Handbook of Research on Serious Games as Educational, Business and Research Tools

Maria Manuela Cruz-Cunha
Polytechnic Institute of Cávado and Ave, Portugal

Volume I

Information Science
REFERENCE

Managing Director: Lindsay Johnston
Senior Editorial Director: Heather Probst
Book Production Manager: Sean Woznicki
Development Manager: Joel Gamon
Development Editor: Hannah Abelbeck
Acquisitions Editor: Erika Gallagher
Typesetters: Deanna Jo Zombro, Russell Spangler
Cover Design: Nick Newcomer, Lisandro Gonzalez

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Copyright © 2012 by IGI Global. All rights reserved. No part of this publication may be reproduced, stored or distributed in any form or by any means, electronic or mechanical, including photocopying, without written permission from the publisher. Product or company names used in this set are for identification purposes only. Inclusion of the names of the products or companies does not indicate a claim of ownership by IGI Global of the trademark or registered trademark.

Library of Congress Cataloging-in-Publication Data

Handbook of research on serious games as educational, business and research tools / Maria Manuela Cruz-Cunha, editor.
p. cm.
Includes bibliographical references and index.
Summary: “This book presents research on the most recent technological developments in all fields of knowledge or disciplines of computer games development, including planning, design, development, marketing, business management, users and behavior”--Provided by publisher.
ISBN 978-1-4666-0149-9 (hardcover) -- ISBN 978-1-4666-0150-5 (ebook) -- ISBN 978-1-4666-0151-2 (print & perpetual access) 1. Computer games--Design. 2. Computer games--Research. 3. Internet games--Design. 4. Internet games--Research. I. Cruz-Cunha, Maria Manuela, 1964-
QA76.76.C672H3518 2012
794.8’1536--dc23
2011052073

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this book is new, previously-unpublished material. The views expressed in this book are those of the authors, but not necessarily of the publisher.

Chapter 62
New Forms of Interaction in Serious Games for Rehabilitation

Paula Alexandra Rego
Instituto Politécnico de Viana do Castelo, Portugal &
Laboratório de Inteligência Artificial e Ciência de Computadores, Portugal

Pedro Miguel Moreira
Instituto Politécnico de Viana do Castelo, Portugal &
Laboratório de Inteligência Artificial e Ciência de Computadores, Portugal

Luís Paulo Reis
University of Porto, Portugal &
Laboratório de Inteligência Artificial e Ciência de Computadores, Portugal

ABSTRACT

This chapter addresses up-to-date research development regarding the adoption of more natural forms of interaction in the Serious Games for Rehabilitation domain of application. The chapter starts by presenting fundamental concepts on Serious Games illustrated by relevant applications. It describes the main problems involved and how Serious Games can benefit the process of rehabilitation. A comprehensive literature survey is presented and accompanied by a proposed set of classification criteria towards a taxonomy. From this study, a main research opportunity the authors identified is the potential benefits of the adoption of natural interaction modalities. The remainder of the chapter presents the authors' recent work on this subject, including the description and design of game prototypes using alternative and natural interaction modalities. The chapter presents experiments and the results of a user study in order to make it possible to conclude about the benefits of the newer forms of interaction. From this study, it was concluded that the introduction of the natural interaction modalities has increased the attractiveness and intuitiveness of the prototyped Serious Game. This important result is a motivating factor to improve the interaction mechanisms and conduct studies with distinct tasks and larger samples of users/patients. Lastly, the authors report identified research opportunities and open problems.

DOI: 10.4018/978-1-4666-0149-9.ch062

Copyright © 2012, IGI Global. Copying or distributing in print or electronic forms without written permission of IGI Global is prohibited.

INTRODUCTION

Serious Games is an emergent field of research that focuses in the use of games with other purposes than mere entertainment and that can have applications in many diverse areas. Nowadays this concept is largely used in respect to computer games. In this chapter we will use Serious Games to refer to computer games (also referred as video games by some authors in the literature). Their popularity is growing so fast that we are assisting to the arising of new audiences of players such as women and older people, as we can see by the growing use of the Nintendo Wii system (Nintendo, 2011), the Microsoft Kinect system (Microsoft, 2010) or the Sony Playstation Move System (Sony, 2011) by people of all ages and/or entire families. A notorious example of a domain area where the field of Serious Games is assuming a relevant role is the rehabilitation area. We can point several advantages of its use in this area. Computer games are becoming more motivating to the patients than traditional therapy solutions: games have a story, a set of challenges and they motivate the patient to accomplish the defined goals, by the use of tasks that were designed for rehabilitation. Besides enabling to accomplish the final "top-level" goal that is rehabilitation, the game offers the patient the possibility of being immersed in a different situation where he tries to accomplish the goals proposed in the game and is distracted from his disability condition and from the fact that is in a rehabilitation activity. Apart the serious goal of the patient recovery, the game gives also to the patient: immersion, challenge, motivation, enjoyment, sensations that he could not feel if he was only repeating a sequence of tasks that were part of his rehabilitation plan.

Additionally, games are becoming more accessible to people in general. Computer systems are becoming more disseminated and affordable to users in general, in the form of several devices: game consoles, portable personal computers, large display TV sets, etc. At the same time, people tend to have more literacy about information systems and computer technologies, and this promotes the accessibility to computer games.

On the other hand, we are assisting to the arising and development of more natural user interfaces that are changing the traditional interaction paradigm of mouse and keyboard to other new forms of input: gestures, forces feedback, balance feedback, facial expression recognition, and voice recognition, to name some of the more relevant modalities of input. These new forms of interaction can be used to create applications that tend to be more natural and free, as they foster the elimination of artificial input devices in the human-computer interaction. These new forms of interaction can be used in order to increase the quality and efficiency of the rehabilitation process.

Another important aspect that can favor Rehabilitation Serious Games is the fact that people are connected to the internet using more bandwidth, which enables network rehabilitation games and the fulfilling of rehabilitation plans at home, without having to move the patient to the clinic/hospital. The rehabilitation plans can be adjusted in some cases by the therapist, at distance, which contributes to a greater comfort, time economy and autonomy development to the patient. Additionally, as patients can be connected by the web, this promotes the introduction of social components in the games, which can be used in the creation of new scenarios of rehabilitation where patients can cooperate and compete at distance.

This chapter reviews relevant work described in the literature concerning natural forms of interaction. It also presents a proof of concept serious game that can be used in a therapy session in order to study how more natural forms of interaction can be used to augment motivation in a rehabilitation session. Another important result is concerned with the identification of research opportunities and open problems.

The rest of the chapter is structured as follows. The next section presents an introduction to Serious Games, including fundamental concepts and terminology, classifications and examples of application. It also describes the importance of simulation in Serious Games, by presenting some examples of the use of simulations in the health field of applications. The section ends with a review on the use of natural interfaces in Rehabilitation Serious Games. Following, section "Natural Interfaces in Serious Games for Rehabilitation" introduces the motivation of Serious Games for Rehabilitation, its issues and problems and describes a reference system in Rehabilitation, the serious game prototype implemented (including the concept, the interaction technology used and some details of the implementation) and the validation of the system, including the discussion of the obtained results. In section "Future Research Directions", directions for future work are suggested and open problems identified. Finally, in section "Conclusion", major conclusions are drawn.

BACKGROUND

In 2002 was formed the Serious Games Initiative (Rejeski & Sawyer, 2009), contributing to organize the area of Serious Games in an industry that merges: game developers, innovation, and projects from distinct areas (education, training, health and public policy). The amount of research in this area has been growing, with seminars and conferences being organized all around the world. However, although the term Serious Game is becoming more and more popular, there is no current single definition of the concept. Zyda was the first author to give a definition of Serious Games (Zyda, 2005):" a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives". Several other authors have defined this term (Chen, 2006; Corti, 2006; Zyda, 2005). In this chapter we adopt our definition (Rego, Moreira, & Reis, 2010a) that defines Serious Games as computer games that allow the player to achieve a specific non entertainment purpose using the entertainment and engagement component provided by the experience of the game.

Some other terms are used that are sometimes related and overlapped with the Serious Games concept: edutainment, e-learning, game-based learning. However, we may consider Serious Games concept a much broader one, in which all of the previous can be included. For example, the edutainment concept refers to any form of education that also entertains, but that is not limited to video-games. On the other hand, Serious Games use games and entertainment, but are not limited to an educational purpose.

Serious Games have been applied in many diverse areas: corporate and military training (Numrich, 2008), health (Sawyer, 2008), education (von Wangenheim & Shull, 2009), cultural training (Zyda, 2007). We refer the interested reader to the work of Rego et al. (Rego, Moreira, & Reis, 2010b) for a comprehensive review on Serious Games applications.

A Serious Game has a specific goal that goes beyond pure entertainment. It aims to create simulations and user experiences that can be used to attain that specific goal. By taking advantage of game technology in order to create more attractive user experiences and increasing playability, the environments and tasks simulated in the serious game can be used to teach or train users in various situations. The same strategy can also be used with other purposes as for the individual growth and development, advertisement, and marketing, to name some relevant applications. In many of these applications the use of simulated models becomes necessary or convenient in order to represent in an accurate way several aspects of the game, as it is the case of other players and their behavior, the surrounding environment, and cognitive or motor processes.

