Serious games as a tool for physical impairment rehabilitation: a review

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Abstract

Background: Videogames is an integral part of contemporary culture. Like music, television and smartphones, videogames are ubiquitous. Consequently, their use as tools in the context of healthcare is not only desirable, but also, unavoidable.

Objective: To review the use of serious games as a tool for physical rehabilitation.

Methods: Systematic literature review of Google Scholar and Cochrane databases.

Results: 26 related articles were found, from which 12 that presented actual results were analyzed.

Conclusions: The use of serious games shows better patient adherence and compliance in therapy sessions. The use of custom developed games, versus commercial off-the-shelf games tends to give better medical results even though commercial games are more motivating and engaging.

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Review Paper

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Serious games as a tool for physical impairment rehabilitation: a review

Abstract

This paper presents a literature review on the use of serious games as tool for rehabilitation of patients recovering from physical impairments resulting from stroke follow-up, multiple sclerosis and cerebral palsy.
Background: Videogames is an integral part of contemporary culture. Like music, television and smartphones, videogames are ubiquitous. Consequently, their use as tools in the context of healthcare is not only desirable, but also, unavoidable.
Objective: To review the use of serious games as a tool for physical rehabilitation.
Methods: Systematic literature review of Google Scholar and Cochrane databases.
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Conclusions: The use of serious games shows better patient adherence and compliance in therapy sessions. The use of custom developed games, versus commercial off-the-shelf games tends to give better medical results even though commercial games are more motivating and engaging.

Keywords: serious games; physical rehabilitation; literature review; physical impairment

Introduction

Serious games are defined as games that are used for a serious purpose while still carrying the defining traits of standard video games and allowing the users to experience positive emotions, such as feelings of perceived fun [1]. Besides, they aim to promote “collateral learning”, which can be described as a way of acquiring certain skills through non-conventional learning methods. Serious games can also be defined as “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” [2]. It is also important to mention that “fun” is not necessarily an ingredient in the game design, but an outcome of said game, this is, a feeling the players should experience as they interact with the video game [1].

In the context of healthcare, there are two ways of approaching physical rehabilitation through the

use of games: serious games designed to answer the needs of the therapy in question or through commercial off-the-shelf (COTS) games aimed at the entertainment market but applied to a serious situation or goal [3]. This allows all kinds of games to be seen as “serious” as long as they serve a serious purpose, which can be completely unrelated to the reason why the game was designed and developed in the first place [4].

In this paper, we present a literature review, where several cases where games have been applied to healthcare, more specifically, to rehabilitation, were analyzed in order to assess the pertinence of the use of video games as clinical therapeutic tools. The games selected focused on the rehabilitation of physical impairments resulting from conditions such as stroke follow-up [5–9], multiple sclerosis [3, 10] and cerebral palsy [4]. Additionally, some of the studies [11, 12] focuses on the perception of the games among healthy players in order to refine the games or evaluate the pertinency of their application in therapy with actual patients. Some studies also conducted multiple tests in order to reach plausible and viable conclusions on the topic at hand [11, 13–15]. Some of the selected cases also resorted to different kinds of games, from custom made serious games designed specifically for rehabilitation purposes to COTS, eventually even establishing a comparison of the efficacy observed between the two [3, 9, 10].

Methods

Literature Review

This literature review started by searching keywords related to the field of study, namely “serious games + healthcare + physical rehabilitation” in the Google Scholar and Cochrane databases. The results obtained were filtered by title, and then by abstract according to their relevance to the problematic proposed by this paper. The selected papers were read, and a recursive analysis of the references presented in the primary articles was done. This totaled 26 papers discussing relevant issues (including other survey papers), but only 12 described results of specific games applied to physical rehabilitation. These 12 articles were then analyzed from a therapeutic point of view and from a game development and design point of view.
Figure 1 displays and overview of the review process. Appendix A presents a summarized table with the review analysis.

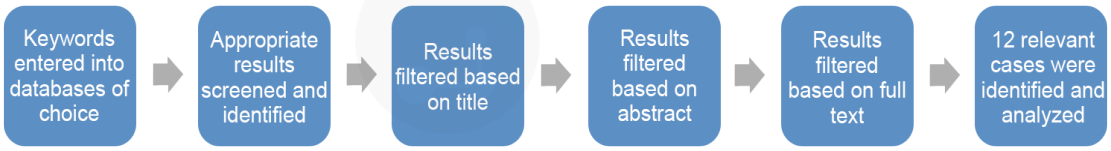

Figure 1. Article selection process for systematic literature review.

