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MOTION TRACKING EXERGAMES FOR ELDERLY USERS

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ABSTRACT

This paper reports the results from the field tests of two custom made exergames, based on a commercial off-the-shelf technology, aimed for the elderly people. First game resembles the guided mobility and stretching class, and the second one is more game-like with youthful theme and active movement. Both exergames were tested on two sites, urban and rural setting, totaling 19 elderlies. Usability findings are reported in a form of System Usability Scale (SUS) score analysis, and playability aspects as a Game Experience Questionnaire (GEQ) analysis. Results from the questionnaires are supplemented with observation and interview material. The second game, which had more familiar setting and appropriate pacing, received positive feedback and higher scores from the tests. Based on this material we discuss about the design of exergames aimed for the elderly persons who are not experienced computer game players, the importance of graphical clarity and the need for specialized game experience questionnaire for the elderlies.

KEYWORDS

Exergames, Motion Tracking, Elderly, Serious Game.

1. INTRODUCTION

The number and proportion of the elderly in the population is growing, especially in the industrialized countries, and are one of the fastest growing age groups (UN, 2014). Age-related decline of physical and cognitive capabilities have severe impact on individuals quality of life as well as to the need for additional social and health related services. This combination leads to a rising costs on individual and societal levels.

Our goal is to implement games that can be used by the elderly users to improve their physical well-being. In our case the target population are elderlies who are not yet physically active or are active but need new ways of doing exercises. Reason behind this need might be change in personal health that prevents the participation to regular exercise activities or other conditions that cause them to become more sedentary.

In this article, we present two different kind of exergames, a sports game and a gamified exercise game, targeted to increase the physical wellbeing of elderly users. To achieve this goal, both games track the users' body movements by using off the shelf hardware and software.

The main objectives of this paper are 1) to report the usability findings from SUS questionnaire, 2) to report the gaming experience felt by the elderly based on the Game Experience Questionnaire (GEQ), interviews and observations, 3) to discuss what kind of features the elderly liked and disliked in these games and 4) to summarize the findings related to design decisions of these games.

The paper is organized as follows. At first, the Section 2 introduces the readers to the background of the study, in Section 3 the implemented games and the testing procedures are described in detail, and then in the results from the testing sessions are reported in Section 4. Finally, in Section 5 we discuss about the finding and the potential for the future studies.

2. BACKGROUND

It is known that exercising the muscles (e.g. Orsega-Smith et al., 2012) and brain (Boot et al., 2013) helps to slow down, reverse and even stop the age-related decline (e.g. Anguera et al., 2013; Kuhn et al., 2014). In addition to discomfort and decrease in quality of life, declining physical and cognitive well-being also increase the elderlies potential to get depressed in later life. According to VanItallie (2005), 5.7 percent of US residents aged 65 years or older have major depressive illness, and subsyndromal depression affects much as 15 percent of the elderly population.

Physical and mental exercises can be done either independently or with an assistance (e.g. with physiotherapist or nurse). Common problems with either choice is the relapses from the chosen program due to repetitive and sometimes even boring nature of these exercises. People need ongoing motivation to keep on doing the repetitive tasks, and for this task the games and gamified solutions have been seen as a possible motivator (e.g. Brox et al., 2011).

During the last decade, the usage of videogames has expanded into the health market with devices like Nintendo's Wii (Nintendo of America, Redmond, WA) and the different versions of Microsoft's (Microsoft, Redmond, WA) Kinect motion-sensing input device, and with engaging games with health-promoting activities like Ubisoft's "Your Sharp, Fitness Evolved" (Ubisoft, Montreuil, Paris, France) (more on games like these, see e.g. Boulos, 2012). These devices and games have also been studied for their potential as a tool to persuade seniors to increase physical activity (e.g. Hall et al., 2012).

Games using the physical movement of the player as the input method are called exergames. These games or game-like applications have been seen as one potential tool to be used to prevent the decline of physical and cognitive skills. Exergames combine the motivational factors found in games with the needed physical exercises (Brox et al., 2011).

