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Álvaro Rocha
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Second Iberian Workshop on Serious Games and Meaningful Play
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Virtual Centre for the Rehabilitation of Road Accident Victims (VICERAVI)

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***Abstract* — The main objective of this work is to describe the Virtual Center for the Rehabilitation of Road Accident Victims - VICERAVI and the serious games it includes for the purpose of neuropsychological rehabilitation. The validation of the VICERAVI as a rehabilitation system involves 30 participants of both sexes, with brain injury due to road accidents. The applicability and the benefits of virtual worlds for a holistic neuropsychological rehabilitation will be tested using virtual reality (OpenSimulator) to simulate tasks of everyday life, enabling participants to perform cognitive and social skills training through their avatars. The progresses of this group will be compared with a group of conventional neuropsychological rehabilitation. The main innovation of the work is the possibility of administering neuropsychological rehabilitation at distance, via ecological virtual environments. Moreover, the paper discusses also relevant criteria and issues in respect to the use of serious games, simulation and virtual environments in rehabilitation.**

Keywords- Road accident, virtual worlds, neuropsychological rehabilitation, serious games.

I. INTRODUCTION

The applicability of virtual reality (VR) in psychology/psychiatry and neuropsychology has been studied for decades. VR allows both the stimulation – using complex, dynamic and interactive stimuli, and the assessment of cognitive, behavioral and functional impairments, placing the individual in situations that are similar to everyday life.

Rapid technological change has facilitated the development of materials for neuropsychological assessment and rehabilitation of specific cognitive functions, such as attention, memory, planning, visuospatial abilities, and language [1, 2].

The clinical populations in which VR environments have been tested is diverse, including individuals showing disorders of attention, memory impairments, and executive dysfunctions resulting from brain injury.

Virtual environments improve the users' motivation, as the rehabilitation tasks become more attractive. Also, VR provides controlled environments, where rehab tasks can be structured approximately as the real situation we want to emulate. Even hazardous situations can be performed without risk, allowing feedback and positive reinforcement [3].

For the above reasons, VR has proved to be an important resource to improve the ecological validity of the neuropsychological rehab. Although in some circumstances it may be impractical, because it is too expensive [4], it may also be very profitable in other conditions, favoring a virtual therapeutic tool that is at the range of different populations [5], even if they live very far from rehab centers, or their socio-economic or physical status prevent their mobility. This is often the case of the victims of road accidents.

In Portugal in 2010 there were 35426 car accidents with victims [6]. A considerable percentage of them (11%) require not only physical, but also psychosocial and neuropsychological rehabilitation due to brain injuries resulting from the accidents. Amongst the most frequent neuropsychological sequels, we can find attention deficits, memory impairments, executive dysfunction, and impaired language [7]. In addition, these victims often go through emotional, personality and behavioral changes that interfere with their psychological and social adjustment. The holistic rehab programs are the most suitable to deal with this broad range of problems, but new methodologies are needed, as the conventional ones are time-consuming and high-priced, both for users and rehabilitation centers. Also, conventional rehab programs demand the physical presence of individuals who commonly have limited mobility, and have not yet proven to be very effective concerning the generalization of trained skills to the real-life environment (meaning that their ecological validity is not fully satisfactory).

Summing up, the VR appears to have a great potential for the neuropsychological rehabilitation [8], even for holistic

models that comprise neurocognitive tasks together with other individual and group interventions. This potential ought to be implemented and tested, as we try to do in this research. More precisely, this research project had three main objectives: (1) to develop a VR-based neuropsychological rehab program taking into account neurocognitive stimulation, psychological support and psychosocial intervention; (2) to study the effectiveness of this program in individuals who have suffered mild traumatic brain injury (TBI) as a result of road-accidents; (3) to compare the results of this program with those of conventional rehabilitation programs, administered face-to-face.

The rest of the paper is structured as follows. Section II presents the Serious Game concept, its main applications and the relevant criteria that can be used in classifications of Serious Games for rehabilitation. Section III presents a discussion of the use of simulation and virtual environments in the health field of applications, focusing the rehabilitation area. In Section IV is described the method that will be used to validate the VICERAVI system. Finally, in Section V, major conclusions are drawn and directions for future work are suggested.