Results

Case studies analysis

Case studies analysis: Intervention Setting, Design and Sample

As mentioned previously, this review analyzed 12 articles. 8 cases took place in a clinical or hospital setting [5, 7–9, 11, 13–15], 2 took place in investigation centers [6, 12], 1 took place in a

rehabilitation facility [3], and 1 took place in a secondary care service and in the homes of the participants (but, beforehand, the patients participated in two orientation sessions in the hospital) [10]. This paper also considers the systematic review on cases where serious games were used in order to rehabilitate patients suffering from cerebral palsy by Lopes et al. [4]. 7 of the 16 cases abridged in the article took place in the home of the participants and the remaining 9 were clinical context cases.

In terms of design and sample, most of studies were blind trials in order to avoid bias and the participants totaled 236 participants (including patients, healthy subjects and control groups). Geographically speaking, the analyzed cases are from Europe (UK, France, The Netherlands, Italy, Sweden, Spain), America (USA, Canada) and Australia. Cameirão et al. [5] presented a randomized longitudinal study with controls with the goal of analyzing the relevance of using Virtual Reality (VR) as a physical rehabilitation tool in impaired patients who are recovering from stroke. The sample consisted of 17 patients, within 3 weeks post first-time stroke. The patients that took part in this intervention showed severe to mild deficit of the paretic upper extremity but bore no aphasia or other cognitive deficits. Ma and Bechkoum [6] presented a pilot study that intended to prove the efficacy of using games to rehabilitate patients who are recovering from stroke by encouraging the practice of physical exercises using custom designed games. The sample consisted of 8 post-stroke patients (mean time since stroke until beginning of the intervention: 10.7 months) suffering from upper limb motor disorders (aged 56.4±4.3). Jack et al. [7] conducted pilot clinical trials in order to assess the use of VR environments as rehabilitation technique. The sample of this study featured 3 chronic stroke patients, aged between 50-83, that had experienced stroke 3 to 6 years prior to the time when the intervention took place, and that hadn't engaged in any sort of therapy in the previous two years. Jonsdottir et al. [3] presented a pilot single-blind randomized (2:1) study, controlled in clinical trial with 16 multiple sclerosis (cognitively capable and able to follow instructions) patients with a mean age of 56.8, who suffered from upper extremity motor deficits, but were able to flex their shoulder and elbow at least 45 degrees. Delbressine et al. [14] conducted a user test with the first iteration of the *Playful Rehabilitation System* and this system was tested with 7 sub-acute and 3 chronic stroke patients. Ghassemi et al. [12] conducted a pilot study that had the objective of assessing the performance of an EMG-controlled[1] serious game for rehabilitation. This study analyzed the performance of 20 neurologically healthy individuals (adults, 7 women, 13 men, ages ranging from 21-40 years).

Four studies featured more than just one phase. Broeren et al. [8] described three different studies of rehabilitation medicine with a control group of healthy individuals. For the stroke patient group, this experiment selected 29 individuals (aged 44-85). Hocine et al. [13] conducted a study divided in three distinct test phases, based on a participatory design that involved physicians, therapists and stroke patients. Abdelkader et al. [11] described two experiments: the first one tested the use of Mixed Reality[2] (MR) with professionals in the area of stroke rehabilitation and had the primary goal of assessing the perceived utility, usability and likeability of the MR system through affective evaluation, while the second experiment was a pilot study with healthy players, and aimed to compare the difficulty proposed by the used algorithm to the real difficulty perceived by the player. The first experiment had 17 participants, all members of the medical staff of the rehabilitation department of a French hospital[3] (with an average of 17 years of experience in the field), the second experiment followed an independent-measures design with two independent groups formed by a total of 8 healthy players: group 1 (composed by 4 people, 3 men and 1 woman) and group 2 (composed

[1] EMG-controlled stands for electromyographic controlled and it is a type of biofeedback.

[2] Mixed reality aims to merge real life with virtual worlds, by creating a new paradigm that allows real-time interaction between physical objects and digital objects [11].

[3] 3 occupational therapists, 9 physiotherapists, 3 students in physiotherapy and 2 general doctors.

by 4 people, 1 man and 3 women). Bower et al. [15] conducted a study divided in 2 phases whose objective was to "*investigate the feasibility of using a suite of motion-controlled games in individuals with stroke undergoing rehabilitation*". Phase 1 consisted in an initial feasibility testing while phase 2 was a pilot randomized controlled trial. For phase 1, 40 individuals (mean age 63 years) who were stroke patients and were able to sit unsupported were recruited. They showed no cognitive deficits nor visual problems. For phase 2, 16 participants (mean age 61 years) from phase 1 were selected.