In addition to the potential effect the exergames have on the physical and cognitive abilities of their users, Rosenberg et al. (2005) found significant improvements in depressive symptoms, mental health-related quality of life, and cognitive performance in their 12-week intervention using exergames. Noteworthy point is that they did not find significant change in the physical health-related quality of life.

With the rise mobile gaming during recent years, games have become even more pervasive than before, and the average age of gamers has risen to 35 years with the average age of female players being 43 years, and for males the average is 35 years (ESA, 2015). But, elderlies are still an age group that is not among the typical gamers (e.g. Gerling et al., 2011A; Mäyrä and Ermi, 2014). According to Mäyrä and Ermi (2014), in Finland 73.6 percent of the population plays digital games in some form, the solitaire-type games being the most popular ones. In the age groups between 60 and 75 years the most popular games are single-player computer games followed by games played in browser. Mobile games (1.1.-1.6%), multiplayer games (0.0-0.6%) and console games (0.0%) are trailing far behind.

Allaire et al. (2013) did an interesting study about the effect of gaming itself to the well-being of elderlies. In their study they compared three group of elderlies, Regular Gamers (played least once per week), Occasional Gamers (played few times per month), and Non-gamers (did not currently play any games) to each other. From the sample of 140 elderlies that took part to their study, the Regular and Occasional Gamers had higher levels of well-being, lower levels of negative affect, and to some extent less depression. But, half of the games played by the gaming groups were digital versions of traditional card (e.g. solitaire) and puzzle games (e.g. Sudoku), not digital games in their usual meaning.

3. GAMES AND RESEARCH METHOD

In this section we describe the exergames that were implemented as a part of this study. Descriptions include reasoning for the design decisions and introduction to the technological choices made. The section about the research method includes the details of our participants and the tools that we used to collect the needed data about the games.

3.1 Game Design and Creation

To conduct our research, two games were created. Before the design and implementation were started, selection for the technology was carried. The intent was to implement motion controlled games, so the first choice was between the motion-detection candidates, Kinect 2 (Microsoft, Redmond, USA) and Extreme Motion (Extreme Reality, Israel). As we knew based on previous knowledge about our target group that they do not like overly complicated technology, we selected the Extreme Motion which uses a regular 2D web camera as its motion detector, instead of Kinect 2 which is a device made especially for motion-controlled games but requires its own power adapter. It should be also noted that Game A was also considered to be used for intergenerational gaming on outdoor parks. Technology used in Kinect 2 is based on infrared detectors, and outdoor environments are filled with infrared radiation coming from the Sun. Extreme Motion is not affected by the infrared, so it was also technically more feasible solution for this option.

The selection for the game engine was more straightforward, as it would save time to use something that was already familiar to the implementation team and that we knew that had all the required functionality. For this reason the Unity engine by Unity Technologies was chosen (http://unity3d.com).

First game, Game A, which is a motion-detection based exercise game was based on an idea of letting the elderlies to do light and simple exercises at their own living rooms. For this reason the game idea was required to be simple, so that the control mechanics would be easy to learn, and the game would not require extensive training or instructions.

The second game, Game B, started as a fast paced dance game, but this idea was pivoted to become a more targeted physiotherapeutic exercise than the Game A. Pivot was caused by experiences with the elderlies belonging to the target group. For this version of the game, physiotherapist selected movements that could be performed by most of the elderlies and which would be beneficial to wide target audience. The gamified design concerned mainly the visual look, means of feedback and motivational support provided by the game.

Design decisions were guided by previous research and groups experiences with elderlies in related research activities. Guidelines provided by previous research (e.g. Gerling et al., 2010; Gerling et al., 2011A; Join-In Project, 2011; Whitlock et al., 2011; Lohse et al., 2013) were used to adjust the games visual look and speed before iterative tests were started with the focus groups (suggested by Gerling et al., 2010). The development team behind the implementation of this game had previous experience with selected technologies, so technology selections did not impose additional limitations for the design. Players view to the implemented games are presented in the following Figure 1.

Figure 1. Game A (left) and Game B (right) from the player's point of view.

