Serious Games for Rehabilitation
A Survey and a Classification Towards a Taxonomy

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Abstract—Serious Games are growing into a significant area spurred by the growth in the use of video games and of new methods for their development. They have important applications in several distinct areas such as: military, health, government, and education. The design of computer games can offer valuable contributions to develop effective games in the rehabilitation area. This paper presents fundamental concepts relating to Serious Games followed by a survey of relevant work and applications on Serious Games for Rehabilitation. We propose a classification designed to properly distinguish and compare Serious Games for Rehabilitation systems in what concerns their fundamental characteristics. We also describe a particular Serious Game for Rehabilitation, RehaCom, as a case study. Finally, the paper presents some challenges and research opportunities in this area.

Keywords—Serious Games, Rehabilitation, Game Design, Health Informatics

I. INTRODUCTION

Serious games are growing into a significant research area spurred by the advances in game development and in computer graphics hardware, in turn driven by the success of video games. They are becoming so popular that we are assisting the arising of new audiences that before were turned off for the most traditional games. An example of this can be seen by the popularity gained by the Wii system from Nintendo which is being played among families, women, older people and not only by the most “hard-core” players.

As the success and proliferation of video games grows, they have the potential to be more than just entertainment, just like books, movies and television. According to Michael & Chen [1], the time has come for video games to become more relevant, more responsible, and more important or, in other words, to get serious. Consequently, the research community and the game industry moved towards the development of more elaborated games, incorporating both pedagogical and entertaining elements.

The amount of research in this relatively new field has grown significantly during the past decade. All around the world a growing number of seminars and conferences are arranged. In 2002, was formed the Serious Games Initiative [2] that helps the area of serious games emerge into an organized industry of developers aiming to solve problems in diverse areas and informs us about the potential of games and how to merge innovation and developers from one discipline with those in another. In 2009 was organized the first conference specialized in serious games: VS-GAMES’09 – First IEEE International Conference in Games and Virtual Worlds for Serious Applications, in the World’s premier Serious Games Institute in UK.

Although, there are many definitions of the term, it is agreed by the different authors that the term refers to the use of computer games that have a main purpose that is not pure entertainment. In fact, Serious Games have been applied in many diverse areas: corporate and military training [3], health [4]–[6], education [7]–[12], cultural training [4], [10], [13]–[16]. Many of these areas are related and sometimes overlapped areas like e-learning, education, game-based learning and digital game-based learning. A notorious example of such overlapping is games classified under the concept of edutainment. Edutainment, or education through entertainment, is not limited to video games, as it refers to any form of education that also seeks to entertain [1]. Serious games refers to games, and thus to their entertainment nature, but are not restricted to educational purposes. Therefore, all previous applications can be incorporated into the broader concept of Serious Games.

This paper focuses on Serious Games in the rehabilitation area. Rehabilitation is defined in [17] as a dynamic process of planned adaptive change in lifestyle in response to unplanned change imposed on the individual by disease or traumatic incident. 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. The success of a rehabilitation program depends on various factors: appropriate timing, patient selection, choice of rehabilitation program, continued medical management and appropriate discharge planning. This can be achieved in a multidisciplinary way (medical, nursing, social personnel) and with an appropriately equipped rehabilitation department where adequate therapy treatments (physical therapy, occupational therapy, speech and language therapy, clinical psychology and social work) are combined in a planned and coordinated way towards a common goal [17].

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. We believe that the design of computer games can offer valuable contributions about how to develop more effective games for rehabilitation programs. In that sense, one of the fundamental goals of our research is to identify, classify and assess game features that are relevant for the design of computer games in this area. The work herein presented reviews relevant work described in the literature. This paper also presents our developments and proposes of a classification scheme towards a taxonomy based on a set of criteria for the design of more effective rehabilitation games. This classification framework enabled us to present a comparison of serious games for rehabilitation. Another important result herein presented concerns with the identification of research opportunities and open problems.