Next we describe the importance of the use of simulation in Serious Games, by presenting some of the more relevant works reported in the literature in the health and rehabilitation application field.

Simulation and Serious Games

As systems are getting more complex and more dynamic, simulation can be used in many domains as a way to understand and integrate their complexity and changeability. Simulation is the imitation of some real thing, state of affairs, or process, over time, seeking to represent certain key characteristics or behaviors of the selected physical or abstract system. It is used in many contexts which vary from decision making, to the modeling of natural systems or human systems in order to gain insight into their functioning or the simulation of technology for performance optimization, safety engineering, testing, training and education (Law, 2007; Zeigler, Praehofer, & Kim, 2000). Simulation is very important in Serious Games for Rehabilitation as it is used to simulate the environment and the tasks the patient has to do in a rehabilitation session.

Simulation can be used in many domains with varying goals but mainly to control system complexity and improve its performance. In health field of applications, the simulation can be used on different levels: environment, patient, therapist or all (environment and users of the environment).

The simulation of the environment can be done by placing the patient in a more controlled environment and measuring his progress over time, adjusting practice sessions to patient needs or impairments. In a controlled environment, close to the real world, the patient progress can be measured, facilitating experiments and predictions and creating a risk free and/or cost effective solution. In many applications Virtual Reality (VR) is used to provide immersion. Example of these applications can be seen in (Inoue et al., 2006) that describe the use of a driving simulator, in (Niniss & Inoue, 2010) describing the use of an electric wheelchair simulator, in (Kim, Kim, & Kwon, 2006) describing a VR Bicycle Simulator and in (ArmNews, 2010) that describes a computer assisted rehabilitation environment system for civilian and military patient recovery.

The simulation of the patient can be seen by the use of a physical representation of the patient body or of a part of the patient's body. The former consists in an artificial patient that is a computer connected to a life size mannequin which mimics body functions (heartbeat, respiration, replicate symptoms of illness) and that can be programmed to recreate life-threatening emergency situations and to respond to injected drugs (Fernandez, Parker, Kalus, Miller, & Compton, 2007; Kincaid & Westerlund, 2009). This has the advantage of teaching trainees technical abilities and to establish pre-clinical proficiency by allowing unlimited and consequence-free practice, transfer of skills learned in the simulated environment into the real-world clinical environment, and providing motivation to learning by giving feedback from decisions and actions. An example of the later is given by Hageman (Hagemann, 2009) that describes the use of a hand model as a training tool to make orthoses. In other simulations, visual and virtual representations of medical processes are reproduced using computer graphics techniques, haptic feedback devices, and physical simulation. Examples of these applications are described in (Dankelman & Di Lorenzo, 2005) and seen from the virtual laparoscopic simulator (LapSimÂ, 2009) of the University of Mississippi Medical Center which describes suturing tasks and the simulated cholecystectomy procedure. Other examples describe sirurgical simulations such as a cataract surgery simulation (Allard, Marchal, & Cotin, 2007).

The simulation of the therapist can be seen in systems that minimize the presence of the therapist in the rehabilitation session. Examples of these applications include mainly the use of robotic systems that assist the patient in the rehabilitation session and help to reduce dependency from the therapist (Kan, 2008; Masiero, Carraro, Gallina, Rossi, & Rosati, 2009).

On the other hand, the environment and users simulation is used to simulate an envisioned facility to allow the planning, predicting and improvement of operation and procedures. Examples of applications included in this category can be seen in (Findlay, 2010) that consists in a medical simulation in the virtual world of Second Life platform, used in nursing courses, which represents virtually the environment of a envisioned clinic, the virtual patient, the virtual therapist and the clinic functioning and procedures. Another example can be seen in (Vidani & Chittaro, 2010) which describes a serious game demo application that can be used to train medical first responders, representing virtually the patient and the procedures the therapist has to do.

In rehabilitation area, simulation has been used to simulate the system environment and mostly the therapist: by means of a computer game, the rehabilitation training exercise is simulated for the patient, minimizing the presence of the therapist. This paper focuses the use of simulation on the rehabilitation area by means of a serious game that simulates the training exercises of the patients in rehabilitation. The serious game aims to represent the training exercise the patient has to do in a cognitive rehabilitation session.

Serious Games for Rehabilitation

High social costs result in a major part from high costs in the rehabilitation of a variety of deficits resulting from diseases or traumatic incidents. Rehabilitation is a dynamic process of planned adaptive change in lifestyle in response to unplanned change imposed on the individual by disease or traumatic incident (Gunasekera & Bendall, 2005).

Stroke has been referred in literature as the major cause of the long term disabilities among adults in industrialized nations (Warlow et al., 2008). A stroke usually occurs when a blood clot stops the flow of blood to a portion of the brain. After a few minutes, the cells of the brain that are lacking the blood begin to die and patients who survive a stroke can suffer cognitive, visual and motor losses. In terms of cognitive functions, stroke survivors may have losses in memory and speech that can affect highly his interaction with the world (Alankus, Lazar, May, & Kelleher, 2010). Some of the patients, as a result of stroke, lack the perception in one side of their visual side. Sometimes they have motor problems like paralysis or weakness on one side of their bodies. When patients lose the ability to use their arm, they are limited in activities of daily life like feeding, dressing and bathing. All these problems make difficult for the patients to get back to their normal life. They have to be encouraged to use the affected members of the body through exercise so they can relearn the ability to use them again. This process is usually very slow and demanding and may require hundreds of repeated movements every day.

Major tests reported from rehabilitation programs of patients with impairments and disabilities show that patients function improves with an intensive training that is oriented in the achievement of a goal and is divided in specific tasks. The main problem with this task-specific treatment approaches, however, is the lack of patient interest in performing repetitive tasks and in ensuring that they finish the treatment program (Burke et al., 2009). Games can play here a very important role. In fact, it has been showed that games contribute to increase motivation in rehabilitation sessions, which is the major problem in therapy sessions, caused by the repetitive nature of exercises (Burke, et al., 2009; Kizony, Raz, Katz, Weingarden, & Weiss, 2005). Various research projects have been studying how to use games to help patients recovering from impairments or disabilities (Conconi et al., 2008; Ryan et al., 2009).

Several works have been reported in the literature that identify important game characteristics in the rehabilitation area (Rego, et al., 2010b). In a previous work (Rego, et al., 2010a) we identified relevant criteria for the classification of Serious Games in rehabilitation area. These criteria could be used for the design of more effective rehabilitation games and also to make a synthesis and comparison of existing Serious Games for rehabilitation. The criteria identified are the following ones: Application area (Cognitive/ Motor), Interaction Technology (used by the patient to interact with the system), Game interface (2D or 3D), Number of players (single or multi-player), Game Genre (from catch, reach and grasp, to simulation or strategy), Adaptability (the capability of the system to adapt dynamically game difficulty or challenge, according to the patient performance and abilities in the game), Performance Feedback (capability of the system to transmit to the patient the results of the interaction), Progress monitoring (capability of the system to allow saving the results of patients interaction with the system) and Game portability (capability of the system to be used at home, or at a hospital or clinic). In this chapter we focus on the interaction technology criterion and study how it can be used in a game in order to make it a more motivational tool for rehabilitation therapy.

There are many recent rehabilitation serious game projects reported in the literature that use different forms of interaction, yet the majority of these use traditional forms like the mouse and/ or keyboard. Next we present some of the applications of rehabilitation Serious Games that we reviewed, focusing the following aspects: the interaction technology used, the evaluation test done and the introduction of social components like cooperation or competitiveness.

In (Ma & Bechkoum, 2008) the authors described a serious game based movement therapy for stroke patients with upper limb motor disorders. Their system uses functional tasks, such as wrist extension, reaching, grasping and catching, and Serious Games. Input devices include the mouse and keyboard for the operator and a range of real-time motion tracking devices: data gloves to capture finger flex and hand postures; and wireless magnetic sensors to track the patient's hand, arm and upper body movements. The dual output visual interface includes a desktop computer LCD for the operator and a high resolution HMD for patients. The HMD equipment displays an immersive virtual environment.

PlayMancer (Conconi, et al., 2008) was introduced as a platform for rapid development of Serious Games, applied to physical rehabilitation and therapeutic support and lifestyle management programs for behavioral and addictive disorders. The platform is modular and combines techniques from multimodal interaction (speech, touch, biosensors and motion-tracking), 3D engines, virtual and augmented reality, speech recognition and natural language processing.

The Rehabilitation Gaming System (RGS) (Cameirão, Badia, Zimmerli, Oller, & Vershure, 2009), a VR based system developed for the rehabilitation of patients suffering from stroke and TBI combines a camera based motion capture system with gaming technologies. In this system, the movements of the patients' arms are visually captured by a camera that is on the top of the display and that detects color patches located on wrists and elbows of the subject. A pair of data gloves measures finger flexure. According to the movements of the user, an avatar performs a task in the virtual scenario.

