

Lessons Learned from the Gamified Solutions in Healthcare Project: Usability Studies of Digital Game-based Physical Exercises for Elderly People

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Abstract

In this paper, we report the usability lessons learned from the usability studies of digital game-based physical exercises for elderly people. We conducted four usability studies of digital games for elderly people's physical exercise activities in Finland and Japan. The usability studies include the evaluation of commercial digital games (e.g. Microsoft Xbox game), the existing in-house game by Puuha Group Finland (e.g. SportWall), the Finnish, and Japanese usability testing of the Skiing game. We used both quantitative (e.g. questionnaires) and qualitative (e.g. observation and interviews) methods to understand the elderly participants' user experiences in playing digital game-based physical exercises and the usability problems of the games. Based on the findings from the analysis of data, we discuss the important usability lessons that should be taken into consideration while designing digital game-based physical exercises for elderly people. The discussion in this paper can provide insights for game designers and developers into design and development of digital game-based physical exercises for elderly people.

Keywords: exergames, usability, game design, human-computer interaction, gerontechnology.

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1. Introduction

In recent years, digital games have been used as a tool to promote elderly people's quality of life in terms of physical health, cognitive well-being, and social connectedness [1, 2, 3, and 4]. People (e.g. researchers and healthcare practitioners) have used digital games to encourage and motivate elderly people to engage in regular physical exercise activities that lead to active ageing [5]. In the context of physical rehabilitation, digital games have shown promises to improve elderly people's balance and motor skills, as well as reduce risks of fall [6]. Healthcare practitioners such as doctors, nurses, and therapists have used game-based intervention for elderly people's

cognitive impairment as an alternative approach to conventional rehabilitation [7]. In addition, digital games are also used to promote elderly people's social connection and communication with others such as family and friends. As an example, digital games are used for the intergenerational gameplay between older people and younger people. According to [8], intergenerational games can improve social bonding between older and younger generations. The literature shows that commercial games available in the market also have been used to improve elderly people's physical, social, and cognitive well-being. For instance, Nintendo Wii Sport games and Microsoft's Xbox Kinect-based Fitness games showed the potential for promoting elderly people's socialization and physical healthcare [8, 9, and 10].

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In the existing literature, there have been a relatively few studies about the usability and usefulness of digital games for elderly people. However, this research area is relatively young, compared with the traditional Human-Computer Interaction (HCI). Thus, more studies need to be undertaken to understand elderly people's user experiences and the usability of digital games for them. By understanding elderly people's user experiences in playing digital games, designers and developers can create more usable, useful, and user-friendly digital games for elderly people.

Ijsselsteijn et al. [11] point out that elderly people are at a higher risk of facing more usability problems in using technology, compared with the younger users. The authors also highlight that game developers today are paying more attention to younger audience, and most of them are not aware of basic guidelines for game usability and accessibility for elderly people [11]. These challenges can be addressed by conducting extensive usability testing with elderly or older users. Garcia et al. [12] advocate that the use of digital games for elderly people's healthcare has shown positive outcomes, but it is critical to expand the study of usability and suitability of digital games for them.

In this paper, we report the usability lessons learned from the Gamified Solutions in Healthcare project in which we conducted four usability studies of digital game-based physical exercises for elderly people. The usability studies include the pilot user testing of commercial games (e.g. Microsoft Xbox games) and existing game (e.g. SportWall game), and the evaluation of the Skiing game with the Finnish and Japanese elderly people in Finland and Japan. These usability lessons were observed and identified through the observational study, interview, questionnaires, and the elderly participants' feedback and comments towards the games in different usability studies. We discuss each usability lesson and why it is important in designing digital game-based physical exercises for elderly people. These usability lessons can provide insights for game designers and developers into designing digital games for elderly people's physical exercise activities.