The rest of the paper is structured as follows. Section 2 presents an introduction on Serious games including fundamental terminology and concepts, classifications and examples of application. Following, Section 3, introduces the motivation of Serious Games for Rehabilitation. Section 4 introduces our proposed classification criteria towards a taxonomy for Rehabilitation Serious Games and the following Section 5 presents a review of Serious Games for Rehabilitation. In Section 6, a reference system - RehaCom System - is described. Finally, in Section 7, major conclusions are drawn and directions for future work are suggested.

II. SERIOUS GAMES

Today, the term serious game is becoming more and more popular and, although all authors agree that entertainment in these applications is not the primary goal, there is no current single definition of the concept. Zyda [18] defines a serious game as: "a mental contest, played with a computer in accordance with specific rules, which uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives." For this author the pedagogic component of serious games is the one that makes them serious, not just the story, art and software elements that compose them. Although the entertainment component is the first one to arise, the pedagogic component subordinated to the story of the game gives the education or instruction that will enable the knowledge and skills that characterize serious games applications.

Michael and Chen [1] define serious games as "games that do not have entertainment, enjoyment or fun as their primary purpose". Serious games are not only the application of games and games technology, they are entertaining, enjoyable and fun, but their main purpose is other that was conceived by the game designer when designing the game or that the user defined when played the game.

Serious games can be of any genre, use any game technology, and be developed for any platform. They can be entertaining, but usually they teach the user something or permit him to develop skills. In our work we define Serious Games as games that allow the player to achieve a specific purpose using the entertainment and engagement component provided by the experience of the game.

Serious games can also be classified in a number of different ways. Zyda [18] states that serious games technology can be applied to domains as diverse as healthcare, public policy, strategic communication, defense, training, and education. Michael and Chen [1] classify serious games into a number of markets: military games, government games, educational games, corporate games, healthcare games, and political, religious and art games. Susi et al. give an overview of Serious Games [19]. Despite such classifications, many games could belong to more than one category. Sawyer and Smith introduced in 2008 a Serious Games taxonomy to serve as a starting point to define serious games moving forward and invited community research to contribute to a next version of their classification.

Serious games can be applied to a broad spectrum of areas. For example, the Military area has a long history of using games for training. An example of a serious game for training in this area is “Army Battlezone”, designed in 1980 by Atari. However, “America’s Army” was one of the most well known, released in 2002. Examples of serious games application can be found in several other diverse areas as referred before. A major application is in the rehabilitation area which is the main focus of the current research and is presented in the next section.

III. SERIOUS GAMES FOR REHABILITATION

Many tests 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 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 [20].

As traditional treatment approaches include exercises often considered repetitive and boring for patients, using computer games to augment physical and cognitive rehabilitation can offer the potential for a significant therapeutic benefit. Games require cognitive and motor activity so they can engage a person’s attention [21]. Besides, most games offer increasingly difficult levels that give the player the sense of challenge in his progress and in a way that is also adapted to his skills. Another very important aspect is that games distract the patient's attention and as such they can be used to aid in the management of pain [20], [21].

The application of Virtual Reality (VR) technology for the rehabilitation of cognitive and motor deficits has been growing in the last decade and stroke patients have been one of the main target populations for these new rehabilitation methods [20]. These VR based-methods can offer the patients to be part of immersive experiences that are engaging and rewarding for them.

In this work we want to identify important game characteristics in the rehabilitation area. Several similar works have been reported in the literature in this area. Flores et al. [22] proposed a classification of games for elderly rehabilitation that could serve as a general indicator for the appropriateness or adaptability of each game in that area. They combined two sets of criteria: game design criteria for stroke rehabilitation and criteria for design entertainment in elderly population. The ideal game for use in stroke rehabilitation.
would satisfy all the criteria defined in the two sets. They analyzed and compared two sets of games, according to these criteria: existing games currently used in stroke rehabilitation (chosen subjectively as the most entertaining for elderly users), and other popular games not currently used in this area, but that could have advantages over existing games for stroke rehabilitation, and thus could be adapted for this purpose. They concluded that current rehabilitation games lack entertainment qualities and popular games lack essential components for rehabilitation effectiveness.

