-efficacy and behavior," *Cognitive Therapy and Research*, vol. 9, no. 4, pp. 357–365, 1985.

[31] A. G. Thin, L. Hansen, and D. McEachen, "Flow experience and mood states while playing body movement-controlled video games," *Games and Culture*, vol. 6, no. 5, pp. 414–428, 2011.

[32] I. Bogost, *Persuasive Games: The Expressive Power of Videogames*, The MIT Press, Cambridge, Mass, USA, 2007.

[33] D. M. Brennan and L. M. Barker, "Human factors in the development and implementation of telerehabilitation systems," *Journal of Telemedicine and Telecare*, vol. 14, no. 2, pp. 55–58, 2008.