Game A was designed to activate the large muscle groups while also being a fun experience. In the game the player controls a boy with a scooter. The aim is to collect as many raspberries as possible while avoiding obstacles. The player can control character by moving himself in front of the camera. While the player moves left or right, character does the same. Character will move forward automatically and can also perform jumps and crouches if the player makes these movements. During the short level the speed of the character will gradually increase if he does not hit any obstacles. Hitting anything will also make the player lose some raspberries. After crossing the finish line, the player is given a number how many raspberries he managed to gather. For these test scenarios, mechanic that made character to lose speed and raspberries was disabled.

The aim of the Game B is to practice a set of physiotherapeutic gymnastic moves, engaging the player with visual feedback and relaxed environment. A tempo and an atmosphere of the game are deliberately designed to be calmer than in the game A. This game works as a body maintenance exercise more than a muscle exercise. The game gives most of the feedback for the player after the performance, so the player can focus on the exercise and the correct moves instead of their performance.

During the implementation process, both of the games were iteratively tested and modified to be more suitable for the elderly. The pace of the Game A was slowed down because the original speed was considered to be too hectic for the target group. During the testing, a function that made player lose a point when colliding on something was removed, so no-one would be left with zero points at the end of the game. Also the jumping was tweaked to be so sensitive that the players could perform it by only nudging upwards. This allowed the users with balance or joint problems to complete the game session without actually jumping upwards, which in some cases could be dangerous to their health. In Game B the user interface graphics needed a modification, as the original version was too unclear for the testers.

3.2 Participants

Inclusion criteria for the study participant required that they are over 60 years old and are able to complete the games safely. This limited the recruitment of elderlies with severe physical disabilities or problems with balance. Also elderlies with advanced memory related problems were excluded as they might have problems on remembering what they were doing or were doing before the questionnaire part of the research protocol.

The testing was carried out in two different settings; rural and urban. First testing session was arranged in urban area with c. 200 000 inhabitants in South-Western Finland where the participants were recruited from an activity centers and associations for elderly citizens. Urban testing was carried out during single day as all the participants were invited and scheduled before the event itself.

Second testing session was arranged in rural area with c. 2500 inhabitants in Eastern Finland. Here the participants were recruited beforehand by contacting local pensioner’s society and by advertisement in local newspaper. As the rural testing was conducted in time span of three days and it was not possible to know when and how many participants there would be, additional participants were recruited by asking the elderlies visiting the testing locations (facilities of local service home) to take part to the study.

3.3 Data Collection

Main interest of our study was to find out how the elderlies reacted to our games and what their experience was during the gameplay. Other interests were the overall usability and functionality of the games. Additionally we had small survey about the activities, exercises, relevant health problems and gaming habits that the participants had. As a part of this survey there was also the question for their consent for the team to record the session.

To get quantitative data about the games and their usability we used the System Usability Scale (SUS). SUS is a short 10 item questionnaire used to collect usability where questions are rated on 5-point Likert Scale (Brooke, 1996). As our systems were exergaming products, we modified the SUS questions to reflect this. In practice this was done by replacing the word “system” with “game” and “use” by “play” with required conjugations. As our results are used by larger interest group, the SUS scores were converted to grades by using the scale defined by Bangor et al. (2009).

The experience and reactions of the elderlies were collected by quantitative and qualitative means. The qualitative data was collected by using the Game Experience Questionnaire (GEQ) by Poels et al. (2007). GEQ is a multipart questionnaire aimed on exploring the players emotions related to various aspects of the game in question. These aspects include their feelings of competence as players, was the gaming experience negative or positive and how challenging the experience was to them.

Main parts of the questionnaire are the Core Module, Post-Game Module and the Social Presence Module for multiplayer settings. In total GEQ has 50 questions for players that played the game alone, and 67 to players who played game with one or more partners i.e. in a multiplayer setting. Components in these modules have a range from 0 to 4, and they represent the players’ self-reported view of their experience during the gameplay. These experiences can be positive ("I felt skillful") or negative ("I felt frustrated").

In addition to the quantitative data, qualitative data was collected in a form of observation notes, recordings of the gaming sessions and by interviewing the participants. All the sessions where we had the relevant consent, we recorded from two angles and observed by several members of the research team. Following Figure 2 depicts the settings in Urban setting on the left, and in the Rural setting on the right.