II. SERIOUS GAMES AND APPLICATIONS

A. Serious Games

Serious Games is an emergent field of research with applications in many diverse areas such as: corporate and military training, health and rehabilitation, education and cultural training. Although many definitions of the term are used, all authors agree that serious games do not use the entertainment or enjoyment component provided by the game as their primary purpose [9-11]. In this study we will use the term to refer to computer games that enable the player (patient) to attain a specific rehabilitation purpose, using the entertainment and engagement features provided by the experience of the game. While the game is fun and engaging, it will enable the player to develop some skills.

B. Serious Games in Rehabilitation

Health rehabilitation is a major area where Serious Games are assuming a relevant role. It has been shown that games can contribute to increase motivation in rehabilitation sessions [12]. Games require cognitive and motor activity; thereby they can engage users' attention. Additionally, they offer mechanisms with levels of difficulty that can be used to give the player the sense of challenge in his progress, and this can also be adapted to his skills.

In a previous study by Rego et al. [13, 14], relevant criteria for the classification of Serious Games in rehabilitation area were identified. The authors noticed that the adoption of Serious Games as a rehabilitation tool is very recent in general. A significant number of reported researches refer to prototypes and to games in early stages of development and testing. Furthermore, there are few examples where a significant sample of real patients was used to validate the proposed approaches. Consequently, definitive conclusions about their effectiveness are hard to take and must be validated by further research. There exist however some commercial serious game systems for cognitive rehabilitation such as the RehaCom system [15], the StrongArm System [16] and Parrot Software System [17]. These systems can be used for home rehabilitation, besides being used in clinics or rehabilitation centers.

As a result of the aforementioned study it was also found in [13] that interaction technology is a relevant criterion for the classification of rehabilitation Serious Games. Most of the reviewed games presented simple interfaces and traditional forms of interaction. It was noticed that the application of VR technology for the rehabilitation of cognitive and motor deficits has been growing in the last decade and that stroke patients have been one of the main target populations. These VR based-methods enable the patients to be part of immersive experiences that are engaging and rewarding to them. It was also found also that the use of more natural user interfaces was exploited in some recent games, but they were little evaluated in terms of the rehabilitation process. Natural user interfaces offer users the sense of an easier, intuitive and more free form of interaction with the computer system, eliminating the use of artificial communication devices such as the mouse or the keyboard [18].

One of the most used natural modalities in the first study is motion detection, due mostly by the gesture game play implemented by major game consoles in the entertainment area such as: Nintendo Wii, PlayStation 2, PlayStation 3 Move systems and Microsoft Kinnect.

In these systems, real-world interaction is replicated using natural interaction techniques such as the use of user body movements, gestures, voice or sound input recognition, similar to those used in the physical world to accomplish the same task. Figure 1 presents a taxonomy of natural user interfaces using motion detection based on the works reviewed at [13].

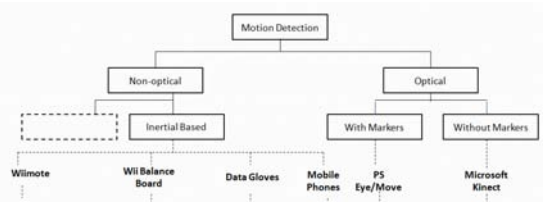

Figure 1. Natural User Interfaces using Motion Detection

C. Social dimension in Games

Social dimension was also another important criterion identified as relevant in rehabilitation Serious Games [13]. Family and friends can have a relevant role in the rehabilitation process, by offering a social support to patients in rehabilitation and this can go beyond an increase in the patients' motivation. This social support can also come from other fellow's patients or therapists for instance.

Rego et al. [19] found reports on the use of multi-player games where the collaboration and competitiveness facility exists. However, the evaluations done are inexistent, or conducted with a very small number of patients.

III. Simulation and Virtual Environments

A. Simulation

A simulation is the imitation of a process, over time, in order to represent the relevant characteristics or behaviors of the chosen physical or abstract system. Simulations can be used in many contexts and with varied goals such as to understand and control system complexity and functioning, in which tasks or actions of the real situation can be emulated; to optimize system performance; to reduce costs and/or risks involved in the real process/situation; to train and/or educate.