2. Gamified Solutions in Healthcare (GSH)

Gamified Solutions in Healthcare (GSH) is a collaborative project between the Turku University of Applied Sciences and the University of Turku in Finland. In GSH, we aim to provide gamified services or digital game-based solutions for elderly people in Finland. These services include socialization, rehabilitation, entertainment, and counselling services. In this paper, we only focused on the rehabilitation service, which uses digital games to promote elderly people's engagement and motivation in doing physical exercise activities. To design and develop game-based rehabilitative services for elderly people, we applied the User-Centered Design (UCD) approach, which includes major four stages: requirements gathering, design and analysis, prototyping, and evaluation.

For requirements gathering, we conducted a number of pre-studies, including interviews, observations, pilot usability testing of an existing game and commercial digital games for elderly people and literature review [13, 14, 15, 16, 17, & 18]. For prototyping, we designed and implemented the digital game-based Skiing game for elderly people. Then, we evaluated the digital Skiing game with the Finnish elderly participants in Finland, as well as the Japanese elderly participants in Japan. In this report, we analyzed and compiled the findings from four different usability studies, including two pilot usability testing of commercial games and SportWall game, and two usability studies of the Skiing game.

In each study, we observed and collected the data about the elderly participants' user experiences and usability issues that they encountered in playing digital game-based physical exercises. To identify elderly participants' user experiences and usability issues, we applied participants observation technique, video recording, and note taking in all studies. Then, we analyzed the data by using the qualitative analysis method and tools (e.g. NVivo). Based on the findings from the qualitative data analysis, we reported the lessons that we have learned from the usability studies of GSH project. These usability lessons can provide insights for game designers and developers in designing digital game-based exercises for elderly people.

3. Usability Studies

3.1. Usability testing of commercial digital games

We conducted the pilot usability testing of commercial games with the Finnish elderly participants in Finland. In this pilot testing, we used Microsoft Xbox Kinect-based Climbing and Bowling game, and PlayStation's PlayMove Tennis game [16]. We conducted this study at a summer sport event in Finland. Then, we tested the commercial games with 12 elderly participants. During the study, the elderly participants randomly played three games. After the gameplay, we asked questionnaires and open-ended interview questions to each participant to understand their experiences and usability problems in playing games. We also observed their gameplay by using a video recorder and by taking notes during the study.

3.2. Usability testing of commercial and SportWall games

We conducted another usability testing of commercial and the existing games (e.g. SportWall game) at two elderly service homes in Finland. For commercial games, we used Xbox Kinect-based Climbing game and PlayStation's PlayMove game. For the existing game, we used SportWall game developed by Puuha Group Finland (See Figure 1). The SportWall game is a motion-based game that uses a

traditional webcam using Extreme Reality technology. In this game, the elderly participants played a simple skateboarding activity by using body movements. In this study, we recruited two elderly groups: functionally independent elderly group and least independent elderly group. The functionally independent elderly group includes the elderly people who perform physical exercises daily or weekly, and they are relatively active in social activities. For the least independent elderly group, they are physically weak, and they rely on therapists and caregivers to do their activities of daily living (ADLs). In general, this elderly group is socially inactive.



Figure 1. The SportWall game

Firstly, we conducted the usability test with five elderly participants from the functionally independent group. They played all three games in this testing. After they have played each game, we asked the elderly participants regarding the usability of the game by using questionnaires. We conducted a general interview session after they have finished playing all games. We followed the same procedure for the second elderly group who are the least independent. We observed the elderly participants' gameplay by using a video recorder. Figure 2 shows the usability testing of SportWall game.



Figure 2. The usability testing of the commercial game.

3.3. Usability testing of the Skiing game with the Finnish elderly participants

We evaluated the digital Skiing game with 21 elderly participants in Finland [17]. The study took place at one of the elderly service homes in Finland. The Skiing game is basically a webcam-based motion activity game. We used Extreme Reality technology in this game to detect the elderly participants' movements. The gameplay is based on a simple skiing activity by using body movements. In this usability testing, the elderly participants played the game for 20 to 30 minutes. Then, we asked usability questionnaires and open-ended interview questions to all elderly participants after they have played the game. We used a video recorder to capture elderly participants' user experiences and usability issues that they encountered in the gameplay. Figure 3 shows the usability testing of the Skiing game conducted in Finland.