The Balance Rehabilitation Games project (Ryan, et al., 2009) developed at University of New South Wales (UNSW), in Australia, aims to design a game to older adults while incorporating appropriate balance exercises. The game is a maze-solving problem for one or two players. The goal of the game is to navigate the maze and collect all the treasures. The player's score is the final time through the maze. Players move forward by walking in place on a Wii Fit balance board. Longer `strides' produce more rapid progress, to reward better balance rather over rapid stepping. Cooperative and competitive two-player versions of the game are also being prototyped. In the cooperative version, the players work together to collect all the treasures and finish the maze as quickly as possible. In the competitive version the treasures are omitted and it is simply a race to complete the maze as quickly as possible.

Several games for upper limb stroke rehabilitation were described in (Burke, et al., 2009), which use low-cost webcams as input technology to capture video data of user's movements. The position of the player hands are tracked, so he has to wear a glove or hold a marker which can be an object of a single color, such as a piece of card. The games use user profiling and an option to adaptability.

In (Burke et al., 2010) the authors extended the work presented in (Burke, et al., 2009) to include augmented reality (AR) techniques for the upper-limb rehabilitation games developed. The real objects have attached AR markers and with a webcam it is possible to track the position and orientation of the real object as it is moved. The system can then augment the captured image of the real environment with virtual objects and then it is possible to present diverse games and scenarios to the patient. This has the potential to increase the engagement of the patient in the created rehabilitation scenarios.

A collaborative game developed for arm rehabilitation of patients with multiple sclerosis (MS) was described in (Vanacken et al., 2009). In this game, the patient has to make specific movement tasks with his arm, using a force feedback device, the HapticMaster with a gimbal. The patient has to play the game with the collaboration of a co-player which will use a Wiimote or a force-feedback device. The input devices used can be a force-feedback device to control the pump, or a WiiMote.

In (Alankus, et al., 2010), the authors described the development, testing and improvement of nine games, two of them were two-player collaborative games, two were two-player competitive games and the remaining were single-player games. They used as input devices a webcam to track the positions of the colorful objects held by the patient and Wii remotes. Wii remotes have the advantage of being wireless and inexpensive devices. To detect compensatory motions, they attach additional Wii remotes to the body parts that are supposed to remain stationary. They tested the games with four stroke patients.

In order to study collaboration and social skills in children with Autistic Spectrum Disorders (ASD), a Collaborative Puzzle Game (CPG) (Battocchi et al., 2008) that runs on an interactive table supporting multi-user interaction was developed. The actions on digital objects can be performed only through simultaneous touch of two or more users. In the game, the participants have to drag the pieces to complete a puzzle.

The work herein presented reviews relevant work described in the literature in rehabilitation Serious Games in what concerns the interaction technology used and specific rehabilitation criteria like adaptability, progress monitoring, etc. *Figure 1* summarizes the applications described above (in the table, the "--" means that this feature is not mentioned in the paper reviewed).

NATURAL INTERFACES IN SERIOUS GAMES FOR REHABILITATION

Issues and Problems

Traditional rehabilitation therapies are usually considered boring and uninteresting by patients in rehabilitation. It is important to increase the motivation of these patients in the practicing of the exercises, because an intensive repetition of the exercises is essential for their recovery. Game-based therapies have shown an increasing in the motivation of these patients due to the playful and engaging components of the game. Serious Games can therefore play a relevant role in the motivation of patients in rehabilitation and therefore in obtaining better results in their recovery. Games engage the patient in the associated narrative and distract his attention of the rehabilitation activity (necessary for his recovery)

Figure 1. Synthesis and comparison of the rehabilitation serious games reviewed

	Game Criteria		Rehabilitation Criteria					Evaluation Test
	Interaction Technology	Competitive/ Collaborative	Application Area	Adaptability	Progress Monitoring	Performance Feedback	Portability	Sample size
Betker et al., 2008	Body Weight Movement	None	Motor	Yes	Yes	Yes	Home	3
Ma et Bechkoum, 2008	Motion Tracking + HMD	None	Motor	Yes	Yes	Yes	Clinic	8
Conconi et al., 2008	Speech + Touch+ Motion Tracking +Biosensors	None	Cognitive	Yes	Yes	Yes	Clinic	--
Battochi et al., 2008	Multi-touch table	Collaborative	Motor	--	--	--	Clinic	4
Caglio et al., 2009	Keyboard	None	Cognitive	No	No	--	Clinic	1
Cameirão et al., 2009	Motion Tracking	None	Motor and Cognitive	Yes	Yes	Yes	Clinic/Home	6
Burke et al., 2009	Motion Tracking	None	Motor	Yes	Yes	Yes	Home	3
Vanaken et al., 2009	Force-feedback device + WiiMote	Collaborative	Motor	--	--	--	Clinic	--
Ryan et al., 2009	WiiMote Wii Balance	None	Motor	--	--	--	--	--
Alankus et al., 2010	Wii Remotes + Webcam	Competitive and Collaborative	Motor	Yes	No	Yes	Clinic	4
Burke et al., 2010	Webcam + AR markers	None	Motor	Yes	Yes	Yes	Clinic	--
Our system	Webcam + Microphone + Keyboard	None	Cognitive	Yes	No	Yes	Home	20*

itself, at the same time they lead the patient to the practice of the exercises necessary to fulfill the goals defined by the game. However, most of the applications reported in the literature of this area misses yet essential components for games to be considered fully functional and efficient tools in rehabilitation. In our previous work (Rego, et al., 2010a) we found a set of criteria for the design of more effective rehabilitation games and that were referred in the previous section.

From the literature review and from analysis of *Figure 1* we can conclude that although exist many recent projects of rehabilitation Serious Games reported in the literature, most of them are only prototypes and were experimented with a small number of patients, which makes difficult to take more precise conclusions from their effectiveness.

Interaction technology was found as a relevant criterion to achieve a more motivational purpose in rehabilitation therapy, using computer games. However, most of reviewed games have very simple interfaces and traditional forms of interaction. Natural interfaces appear in some games (Alankus, et al., 2010; Battocchi, et al., 2008; Burke, et al., 2009, 2010; Cameirão, et al., 2009; Conconi, et al., 2008; Ma & Bechkoum, 2008; Ryan, et al., 2009; Vanacken, et al., 2009), but are poor evaluated in terms of the rehabilitation process.

The interaction technology reviewed in those works can vary from the traditional methods using a mouse or keyboard process to VR based methods. For instance, in VR, patients can have visual interfaces including desktop monitors and head-mounted displays (HMDs), haptic interfaces, and real-time motion tracking devices that are used to create environments that allow users to interact with images and virtual objects in real-time through multiple sensory modalities (vision, haptics, audition). In fact, the use of VR technology in the rehabilitation of cognitive and motor deficits has been growing in the last decade and one of the main target populations are stroke patients (Burke, et al., 2009). With these new methods patients can be part of immersive experiences that are engaging and rewarding for them, which promotes their recovery. In telerehabilitation the most used modalities are webcams, tele-videoconferencing over phone lines, videophones and web pages containing rich internet applications.

We believe that the use of more natural user interfaces can benefit the process of rehabilitation since the patients have several cognitive and motor disabilities which difficult the way they interact with the system. This interaction with the system should then be more intuitive and easy to use, due to patient's disabilities.

Another important aspect to have in consideration is to choose an interaction technology that can be inexpensive to be feasible for home use and thus promoting for the patients to play more frequently the games. The existence of home-based technologies that can motivate the patients to continue practicing the exercises out of rehabilitation clinic assumes therefore a very important role.

Additionally, the social dimension of the games is very poor. Most of the games are for a single user player. However, to study the increase of motivation in the rehabilitation programs several approaches have recently been reported that seek to add a social dimension in the games. In the very few and recent multi-player games reported (Alankus, et al., 2010; Battocchi, et al., 2008; Vanacken, et al., 2009), the collaboration and competitiveness facility exists, but the evaluations done are inexistent (yet planned for future studies), or with a very small number of patients. The family and friends can also give a contribution in the rehabilitation process, by adding a social support and this can go beyond an increase in the patients' motivation. This social support can come also from other fellow patients or therapists for instance.

However, in all of these works rehabilitation criteria such as progress monitoring, performance feedback and adaptability are present. The solution adopted should be technologically advanced to detect, log, and analyze patients' motions and tasks prescribed by the therapists.

On the other hand, the design of the rehabilitation tasks is a very complex issue that depends in the kind of disabilities of the patient in rehabilitation. These disabilities can be diverse and so it would be necessary a program adapted to the patient needs in order to achieve the best results in the rehabilitation program. Based on that, the design of the rehabilitation tasks would require a multidisciplinary team from the medical field composed with doctors, nurses, psychologists, physiotherapists, and therapists. Also it would require professionals of the game design field. This is difficult since it implies communication between different professionals (and languages).

It is our intention to further research if the use of new forms of interaction in a serious game can increase the motivation of the rehabilitation program, having in account all the aspects referred above.