Burke et al. [20] identified the game design principles important for upper limb stroke rehabilitation, presented several games which have been designed using these principles, and evaluated them using questionnaires made to a small number of participants. The two principles defined were: meaningful play and challenge. Meaningful play emerges from a game in the relationship between a player’s actions and the system’s outcome [20].

In the next Section we present a set of criteria relevant to the classification and comparison of serious games for rehabilitation. In Section 5 we present in detail a review of more relevant works found in literature, and a table comparing their characteristics.

IV. TOWARDS A TAXONOMY FOR REHABILITATION SERIOUS GAMES

Based on the literature reviewed we identify as important main criteria for the classification of Serious games in the rehabilitation area the following ones:

- **Application area**: is the domain application in which a game can be applied; despite this domain can be very vast, we may consider however two main applications: cognitive rehabilitation (Cognitive) and physical/motor rehabilitation (Motor). Cognitive rehabilitation is a process focused on the patient’s reacquisition of the most independent or highest level of functioning. Cognition can be described as the process of thinking and awareness and includes mental faculties such as memory, attention and concentration, reasoning and problem-solving, sentence, language, volition and judgment, amongst others. These faculties are very sensitive and are prone to influences from psychiatric conditions, neurological diseases, medical conditions and head injuries. The rehabilitation is based on goals adapted to the patient’s current strengths and weaknesses. In Traumatic brain injury (TBI), a disruption of brain functioning occurs when a mechanical force causes damage to brain tissue, and cognition is frequently affected after that. Motor rehabilitation can include: stroke rehabilitation (upper and lower limb extremity training, spatial and perceptual-motor training), balance training [23], [25], acquired brain injury, wheelchair mobility, Parkinson’s disease, orthopedic rehabilitation, functional activities of daily living training, and telerhabilitation [23].

- **Interaction Technology**: the technology used by the patient to interact with the system. This can vary from the traditional methods using a mouse or keyboard process to VR based methods. For instance, in VR, interface devices that can be used are: visual interfaces that include head-mounted displays (HMDs) and desktop monitors; haptic interfaces like data gloves; and motion tracking devices. With these patients can interact with virtual objects in the environment in real-time using several sensory modalities (vision, haptics, audition). In telerhabilitation the devices used are webcams, videophones, tele-videoconferencing over phone lines, and webpages with rich internet applications.

- **Game interface**: the interface used in the game. It can be two-dimensional (2D) or three-dimensional (3D).

- **Number of players**: number of patients playing the game: single player (single) or multi-player (multi).

- **Game Genre**: the games genre can vary in relation with the technology used. Examples found include: games to evaluate the movement (catch, reach and grasp) and games that are simulations, strategy, or a combination of several (assorted).

- **Adaptability (Yes/No)**: the system capability to adapt dynamically game difficulty or challenge, according to the patient performance in the game. At the start of a new game, and because the player is not familiar with the game, he usually wants a low level of challenge. Many games use levels to compose difficulty. Other games may not have identifiable levels, but indicate that the player has achieved an adequate level of comprehension and skills, by increasing challenge as specific points in the game are reached. In other games player actions are recorded and analyzed and game elements may change dynamically to maintain an adequate level of challenge, making the game easier or harder to play, according to the player abilities.

- **Performance Feedback (Yes/No)**: this dimension is related with the system capability to transmit to the patient the results of the interaction. This feature gives the patient a measure of his progress in achieving goals, or in their skills over time. It can be used to identify correct or incorrect actions or responses, necessary to give the patient a visible meaning of the result of his interaction with the system and can have multiples modalities (aural, visual and haptic).

- **Progress monitoring**: is the capability of the system to allow saving the results of patients interaction with the system.

- **Game portability**: is related with the capability of the system to be used at home, or at a hospital or clinic.

V. REVIEW OF SERIOUS GAMES FOR REHABILITATION

Several serious games for rehabilitation have been reported in literature. In this section we review the work developed in this area, focusing in the main criteria adopted in the previous Section. We make also a reference in each game to the evaluation test done, in particular, the size of the sample used in the test and the evaluation method chosen.