In a Serious Game, simulations and user experiences can enable the accomplishing of the game primary goal (other than pure entertainment), offering the sense of an environment close to the real world. The use of simulated models is necessary in Serious Games in order to represent in an accurate way the various aspects of the game such as: the players involved and their behavior, the surrounding environment, and the motor or cognitive processes. These simulated models aim to enrich user experiences by making them more attractive, immersive, and enjoyable and potentially increase user's motivation. Simulation has a relevant role in rehab Serious Games as it can be used to simulate the environment and the tasks that were defined for the patient to accomplish in a rehabilitation session.

In respect to the health field of applications we can distinguish three different levels on which simulation can be used: patient simulation, therapist simulation, environment simulation, and environment and users simulation.

In the works reviewed, we can see that a patient simulation can take one of two different forms of representation: the first form uses a physical representation of the patient body (an artificial patient) or of part of the patient body (a hand model for example) and the second form uses a virtual and interactive representation of a medical process (involving a part of the human body), usually without enabling user intervention. The former form of representation uses a life size mannequin connected to a computer. The mannequin mimics body functions such as respiration, heartbeat and replicates symptoms of illness. It can be programmed to respond to injected drugs and to recreate life-threatening emergency situations [20, 21]. This form has the advantage of enabling to transfer the skills learned in the simulated environment into the real-world of the clinical environment. It is mainly used to allow teaching trainees technical abilities, promoting a pre-clinical proficiency, through an unlimited and free of risks practice. Additionally, it potentially increases the trainees' motivation to learning, since the mannequin gives feedback from the decisions and actions taken by the trainees. The physical representation can also be only a part of the human body, for example a hand model, such the one described in Hageman [22] that uses the hand model as a training tool to make orthoses. The second form of patient simulation includes simulations in which there is not a model with physical representation, but instead a reproduction of visual and virtual representations of medical processes, using computer graphics techniques, haptic feedback devices, and physical simulation. Examples of these applications include the virtual laparoscopic simulator [23] from the University of Mississippi Medical Center describing suturing tasks and the simulated cholecystectomy procedure. A cataract surgery simulation is described in [24] and other sirurgical training and simulations applications are described in [25].

In therapist simulation the presence of the therapist in the rehabilitation session is minimized. This includes mainly the use of robotic systems that assist the patient in the rehabilitation session help reducing the dependency from the therapist [26, 27].

On environment simulation level, the patient is placed in a more controlled environment, close to the real world, and his progress is measured over time, allowing adjusting the practice sessions to patient needs or impairments. In a controlled environment, experiments and predictions are facilitated and a risk free and/or cost effective solution can be created. In many of these applications VR is used to provide immersion. Examples of these applications include the use of a driving simulator [28], an electric wheelchair simulator [29], a VR Bicycle Simulator [30] and a computer assisted rehabilitation environment system for managing stress and anxiety disorders in civilian and military patients [31].

On environment and users simulation level, an envisioned facility is simulated, allowing the planning, predicting and improvement of operation and procedures involved. Examples of this type of simulation can be found in [32],[33]. Findlay [32] describes a medical simulation in the virtual world of Second Life platform that is used in nursing courses. This simulation represents virtually the environment of the envisioned clinic, the virtual patient, the virtual therapist and the clinic functioning and procedures. Vidani & Chittaro [33] describe a serious game demo application that can be used to train medical first responders. In this demo, the patient is virtually representing, but also the procedures the therapist has to do are visually represented.

In respect to rehabilitation area, simulation has been used mainly to simulate the system environment and mostly the therapist. The various rehabilitation training exercises defined in the rehabilitation program for a specific patient can be simulated, by means of a computer game system, reducing the presence and dependence from the therapist.

B. Virtual Environments

A Virtual environment (VE) can be defined as a three-dimensional environment generated by computer to simulate a real or imaginary world in which the user can control the viewpoint or the orientation of the objects by sensors positioned in his body or by user input devices [5]. VR refers to a collection of computer technologies that generate synthetic tree-dimensional environments. VR technology permits to simulate physical presence in places in the real world or in imaginary worlds, using computational techniques and sensory devices. In VR environments, the user can have the real sensation of being inside of the virtual world (immersion) and/or being participating in it (presence) and believes that is able to manipulate the objects (interactivity) of the VE just like they were real. VR systems can be classified in three types [34]: immersive, semi-immersive and non-immersive. In immersive systems the user wears a head-mounted display

(HMD) (or some other form of head display unit). When the user interacts with the objects in the VE with the joystick, glove or other input devices he can experience the sense of touching, including the weight, texture of the object and the force from the environment, such as the gravity. In a non immersive system the user is placed in a VE that he can manipulate directly with a computer, using a monitor, keyboard and mouse.