RehaCom: A Reference System for Rehabilitation

As it would be difficult to arrange a multidisciplinary team responsible for designing the game, in order to minimize the complexity associated with that task, we use an existing and established system as a reference for the design task of our game – The RehaCom system.

There are other similar systems in cognitive rehabilitation, namely the StrongArm System (StrongArm, 2007), Parrot Software System

(Weiner, 2011), and the cognitive software of Fundación INTRAS (Intras, 2004). The first system, initially developed for head/brain injury patients, but now also used for other treatments like stroke patients, geriatrics, Alzheimer patients and children with learning problems, can be used by individuals at home, besides the rehabilitation centers or public schools and shows results of its efficacy evaluation from a controlled trial held during over 3 years. The Parrot Software System, developed initially for speech rehabilitation, includes now different programs for communication, memory, cognitive reasoning, and attention rehabilitation, can be used at hospitals or rehabilitation centers or at home, providing an internet option as an alternative to purchasing the software. Fundación INTRAS (Intras, 2004) provides programs of cognitive software (with modules for attention, perception, memory, orientation and calculation) for use in rehabilitations centers or clinics but also for home rehabilitation.

Although these cognitive rehabilitation systems are used in many clinics/hospitals, the RehaCom system has results proven scientifically, with a great number of patients. Additionally, another major reason to use RehaCom is that we have access to patients using the system and this will enable us to conduct tests that can validate our approach.

RehaCom is composed of a set of Serious Games that are used in the rehabilitation sessions. This system is widely used and tested in the area of cognitive rehabilitation, in various hospitals and clinics. His effectiveness has been demonstrated in a number of studies all very well referenced

Figure 2. RehaCom system

(with a description of the study conducted) in the RehaCom Catalogue (Schuhfried, 2011). Figure 2 presents a picture of the RehaCom System. The interaction technology used by this system consists in a special panel, the mouse or a touch screen.

RehaCom is a computer-assisted modular system that requires an experienced therapist and is composed of training procedures for training different skills: attention, memory, executive, field of view and visuomotors. Each training procedure consists of a specific task that the patient must accomplish. Figure 3. displays the training procedures RehaCom offers for each training program or application area.

For example in the category "Executive Functions", RehaCom provides the shopping game. In this game, the patient receives a shopping list with all the items that he needs to find in the supermarket and put in his shopping basket. Once he

Figure 3. Training procedures of system RehaCom by application area

Executive Functions	Field of View Training	Visuomotor skills	Memory Training	Attention Training	
Shopping	Saccadic Training	Visuomotor Coordination	Topological Memory	Alertness	- Acoustic Reactivity - Reaction Behaviour
Plan a Day	Exploration		Physiognomic Memory	Vigilance	- Vigilance
Logical Reasoning			Memory of Words	Visuo-spatial Attention	- 2D - 3D
			Figural Memory	Selective Attention	- Attention & Concentration
			Verbal Memory	Divided Attention	- Divided Attention

has all the items in the basket, he can go to the till and leave the supermarket. The difficulty is increased by adding to the number of articles that need to be purchased. In the second mode the article prices must be added up and compared with the amount of money that is available.

In a "Plan a Day" game, the patient has to schedule necessary activities in the best possible sequence. The patient is provided with a map showing buildings (bank, café, post office etc.) that must be visited according with the plan that the client draws up, considering priorities, minimizing distance traveled and maximizing the number of activities completed.

Figure 4 shows the game "Attention and concentration" that is included in the category of "Attention Training". In this game, there is a matrix of pictures on the left and separated on the right a comparison picture. The picture on the right that matches the comparison picture must be identified.

Figure 4 shows the "Memory for Words" game that is included in the "Memory Training" category. In this game the goal is to recognize words that were memorized in a first (learning) phase and that after appear in a sequence of other words.

These games offer characteristics like: adaptability and performance feedback that potentiate the motivational and enjoyment aspects of the game. Adaptability allows that task difficulty increases automatically as learning progresses so the patient is not faced with tasks that are too easy or too difficult for him. In respect to performance feedback, the system informs the patient of his progress in motivational ways. If an error is made the patient receives specific feedback. When a session ends, a performance chart appears on the screen where the patient sees his progress made from session to session.

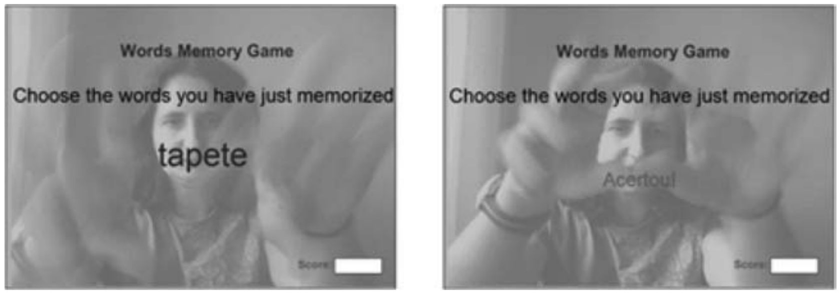
RehaCom system also offers the functionalities specific to rehabilitation like progress monitoring and portability advantages. With progress monitoring, the therapist can analyze the patient's progress and identify and influence his performance deficits and reserves. In terms of portability, RehaCom requires the presence of the therapist in order to discuss the patient's training goal and results at the beginning and end of training. Therefore, it reduces considerably the workload of participants in the therapy.

A Serious Game Prototype for Rehabilitation

We believe that the use of natural forms of interaction and Serious Games can augment the efficacy of the rehabilitation process, by increasing the motivation of the patients in the therapy sessions. In order to investigate this, the approach used was to choose one of the games from RehaCom to design and implement and introduce to it new forms of interaction, not included in RehaCom's games.

Figure 4. RehaCom games: (left) Attention and concentration; (right) Memory for words

Figure 6. Screenshots of the game play



Game Concept

The game prototype developed can serve as a proof-of-concept application to investigate if these new forms of interaction can be applied to increase motivation in rehabilitation patients. Our implementation of the game reproduces the game mechanism of the Memory for Words game of RehaCom system, illustrated in Figure 4 (right). This game is included in the "Memory Training" category of RehaCom, as can be seen in Figure 3. The goal of this game is to recognize a set of words that were memorized in a first (learning) phase and that after appear in a sequence of other words. The interface of the game is two-dimensional.

Game Interaction Technology

In RehaCom "Memory for Words" game the words were chosen by the user using the special panel, the mouse or a touch screen. Our implementation of the game considers three forms of input: using the mouse (mouse detection), using some noise (sound detection), or using some motion (motion detection). Figure 5 shows the screen interface of our game that is presented to the player asking him to choose from one of these forms of interaction. Figure 6 presents some screenshots of the game play.

The hardware required to run this game prototype consists in a laptop or computer desktop with internet access, a microphone and a webcam.

Game Implementation

The game prototype was implemented in the Adobe Flash platform, using the ActionScript 3.0 programming language.

Adobe Flash allows to work with the sound captured from the microphone attached to the computer using the Microphone class which returns the current activity level of the microphone (Keith, 2009). Video input is handled through the Camera class which allows to detect levels of motion and to make the stream of the captured data over the network, or locally to an instance of the Video class which makes the display of the data (Keith, 2009). This allows also to analyze images pixel by pixel and to implement image processing and computer vision filters.

Figure 5. Screen interface of the game asking to choose the input option.

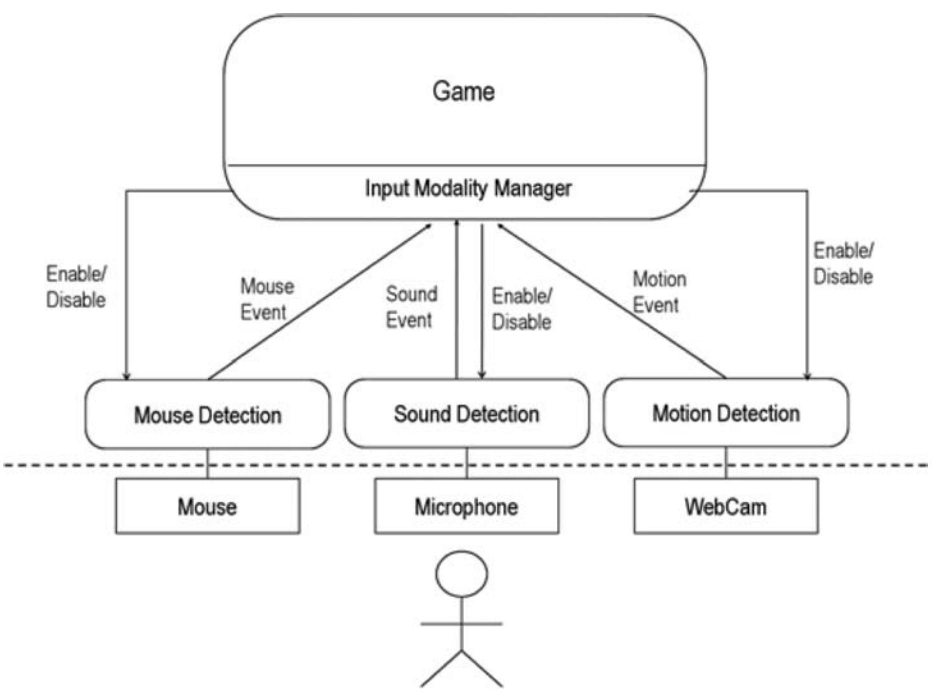
The possibilities of the Flash ActionScript API are encouraging as it provides, besides an OOP language, a rich and complete set of classes devoted and oriented to develop interactive, interconnected and rich-media applications. There are already third-party libraries and frameworks that extend this capabilities with more elaborated tools to handle for instance face recognition tasks - such as the Marilena (Masakazu, 2008) port of the OpenCV (OpenCVWiki, 2010) object recognition, the FlARToolkit (SparkWiki, 2011) - a port of the disseminated ARToolkit (Lamb, 2003) for Augmented Reality, PaperVision3D (PaperVision3D, 2010) to handle three dimensional object representations such as virtual worlds and TUIO AS3 Lib – a library that implements the TUIO (Kaltenbrunner, Bovermann, Bencina, & Costanza, 2005) framework for tangible multi-touch surfaces.