Two studies described clinical randomized trials where the efficacy of Nintendo Wii as a rehabilitation tool was evaluated. Saposnik et al. [9] described a pilot randomized, single-blinded clinical trial with two parallel groups that had the objective of comparing the feasibility, safety and efficacy of using virtual reality as stroke rehabilitation therapy method by determining whether Nintendo Wii (VRWii) enhances post-stroke motor function recovery. The sample counted with 22 randomized patients within two months after stroke (subacute period). The mean age of the patients was 61.3 years (with ages ranging from 41 to 83 years old). Incidentally, the patients that were assigned to the Wii group were younger, had more severe strokes and had a lower arm function at baseline. Thomas et al. [10] presented a pilot randomized controlled trial that aimed to access the acceptability and suitability of a Nintendo Wii-based intervention named *Mii-vitaliSe* as a method for encouraging multiple sclerosis patients to increase their physical activity. 30 randomized multiple sclerosis patients (ambulatory and relatively inactive) participated in this trial and they were divided in two groups: group that received the intervention either immediately (for 12 months) and a group that started after a 6-month wait (for 6 months).

As mentioned previously, Lopes et al. [4] presented a systematic review of 16 cases featuring a total of 203 participants suffering from cerebral palsy. The authors sought to understand the difference between intervention settings (home setting vs. clinical setting). Most of the selected cases dealt with children or teenagers, but 3 of them were conducted with adult participants.

Case studies analysis: Intervention type

Two intervention types were found among the analyzed papers: those that used COTS as their games of choice for rehabilitation therapy and those that resorted to custom-designed serious games for the same purpose. This second category can be subcategorized in 3 subcategories: Point & Click and Drag & Drop, Rehabilitation assisted through Virtual Reality and a Virtual x Real Approach. Two of the selected articles also analyzed the differences in efficacy between COTS and custom-made serious games.

COTS (Commercial Off-the-Shelf Games)

COTS, or commercial off-the-shelf games, are games that were developed with the entertainment market in mind but are considered adaptable and relevant for serious purposes – physical rehabilitation, in this specific case. They can also be considered purpose-shifted video games [16]. In this review paper, two articles described the use of COTS as a therapy tool.

Saposnik et al. [9] aimed to compare the efficacy between COTS and Recreational Therapy. In this sense, the study had the patients taking part in 8 intensive interventional sessions (Wii or Recreational Therapy). Each session lasted for 60 minutes and they were scheduled in a flexible manner over a 14-day period, being separated between them by at least 5 or more hours. As to be expected, the Wii group played COTS (namely Tennis, Bowling and *Cooking Mama*) and aimed to train shoulder movements (rotation, flexion and extension), elbow movements (extension and flexion) and wrist movements (supination, pronation, flexion and extension). Thumb flexion was also involved in all activities. The patients were asked to play the games while in a sitting position

and to use their more debilitated arm or hand (even though Wii is adaptable to answer to patients' needs). The Wii sessions' total time was 364 minutes. The participants in the recreational therapy group played cards, bingo or "Jenga". The recreational therapy sessions totaled a time of 388 minutes.

Another case where the use of COTS was observed is the one reported by Thomas et al. [10]. The intervention was described as consisting of "*two supervised Nintendo Wii familiarization sessions in the hospital followed by home use (Wii Sports, Sports Resort and Fit Plus software) with physiotherapist support and personalized resources"*. During the initial 6 months of the intervention, both groups had a mean usage time of 27 min/day, twice a week and the cost to deliver this intervention to a single patient was of £684 (~799€) per person.

COTS proved to be an efficient and economical way of using games for physical rehabilitation purposes, enhancing the patients' motivation to participate in therapy.

Custom-Made Serious Games: "Point & Click" and "Drag & Drop"

Point & Click and Drag & Drop seem to be popular among the games that are designed and developed for serious purposes. Point & Click games are those centering around the action of moving the cursor to a specific point in the game and then clicking or pressing a button to trigger an action. Drag & Drop games are identical, but the player is expected to simulate the act of grabbing a virtual object (through the cursor, for example) and then dragging it across the screen to a specific location to trigger an action or outcome. This review found 5 cases where games embodying these features were developed with rehabilitation purposes in mind.

In Broeren et al. [8], the intervention resorted to the use of a VR activity station and the patients were invited to reach into a virtual space and to interact with three-dimensional (3D) objects with a handheld stylus pen (haptic device) that had a virtual counterpart positioned in the line of sight. The targets appeared at random locations on the screen, one after the other, and disappeared when the user pointed the stylus at them.