Some of the problems associated with brain injury damage patients are a significant reduction in cerebral activity/arousal following the brain damage, and so inactivity periods in these patients are undesirable [35]. During the time they are in hospital they may suffer from little stimulation and interaction with the exposing environment and researchers agree that this may diminish the subsequent recovery phases. As a consequence, patients may show symptoms of being very easily fatigued and unaccustomed to having to concentrate their attention to different sources [36]. VR can have an important role in the increase of the patients' arousal/cerebral activity levels by offering them an improved environment during and/or between his rehabilitation sessions. VR can create environments highly relevant for the patient everyday life, with the advantages of reduced costs and risks. This enriched environment can include multiple input and output modalities and possibilities for providing a social interaction, either on a more automated and rudimentary form, or on a more advanced form such as serving as a forum for real-time social interaction (e.g. Second Life). All the features referred can contribute to augment the sense of realism and consequently increase the patient's interest and motivation in the rehabilitation tasks.

In Second Life virtual environment users can interact with other users using avatars (a graphical representation of the user in the virtual world), through free client programs, or Viewers. This interaction can include tasks such as: navigation in the world, meeting other resident users, socializing, participating in group and individual activities, and creating new content through the use of a modeling tool [37]. Second Life was developed by Linden Lab and uses the Linden Scripting Language (LSL) to add interactivity to the created objects. It has two main parts: a server that hosts a virtual world composed of a rectangular grid of regions, and the client application that runs on the user's computer and that interacts with the server. The client has a window in which the user explores a perceived three-dimensional space and performs other tasks (search, map view, inventory management, chat communications, user interface settings, and client administration).

An alternative server was developed to serve the client resulting in a project that was designated by OpenSimulator, abbreviated OpenSim [38]. OpenSim is an open-source and multi-platform virtual environment server system, providing a set of services for virtual world construction that can be accessed by a variety of client applications. It can simulate virtual environments compatible with Second Life, allowing developers to customize the created worlds, and provides in world scripting using LSL, C# and VB.NET [38].

IV. METHOD

A. Participants

Thirty participants of both sexes, with mild TBI due to road accidents, will be recruited to this study. Half of them will benefit from a conventional neuropsychological rehab program, according to a holistic model, whereas the other 15 participants will perform neuropsychological rehabilitation at a distance (in their homes or nearby institutions), through the VICERAVI.

B. Materials

The following tests will be used to assess physical, psychosocial, psychological and neuropsychological functioning, prior to and after the rehabilitation program: SF-36 - Medical Outcomes Study; QOLIBRI - Quality of Life After Brain Injury; ACECFfa - battery of tests to assess cognitive performance; HADS – Hospital Anxiety and Depression Scale.

The OpenSimulator is the platform in which the 3D environments of the Rehab Center – VICERAVI - are being developed. Avatars will represent users in these environments, both to play serious games as neurocognitive rehab strategies, and to take part in group-activities.

The VICERAVI, is specifically designed for the administration of neuropsychological rehab tasks, both for individuals and groups, that will enable: (1) real-time communication between avatars; (2) preprogrammed agents with intended therapeutic behaviors; (3) cooperative/competitive gaming as a means to achieve the rehabilitations of neurocognitive functions; (4) the recording of performance measures, in order to allow the evaluation of the effectiveness of the system and its validation for the neuropsychological rehabilitation.

This virtual environment consists of an area divided into three rooms (Fig. 2). One of the rooms (Fig. 3), allows users' avatars to access serious games intended to the training of cognitive functions.

Figure 2. Overview of the VICERAVI environment

The training will be conducted through a set of computer-based tasks for cognitive stimulation and two games that were specially designed for the training of attention and memory, as these are the most important cognitive functions for the neuropsychological rehab.

