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Serious Games to Improve the Physical Health of the Elderly: A Categorization Scheme

Jaime A. Garcia Marin
mHealth Laboratory, iNEXT
University of Technology Sydney, FEIT
Sydney, Australia
Jaime.A.GarciaMarin@student.uts.edu.au

Karla Felix Navarro, Elaine Lawrence
mHealth Laboratory, iNEXT
University of Technology Sydney, FEIT
Sydney, Australia
Karla.FelixNavarro;Elaine.Lawrence@uts.edu.au

***Abstract*— this paper aims to provide a snapshot of the current status in the field of serious games for improving the physical health of the elderly. This work covers recent research projects for stroke rehabilitation and for falls prevention where user-center design methodologies were applied in order to satisfy this audience. A classification of the most relevant work in this area is provided along with a brief description of the platform, technology required and user-center design principles applied.**

Keywords- serious games, classification, categorization scheme, elderly, games for health, user-center design .

I. INTRODUCTION

Based on recent studies, it is stated that the aged population is dramatically increasing in both developing and developed countries. As an example, in Australia the aged population (+65 years old) increased by 94,800 people between June 2009 and Jun 2010, representing a 3.3% increase. In the last decade the aged cohort increased from 11.1% to 13.5%. These increases were also reflected in people over 85 years of age by 6.1 per cent and people over 100 years by 18.2 percent [1]. A government report predicts that the health spending will increase at the same rate as the number of aged Australians which is expected to double over the next four decades [2]. Therefore, the need of supporting this upcoming population has become a concern for governments and health providers around the world.

As a consequence of aging, the human body suffers a series of changes that could lead to the decline of the mental and motor capabilities. Furthermore, diseases such as postural instability, balance disorders and stroke are common at this age and are considered the main cause of disability among the elderly. [3, 4]

Current rehabilitation methods normally require the user to perform repetitive activities in order to recover lost motor abilities. However, the mechanics of this practice are often boring for patients affecting their motivation and commitment to the treatment [3].

Videogames have become popular among the aged population during the last decade, especially since the release of the Nintendo Wii [5]. Its revolutionary remote controller has changed the way to interact with videogames encouraging players to perform physical activities while playing [5].

Specialists and researchers have applied efforts to include interactive games in health treatments looking for a suitable method to keep their patients engaged. According to the literature, a significant number of studies have been conducted showing a positive impact among elderly users who increased their motivation and adherence to rehabilitation [6]. However, this practice could also result in undesirable consequences or poor outcomes for elder players when the aged-related changes are not considered [7, 8]. Usability issues have been found mainly because these games are not designed for this audience leading to negative impacts for the elderly [7-10].In view of that, most recent research projects are more concern about the end user needs, preferences and limitations during the design process as a strategy to guarantee accessibility [11-13]. In fact, the literature suggests that focusing on the intended user and their requirements has shown satisfactory results in games [14, 15].

As the main interest of this work is the usage of video games as an effective tool for improving the health of the elderly, one of the main goals of our research is to identify how the proper design could guarantee optimal results. The work presented here aims to provide a snapshot of the current status in the area trough a literature review and categorization of relevant work. Therefore, special attention was given to research projects that presented tested working prototypes and that incorporated user-centered design for the elderly.

The rest of the paper is structured as follows. Section 2 presents a brief summary of the evolution of this area including previous relevant classifications of this discipline. In Section 3, we describe our methodology and present our criteria of selection in Section 4. Section 5 contains a review of the games and finally, the discussion and conclusions are found in Section 6.

II. RELATED WORK

Over the last decade, the usage of videogames has become popular among different audiences. However such

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video games have a huge potential as a tool for other purposes. "Serious games" is a relatively new field that could be described as the usage of videogames to help users to achieve a specific goal by playing a game [16]. This concept has been used to develop games for a range of areas such as such as medicine, defense, education and health among others.