Figure 7 presents a block diagram of the modular architecture of the system. The detection modules (mouse, sound and motion) have functions to prevent the detection of two levels of consecutive sounds. They also include functions of calibration of the recognition modules to be adjusted to the environment conditions like the background noise level and/or lighting issues.

Adobe Flash provides classes that allow basic mechanisms to activate the detection of some specified level of sound and/or motion. With the sound and/or motion interaction, one of the problems is that the game velocity is limited by the detection process itself. With a sound or motion interaction, a user cannot play as quickly as it would if he was using mouse clicks.

In the developed prototype, the three modes of interaction (mouse, sound and motion) can be enabled and activated at the same time. However, for the purpose of the current study, the actual configuration uses only one mode of the interaction at a time, which the user chooses in the beginning of the game.

Figure7. Representation of the main modules of the prototype system, with particular detail on the input modalities



User Testing

To validate our prototype we conduct a small user study with 20 healthy users. This study can thus serve to evaluate the playability of the game in what concerns the three input forms of interaction before running a usability study with patients in rehabilitation. First we made a small demonstration of the three input options of the game. Each user then played five times the game in each of its three input options and filled a questionnaire. The first two times were for him to become accustomed to the interface and the remaining to evaluate the game. In Figure 8 is presented an excerpt of the questionnaire we used in this study.

The majority of participants enjoyed playing all the input options, with the sound input option being considered the most enjoyable (55% agreeing and 20% strongly agreeing that this option was enjoyable) and the motion option being considered the least enjoyable (65% agreeing and 5% strongly agreeing that this option was enjoyable).

The majority of participants found the input mechanism of the game intuitive, with the mouse option being considered the most intuitive one (25% agreeing and 60% strongly agreeing that this option was intuitive) and the motion option being considered the least intuitive (35% agreeing and 30% strongly agreeing that this option was intuitive).

Relatively to the feedback of the game, the majority of participants found the feedback of the game effective, with the mouse option being considered the most effective (45% agreeing and 45% strongly agreeing that this option was intuitive) and the motion option being considered the least effective (40% agreeing and 25% strongly agreeing that this option was intuitive). To notice here that the results obtained in the sound option were very close to the results of the mouse option (45% agreeing and 35% strongly agreeing that this option was intuitive).

The majority of player considered play again more times the game, with the sound input option being the most chosen to play again (35% agreeing and 40% strongly agreeing that they would play again that option), and the mouse input option being the less chosen (30% agreeing and 25% strongly agreeing that they would play again that option).

Figure 9 presents a chart illustrating the results described relatively to question 1 of the questionnaire.

Figure 10 presents another excerpt of the questionnaire that we used in the study.

Figure 8. An excerpt of the first part of the questionnaire used in the playability study

1) Evaluate the "Memory for Words" game in each version in respect to the following (choose only one option):

1. Strongly disagree **2. Disagree** **3. Neither agree nor disagree** **4. Agree** **5. Strongly agree.**

		1	2	3	4	5
1. The game is enjoyable.	Mouse Detection	☐	☐	☐	☐	☐
	Sound Detection	☐	☐	☐	☐	☐
	Motion Detection	☐	☐	☐	☐	☐
2. The input mechanism is intuitive.	Mouse Detection	☐	☐	☐	☐	☐
	Sound Detection	☐	☐	☐	☐	☐
	Motion Detection	☐	☐	☐	☐	☐
3. The feedback is effective.	Mouse Detection	☐	☐	☐	☐	☐
	Sound Detection	☐	☐	☐	☐	☐
	Motion Detection	☐	☐	☐	☐	☐
4. I would play the game again more times.	Mouse Detection	☐	☐	☐	☐	☐
	Sound Detection	☐	☐	☐	☐	☐
	Motion Detection	☐	☐	☐	☐	☐

Figure 9. Results from the questionnaire relatively to question 1 of the questionnaire

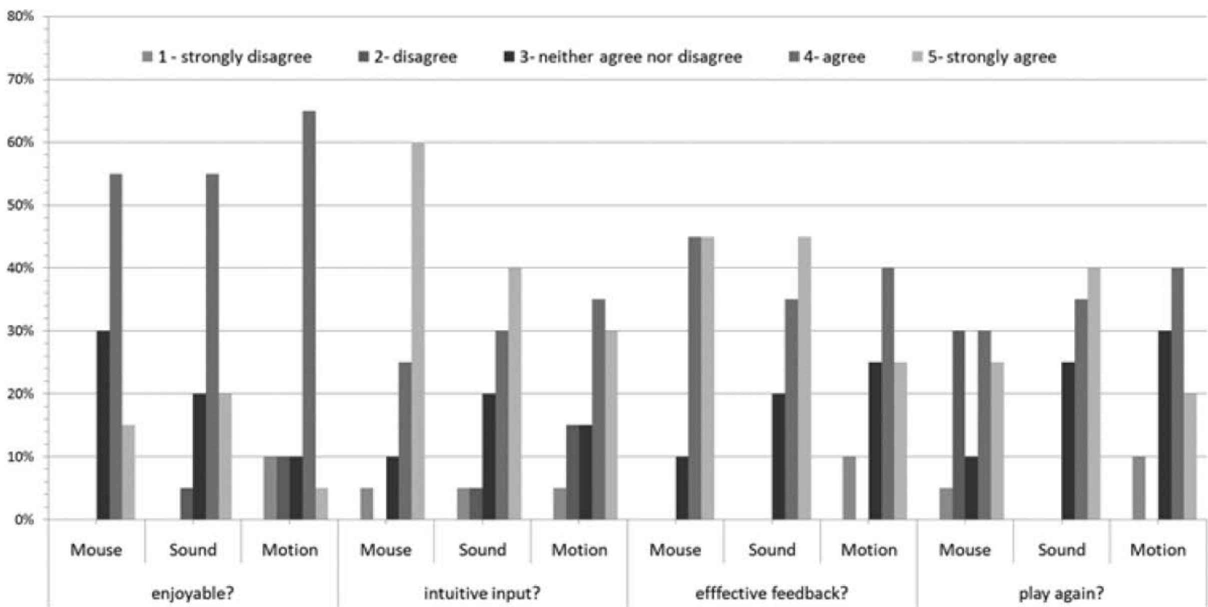


Figure 10. Excerpt of the second of the questionnaire used in the playability study

2) Evaluate the "Memory for Words" game in what concerns the three forms of input:

	Mouse	Sound	Motion
What version of the game did you felt most involved with?	☐	☐	☐
What version did you find most intuitive?	☐	☐	☐
What version would you play again?	☐	☐	☐

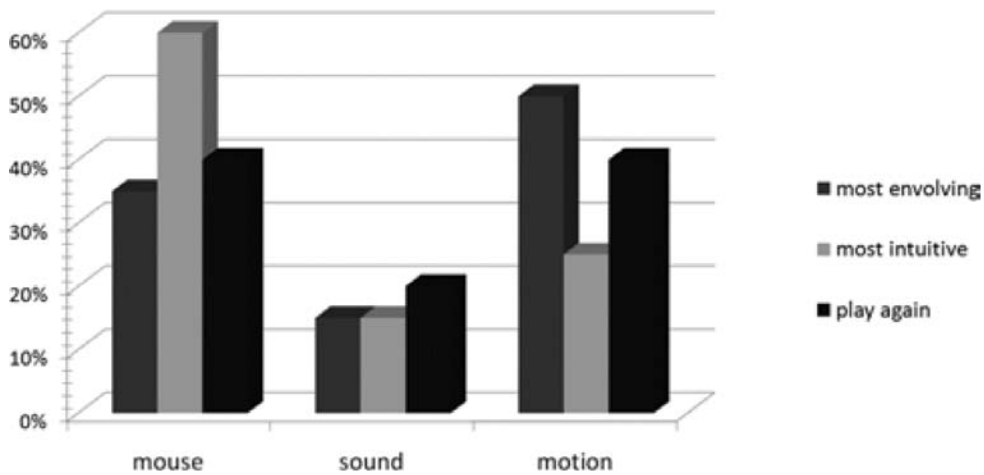
When asked to compare the three input game options, the participants felt more involved with the motion input option (50% against 15% that chosen the sound input option and 35% the mouse input option), they considered the mouse option the most intuitive input (60% against 15% that chosen the sound input option and 25% the motion input option) and would play again the motion and mouse option (40% against 20% that chosen the sound option). Figure 11 presents a chart illustrating the results obtained in each input option in respect question 2 included in the last excerpt shown of the questionnaire.