Bower et al. [15] used four games specifically developed for the intervention and the motion tracking was achieved using a depth-sensing camera named PrimeSense. The participants could play the game either sitting or standing. Three games – Ball Maze, Fridge Frenzy and Tentacle Dash – required torso movement (motion of the shoulders and hips was tracked) and one game – Bubble Fish – was controlled by upper limb movement (motion of the wrist joint relative to the shoulder was tracked). Ball Maze was a game that used leaning movements of the torso in order to tilt a maze board to allow a ball to be guided through it. The objective of this game was to maneuver the ball into the hole. Fridge Frenzy depicted a track inside a fridge and the player's objective was to guide the ball through the track thanks to lateral flexion movements of the torso that resulted in side-to-side movement of the ball. The player must hit milk cartons as they show up along the track. Tentacle Dash was a game that asked the players to perform movements like leaning or side-stepping (torso movement in relation to the initial midline position) in order to make the ball move forward while avoiding hitting the tentacles. The goal was to travel as far as possible in the shortest amount of time. Bubble Fish was a game that resorted to arm movement to shoot bubbles in different directions, aiming to hit the fish (that moved in from both the left and right sides of the screen, as well as at different depths). All the games were adaptable to users in order to match their levels of balance, motor control and possible perceptual problems commonly found on stroke patients. Following the design, sample and intervention setting (explained in its respective section above), the patients from phase 1 were randomly assigned to trial one of the four available games during a single session, under the supervision of a physiotherapist. Participants were expected to complete all 10 levels of the game

they were playing, first in sitting, then standing as able, preferably taking approximately 1 minute to complete each level. For phase 2, the participants were randomly assigned to the intervention group or to the control group. The participants in the intervention group took part in eight 40-minute sessions over the course of 4 weeks (in addition to their standard inpatient or outpatient therapy) and used all 4 available games. During the first two sessions, they were obliged to use all four available games. In the last six sessions, the participants could choose which games they wished to play. Meanwhile, participants in the control group were receiving standard care only.

Ghassemi et al. [12] used a game that was played through electromyographic control, having the user manipulate EMG patterns in order to move the cursor around the tiles of the game - the hand movement controlled the cursor on the screen. The intervention lasted for 3 sessions and each session had 3 phases: calibration, test, and training. This phase lasted for around 30 to 45 minutes and by the end of this phase, another test was conducted. Both groups performed the tests only using their non-dominant hand. Five serious games were developed and were played during the training phase: Target, Picture Reveal, Targeted Picture Reveal, Maze and Coin Collector. In the Target exercise, the patient must provide an appropriate EMG pattern in order to move the cursor to a specified tile. In the Picture exercise, like the previous exercise, the user also is invited to move the cursor to different tiles and, as the authors describe, "*once the cursor meets the stationary criteria, the tile disappears to reveal part of a picture beneath*", which implies that the user is free to choose which tile he/she unveils next. Targeted Picture Reveal was the same as the Picture exercise, but the order to reveal the tiles was chosen at random by the computer and the player must follow the established order. In the Maze exercise, the player must solve the maze, and, for that, the EMG patterns controlled the cursor and allowed the user to navigate through the maze. The Coin Collector is reminiscent of the arcade classic *Space Invaders* and the user was invited to collect coins that appear on the screen by moving the cursor (that takes the shape of a spaceship) without hitting any moving asteroids. The authors state that all game's interface can be described as intuitive.

In Ma and Bechkoum's case [6], the patients participated in around 15 sessions each, where they were invited to play a game named *Whack-a-Mouse*, a game that, like the Coin Collector game from Ghassemi et al.'s study [12], resembled of one of the arcade classics. This game resorted to VR, and simulated a table where mice appeared at random locations, stood there for a couple of seconds, before disappearing and reappearing in a different random location. The player interacted with a game by managing a virtual hammer and the proposed task was to hit the mice while they were still visible. The game featured three difficulty levels: Beginner, Intermediate and Expert (in this level, besides mice, dogs also appear at random locations at the same time as the mice and the player should prove to be able to distinguish the two animals by hitting the correct one with their virtual hammer). This game had the main goal of improving patients' movement accuracy and speed, while encouraging upper limb gross movement. Besides the physical rehabilitation aspect of the game, it also tackles cognitive aspects by promoting visual discrimination and selective attention. *Whack-a-Mouse* is also described by the authors as a highly adaptable, which made it responsive to individual patient needs, by monitoring the player's progress and tracking play sessions data.