In 2002, the 'Serious Games' initiative was formed to establish a formal basis for this emerging industry [17]. Two years later, the 'Games for Health' project was founded [18]. Its objective was to support community, knowledge and business development efforts to use games to improve health and health care. As a result of this movement, an annual conference is celebrated. The annual 'Games for Health' conference covers topics such as: exergaming, physical therapy, rehabilitation and training. In 2006, the ElderGAMES project started [19]. It was based on the use of entertainment in leisure time of the elderly as a tool for rehabilitation and prevention of the common diseases at this age. The project created an interactive-play board that aimed to maintain the elderly cognitive abilities through exercises [13].

In 2008, Sawyer and Smith [15] presented a categorization of serious games. This work establishes a snapshot of the state of this area at that time. The authors presented a general categorization of games and the application fields as well as further details for each category. Within the range of games for health, they present a classification of existing games grouped by intended audience and purpose.

In 2010, Rego et al. [16] extended this work presenting a taxonomy that focuses on games for rehabilitation. This survey covers a range of games to serve people with declines in motor and cognitive capabilities. They identified a set of criteria for the classification that focused on the following dimensions: (1) the purpose of the game, as the game could be intended for cognitive rehabilitation or physical rehabilitation; (2) the way the user interacts with the game; (3) either the game interface was two dimensional or three dimensional; (4) if the game allows more than one simultaneous players; (5) if the challenge was dynamically adapted based on the patient performance; (6) if the system enables the patient to know their progress; (7) progress monitoring capability; (8) capacity of game portability. At the end the authors compared the most relevant work found and used a system called RehaCom as a reference.

This work complements and extends previous classifications by presenting an expert categorization scheme where the use of games for improving the physical health of the elderly is the focal point. Consequently, the existing literature was surveyed focusing on games with this purpose. The inclusion of user centered design as a key element on this survey was incorporated as a result of previous studies conducted by the authors [20-22] as well as for its prevailing highlighted importance on existing literature in the area [11, 14, 15]. On account of the above the following topics were incorporated in this work: (1) games for post-stroke rehabilitation; (2) games for balance training and falls prevention; (3) user-centered design methodologies and evaluation; (4) guidelines for designing games for older adults. It is valuable to mention that stroke rehabilitation and fall prevention prevail through the literature , as stroke and falls are the most common causes of disability among the elderly [3, 23]. The next section set out the methodology used for our classification and the most relevant findings in terms of usability and gaming design for the elderly.

III. METHODOLOGY

A comprehensive search was conducted in order to gather relevant information for our categorization.

Searching for relevant data, peer reviewed journal articles (such as from ELSEVIER Health) and technical articles sourced from databases, for example, IEEE, ACM, EBSCO were reviewed for this work. The first phase of our search focused on identifying key points for a proper design for the elderly. That included understanding the ageing process and changes in the human body and common diseases at this age.

Based on our findings from stage one, we oriented the second phase of this work on technologies that included the entertainment factor to provide tools for physical and cognitive rehabilitation in patients that suffered stroke and games for falls prevention and balance training in older adults.

As our review was of a heterogeneous nature, a concept matrix was created in order to ease the classification of the existing games for improving the physical health of the elderly. For each reviewed project, the following information was registered:

1) *Audience:* As we are focused on games for health and the elderly, one of our goals was to identify if the game was suitable for older adults. This includes testing phases with older users and design evaluation post-playing.
2) *Goal:* this dimension is related to which area of the human body perceives benefits from playing the game, Also it aims to show if the game is designed as a training tool or for rehabilitation and if the main purpose was to either improve physical functions or cognitive processes.
3) *Interaction:* the way the user interacts with the game. Some systems use commercial input devices such as a remote controller, keyboard, mouse, etc. Some others developed their own input devices or ask the user to wear sensors that could be recognized by the platform.
4) *Technology:* a brief description of components and techniques that make it possible to run the game.
5) *Special Age Appropriate Features:* enhancement or mechanism that makes the game suitable for the elderly such as adapting the difficulty of the game dynamically.