Comparison with Reviewed Systems

A comparison with the systems that were described and reviewed in section "Background" of this chapter can be analyzed from Figure 1 which presents the characteristics of our prototyped system, according to the criteria we have chosen to classify the referred reviewed systems.

Our system uses three input devices as interaction technology: a webcam, a microphone and a keyboard. These input devices can be used alternately in the game. In the beginning of the game, the player can choose among three input options: mouse, motion and sound. The player can use only the mouse as input device in the

Figure 11. Results from the questionnaire in respect to question 2



first version of the game; in the second version of the game, he must use movements of his body (hands, head, arms) to make the selections and play the game; in the sound option, the player has to make some sound effect (talk, clapping, yell, etc.) to play the game.

Our system does not provide a facility for collaboration/competition. This facility would be considered in future versions of our game.

In respect to application area, the prototyped game is to be used in a cognitive rehabilitation context. The game implemented is a re-implementation of the game mechanism of a words memory game included in a widely used and tested rehabilitation system that is described in the previous section –the RehaCom system, which use is well proven in cognitive rehabilitation sessions.

For each of the input options of the game, we have considered in its design some of the design principles that should exist in a rehabilitation context such as performance feedback, adaptability, progress monitoring and portability. Performance feedback is created in the game through the feedback given to the player by visual messages for right or wrong answers, information about score, sprites changing text messages and text colors. Adaptability is provided by changing the speed and difficulty of the game, according to player's performance. Beyond the game mechanics, progress monitoring is also a fundamental feature in order to enable track and analysis of the rehabilitation plan. This facility is already prepared, although was not used in this study. In terms of portability, our system can be used for home rehabilitation, as it only requires a laptop/ desktop computer with internet access, a webcam and a microphone.

The problems found as a result of the playability study can be improved in future versions of the game. The next phase of our study will be to involve a larger number of patients in rehabilitation with improved versions of our prototype.

Compared with the reviewed systems, our system gathers a set of advantages that can be enunciated as low cost, portability, easy access, and a large diversity of interaction mechanisms, attracting a larger number of players and a larger number of player interactions with the game. Another major advantage is that it is based in a game well tested in clinic terms and that makes part of a reference system used in cognitive rehabilitation. Our game uses the game mechanism of this widely tested rehabilitation game and augments it with new interaction mechanisms. The systems reviewed are based in games which don´t have rehabilitation requisites in mind in its design.

FUTURE RESEARCH DIRECTIONS

From the conducted study it was clear that many features of the game would require improvements especially in the sound and motion options, such as the introduction of a more reliable and adaptive facility to make a proper calibration of the input sensors and recognition procedures increasing the overall robustness of the system by making it more reliable in varying noise and illumination conditions and also to the patient intrinsic motion and voice characteristics, for instance. Many participants reported they did not like much the motion input option, or considered it less intuitive, simply because they didn't know how much they have to move in front of the camera to make the word selections. In many situations, a similar problem occurred for the sound option. However, this study gave us a good starting point to improve future versions of the game.

As an immediate direction for future work there is the improvement of the above mentioned features. As future work we plan to conduct a more comprehensive study involving a larger sample with patients in rehabilitation.

As a major research opportunity we have identified that more research is still needed in order to demonstrate how distinct and natural input modalities, such as body motion, hand gestures, voice recognition, and facial expressions can increase effectiveness of Serious Games for rehabilitation. In order to accomplish that task we are currently extending a multimodal user interface, originally developed and used in the context of intelligent wheelchairs (Braga, Petry, Moreira, & Reis, 2009; Vasconcelos, 2011).

Complementarily we have identified as a research opportunity the study on how a social dimension in Serious Games, such as collaboration and competiveness, can benefit the effectiveness of the rehabilitation process. Most of the reported games are single player/user games. Only few games provide a multi-player facility in which there is some social activity supported by collaborative or competitive tasks. Moreover, there are few reported evaluations and most of them use a very small sample of patients. We believe that the introduction of social support in the games can be used to increase the motivation in the rehabilitation sessions.

CONCLUSION

In rehabilitation area, there exists many and recent Serious Games reported in the literature. However, the major problem evidenced in this area is the poor motivation of the patients in rehabilitation sessions and most of the rehabilitation reported games have not yet fully exploited the potential of the entertainment that games can provide. Therefore, further improvements are needed to attain higher levels of motivation for patients in rehabilitation programs. Additionally, most of the applications reported are only prototypes and were experimented with a small number of patients, which difficult to take more precise conclusions from their effectiveness.

From our study, supported by a comprehensive literature review, interaction technology was found as a relevant criterion to achieve a more motivational purpose in rehabilitation therapy, using computer games. However, in most of the games reviewed the interfaces are very simple and use traditional forms of interaction, like the mouse and the keyboard devices. We believe that the use of more natural interfaces in the games can contribute to diminish the problem of poor motivation in the rehabilitation sessions, since it can enable the way the patients interact with the system.

To investigate the effect of the interaction technology in the motivation of the users it was developed a serious game prototype which simulates a set of activities that can be used in a rehabilitation session. In the prototype, a set of more natural gestures were simulated that can be extended to more elaborated Serious Games applications in order to make them more motivating to the users.

The game implemented is a word memory game to be used in a cognitive rehabilitation therapy session and can be played in three different versions that differ in the interaction input form: mouse, sound or motion. For the design of the game it was adopted a reference serious game system in rehabilitation.

From the playability study conducted with healthy users some design problems were identified that can be improved in future versions of the game such as the introduction of more appropriate colors in the screens, objects and text messages, the introduction of more instructive text messages and sounds. Other features to improve include the introduction of a facility of game calibration of the range of motion of the users. Some participants in the evaluation test didn´t like the sound and motion input option because they didn´t know how much to move or make noise to make the words selections. However, despite of that, the sound and motion input option of the game provided the most involvement of the users in the game and were the options the users showed more interest to play again.

The developed game has many advantages that can be evidenced by the fact that it can be played online which eases the access to the game platform, making the game more accessible to all users, including the patients in rehabilitation and thus providing a low cost solution to patients training. Due to limitations on therapy much of the work necessary for the patient's recovery must be done at home and so our solution will facilitate a home rehabilitation, in addition to traditional therapy. Our prototype also offers an input mechanism that is more intuitive and can more easily be adopted by people with impairments and disabilities in rehabilitation.

In overall, the conducted user study demonstrated that new forms of interaction were interesting to the users, despite some difficulties, and made the user experience more attractive and intuitive.

REFERENCES

Ahdell, R., & Andresen, G. (2001). *Games and simulations in workplace eLearning "How to align eLearning content with learner needs"*. Master of Science Thesis, Norwegian University of Science and Technology.

Alankus, G., Lazar, A., May, M., & Kelleher, C. (2010). *Towards customizable games for stroke rehabilitation*. Paper presented at the 28th International Conference on Human factors in Computing Systems, Atlanta, Georgia, USA.

Allard, J., Marchal, M., & Cotin, S. (2007). *Cataract surgery simulation*. (Apr 2010). Retrieved from http://www.sofa-framework.org/projects/ophtalmo/cataract.html

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

Battocchi, A., Gal, E., Ben Sasson, A., Painesi, F., Venuti, P., Zancanaro, M., & Weiss, P. L. (2008, 8th - 11th September). *Collaborative puzzle game - An interface for studying collaboration and social interaction for children who are typically developed or who have Autistic Spectrum Disorder*. Paper presented at the 7th International Conference Series on Disability, Virtual Reality and Associated Technologies (ICDVRAT), Maia, Portugal.

Braga, R. A. M., Petry, M., Moreira, A. P., & Reis, L. P. (2009). Concept and design of the intellwheels platform for developing intelligent wheelchairs. *Informatics in Control . Automation and Robotics*, *37*, 191–203.

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. *The Visual Computer*, *25*(12), 1085–1099. doi:10.1007/s00371-009-0387-4

Burke, J. W., McNeill, M. D. J., Charles, D. K., Morrow, P. J., Crosbie, J. H., & McDonough, S. M. (2010, 25-26 March). *Augmented reality games for upper-limb stroke rehabilitation.* Paper presented at the 2010 Second International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES).