The attention game will allow training the ability to maintain a state of alert (sustained attention) in long term, quickly responding to infrequent stimuli at irregular intervals, which appear among other stimuli that have to be neglected. Through this task, users will learn to maintain high levels of alertness, in a situation that promotes monotony. In the task, which is being developed, it is presented a train-rail that is later divided into rail 1 and 2. Trains appear at irregular intervals, some carrying passengers, others carrying goods. Participants must use a lever to separate passengers from goods, as soon as possible (errors and reaction times are recorded).

In the memory game, also in the development phase, it will be stimulated the ability to retain visual and auditory information, recalling or recognizing previously presented stimuli.

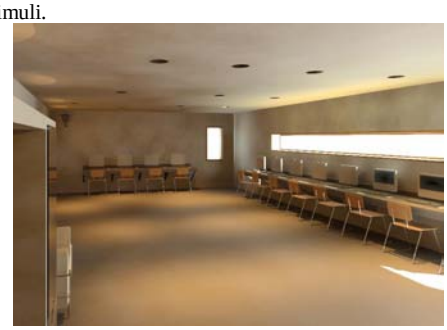

Figure 3. Room where the avatars access the serious games aiming neurocognitive rehabilitation

One or more avatars tell a story or engage in a dialogue. Immediately after or a few minutes later, the participant is asked to recognize or recall elements of the story or dialogue, including who said them, as well as certain characteristics of the storytellers and the context. This game includes also a selective attention task, where participants have to identify target words or letters in the stories/dialogues, while they are being presented.

Trials difficulty increase in both games depending on each participant's performance. At the beginning of each session the participants receive the instructions and, at the end, they are informed on their performance (which is recorded for progress-analysis). Also, games can be performed in a competitive or collaborative mode, in interaction with other users.

As any holistic rehabilitation program should also improve the social functioning through interventions that promote self-regulation [3], the program is also conceived to comprise interactions and group activities in which participants, through their avatars, may practice social skills and learn how to implement adjusted interactions.

At the reception (Fig. 4), a programmed virtual agent (receptionist) will present challenges to the users targeting behavior change through problem solving, while the third room (Fig. 5), is design for group sessions aiming the training of social skills.

C. Procedures

The procedures for the implementation and the evaluation of the rehab program and its components are schematized in the study design presented in Fig. 6. As it may be observed at figure 6, the study design includes a pre post-test design with two matched groups, one of them (the experimental) going through the VR-based rehab program at distance, while the other group (control) goes through a conventional neuropsychological program in a Rehab Centre.

V. CONCLUSIONS AND FUTURE WORK

The use of serious games is very promising for neurocognitive rehabilitation, as long as the gains from the training can be transferred to real life situations.

Figure 4. Reception hall

Figure 5. Room for group session

Serious games embedded in VR, where they can be supplemented with other forms of intervention, even psychosocial, points to a new approach for the neuropsychological rehabilitation: an holistic rehab, provided at distance, and easily generalizable to everyday situations, given that the intervention is delivered in reality-like conditions. By offering stimulating activities, social interaction, and enriched environments that are relevant to patient's everyday life, serious games can contribute to increase the interest and motivation of patients with brain injury due to road accidents in the rehabilitation tasks. This is what we intend to demonstrate in this on-going study.

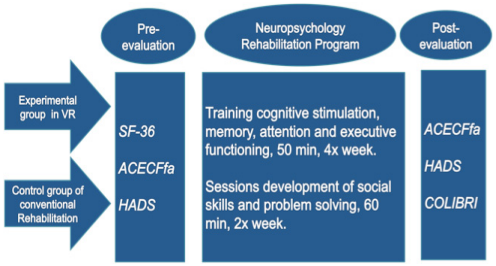

Figure 6. Study Design

REFERENCES

[1] M. S. Cameirão, S. Bermúdez i Badia, and P. F. M. J. Verschure, "Virtual Reality Based Upper Extremity Rehabilitation following Stroke: a Review," *Journal of CyberTherapy & Rehabilitation*, vol. 1, pp. 63-74, 2008.

[2] M. T. Schultheis, J. Himelstein, and A. A. Rizzo, "Virtual Reality and Neuropsychology: Upgrading the Current Tools," *Journal of Head Trauma Rehabilitation. 17(5):*, vol. 17, pp. 378-394, October 2002.