Betker et al. [25] described a serious game for Balance Rehabilitation. The video game-based tool was controlled by a center-of-pressure (COP) for the maintenance of balance in a short-sitting position caused by spinal cord and head injuries. It was developed to use a pressure mat. The flexibility of the pressure mat allows games to be performed on solid, fixed surfaces and allows progression to compliant surfaces, with the pressure mat being placed between the patient and the surface. The games require movements of the patients in one or in all directions. Difficulty levels can also be configured, helping to ensure patient competitiveness while exercising his full range and speed of voluntary movement. This is important to prevent a player from becoming frustrated and quickly losing interest. The portability of the system allows its use in monitored at-home programs, which makes this therapy approach cost-effective. The games also provided the patients and the therapist with instantaneous feedback about performance and goal attainment. The games were evaluated using a questionnaire administered after the exercises and with stability.
measurements obtained during a set of tasks performed before and after exercise.

Ma et Beekhoom [26] described a serious-game based movement therapy which aims to encourage stroke patients with upper limb motor disorders to practice physical exercises. Their framework uses functional tasks, such as wrist extension, reaching, grasping and catching, and serious games. The system allows patients to interact with virtual objects in real-time through multiple modalities and to practice specific motor skills. Physiotherapists are necessary for initializing the system and controlling the scripting of tasks. Input devices include the ordinary devices mouse and keyboard for the operator and a range of real-time motion tracking devices—Data gloves to capture finger flex and hand postures; wireless magnetic sensors to track the patient's hand, arm and upper body movements. Output has visual, audio and haptic modalities. 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, providing a better sense of presence. The software components include a 3D graphic engine and a movement therapy module which creates functional training and non-functional serious games. It has also a dynamic adaptation module that uses patient profiles and progress data to select tasks and initially configure the difficulty level of the tasks and games. A pilot study was made with 8 participants, concluding that serious games intervention did have an impact on the recovery of movement.

Conconi et al. [27] introduced PlayMancer, a platform for rapid development of serious games, with a special focus on therapeutic support games for behavioral and addictive disorders, i.e. eating disorders and pathological gambling. It 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 prototype to be adopted for chronic mental disorders treatment, introduces the player to an interactive scenario which aims to increase his general problem solving strategies, self-control skills and control over general impulsive behaviors. The 3D interactive environment is made up of different islands that will be used as scenario. Each island will permit access to one or several types of resources which will facilitate and improve the game character's, and hence the player’s, relaxation techniques and planning skills. The game encourages the player to learn and develop new confrontation strategies.

Caglio et al. [28] assessed the modifications occurring in cognitive functions, in particular spatial and verbal memory in a TBI patient after a 3D video game rehabilitation training. The video game was a driving simulator. During the training the participant was requested to explore a complex virtual town from a ground-level perspective.

Cameirão et al. [29] developed the Rehabilitation Gaming System (RGS), a VR based system for the rehabilitation of patients suffering from stroke and TBI. The system uses a camera based motion capture system with gaming technologies to activate intact neuronal systems that provide direct stimulation to motor areas affected by brain lesions. The RGS is designed to engage the patients in task specific intensive training tuned to the patients needs and with continuous monitoring [24], [29], [30].

Ryan et al. [31] described the Balance Rehabilitation Games project which 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.

Burke et al. [20] developed several games designed for upper limb stroke rehabilitation, 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.

RehaCom software is used for enabling cognitive rehabilitation [32]–[34]. This system is described in more detail in the next section because we find it to be the reference in rehabilitation serious games.

Table 1 displays the classification proposed used the set of criteria defined in Section 4. The “...” means that this feature is not mentioned in the paper reviewed.

VI. RehaCom – A Reference System

In this section we describe the RehaCom system in more detail, a system widely used and tested in the area of cognitive rehabilitation. His effectiveness has been demonstrated in a number of studies all very well referenced (with a description of the study conducted) in the RehaCom Catalogue [32]. Since this system is well established in various hospitals and clinics, with a great number of patients, we can more easily have access to it and to the patients being treated by it in rehabilitation programs. Consequently we can more easily study his efficiency. For these reasons, we find it to be a reference system in this area and choose it as our case study.