Cameirão, M. S., Badia, S. B., Zimmerli, L., Oller, E. D., & Vershure, P. F. M. J. (2009). The rehabilitation gaming system: A review. *Studies in Health Technology and Informatics*, *145*, 65–83. doi:doi:10.3233/978-1-60750-018-6-65

Chen, S. (2006). *Serious games: Games that educate, train, and inform.* Retrieved from http://www.gamasutra.com/ features/20051031/chen_01.shtml doi:citeulike-article-id:1028229

Conconi, A., Ganchev, T., Kocsis, O., Papadopoulos, G., Fernandez-Aranda, F., & Jimenez-Murcia, S. (2008, 17-19 November). *PlayMancer: A serious gaming 3D environment.* Paper presented at the International Conference on Automated Solutions for Cross Media Content and Multi-channel Distribution (AXMEDIS '08).

Corti, K. (2006). *Games-based learning: a serious business application*. PIXELearning Limited. Retrieved from http://www.pixelearning.com/docs/ games_basedlearning_pixelearning.pdf.

Dankelman, J., & Di Lorenzo, N. (2005). Surgical training and simulation - Guest editorial. *Minimally Invasive Therapy & Allied Technologies*, *14*(4/5), 211–113. doi:10.1080/13645700500275143

Fernandez, R., Parker, D., Kalus, J. S., Miller, D., & Compton, S. (2007). Using a human patient simulation mannequin to teach interdisciplinary team skills to pharmacy students. *American Journal of Pharmaceutical Education*, *71*(3). doi:10.5688/aj710351

Findlay, D. (2010). *Medical simulation in the virtual world of Second Life*. Simulation for Medical Training website. Retrieved from http://sites.wiki.ubc.ca/etec510/ Simulation_for_Medical_Training

Gunasekera, W. S. L., & Bendall, J. (2005). Rehabilitation of neurologically injured patients . In Moore, A. J., & Newell, D. W. (Eds.), *Neurosurgery* (pp. 407–421). London, UK: Springer. doi:10.1007/1-84628-051-6_23

Hagemann, E. (2009). *Role of simulation in rehabilitation: The effectiveness of model hands when learning to make orthoses.* Master's of Science, University of Toronto. Retrieved from https://tspace.library.utoronto.ca/bitstream/1807/17509/1/Hagemann_Eric_N_200906_MSc_Thesis.pdf

Inoue, K., Ito, Y., Ikeda, Y., Tanimura, A., Suzuki, K., & Takahashi, Y. … Komeda, T. (2006). Trial usage of rehabilitation system: Simple driving simulator for the driving skill evaluation of people with cerebrovascular disease: CVD. In K. Miesenberger, J. Klaus, W. Zagler & A. Karshmer (Eds.), *Computers helping people with special needs* (Vol. 4061, pp. 943-949). Berlin, Germany: Springer.

Intras. (2004). *Fundación intras.* Retrieved from http://www.intras.es/index.php?id=75

Kaltenbrunner, M., Bovermann, T., Bencina, R., & Costanza, E. (2005). *TUIO - A protocol for table based tangible user interfaces.* Paper presented at the 6th International Workshop on Gesture in Human-Computer Interaction and Simulation (GW 2005), Vannes, France.

Kan, P. W. L. (2008). *Design of an adaptive system for upper-limb stroke rehabilitation.* Master of Applied Science Thesis M.A.Sc., University of Toronto, Toronto.

Keith, P. (2009). *AdvancED ActionScript 3.0 animation*.

Kim, N.-G., Kim, Y.-Y., & Kwon, T.-K. (2006). Development of a virtual reality bicycle simulator for rehabilitation training of postural balance . In Gavrilova, M., Gervasi, O., Kumar, V., Tan, C., Taniar, D., & Laganà, A. (Eds.), *Computational Science and Its Applications - ICCSA 2006* (*Vol. 3980*, pp. 241–250). Berlin, Germany: Springer. doi:10.1007/11751540_26

Kincaid, J. P., & Westerlund, K. (2009). *Simulation in education and training*. Paper presented at the 2009 Winter Simulation Conference, Austin, TX. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5429337&tag=1

Kizony, R., Raz, L., Katz, N., Weingarden, H., & Weiss, P. L. T. (2005). Video-capture virtual reality system for patients with paraplegic spinal cord injury. *Journal of Rehabilitation Research and Development*, *42*(5), 595–608. doi:10.1682/JRRD.2005.01.0023

Lamb, P. (2003). *ARToolkit - Augmented reality toolkit*. HITLab University of Washington. Retrieved from http://www.hitl.washington.edu/artoolkit/

LapSimÂ. (2009). *Virtual laparoscopy simulator (LapSimÂ®)*. The University Mississippi Medical Center. Retrieved from http://surgery.umc.edu/facultystaff/ learning/SSC/virtual.html

Law, A. M. (2007). *Simulation modeling and analysis* (4th ed.). McGraw-Hill.

Ma, M., & Bechkoum, K. (2008). *Serious games for movement therapy after stroke*. Paper presented at the IEEE International Conference on Systems, Man and Cybernetics, Suntec Singapore, International Convention & Exhibition Center.

Masakazu, O. (2008). *Marilena - Object detection in AS3*. Retrieved from http://maaash.jp/as3/as3marilena-object-detection-in-as3/

Masiero, S., Carraro, E., Gallina, P., Rossi, A., & Rosati, G. (2009). Upper limb rehabilitation robotics after stroke: A perspective from the university of Padua, Italy. *Journal of Rehabilitation Medicine*, *41*(12), 91–985. doi:10.2340/16501977-0404

Microsoft. (2010). *Introducing Kinect for the Xbox 360.* Retrieved from http://www.xbox.com/en-US/kinect

Niniss, H., & Inoue, T. (2010). *Electric wheelchair simulator for rehabilitation of persons with motor disability.* Retrieved from http://www.sbc.org.br/bibliotecadigital/5-16842.pdf

Nintendo. (2011). *Wii console*. Retrieved from http://www.nintendo.com/wii/console

Numrich, S. K. (2008). Culture, models, and games: Incorporating warfare's human dimension. *IEEE Intelligent Systems*, *23*(4), 58–61. doi:10.1109/MIS.2008.63

OpenCVWiki. (2010). *OpenCV Wiki*. Retrieved from http://opencv.willowgarage.com/wiki/

PaperVision3D. (2010). *PaperVision3D*. Retrieved from http://www.papervision3d.org/

Rego, P., Moreira, P. M., & Reis, L. P. (2010a, 16-19 June). *Serious games for rehabilitation: A survey and a classification towards a taxonomy.* Paper presented at the 5th Iberian Conference on Information Systems and Technologies, Santiago de Compostela, Spain.

Rego, P., Moreira, P. M., & Reis, L. P. (2010b, 28-29 January 2010). *A survey on serious games for rehabilitation.* Paper presented at the 5th DSIE'10 Doctoral Symposium in Informatics Engineering, FEUP, Porto.

Rejeski, D., & Sawyer, B. (2009). *Serious games initiative.* Retrieved from http://www.serious-games.org/

Ryan, M., Smith, S., Chung, B., Cossell, S., Jackman, N., Kong, J., et al. (2009). *Rehabilitation games: Designing computer games for balance rehabilitation in the elderly.* Retrieved from http://oscarmak.net/fdg09.pdf

Sawyer, B. (2008). From cells to cell processors: The integration of health and video games. *IEEE Computer Graphics and Applications*, *28*(6), 83–85. doi:10.1109/MCG.2008.114

Schuhfried. (2011). *RehaCom catalogue*. Retrieved from http://www.schuhfried.at/fileadmin/pdf_eng/catalog_RehaCom_en.pdf

Sony. (2011). *PlayStation Move*. Retrieved from http://pt.playstation.com/psmove/

SparkWiki. (2011). *FLARToolkit*. Retrieved from http://www.libspark.org/wiki/ saqoosha/FLARToolKit/en

StrongArm. (2007). *StrongArm Systems.* from http://www.strongarm.org.uk/

Vanacken, L., Notelaers, S., Raymaekers, C., Luyten, K., Coninx, K., & van den Hoogen, W. … Feys, P. (2009, March 25-26). *Game-based collaborative training for arm rehabilitation of MS patients: A proof-of-concept game.* Paper presented at the GameDays 2009.

Vasconcelos, S. M. F. (2011). *Multimodal interface for an intelligent wheelchair.* Master Thesis, Faculty of Engineering, Porto University.

Vidani, A. C., & Chittaro, L. (2010). *A serious game for training medical first responders*. Human-Computer Interaction Laboratory, University of Udine. Retrieved from http://hcilab.uniud.it/soccorsodisabili/results.html

von Wangenheim, C. G., & Shull, F. (2009). To game or not to game? *IEEE Software*, *26*(2), 92–94. doi:10.1109/MS.2009.54

Warlow, C. P., Gijn, J. v., Dennis, M. S., Wardlaw, J. M., Bamford, J. M., & Hankey, G. J. … Rothwell, P. (2008). *Stroke: Practical management*. Blackwell Publishing.

Weiner, F. (2011). *Parrot Software.* Retrieved from http://www.parrotsoftware.com/default/default.aspx

Zeigler, B. P., Praehofer, H., & Kim, T. G. (2000). *Theory of modeling and simulation* (2nd ed.). Academic Press.