In Hocine et al. [13], PRehab (Platform Games for Rehabilitation) was used. It can be played on a graphics tablet and it had the main therapeutic goal of increasing both the range of motion and the training volume of an average rehabilitation session. The first phase consisted of a playtest with healthy players and medical experts and had the objective of identifying game bugs as well as determining whether the gameplay[4] was perceived as fun or not; the second phase was a usability test that was conducted in hopes of evaluating the adequacy of the graphic user interface for stroke

[4] Gameplay refers to "the pattern defined through the game rules which connects the player and the game" [20].

patients by having a single patient play the game for thirty minutes, based on the proposed Difficulty Adaptation Technique, while being observed by five therapists; and the last phase, that was conducted over a 2-week period, in which each patient took part in three 20-minute rehabilitation sessions, followed a repeated-measure single-blinded design that could be described as an experiment to assess patient performance. Aesthetic and gameplay wise, the games designed for PRehab looked very much like Nintendo's *Super Mario Bros.* games and invited the users to reach for virtual targets within the game. Three games were tested (Turtle game, Rabbit game and Cat game), and each game offered a different difficulty strategy in order to determine which would be the best way to assess physical therapy. Moreover, the gameplay was identical in each difficulty version, but the graphics (namely characters, images, backgrounds, animations) were different in order to grant the player a sense of novelty. The third test had the patients play all game version and experience each difficulty strategy that had been selected at random. The participants of the first test suggested adding more feedback moments to the game in order to boost patients' motivation.

In this sense, games using Point & Click or Drag & Drop approaches are efficient and allow the designers a large versatility, since these simple mechanics can be applied to a broad range of games and objectives.

Custom-Made Serious Games: Rehabilitation assisted through Virtual Reality

Michael A. Gigante, in the book "*Virtual Reality Systems*", defines Virtual Reality (VR) as "*the illusion of participation in a synthetic environment than external observation of such an environment. It relies on three-dimensional, stereoscopic, head-tracked displays, hand/body tracking, and binaural sound. VR is an immersive, multisensory experience.*" [17]. VR also embodies three essential concepts that are complementary to each other: Interaction, Immersion and Imagination [18]. VR is widely used as a way to approach rehabilitation assisted through virtual methods, such as games. This review found 2 articles where virtual reality was used as a training assistant for the patients who were undergoing rehabilitation.

The patients that participated in the study presented by Cameirão et al. [5] were divided in three groups: a group of seven patients that used the proposed rehabilitation system (Rehabilitation Gaming System – RGS) and two control groups (A, composed by 4 patients and B, 3 patients). The rehabilitation game used in this study (RGS) is described as an innovative VR tool for motor deficits of the upper extremities' rehabilitation (following brain lesion caused by stroke). The system offers a specific deficit-oriented game, molded to match the patient's needs by combining movement execution with the mirroring (first-person perspective) of the action by virtual limbs. In this case, it featured three training tasks of graded complexity and could be described as a "*virtual reality-based system that is targeted for the induction and enhancement of functional recovery after lesions to the nervous system using non-invasive multi-modal stimulation*". The rehabilitation therapy sessions had the duration of 20 minutes and happened three times per week, over the course of 12 weeks, with a 12-week follow-up.

The selected protocol of Jack et al. [7] was used daily, for 2 weeks and each session consisted of 4 blocks of 10 trials. Each block aimed to improve parameters such as range, speed, fractionation or movement strength. The patients engaged in VR sessions around 1-1.5 hours per day and the remaining time was spent participating in traditional therapy procedures. This protocol can be described as a computer-based rehabilitation workstation, running both VR simulation exercises and a database.

Virtual Reality is a powerful tool that can elevate physical rehabilitation to a new level by allowing the patient to experience a virtual universe that aims to make therapy more motivating and engaging. Although VR offers these possibilities, further studies need to be conducted, analyzing the influence the virtual world design has on the clinical results.

Custom-Made Serious Games: Virtual x Real Approach

Two cases used an approach where real objects were paired with a virtual universe.
Delbressine et al. [14] resorted to the T-TOAT (Technology-supported Task-oriented Arm-hand Training), since this method had been verified as effective in previous clinical trials and aimed to improve the state-of-the-art of the proposed paradigm by providing changes that would enhance the challenge, fun, performance feedback and exercise variability offered by the T-TOAT. Before starting the experiment, the authors conducted an interview with 12 chronic stroke patients and a therapist, in order to identify the design challenges to be tackled. The interview resulted in the acknowledgement that it was important to support task-oriented training for arm-hand rehabilitation while avoiding compensatory movements with shoulder and trunk. Another challenge that arose after the interview was the necessity to ensure that engagement and motivation were achieved using an interactive game. The feedback obtained through the interview culminated in the design of a tabletop game where physical objects had to be manipulated (for example, there is a task-oriented game that uses an actual fork and knife on a pressure sensitive touchscreen device. The game then offers graphical vibrotactile feedback regarding the patient's posture through a motion sensing jacket, and it directly influences the gameplay while aiming to control possible compensation movements).