[3] R. C. Davies, G. Johansson, K. Boschian, A. Lindén, U. Minör, and B. Sonesson, "A Practical Example Using VR in the Assessment of Brain Injury " *The International Journal of Virtual Reality* vol. 3, pp. 1-7, 1998.

[4] F. D. Rose, "Virtual reality in rehabilitation following traumatic brain injury," in *Proc. 1 st Euro. Conf. Disability, Virtual Reality & Assoc. Tech.*, Maidenhead, UK, 1996.

[5] R. M. E. M. Costa, L. A. V. Carvalho, and D. F. Aragon, "Virtual city for cognitive rehabilitation " in *Proc. 3rd Intl. Conf. Disability, Virtual Reality & Assos. Tech.*, Alghero, Italy, 2000.

[6] ANSR. (2010, 2 February 2012). *Dados de sinistralidade*. Available: http://www.ansr.pt/default

[7] T. Meulemans and X. Seron, *L'Examen neuropsychologique dans le cadre de l'expertise médico-légale*, 2004.

[8] B. Wiederhold and A. Rizzo, "Virtual Reality and Applied Psychophysiology," *Applied Psychophysiology and Biofeedback*, vol. 30, pp. 183-185, 2005.

[9] M. Zyda, "From Visual Simulation to Virtual Reality to Games," *Computer*, vol. 38, pp. 25-32, 2005.

[10] D. Michael and S. Chen. (2006). *Serious Games: Games That Educate, Train, and Inform*. Available: http://www.gamasutra.com/features/20051031/chen_01.shtml

[11] T. Susi, M. Johannesson, and P. Backlund, "Serious Games – An Overview," School of Humanities and Informatics
University of Skövde, Sweden Technical Report HS- IKI -TR-07-001, 2007-02-05 2005.

[12] J. W. Burke, M. D. J. McNeill, D. K. Charles, P. J. Morrow, J. H. Crosbie, and S. M. McDonough, "Optimising engagement for stroke rehabilitation using serious games," *The Visual Computer*, vol. 25, pp. 1085-1099, 2009.

[13] P. Rego, P. M. Moreira, and L. P. Reis, "Serious Games for Rehabilitation: A Survey and a Classification towards a Taxonomy," in *5th Iberian Conference on Information Systems and Technologies*, Santiago de Compostela, Spain, 2010, pp. 349-354.

[14] P. Rego, P. M. Moreira, and L. P. Reis, "A Survey on Serious Games for Rehabilitation," in *5th DSIE'10 Doctoral Symposium in Informatics Engineering*, FEUP, Porto, 2010, pp. 267-278.

[15] Hasomed. (2003, 21 Dec 2009). RehaCom Basic Manual. Available: http://www.hasomed.de/fileadmin/user_upload/Rehacom/Manuale/ENG/RehaComEN.pdf.

[16] StrongArm. (2007). *StrongArm Systems*. Available: http://www.strongarm.org.uk/

[17] F. Weiner. (2011). *Parrot Software*. Available: http://www.parrotsoftware.com/default/default.aspx

[18] P. A. Rego, P. M. Moreira, and L. P. Reis, "New Forms of Interaction in Serious Games for Rehabilitation," in *Handbook of Research on Serious Games as Educational, Business, and Research Tools: Development and Design*, M. M. Cruz-Cunha, Ed., ed: IGI Global, 2012 (in press).

[19] P. A. Rego, P. M. Moreira, and L. P. Reis, "Natural User Interfaces in Serious Games for Rehabilitation: a Prototype and Playability Study," in *First Iberian Workshop on Serious Games and Meaningful Play (SGaMePlay'2011) - Proceedings of the 6th Iberian Conference on Information Systems and Technologies*, Chaves, Portugal, 2011, pp. 229-232.

[20] R. Fernandez, D. Parker, J. S. Kalus, D. Miller, and S. Compton, "Using a Human Patient Simulation Mannequin to Teach Interdisciplinary Team Skills to Pharmacy Students," *American Journal of Pharmaceutical Education*, vol. 71, 2007.

[21] J. P. Kincaid and K. Westerlund, "Simulation in Education and Training," presented at the Proceedings of the 2009 Winter Simulation Conference, Austin, TX 2009.