Figure 2. Setup of the gaming sessions, Urban (left) and Rural (right).

First camera was situated behind the player so that it could capture the players’ movements and the action on the screen simultaneously. Second camera recorded the movements and expressions of the player from the frontal view. This material was used to observe how well the players could follow the tasks presented on the games. The recordings were also used to inspect how the players used their bodies in different situations and how confident they were on their movements and actions.

All the sessions were observed by participating research team. In the Urban setting two of the team members were guiding the gaming part of the session and helped the participants with the filling of the questionnaires, while one member was observing the gaming part and doing the interview after that. In the Rural setting two of the team members were guiding the gaming part of the session, one helped the participants with the filling of the questionnaires, and two additional members were observing the gaming session from the side. These qualitative observations are used to support the interpretation of the questionnaire results and recordings. In both sites, the Game A was first for the odd numbered participants, and Game B first for even numbered participants. This made the switching between participants easier, and also mitigated the effect the fixed order of games could have on the opinions of the elderlies.

After the gaming session was over, the players answered to series of yes/no questions that acted as a themes for short interview. These questions were based on the quantitative STAM questionnaire (by Renaud et al., 2008) as it gave us a well-reasoned background related to our focus group. With these questions we conducted a short themed interviews of the participating elderlies to get their own opinions and thoughts about the games they just had played.

4. RESULTS

In total we had 19 participants with overall average age 72±11 years (n=19). In the urban setting we had seven participants (n=7, 3 female and 4 male), and in the second testing session in the rural settings we had 12 (n=12, 7 female and 5 male) participants. Age distribution was similar in both settings, and both genders were represented equally (10 female, 9 male).

All the participants were active elderlies who live independently, do not have trustee, and have a physically active life. In average they had light or moderate exercise for 1½ hours per day, including some guided exercise groups or activities. Daily activities included walking, cycling, gardening, and chores related on the upkeep of their houses. Guided exercises varied from gym exercising to water aerobics and group exercises.

As part of the presurvey we got information about our participants experience about digital games. Three out of 19 participants reported on playing Solitaire occasionally, and one of the participants used to play puzzle games on tablet computer. Otherwise digital gaming as an activity was something they had not tried ever, or they had just seen how their grandchild's were playing something with their devices. This is in line with the Mäyrä and Ermi’s (2014) report on digital gaming related to the elderlies.

Reported health related problems in this group included variety of problems with knees, hips and hands. Most severe problems were heart attacks which in practice meant that these participants could not raise their hands too high for prolonged periods of time or at all. One of the participant had a recent breast cancer operation and another one a shoulder surgery, which both prevented the use of one of their hand as the operations were quite recent and they still had stitches. Other mentioned problems included mild depression and cases of epilepsy. Participants did not report memory related problems or diagnoses.

4.1 System Usability Scale Scores

Previously a sample of at least 12 participants has been calculated as minimum to obtain sufficient data on the SUS questionnaire (Lewis et al., 2009). Our sample had an n = 19, so the sample size for the combined results fill this requirement for the reliability in the context of usability studies. The mean SUS score for Game A was 58.29 Ok/F, and for Game B 79.44 Good/C. Following Table 1 shows the SUS scores and grades for both games.

Table 1. SUS scores

	SUS	Min.	Max.	Median	Grade
Game A	58.29	30	80	62.5	Ok / F
Game B	79.44	45	100	81.25	Good / C

Based on the earlier SUS research, product evaluated with SUS should achieve around 70 points from the test to be considered to be ‘passing the test’ (e.g. 70 points in Bangor et al. 2009; 68 points in DoHHS, 2014). When we use these limits to evaluate Game A (58.29) and Game B (79.44), Game A fails to reach this level of minimum acceptable usability with this group of users.

When we analyze the SUS score on the level of individual questions, we find some key differences between our games. Game B gains its advantage on three questions; 3. “I thought that playing the game was easy”, 8. “I found the game very cumbersome to use” and 9. “I felt very confident while playing the game”. In these questions Game B was seen in much more positive light, while Game A was seen as cumbersome and complex.