Figure 3. The usability testing of the Skiing game with a Finnish elderly participant.

3.4. Usability testing of the Skiing game with the Japanese elderly participants

We also conducted another usability testing of the Skiing game in Japan with 24 Japanese elderly participants [18]. The main objective of this usability testing is to understand the Japanese elderly people's feedback towards the usability of the game. We followed the same procedure that we used in the usability testing of the Skiing game in Finland. The elderly participants played the game, followed by the general interview session and questionnaires to investigate their user experiences and the usability of the game. We observed the elderly participants' gameplay by using a video recorder and taking notes during the gameplay. Figure 4 shows the usability testing of Skiing game in Japan.



Figure 4. The usability testing of the Skiing game with a Japanese elderly participant.

4. Usability Lessons

In each usability study, we analysed the data by using the qualitative analysis method and tools (e.g. NVivo) to find out the elderly participants' user experiences and the usability issues that they encountered during the gameplay sessions. We analysed the data collected from various sources, including video observations, note taking, interviews, and questionnaires. Based on the findings from the qualitative analysis, we identified the most important usability lessons that we have learned from each usability study. Then, we compiled these lessons and analysed again by categorizing the similar patterns. Lastly, we reported the most important usability lessons that we learned from different usability studies of digital game-based physical exercises in the GSH project.

Game tutorials and calibration should be simple and easy for elderly people to follow. Game tutorial is an important part of digital game-based physical exercises for elderly people so that they can easily learn how to play the game without difficulties. In commercial games, game tutorials are provided for elderly people to learn how to play the game. However, these tutorials are not easy and user-friendly for elderly people to follow. In the usability evaluation of the SportWall game [16], we learned that the elderly participants could not follow the instructions given in the game tutorial. As a result, the researcher had to guide them how to play the game. The elderly participants also provide feedback in the interview session that the game tutorial should be easy for them to understand and follow. Thus, in designing digital games for elderly people, designers and developers should take into account how to design effective and user-friendly game tutorials for them.

Game calibration is also an important game feature for the individual elderly player so that he or she can personalize the game according to his or her physical capabilities and needs. For instance, in the calibration of the Skiing game, the elderly participants needed to raise their hands so that the webcam can detect their movement and trigger the game. According to the findings from the usability testing of the Skiing game with the Finnish and Japanese elderly participants [17, 18], we found that most

of them could not follow the instructions to calibrate the game before they play. Consequently, the researcher had to guide them in calibrating the game. Based on this lesson, we suggest that in designing digital game-based physical exercises for elderly people, it is important to take into consideration how game calibration and tutorial can be designed to be simple, easy, user-friendly, and effective for elderly people.

Game instructions and feedback should be user-friendly for elderly people. In the physical activity games (e.g. Skiing game), we used simple instructions and labels for the elderly participants. However, we found that it cannot provide clear instructions and feedback that the elderly participants can easily understand the status of the game such as their achievements in the game, in-game instructions, and how to proceed to the next step. For instance, in the Skiing game, we used simple and short text-based instructions. However, according to the findings from the usability testing, we observe that it was a challenge for the elderly participants to understand the game instructions, and they needed the assistance from the researcher. With regard to the game feedback, we used different metaphors in the game such as icons, audio feedback, and animation. Nevertheless, we realize that the feedback in our games is not intuitive enough for the elderly participants to understand what it means. Therefore, we suggest that in designing physical game-based exercise games for elderly people, it is important to design and develop simple but effective game instructions and feedback for them.