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer, 38*(9), 25-32. doi: citeulike-article-id:3397470

Zyda, M. (2007). Creating a science of games: Introduction. *Communications of the ACM, Special Issue: Creating a Science of Games, 50*(7), 26-29. doi: citeulike-article-id:1450068

ADDITIONAL READING

Allard, J., Marchal, M., & Cotin, S. (2009). Fiber-based fracture model for simulating soft tissue tearing. *Medicine Meets Virtual Reality*, *17*, 13–18.

Anderson, E. F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P., & Freitas, S. d. (2009). *Serious games in cultural heritage*. Paper presented at the 10th International Symposium on Virtual Reality, Archeology and Cultural Heritage (VAST'09) Short and Project Proceedings, Malta. Retrieved from http://academia.edu.documents.s3.amazonaws.com/ 381115/vast09.pdf

Barnes, T., Encarnação, L. M., & Shaw, C. D. (2009). Serious games. *IEEE Computer Graphics and Applications*, *29*(2), 18–19. doi:10.1109/MCG.2009.29

Bergeron, B. (2006). *Developing serious games* (1st ed.). Charles River Media.

Blackman, S. (2005). Serious games...and less! *SIGGRAPH Comput. Graph.*, *39*(1), 12–16. doi:10.1145/1057792.1057802

Brito, A. E. S. C., & Teixeira, J. M. F. (2010). *Simulação por computador fundamentos e implementação de código em C e C* (1st ed.). Publindústria.

Chen, S. (2005, October 19). Proof of learning: Assessment in serious games.

Cicerone, K. D., Dahlberg, C., Malec, J. F., Langenbahn, D. M., Felicetti, T., & Kneipp, S. (2005). Evidence-based cognitive rehabilitation: updated review of the literature from 1998 through 2002. *Archives of Physical Medicine and Rehabilitation*, *87*(8), 1681–1692. doi:10.1016/j.apmr.2005.03.024

Colombo, R., Pisano, F., Mazzone, A., Delconte, C., Micera, S., & Carrozza, M. C. (2007). Design strategies to improve patient motivation during robot-aided rehabilitation. *Journal of Neuroengineering and Rehabilitation*, *4*(3). doi:doi:10.1186/1743-0003-4-3

De Freitas, S., & Jarvis, S. (2007). Serious games—Engaging training solutions: A research and development project for supporting training needs. *British Journal of Educational Technology*, *38*(3), 523–525. doi:10.1111/j.1467-8535.2007.00716.x

Decker, J., Li, H., Losowyj, D., & Prakash, V. (2009). *Wiihabilitation: Rehabilitation of wrist flexion and extension using a Wiimote-based game system*. Retrieved from http://www.osd.rutgers.edu/gs/09papers/Wii.pdf

Flynn, S., Palma, P., & Bender, A. (2007). Feasibility of using the Sony PlayStation 2 gaming platform for an individual poststroke: A case report. *Journal of Neurologic Physical Therapy; JNPT*, *31*, 180–189.

Huber, M., Rabin, B., Docan, C., Burdea, G., Nwosu, M. E., Abdelbaky, M., & Golomb, M. R. (2008). *PlayStation 3-based tele-rehabilitation for children with hemiplegia*. Paper presented at the Virtual Rehabilitation 2008 Conference, Vancouver (Canada). Retrieved from http://ieeexplore.ieee.org/stamp/ stamp.jsp?arnumber=04625145

Jack, D., Boian, R., Merians, A. S., Tremaine, M., Burdea, G. C., Adamovich, S. V., … Poizner, H. (2001). Virtual reality-enhanced stroke rehabilitation. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 9*(3), 308-318. IEEE Engineering in Medicine and Biology Society. doi: 10.1109/7333.948460

Johnson, M., Loureiro, R., & Harwin, W. (2008). Collaborative tele-rehabilitation and robot-mediated therapy for stroke rehabilitation at home or clinic. *Intelligent Service Robotics*, *1*(2), 109–121. doi:10.1007/s11370-007-0010-3

Kelly, H., Howell, K., Glinert, E., Holding, L., Swain, C., Burrowbridge, A., & Roper, M. (2007). How to build serious games. *Communications of the ACM*, *50*(7), 44–49. doi:10.1145/1272516.1272538

Lam, P., Hebert, D., Boger, J., Lacheray, H., Gardner, D., Apkarian, J., & Mihailidis, A. (2008). A haptic-robotic platform for upper-limb reaching stroke therapy: Preliminary design and evaluation results. *Journal of Neuroengineering and Rehabilitation*, *5*(15). doi:doi:10.1186/1743-0003-5-15

Law, A. (2007). *Simulation modeling and analysis* (4th ed.). McGraw-Hill Science/Engineering/Math.

McGrath, D., & Hill, D. (2004). *UnrealTriage: A game-based simulation for emergency response*. Paper presented at the Huntsville Simulation Conference.

Nef, T., Mihelj, M., & Riener, R. (2007). ARMin: A robot for patient-cooperative arm therapy. *Medical & Biological Engineering & Computing*, *45*(9), 887–900. doi:10.1007/s11517-007-0226-6

Pareto, L., Broeren, J., Goude, D., & Rydmark, M. (2008). *Virtual reality, haptics and post-stroke rehabilitation in practical therapy*. Paper presented at the 7th International Conference on Disability, Virtual Reality and Associated Technologies.

Prensky, M. (2001). Fun, play and games: What makes games engaging? In *Digital game-based learning*. Mcgraw-Hill.

Sliney, A., & Murphy, D. (2008). *JDoc: A serious game for medical learning*. Paper presented at the First International Conference on Advances in Computer-Human Interaction.

Vidani, A. C., Chittaro, L., & Carchietti, E. (2010). *Assessing nurses' acceptance of a serious game for emergency medical services*. Paper presented at the VS-GAMES 2010: 2nd International Conference on Games and Virtual Worlds for Serious Applications, Los Alamitos, CA, USA. Retrieved from http://hcilab.uniud.it/publications/ 2010-01/SeriousGame_VS-GAMES2010.pdf

Wege, A., Kondak, K., & Hommel, G. (2006). Development and control of a hand exoskeleton for rehabilitation . In Hommel, G., & Huanye, S. (Eds.), *Human interaction with machines* (pp. 149–157). Springer. doi:10.1007/1-4020-4043-1_16

Winn, B. (2008). Design, play, and experience: A framework for the design of serious games for learning . In Ferdig, R. E. (Ed.), *Handbook of research on effective electronic gaming in education*. Hershey, PA: IGI Global.

Yeh, S.-C., Rizzo, A., Zhu, W., Stewart, J., McLaughlin, M., & Cohen, I. … Peng, W. (2005). *An integrated system: Virtual reality, haptics and modern sensing technique (VHS) for post-stroke rehabilitation*. Paper presented at the ACM Symposium on Virtual Reality Software and Technology, Monterey, CA, USA.

KEY TERMS AND DEFINITIONS

Collaboration: Refers to the act of working together in a joint effort to fulfill a common set of goals. The term collaboration is used here in the sense of having games that include collaborative tasks where users cooperate in order to reach the same goals and promote social interaction between the players.

Disability: Any limitation or inability (resulting from an impairment) to accomplish an activity in the way or range considered normal for an individual.

Edutainment: Refers to the act of learning using a medium that educates and also seeks to entertain and that is not limited to the use of video games.

E-Learning: Refers to a computer-based-training in which the learning content is delivered to many users, through different media, (using internet technology) mostly over the Internet or on Intranets, and therefore accessible anywhere and anytime. For some authors the "e" in e-Learning means electronically delivered learning. However, for others (Ahdell & Andresen, 2001) the "e" must also imply effective and engaging learning, in order to exploit the true potential of e-Learning.

Impairment: Refers to any functioning problem in a psychological, physiological or anatomical structure or function of the body.

Natural User Interfaces: The system by which users interact with the computer composed by input devices other than the traditional keyboard or mouse devices that do not use wires or commands and that give the user the sense of an easier and intuitive interaction with the system, making him to learn more rapidly how to control the computer application.

Rehabilitation: Therapy used to recover the patient cognitive and motor functions that have been diminished by disease or traumatic injury. It can include two main applications: cognitive rehabilitation and physical/motor rehabilitation. Cognitive rehabilitation is focused on the patient's reacquisition of the most independent or highest level of functioning. Motor rehabilitation focuses the functional reorganization of the motor system after damage.

Serious Game: A computer game that allows the player to achieve a specific purpose other than pure entertainment, using the entertainment and engagement components provided when playing the game.

Simulation: The imitation of some activities of the real world, or process, over time, representing certain key characteristics or behaviors of the selected physical or abstract system for various purposes: training, analysis, or prediction. Simulation permits users to undertake tasks and experience situations which would sometimes be impossible or difficult for reasons of logistical, safety, cost and time.

Virtual Reality: Refers to computer created environments that simulate physical presence in places in the real world or in imaginary worlds, by using computational techniques and devices. The user has the real sensation of being inside of the virtual world (immersion) and that is able to manipulate the objects (interactivity) of the virtual environment just like they were real.