4.2 Game Experience Questionnaire

GEQ has three parts that probe on different aspect related to the players experience with the game. The Core module which is split on seven components represents the players’ self-reported experience during the gaming session. Results of this module are presented on Table 2.

Table 2. GEQ Core (n = 19)

	Competence	Sensory and Imaginative Immersion	Flow	Tension / Annoyance	Challenge	Negative affect	Positive affect
Game A	1,47	2	1,85	0,49	1,29	0,3	2,4
Game B	2,3	2,36	2,25	0,14	0,78	0,07	2,75

Game B has favorable scores on all the seven components. It gets higher scores on four components that have positive connotations attached to them, and lower scores on the negative ones. Especially Game B receives high score on the Competence factor which represents the players feeling about how well she was doing during the gameplay. Challenge is a component that can be either positive or negative. In the case of Game B the score is lower, which can be interpreted that game was easier for the participants and/or that thanks to other factors like Competence, the participants did not notice the Challenge so much as with Game A. Overall, Game A was deemed to be more frustrating than Game B.

The Post-game module measures how the players feel about the game after the gaming session has ended. This module has four components on it, and these are presented on Table 3.

Table 3. GEQ – Post-game module (n = 19)

	Positive experience	Negative experience	Tiredness	Returning to Reality
Game A	1,76	0,23	0,31	0,6
Game B	1,989	0,06	0,21	0,5

Returning to Reality component represents the players return from the immersed state to the out of the game world. In this case the gaming sessions were short (typically under 15 minutes) and game world was not designed to be the immersive and total experience. These factors might render this component to be irrelevant, but Game A received higher value indicating that participants were more immersed on it. Game B is again coming out as more positive experience than Game A.

Social Presence module is used when game in question is played with co-player or players. In this case, seven of our participants played the game in pairs or in a group of three (n = 7). This module measures how the other player(s) affected the behavior and feelings of the questioned player. These results are presented on the following Table 4.

Table 4. GEQ – Social Presence module (n = 7)

	Psychological Involvement – Empathy	Psychological Involvement – Negative Feelings	Behavioral Involvement
Game A	1,5	0,32	0,45
Game B	1,323	0,51	0,3

Regarding the Social Presence both games scored quite low scores, but Game A had slightly better social impact. Accordingly, both factors related on the feelings towards the other player and their actions during the gaming session generated low scores. The observations during the gameplay confirmed that participants did not give notes to each other or learnt what to do to improve their performance in the game from each other. Observations also revealed that these games did not create shared gaming experience for the participants. This might be due the fact that the gaming sessions were short, so the participants did not have enough time to start commenting the actions of the other player or to take notes on what they were doing.

4.3 Interviews

The interviews were conducted by first asking a simple yes/no question that related to the games that were tested, and then elaborating the answer to a discussion about the reasoning for the answer. The results of the yes/no questions are on the following Table 5.

Table 5. Qualitative results

		Yes	No
Perceived usefulness	Could the playing of games be an efficient and easy way to do exercises?	17	3
Perceived ease-of-use	Was playing the games easy?	15	5
Gerontechnology self-efficacy	Could you play the games after you got the instructions? Would the instructions manual be enough?	17	4
Gerontechnology anxiety	Were you scared of making mistakes while you were playing the games?		19

The total amount of answers per question is higher than the number of participants we had. This is due the fact that many of them gave two answers, one for both games as they had differing experiences from them. In the case of perceived usefulness, the elderly thought that games could be useful way to do exercises. But, they almost unanimously preferred to do their exercises either on gym-like environment or by outside from their apartments. Exception to this was that several of them said that games could be useful when the weather conditions are bad and therefore it is not possible to do exercises outside.

Despite the reported negative feelings and frustrations related to the gaming sessions or notes about how they do not know how to use computers, after the gaming session our participants did not think that these games were difficult for them. In general the perceived ease of use was favorable, but some elderlies said that games are not designed for elderlies or for especially for them as individuals.

In the theme falling under the gerontechnology self-efficacy, most of our participants said that they could use the games without help, but it would create “of course” more problems and they would have to learn new skills. But they did not see this as a major problem and thought that they could learn to use the system after the initial learning period. Some of the elderly thought that they would require an assistance on the usage of this kind of a system at home as they were not accustomed to use technology.