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6) *Home-based: (yes/no)* as many games are developed to be used at medical centers or rehabilitation centers. It is worth mentioning that games to be played at home could be more beneficial to users because this reduces the need to travel to rehabilitation centers.
7) *Feedback:* this dimension is related to the kind of feedback provided. Some games only use images and graphics on the screen to represent user actions (visual). Some others emit sounds (audio) or use vibration alerts (haptics) to notify actions to the user.
8) *Measurement:* this dimension is related to measurements that can be obtained during or after playing the game and could help specialists to determine improvements through medical assessment.
9) *Progress Record:* game characteristics that record user results (score, performance, etc).

IV. CRITERIA OF SELECTION

Overall, the reviewed literature showed that using games as a tool for rehabilitation and training has shown a positive outcome for the elderly. However, many tests have revealed that seniors could perceive this practice as an unpleasant experience and unfavorable results could be obtained. The main cause of this lies on usability issues related to changes in the human body over the years. Therefore, much effort has been applied to establish guidelines in order to create suitable games for this audience [24].

IJsselsteijn et al. [10] and presented a compilation of age related changes that must be considered when designing digital games for elderly users. They state that, although each individual differs from others in terms of abilities and experience, the human body normally tends to suffer a series of changes in sensory-perceptual processes, motor abilities and cognitive processes when getting older. For these reasons, the elderly user may not find these games enjoyable or beneficial if the games are not properly designed.

Flores et al. [9] conducted a search of journals and databases as a methodology to gather information regarding the most important game design principles for post-stroke rehabilitation. This review was focused on finding a set of criteria for both; a) designing effective therapy for post-stroke patients and b) entertainment for the elderly. It was found that the most of the games for post-stroke rehabilitation did not include enjoyable content for the elderly. Furthermore, they proposed a set of criteria for both which is set out in Table 1.

Based on these guidelines, key points for suitable design for the elderly were identified and used for classification. Thus, the concept matrix was used as a tool for filtering data and identifying the most relevant work. Our criteria of selection are set in Table 2.

Table 1: Gaming design criteria for stroke rehabilitation programs serving elderly users [9]

Criteria for Stroke Rehabilitation	Criteria for Elderly Entertainment
• Adaptability to motor skill level • Meaningful tasks • Appropriate feedback • Therapy-Appropriate Range of Motion • Focus diverted from exercise	• Appropriate cognitive challenge • Simple objective/interface • Motivational Feedback • Element of social activity • Appropriateness of genre • Creation of new learning following guidelines of experts • Sensitivity to decreased sensory acuity and slower responses

Table 2: Criteria of Selection

Parameter	Value
Audience	Elderly
Goal	Improve physical health (upper limbs, lower limbs, balance)
Interaction	Any of these: Shifting weight, Wearing Sensor (Image Recognition), Stepping on Surfaces, Touching Surfaces, and Grasping Objects.
Technology	Any of these: commercial platforms (Wii, PS, Xbox, Kinect), PC Games, Robot, Balance Board, commercial remote controller, Camera / WebCam, Dancing Pad, MultiTouch Tabletop.
Special Age Appropriate Features	Large visual instructions, audio assistance, mechanisms to dynamically adapt challenge, monitored by the Occupation Therapist.
Home-based	Preferable
Feedback	Any of these: Visual, Haptics, Audio
Measurement	Any of these: range of motion, user movements and trajectories, high scores, game results.
Progress Record	Preferable

V. REVIEW OF GAMES FOR IMPROVING THE PHYSICAL HEALTH OF THE ELDERLY

This section focuses on providing a brief description of each game(s), the range of technology used in this field, interactions with the games and usability studies and relevant results. As it was mentioned before, much attention was given to working prototypes that followed a user-centered design methodology. We present here some of the research projects that meet the criteria of selection. They are grouped by as follows: (1) games for improving lower-limbs functions and balance training (see Table 3). (2) Games for rehabilitation / exercising of upper-limbs (see Table 4).