Abdelkader et al. [11] presented a study divided in two parts. The first experiment consisted of several 10-minute sessions that aimed to test a MR game (developed solely for therapy purposes) using a computer, a mouse and a Wiimote (it is important to mention that the game played in MR was identical, design wise, to the one played on the computer and thus, aimed to prove the relation between hardware and efficacy). The gameplay of the MR game depicted a maize plantation being attacked by crows and the objective of the game was to chase away the intruders while training free movements. The second experiment aimed to compare the difficulty level perceived to that assumed by the algorithm, by simulating difficulty conditions that are similar to those experienced by patients while partaking in their rehabilitation programs. In this sense, group 1 used a strategy of difficulty adjustment that would increase the difficulty level if the player succeeds in the previous one, while group 2 used the difficulty adjustment strategy proposed by the authors.

The mixture of real physical objects with a virtual universe can be very interesting because it allows the patients to keep a tactile and visual sense of reality while being immersed in a parallel world. This also allows a broad range of game designs and permits a large versatility in terms of clinical objectives.

Comparison between Custom-Made Serious Games versus COTS

Two of the articles found for this review featured, in a way or another, a comparison between the efficacy of custom-made serious games and COTS.
In Jonsdottir et al. [3], the participants were then divided in two different groups: 10 patients used the serious game platform – Rehab@Home – while the remaining 6 patients were part of the control group and used the commercial Nintendo Wii Console™ and were invited to play COTS that were selected in function of their motion requirements such as holding or gripping the controller and pressing the main buttons of the object. This division had the objective of comparing the efficacy and pertinency of use between the two types of games by accessing, as explained by the authors: "*the feasibility of using the final therapeutic gaming system Rehab@Home to augment upper extremity*

neurorehabilitation services and to provide preliminary evidence of clinical efficacy of the gaming approach in increasing arm performance and health related quality of life" of people with multiple sclerosis. The intervention lasted for 4 weeks and a total of twelve 40-minute sessions (4-5 sessions per week). Rehab@Home offered six arm rehabilitation games that could have their difficulty levels adjusted to match the patient's need. Besides, because they required the player to perform a large variety of hand/arm movements by demanding the player to grab or grasp various virtual objects in a virtual space, the game was expected to improve patients' movement coordination, reaction speed and timing, hand-eye coordination and spatial awareness.

Lopes et al. [4], besides comparing the effectiveness of playing games as part of physical rehabilitation at home versus clinical setting, also offered some insight in the comparison between COTS and custom-made serious games. Most of the cases in this intervention setting resorted to COTS, which lead to the conclusion that it is important to offer the patients a large variety of objectives to do within the game in order to keep long-term interest. Another way suggested by the authors to fight this problem is keeping therapy interventions short but intensive. The authors claimed that the home setting cases aimed to "*evaluate the efficacy of autonomously playing a game, or a set of games, at home*" and showed mixed results in terms of improvements of the trained skills. Nonetheless, the familiar setting allowed participants to keep focused for longer periods of time and to foment and deepen family bonds. On the other hand, the clinical setting experiments had the objective of evaluating "*the efficacy of playing a game, or a set of games, in a clinical setting, usually under the supervision of a therapist*". Unlike the home setting cases, the ones that took place in a clinical setting got positive results and showed measurable improvements in the skills abridged by the intervention. This analysis mentioned that patients usually prefer to participate in multiplayer versions of the games, but therapists suggest the use of single player versions instead, in order to achieve better practical results, although sacrificing some of the motivation levels achieved through group participation. Both studies conclude that "*game-based training should be regarded as a complement of traditional rehabilitation sessions, particularly with the possibility of including competitive and collaborative play*".

Although COTS can be beneficial by enhancing the patients' motivation, the studies explored above prove that there is still a lot to be done in order for commercial titles to answer what is considered clinically desirable.