Repetitive game actions can decrease the elderly participants' interest in the game. Game designers and developers design digital games to be suitable and relevant for elderly people. Sometimes, we may underestimate their abilities in playing digital game-based exercises. Therefore, we design digital games, which include simple and easy gameplay and interaction for elderly people. Consequently, elderly people may find digital games less interesting. Furthermore, poor game design can make elderly people feel less interested and motivated in the game. Furthermore, they might feel bored after they have played the game for a certain time. We may design simple and easy game actions for elderly people by taking into account their limited functional abilities. As a result, when they perform a particular game action repetitively for a certain time, it may become monotonous for them, and they may feel less motivated and even discouraged.

In the Skiing game, we designed the game action of the skiing activity for elderly people. The elderly participants move both hands forward and backward to play skiing activity. According to the findings from the elderly participants' feedback towards the Skiing game [16], we found that repetitive game actions made some elderly participants bored in the gameplay. The findings from the interview session [16] show that the elderly participants prefer to play different game actions, and it can make them feel more motivated. Furthermore, we also find that the elderly participants like game activities that can be related to real-life activities such as bowling, biking, and playing

tennis. Based on this, we recommend that we should take into account designing different real-world game actions for elderly people to play so that they may be more motivated and engaged in the gameplay.

Fun factors are important in digital game-based physical exercises for elderly people. The main objective of designing digital game-based exercises for elderly people is to improve their physical well-being, as well as to create a fun and entertaining activity for them. In our study, most elderly participants in the usability testing of the commercial and existing games gave positive feedback towards the games, and they mentioned that the games are fun to play. For instance, in the usability testing of the Skiing game with both Finnish and Japanese elderly, we observe that Skiing game-based activity is enjoyable for them because most of them enjoy skiing activity in the real world when they were young [17, 18].

According to the findings from the usability testing of digital game-based physical exercises in the GSH project, we found that some elderly participants claim that physical activity games are not fun because they encountered negative experiences in playing game. For instance, in the usability testing of PlayStation's PlayMove Tennis game [16], we found that most elderly participants encountered usability problems in using the controller. As a result, they mentioned that playing Move Tennis game was not enjoyable for them although some of them expressed that they like to play tennis. The fun factors in physical activity games can depend on many factors, including game context, contents, interaction experience, and gameplay. Based on this lesson, we suggest that in designing digital game-based physical exercises for elderly people, we should take into account different factors (e.g. game design, story, and play) that can have an influence on elderly players' enjoyment in the gameplay.

Social elements are important in digital game-based physical exercises for elderly people. Social contact is important for elderly people to remain active in society at an old age. In the existing literature, scholarly studies reported the positive effects of social and intergenerational games on elderly people's social connectedness with others [8, 19, and 20]. In commercial, there are different types of social-based games that have the potential to improve elderly people's socialization, including multiplayer game, online games, intergenerational game, and competition games.

In the SportWall and Skiing game, being first generational prototypes, we did not integrate social elements in these games. Furthermore, in the usability testing, there was no co-gameplay for them. According to the findings from the interview sessions in the usability testing, most elderly participants expressed their interests in multiplayer or co-gameplay. The therapists and caregivers involved in our usability testing also insist that the game system should allow the elderly participants to play together so that they can improve their social bonding among peers. Therefore, we suggest that integrating social elements in designing digital game-based exercises for elderly people is important.

Interaction techniques and devices should be user-friendly for elderly people. In commercial games, there are different types of interaction techniques that elderly players can use to play games such as traditional controller (e.g. Xbox game controller), touch-based interaction (e.g., mobile phones), stylus-based interaction (e.g. stylus for iPad), motion-based interaction (e.g. Microsoft Kinect), and device-based interaction (e.g. Wii balance board). In the usability testing of digital game-based exercises in the GSH project, we used different types of interaction devices that include Microsoft Kinect, PlayStation's Move controller, and webcam-based Extreme Reality Motion detection technology [16].