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Table 3: Games for balance training and for lower-limbs rehabilitation / exercising.

	Game	Interaction	Technology	Special Feature	home-based	Feedback	Measure	Progress Record
Smith et al [25]	DDR	Stepping on pad	PC Dancing Pad	Music Thematic of the game Share progress with OT (Number of Participants not stated)	Yes	Visual Audio	Game Results	Yes
Doyle et al. [26]	Otago Exercises	Shifting weight	PC Wii Balance Board	Monitored by therapist Can skip non-playable content (6 Participants)	Yes	Visual Audio	Game Results	Yes
Gerling et al [27]	Task 1	Shifting weight	PC Wii Balance Board	Simplistic design single tasks adaptive difficulty (9 Participants, Ages 77-91)	Yes	Visual	Game Results High Scores	Yes
	Task 2	Jumping						

Smith et al. [25] uses a modified version of the game Dance Dance Revolution. The main purpose of this game is to provide a tool to train the stepping abilities of the elderly, a common problem experienced by this population. In order to interact with the game, the player must step on a dance pad sensor that has eight arrows. A display (TV or PC Monitor) provides step direction instructions to the player by scrolling arrows from the bottom to the top of the screen. The game is adapted for slower responses the elderly. Also, the author presents a design for monitoring the user performance by using mobile technology. This aims to enhance cooperation among patients and therapists by sending information about user performance to the practitioner. Finally, the system is designed to be used at home.

Doyle et al. [26] developed a game to deliver balance and strength exercises. This project aims to help elderly users to improve their motor capabilities in lower-limbs in order to avoid falls. This system is made of a flash application running on a Laptop, a camera (webcam), a set of markers for upper and lower limbs and SHIMMER kinematic sensor for walking exercises. The game provides five exercises from the OTAGO exercise programme [28]. As the user performs the exercises, his/her performance is remotely monitored by the instructor in order to validate the correct completion of each exercise. Additionally, the author conducted a series of usability tests in order to identify the user preferences to make the platform more attractive to elderly users. These tests focused on evaluating visual and audio feedback, navigating through the application, providing instructions and measuring attitudes / motivation to exercise. The most important aspect found were: (1) users are more likely to play games that use an avatar instead of seeing themselves on screen (visual feedback). (2) With audio feedback, users prefer counters that emit single sounds (like: 'ding') instead of listening to number countdowns. The latter could be distracting for patients leading to lack of concentration. (3) It was found that providing options to pause / resume the game or skip to the next exercise eases the navigation through the application. (4) The notion of being under observation by a therapist increases the motivation of the patient.

Gerling et al. [27] present a case study where they developed a game for balance training considering the needs of the elderly. Their prototype, called SilverBalance, uses the Wii Balance Board and consists of two single tasks with a simplistic graphic design. In task 1, a series of obstacles randomly appear aligned to the left or right and the user must shift weight to the opposite way in order to avoid the obstacles. As long as the user plays, the speed increases until the player is not able to achieve the goal. In task 2, the obstacles cover the width of the screen and the user must 'jump' to avoid collisions. At the end of each task, the system shows the user performance and saves high scores. Both activities can be performed either sitting or standing, which is more accessible for this audience and allows people in wheelchairs to participate. The focus group test was composed of nine older adults with an average age of 84. After testing the usability of this prototype, it was found that simplistic designs allow the user to concentrate on the game encouraging them to perform the exercises. Also, this work shows that applying design principles has a positive outcome for elder users.

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Table 4: Games for upper-limbs exercising / rehabilitation.