In spite of the challenges with technology, games and health, gerontechnology anxiety was unanimously dismissed. Our participants did not fear the technology or about making mistakes with the games, instead they noted that the ‘fear’ they felt was about losing points in the game.

The participants were also given a chance to tell their own opinions freely about the gaming session they had participated on. On these comments they commented on how in general exercising is a good thing for their age group as it keeps them active and also helps them to stay healthy. The gaming as an activity was commented to be something that they had not tried and experienced previously, but it had been an interesting experience nevertheless.

5. CONCLUSION

Our goal is to activate elderlies that are not already actively engaged in physically demanding activities. To achieve this goal, we have built on the experiences of previous projects done by others (e.g. such as Join -in, 2011; Gerling et al, 2011A) and by us with the elderlies in our other activities. Game A and B have been our first games that were tested with the participants that belong to our targeted age group. From these games we have learned what kind of things seem to work with our target group and what does not work. To remedy the problems we found during the testing, we have redesigned these games and also produced a new game with updated specifications. Among the changes this new game has more familiar setting for the elderlies which they seem to like based on our first tests.

We had designed the games to have clear graphics without a screen clutter which is seen on games aimed for younger players. Despite our efforts, the participants still had problems with knowing what they should avoid and what they could collect on the Game A. In the players path there are fallen trees and rocks that they should either avoid or jump over, but this was not clear to them despite the effect caused by the collision. Also, the game has raspberries that they should collect to get points, but several elderlies told in the interviews that they did not know that, and that they tried to avoid them. The graphics problem might be partially caused by the unfamiliarity of the activity represented in the game A as the interviews and comments by the elderlies during the gameplay revealed their confusion about these matters.

The speed in which things happen on the Game A was also a problem, albeit the game was significantly slower than the original version which was designed for the intergenerational and was pretested with elderly players.

Game B had a virtual instructor whose movements' player should match, and a graph that showed what kind of movements will be coming after the current one. This caused confusion as some of the participants were not sure which one to follow, or they missed the correct movements because the information provided by the graph grabbed their attention. In Game B players have to raise their hands several times above their heads as part of the shoulder exercises. This was a problematic procedure for several of the participating elderlies, and prevented them from completing the required movements and caused frustration. These problems are addressed in the new version of the game where e.g. the indicator for the upcoming motion has been removed to provide only necessary information for the current movement.

We also learn valuable lessons in conducting gaming related tests with participants that are not familiar with such activities. By nature our games are quite short, which means that if participant is not familiar with similar type of games, their first runs will be all about learning and familiarization. They will be also very conscious about their surroundings and the observers, making the situation more artificial than it already is in terms of gameplay. In the future field tests, the gaming sessions should be longer. The longer sessions might help the participants to relax and immerse more on the game as they have more time to learn the game. Longer sessions also increase the portion of gaming versus the questionnaires. With this setup they had few minutes of gameplay and after that they spend 15 minutes or more filling questionnaires and answering to questions.

SUS is a simple tool for measuring basic usability of a software-based artefact, and it proved to be usable and informative also with the elderlies and exergames, mainly thanks to its brevity. GEQ in other hand was a questionnaire which contains 50 or in case of multiplayer situation 67 questions. The length of the GEQ brought up questions and comments from the participants during the testing sessions (e.g. "When this questionnaire will end..?", "How many questions there are left?"). The length of the GEQ was commented on Gerling et al. (2011B), but we used in during these tests as it was used in pretests, and in there it did not cause noticeable problems. In future the game experience research with elderlies, or with other people who do not play games regularly or at all, would benefit from a shorter and more understandable questionnaire.

Additionally, GEQ also has several questions that are unfamiliar to persons who have not played games or are not fitting for games in exergaming genre. In example, questions about if they felt shame or regret during gameplay, or if they were interested about the games story felt weird and confusing to elderlies. Partially our own setup also caused incompatibility with GEQ as the short playtime did not allow them to immerse themselves in the game and answer to some of the questions related to the immersion component.

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