Discussion

The efficacy of the use of video games was measured differently from case to case. Some of them adopted questionnaires in order to access a qualitative evaluation of the affective dimension experienced by the player upon the contact with the game world, while others opted for quantitative results in terms of movement improvement. Some of the tests used for this were Functional Independence Measure ([5], [15]), Box and Block Test ([3], [9]), Fugel-Meyer Assessment test ([5], [7]), ANOVA ([12], [13]) or the Motricity Index ([5], [6]) (see Appendix A[5]).
All studies showed positive results in terms of therapy efficiency and claimed that the patients that tested the games found them motivating.
Cameirão et al. [5] mentioned that the in-game achievements would turn to measurable improvements in the real world. Ma and Bechkoum [6] pointed out the motivating nature of games and how the relation between the improvements in terms of game performance would match real world improvements. This study also showed that games proved to be more efficient than traditional therapy methods. Jack et al. [7] claimed that the use of video games resulted in hand movement

[5] See Appendix A for the full measures list.

improvements. Broeren et al. [8] got positive results in improving movement range and speed through the use of VR-based games. Jonsdottir et al. [3] pointed out that games specifically designed for therapy interventions were effective, but needed to embody the motivating and fun characteristics of COTS (for example, Wii games). Hocine et al. [13] mentioned the importance of giving patients feedback during rehabilitation gaming sessions in order to achieve better results and proved that having difficulty levels that can adapt to patients' needs was crucial for success. Delbressine et al. [14] showed that due to video games effectiveness in rehabilitation therapies, they can be used as a variation to regular traditional therapy methods. Once again, this study also mentions the need of adapting difficulty levels to match the patients' physical conditions. Abdelkader et al. [11] showed that Mixed Reality was an interesting approach to video game-based therapy and pointed out that it would be beneficial to mix video games with traditional therapy sessions. Lopes et al. [4], in their systematic review of serious games applied to cerebral palsy rehabilitation, concluded that it is important to offer the patients a large variety of games or in-game-objectives in order to keep their motivation levels throughout the duration of the therapy. Besides, the authors state that games shouldn't be used as a first-line therapy procedure but as a complement to traditional rehabilitation sessions. Saposnik et al. [9] accessed the feasibility of using Wii games for stroke rehabilitation, which proved to be successful, fairly inexpensive and a better alternative to recreational therapy. In this sense, Thomas et al. [10] also presented a rehabilitation intervention based on the use of Nintendo Wii, but for multiple sclerosis patients. The intervention was successful but this study pointed out that it might be necessary to think of ways to allow rehabilitation sessions to be performed in the home of the patients in their totality, since traveling to a specific site might be complicated for these patients due to their lack of autonomy and the fact that they tire easily. Ghassemi et al. [12] concluded that using EMG might be a new way to perform rehabilitation but this method needs further testing, since the study was based on healthy subjects. Bower et al. [15] concluded (like other studies mentioned above) that using games for rehabilitation was a great way to motivate and interest patients to participate more actively in therapy, besides being effective as rehabilitation method.

From a game development and design point of view, the studies analyzed in this paper prove that there is a need to make serious games more "fun", as Jonsdottir et al. [3] pointed out that patients perceived more improvements when playing Wii games (COTS) than when playing a game specifically designed for therapy.

In this sense, there is a lack of information when it comes to the actual development or design of a video game for medical rehabilitation purposes from an artistic or conceptual point of view, as most of the studies found focus on the clinical aspect of using games for therapy, overlooking the creative and artistic side of games of such nature. This is something that needs to be further explored and researched, as it has been pointed out that there is a need to implement characteristics of commercial games to those specifically designed for the health sector, thus enhancing the potential to be creative and imaginative in serious games for healthcare.

Some of the games used in the cases mentioned in this paper seem to be inspired by classic arcade games, following their gameplay, aesthetic and dynamic. *The Whack-a-Mouse* game described by Ma and Bechkoum [6] readapts a former well known arcade game to a rehabilitation game that has the same purposes, but works through VR. The same happens in one of the games presented by Ghassemi et al. [12], since one of the games presented in this study highly resembles (theme, gameplay and visual wise) the classic arcade game *Space Invaders*.

In other situations, the games used appear as adaptations of all-time famous video game titles. Hocine et al. [13] resorts to this method and the game used (PRehab) is based off the *Super Mario Bros.* games, both visual and structure wise. *Mario* games have a main goal and, to achieve said goal, the player must complete several stages while achieving objective stage goals that will lead up to the final main goal. In a rehabilitation context, the authors explain that the game itself will define the

goal that the patients must reach by the end of the rehabilitation program, and therefore, each game act or level will correspond to a 20-minute training session. Each level will have achievable and objective goals, in order to keep the patient motivated, without experiencing feelings of frustration. However, it is important to point out that while *Mario* games feature a large number of levels/stages and worlds, all featuring identical gameplay (although, in *Mario*, as the player advances in the game, they experience increasing difficulty) but different graphics (strategy employed by PRehab), the game used in this case only has three different stages, which makes the game's scale much inferior to that of *Mario*'s. But this doesn't seem to be a problem, since rehabilitation programs only last for a predetermined number of weeks and sessions and, as long as the game is able to retain patients' interest throughout the duration of the treatment, it is possible to conclude that the game was successful while not being perceived as boring.