RehaCom is a computer-assisted modular system that requires an experienced therapist. The system concept was developed by Hans Regel in 1986 and since then it has been refined over 20 years in clinics, with input from experts in the area. Since 1996 it has been developed by Hasomed (Inc, Ltd). For a few years, it has been market leader in Europe [32] and is currently available in 15 languages. The system 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. Table 2 displays the training procedures RehaCom offers for each training program or application area.
RehaCom may be classified according with the classification proposed in the previous section, as follows:

- **Application Area**: The system assists in cognitive rehabilitation. In this field, applications can be various: clinical psychology, geriatrics, developmental psychology, sport psychology, work psychology and driving.

- **Interaction Technology**: Training with the system can be carried out using a special panel, the computer keyboard, the mouse or a touch screen. Game Interface: the interface of the games that compose the computer system are all two-dimensional.

- **Number of Players (Single/Multi-player)**: RehaCom games are to be played with only one participant at a time.

- **Competitive/Collaborative**: the system only allows one participant at a time, consequently it doesn’t permit an interaction competitive or collaborative with other patients.

- **Game Genre**: the system supports games of varying genres. Games classification can be made by category area in which they are included. These categories are shown in Table 2.

- **Adaptability**: The training programs are adaptive which means that task difficulties increase automatically during training progress so that tasks cannot be too easy or too difficult to the patient.

- **Progress monitoring**: It enables to monitor progress and adjust the training goals as necessary. The results of all training sessions are recorded and a new session begins where the last one ended. When the training time defined is up, the session ends. During the training, the therapist can analyze the patient’s progress and identify and influence his performance weaknesses.

- **Performance feedback**: The patient gets information of his progress from the system in several ways. If the patient makes a mistake, he receives specific feedback. In the begin of the training, the patient reads the instructions. In many programs the instructions are based on the “learning by doing” principle. In the end of a session, the patient can see his progress, from session to session, by means of a performance chart that appears on the screen. In addition, a more detailed description of the results is also available.

- **Portability**: Training requires the presence of the therapist at the beginning and at end of training in order to discuss the patient’s training goal and results, but the programs are designed to enable the patient to train on his own most of the time. Therefore, it reduces considerably the workload of participants in the therapy.

**Table I. Classification and Comparison of Rehabilitation Serious Games**

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VII. Conclusions and Future Work

Serious games design is a recent and active research area. Making use of design methodologies, narrative structure, visual arts, interaction techniques and modalities and technologies commonly available in computer games, is proven to be effective in applications without entertainment as the main purpose. In this paper we reviewed the main concepts of serious games and focused on those used with rehabilitation purposes.

We conducted a survey of the most relevant work available in the literature. As the described systems can be very different we proposed a classification in order to assist the comparison and classification of such systems in respect to the more relevant features identified. Based on this classification, existing games could be modified in order to satisfy a large number of the classification criteria and become more functional tools for the rehabilitation therapy. We adopted as a reference system the RehaCom System, a serious game application widely used for cognitive rehabilitation and well grounded in neuro-scientific theory.

Although traditional games have their primary purpose of being compared to popular games that are designed to be fun and engaging, we have seen from literature review that rehabilitation games have not yet fully explored most of the entertainment characteristics games can provide. Thus, further improvements are needed to attain higher levels of motivation for patients in rehabilitation programs. Thus, a direction for future work is to identify and measure the impact of the more relevant aspects that can improve the suitability and effectiveness of a game for rehabilitation. We also noticed that almost all reported work is tested with a small number of patients/users.

As another major research opportunity we identify the study of how the effectiveness of computer games for rehabilitation can be increased by incorporation of a social dimension. There is not reported work for systems where collaboration or competitiveness performs a major role on the rehabilitation process.
Collaboration and competition add a new dimension that could allow the patients to enjoy the interaction and found the motivation and encouragement from others playing the same game. How to attain collaboration or competition, when patients are at different stages of the rehabilitation process or have different handicaps is an important research problem.

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