[22] E. Hagemann, "Role of simulation in rehabilitation: the effectiveness of model hands when learning to make orthoses," Master's of Science, Graduate Department of Rehabilitation Science, University of Toronto, 2009.

[23] LapSimÂ. (2009, 21 December 2010). Virtual Laparoscopy Simulator (LapSimÂ®). Available: http://surgery.umc.edu/facultystaff/learning/SSC/virtual.html

[24] J. Allard, M. Marchal, and S. Cotin. (2007, Cataract Surgery Simulation. *(Apr 2010)*. Available: http://www.sofa-framework.org/projects/ophtalmo/cataract.html

[25] J. Dankelman and N. Di Lorenzo, "Surgical training and simulation - Guest Editorial," *Minimally Invasive Therapy and Allied Technologies*, vol. 14, pp. 211-113, 2005.

[26] S. Masiero, E. Carraro, P. Gallina, A. Rossi, and G. Rosati, "Upper limb rehabilitation robotics after stroke: a perspective from the university of Padua, Italy," *Journal of Rehabilitation Medicine*, vol. 41, pp. 91-985, 2009.

[27] P. W. L. Kan, "Design of an adaptive system for upper-limb stroke rehabilitation," Master of Applied Science Thesis M.A.Sc., Institute of Biomaterials and Biomedical Engineering, University of Toronto, Toronto, 2008.

[28] K. Inoue, Y. Ito, Y. Ikeda, A. Tanimura, K. Suzuki, Y. Takahashi, T. Suzuki, M. Fujimoto, M. Tsuchijima, and T. Komeda, "Trial Usage of Rehabilitation System: Simple Driving Simulator for the Driving Skill Evaluation of People with Cerebrovascular Disease: CVD," in *Computers Helping People with Special Needs*. vol. 4061, K. Miesenberger, *et al.*, Eds., ed: Springer Berlin / Heidelberg, 2006, pp. 943-949.

[29] H. Niniss and T. Inoue. (2010, Apr 2010). Electric wheelchair simulator for rehabilitation of persons with motor disability. Available: http://www.sbc.org.br/bibliotecadigital/5-16842.pdf

[30] N.-G. Kim, Y.-Y. Kim, and T.-K. Kwon, "Development of a Virtual Reality Bicycle Simulator for Rehabilitation Training of Postural Balance," in *Computational Science and Its Applications - ICCSA 2006*. vol. 3980, M. Gavrilova, *et al.*, Eds., ed: Springer Berlin / Heidelberg, 2006, pp. 241-250.

[31] ArmNews. (2010). *ArmNews - Virtual reality system to help injured soldiers*. Available: http://www.youtube.com/watch?v=rnpOJKPIe8U

[32] D. Findlay. (2010, Apr 2010). Medical Simulation in the virtual world of second life. Available: http://sites.wiki.ubc.ca/etec510/Simulation_for_Medical_Training

[33] A. C. Vidani and L. Chittaro. (2010, Sept 2010). A serious game for training medical first responders. Available: http://hcilab.uniud.it/soccorsodisabili/results.html

[34] M. Ma and H. Zheng, "Virtual Reality and Serious Games in Healthcare," in *Advanced Computational Intelligence Paradigms in Healthcare 6. Virtual Reality in Psychotherapy, Rehabilitation, and Assessment*. vol. 337, S. Brahnam and L. Jain, Eds., ed: Springer Berlin / Heidelberg, 2011, pp. 169-192.

[35] P. R. Penn, F. D. Rose, and D. A. Johnson, "Virtual enriched environments in paediatric neuropsychological rehabilitation following traumatic brain injury: feasibility, benefits and challenges," *Developmental Neurorehabilitation*, vol. 12, pp. 32-43, 2009.

[36] P. Penn and D. Rose. (2010) Virtual Environments for Brain Injury: Virtual Reality's Forgotten Silver Bullet? . *CyberTherapy & Rehabilitation*.

[37] OpenSimulator. (2012, 30 Jan. 2012). Available: http://opensimulator.org/

[38] P. A. Fishwick, "An introduction to OpenSimulator and virtual environment agent-based M&S applications," in *Simulation Conference (WSC), Proceedings of the 2009 Winter*, 2009, pp. 177-183.