When studies resort to COTS, they generally opt for *Wii* games that require the player to move around and, therefore, execute the needed motions for rehabilitation. Although this seems like a great way to avoid the production costs of customized serious games, these did not prove to be as effective as the games purposefully developed to be used in therapy, although they were perceived by the patients as "fun" and "engaging", bringing to light a need to make serious games embody these traits, perhaps by paying more attention to the visuals or the ambience created by the virtual world [3]. In this sense, Laamarti et al. [19] points out some of the cons of using Wii games for rehabilitation: as the tracking of the movements solely relies on the joystick, it makes it possible to cheat, this is: the player can just sit on the sofa and, as long as the correct movements are detected based on the motion executed by the joystick, the game will perceive the achieving of its objectives as successful, even though medical efficacy may suffer due to incorrect postures or movements driving from this possibility to cheat. The authors then propose a way to avoid this situation: using intelligent interfaces in order to enhance the sense of realism, which will avoid the situation mentioned above. Bower et al. [15] mentioned that using COTS (Wii games or Xbox Kinect games) for rehabilitation can be very limiting and therefore suggests the use of serious games designed specifically for rehabilitation purposes. Hocine et al. [13] mentions the importance of graphics in games: the authors state that, for a therapy to be effective, it is important to keep patients' motivation levels and one of the ways of doing that is presenting new game content in the form of new visuals. This allows for the gameplay to remain the same and, therefore, keeps the patients repeating the necessary movement, while providing a sense of newness through graphics. Changing the game's scenery can, according to the authors, be effective because it makes the players feel like they're playing a new game, whilst the gameplay remains the same, only the graphics change.

Point and Click games ([8]), games to guide a cursor or a ball through a specific track of path ([12], [15]) or games that invite the patients to grab and manipulate virtual objects ([3], [13]) also seem to be popular. These usually feature simple designs and objectives (which can answer the rehabilitation needs and requirements) and revolve around the virtual playout of mundane situations or tasks. Most of the games described above don't seem to involve anything that can equal the quests found in popular commercial video games. MR can be a way to spice things up, as described by Abdelkader et al. [11], whose game features the simple task of chasing away crows that are attacking a maize plantation, by presenting a new form of interaction that allows real objects to be used in order to manipulate a virtual world. Delbressine et al. [14] also uses a game that combines physical objects with a virtual universe.

Conclusions

After analyzing all the selected cases, it is possible to conclude that the most relevant aspect of the application of video games to therapy is their ability to both motivate and captivate the patients' attention, which intrinsically leads to better adherence and compliance to therapy sessions. Video games proved to be useful in multiple health issues (from stroke to multiple sclerosis) by enhancing and promoting patients' motivation, which acts as a facilitator to obtain better post-therapy results.

However, it was often mentioned in the outcomes of the analyzed studies that some of the serious games that had been purposefully designed for therapy did not fully embody the characteristics that make people perceive a video game as a “fun” experience. Patients find COTS more engaging and motivating, however, the outcomes show that COTS do not deliver the same results in terms of therapy efficiency. This leads to the conclusion that it might be beneficial as well as imperative to merge both aspects in a single game: design a serious game that fully embodies the characteristics that make COTS be seen as “fun” and “exciting”, by focusing more on the aesthetic, gameplay and design aspects and not only the way the game will serve its serious purpose.

Several authors also conclude that serious games might be a great addition to regular therapy but should not be used solely as the main therapy course of action. This said, all the cases analyzed prove that the use of serious games as rehabilitation tools is relevant and should be further investigated and implemented.

From a game development and design point of view, the authors stated that it is crucial that the games used in therapy are understood as fun and motivating experience, in order to keep therapy adherence levels high. The authors concluded that it is important to pay attention to the game’s graphics and that a large variety of game universes within a single game can grant the players a sense of newness that will make up for the game play, if it remains the same. Although the number of published sources on what makes serious games appealing (from a development point of view) is scarce, those two aspects were pointed out in the papers that were included in this survey, therefore making them relevant and worth of considering. In this sense, it is important to analyze several games used in rehabilitation therapies in order to understand what patients prefer, from the point of view of game enjoyment, but without discarding medical results and improvements.

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Conflicts of Interest

No conflicts of interest to report.

Abbreviations

3D: three-dimensional.
COTS: commercial off-the-shelf.
EMG: electromyographic controlled.
MR: mixed reality.
PRehab: platform games for rehabilitation.
RGS: rehabilitation gaming system.
T-TOAT: technology-supported task-oriented arm-hand training.
VR: virtual reality.

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Supplementary Files

Multimedia Appendixes

Summarized analysis table.
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