	Game	Interaction	Technology	Special Feature	home-based	Feedback	Measure	Progress Record
Burke et al. [3]	RabbitChase Bubble Trouble ArrowAttack	Hand movements wearing gloves (image recognition)	PC Camera Webcam Markers	Mechanism to adapt difficulty based on user performance Tool for analyzing recorded log files (3 Participants, Ages 65-73)	Yes	Visual Audio	Player's movement trajectories Range of motion,	Yes
Fasola & Mataric [29]	Workout game Imitation game Memory games	Image Recognition without Markers	Robot Camera Wiimote	Social Factor Motivation (11 Participants, Ages > 65)	No	Audio Visual	Hand location, Arm angles	Not mentioned
Annet et al.[30]	Pop those balloons Drumhab Paint by number Picture tracing Therapist Do-It-Yourself	Touching screen	PC MultiTouch tabletop	Therapist can modify the difficulty of the game, changed touch sensitivity (Number of participants not stated)	No	Visual	Touch pressure	Not mentioned

Burke et al. [3, 31] developed a series of webcam games considering the theory for design and rehabilitation (meaningful games, appropriate challenge). This project aims to provide a low-cost tool for upper limbs rehabilitation that can be used at home. This platform was developed using a commercial development kit and libraries and requires a webcam, a PC and colored gloves in order to operate. Four games are provided:

1) RabbitChase: the game presents four holes and one rabbit. Eventually, the rabbit comes out of one hole, walks and gets in another hole, both randomly chosen by the game. The player must point at the hole into which the rabbit hid. If the player is correct, encouraging visual/audio feedback is given. Also, these researchers developed a mechanism that automatically adapts the difficulty of the game based on patient success.
2) Bubble Trouble: Floating bubbles randomly appear on the screen, then after a short period of time they disappear. They user must touch them before they disappear, making them burst.
3) ArrowAttack: This game shows two arrows that are colored according to the user gloves or markers. One points to the left and the other to the right. Also four boxes are shown. The arrows move from one box to another and the user must imitate this movement with their hands as long as they move.

The system also includes a tool that analyses saved log files that are given to the therapist. Additionally, two playability studies were conducted. It was found that the adaptive mechanism that increases and decreases the difficulty of the game, was too aggressive when adjusting the challenges so it must be refined to be more 'gentle'.

Fasola & Mataríc [29] implement an assistive robot to deliver arm exercises for the elderly. This robot monitors the performance of the user and provides motivation to the player promoting an increased range of motion. In order to operate, the user must sit in front of the robot and three different games are given:

1) *Workout game*: the robot acts as a traditional instructor giving a series of exercise that the user must perform;
2) *Imitation game*: the player acts as the instructor and the robot imitates the user movements; and
3) *Memory games*: the robot provides a sequence of arm gestures and the player must memorize them and repeat them.

In order to capture the user movements, the research team developed a vision module that recognizes the users' faces and determines hand location. In order to simplify the visual recognition, they installed a black curtain behind the user to provide a contrasting and static background. At the end of the trials, a survey was conducted to determine the participants' feeling and perceptions towards the robot. The results suggest that

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the participants perceive the robot as a trustable entity able to help them in exercising training.

Annet et al. [30] developed a multi-touch table system to deliver training for upper-limbs. This platform was built under the guidance of occupational therapists, specialists who normally work with patients to help restore or improve motor functions. Three objectives were established at the beginning: (1) engage the user and provide easy to learn activities; (2) create repeatable activities, measure user performance and record it; (3) build on the therapist's expertise and knowledge of a patient. The whole system is made of an existing multi-touch technology in conjunction with a set of applications for rehabilitation. Five games are given:

1) *Pop those balloons*: a landscape and a number of floating balloons are shown. The user must touch them in order to pop the balloons. Once the player touches the balloon, it disappears and increases the score. The therapist is able to modify the number of balloons and their speed while the patient is playing the game, in order to increase or decrease the difficulty of the activity.
2) *Drumhab*: this game presents a center orb that emits 'beats' from the middle of the screen to the four corners. Each corner has a drum that must be touched when a beat reaches its position. If the player hits the drum at the correct time, the 'beat' disappears. The therapists can control the game by changing the number of beats and their speed as well as which drums are targets.
3) *Paint by number*: this game shows a group of paint buckets and an outline with numbers. Each paint bucket has a number and a different color. The user must use their hand as a paintbrush and paint the image.
4) Picture tracing: In this game, the therapist draws a pattern on the surface of the tabletop and the patient is asked to trace overtop of the pattern.
5) Therapist Do-It-Yourself: the therapist creates a sequence of points (targets) and the user must reach them. Once he/she touches a target, it disappears and the next one comes up.

VI. DISCUSSION AND RESULTS

One of the main limitations for this work was the lack of research across the area of the elderly and the user of serious games for health purposes. For that reason, literature from intersecting disciplines such as the use of games for stroke treatment and games for improving balance function was reviewed to obtain more data. In spite of that, it is valuable to mention that some work was conducted in the late eighties and early nineties. Some improvements in cognitive processes were observed after conducting trials with elderly patients who played specifically selected computer games [32, 33].

On our previous research on the Nintendo Wii, the suitability and usability of six commercial balance games were assessed by three conventional health professionals and three alternative health professionals [11, 14, 15]. They identified a series of problems that could lead to negative results for the elderly cohort, as their needs were not considered during the design process. For instance, the health professionals stated that the elderly could learn inappropriate movements in response to game actions; resulting in risks for their physical condition. Also, they stated that hearing impairments and sight problems were not properly addressed when providing rules and instructions which could lead to confusion and frustration. However, we have learnt that current rehabilitation techniques that apply user-centered design principles are being well accepted by older patients, especially when the games and exercises involve fun factors. This highlights the importance of adequate design for this audience in order to obtain positive results.

Additionally, we noticed that much effort is applied on developing games for improving upper-limb function. Some of the noted reasons for that in the literature were: (1) daily activities require the use of arms and hands such as grasping objects and brushing teeth among other daily activities [4, 34]. (2) A significant number of elder users could require a wheelchair, so they would not be able to perform activities that require the whole body [27, 35, 36].

In addition to the above, it is important to take into account that the use of webcams has been a popular low-cost input device solution. The nature of the device imposes inherent technological limitations to capture accurately the whole body. It is worth mentioning that costing of those games was not mentioned as the researchers developed extra items such as robots or mechanical arms and employed programmers to assist in the games' construction.

Regarding the usage of commercial platforms for this purpose, we found that there is a tendency towards the utilization of their input devices rather than the whole system. Although these innovative ways to interact increase the accessibility and motivation of patients, the coverage could be limited due to the lack of standardization among platforms.

Finally, it was observed that even though most of the studied prototypes included progress monitoring and some type of measurement [3, 25], only a small number of these leverage on the therapist knowledge to assess the effectiveness of the therapy [30]. Hence, future work on the inclusion of mechanisms to perform medical validation and assessment in real-time could bring important benefits for patients and therapists alike.

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VII. CONCLUSIONS

In this paper we have classified the work of serious games for the elderly according to their specific goal and key design elements for improving the physical health of the target audience. This expert categorization scheme aims to help researchers in the area to identify the current status and major needs in this new field of research. It was found that current projects tended to have an increased awareness of the elder user needs in gaming design for health purposes. Yet, little effort has been made to take into account the limitations of the aged cohort along the entire design process. This could be attributed to the favorable results that have been obtained in the past on the incorporation of elderly specific human centered design guidelines to assists the design process. However, its theoretical nature could not be sufficient to guarantee optimal results, so testing phases and usability evaluation are needed. As a final point, the use of modern input devices has allowed specialists to determine the patient performance in terms of motor functions. Nevertheless, the potential of use this capabilities to accurately perform medical assessment as a tool to guarantee effectiveness is not being exploited. This has been identified by the authors as an important direction for future research in the area and it is intended to be the next stage of our research.

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