Based on the findings from the usability studies, we realize that controller-free interaction technique is easy and effective for the elderly participants. We also observe that the elderly participants' interaction experiences can have an impact on their gameplay. For instance, in the usability testing of the PlayMove controller, most of the elderly participants reported that they had difficulties in using this controller. As a result, they could not enjoy the gameplay. Based on this usability lesson, we suggest that it is important to consider what type of interaction technique and devices will be effectively used for digital games for elderly people's physical exercises before we design games.

Game graphics should be simple and user-friendly for elderly people. Game graphic plays an important role in a game system. When we design physical activity game for elderly people, it is important to understand what type of graphics elderly people prefer. According to our pre-studies [13, 15], we found that graphical contents in commercial games are not appropriated for elderly people, and cluttered user interface with sophisticated graphics can make them confused in their gameplay.

For instance, in the Xbox Kinect-based Climbing game, the graphical representation is cluttered, and as a result, sometimes the elderly participants were distracted in the gameplay. The findings from the pre-studies of GSH highlight that the elderly participants prefer game context and contents that can be related to the real-life environment and activity. As an example, they prefer card games, bowling, and sport-based games. Thus, in designing the Skiing game in the GSH project, we used snowy mountains and skiing activity as game context and contents because most of the Finnish elderly people enjoyed skiing activity when they were young. In the usability testing of the Skiing game, we found that the elderly participants enjoyed doing game-based skiing activity. Therefore, in designing digital game-based exercises for elderly people, we recommend that the graphical representation of a game should be simple and user-friendly.

Game music and sound should be appropriate for elderly people. Generally, commercial games use game music and sound that is more appropriate for younger players. Choosing appropriate game music and sound in designing digital game-based exercises for elderly people is important so that they can engage in the game. To our knowledge, there are very limited or no studies that

investigate elderly people's preferences in-game music, especially for digital game-based exercises. Based on the findings from our pre-studies [13], we realize that the elderly participants do not prefer noisy game background music and audio feedback, especially in commercial games. It can make them distracted in their gameplay. We generally assume that elderly people may prefer old-fashioned music and songs. However, there is no evidence that they will prefer that kind of music in playing digital game-based exercises. Thus, we recommend that it is important to understand elderly people's preferences in-game music and audio feedback when we design digital game-based physical exercises for them.

Game scores and rewards should be meaningful for elderly people. Designing meaningful game scores and rewards is an important step in digital game-based exercises for elderly people. In commercial games that we used for our usability testing, we observe that the game scores and rewards are not intuitive for the elderly participants. For instance, in the SportWall and Skiing games, we used simple scores that display digits and text-based descriptions (e.g., "Excellent", "Try again"). According to the findings from the usability testing, we found that the game scores and rewards showing in graphical icons such as points, coins, and money, are not intuitive enough for the elderly participants because they do not understand what these scores and rewards mean. As a result, most of them do not know their performance and progress in the gameplay. Therefore, when we design digital game-based physical exercises for elderly people, it is important to consider how to design simple and effective game scores and rewards that are easy to understand.

Most elderly people do not know the status of the game. The findings from the usability testing of commercial games in the GSH project show that the elderly participants sometimes have lost their focus in the game because of the cluttered user interface, unclear game labels, and noisy audio feedback. As a result, we observe that most elderly participants cannot proceed to the next action in the game. As a result, they need someone's help to be able to move forward in the game. Another usability issue is that most elderly participants cannot pay attention to the rewards or points to collect. Thus, they miss the opportunities to improve scores and points. The same situation happens in avoiding obstacles in the game. Because of these distractions, sometimes, the elderly participants cannot avoid the obstacles, and it delays them to move forward. Therefore, in designing digital game-based physical exercises for elderly people, it is important to design simple and clear game context and content, effective game actions, intuitive game instructions, and appealing reward system so that they can be more engaged in the game itself.

Elderly people do not know their goal in the game. Another usability issue that we identified in our usability testing is that the elderly participants do not know where they are heading to in the game. They do not know what their goal in the game is. Generally, most commercial and existing games lack providing intuitive and easy-to-

understand information about their progress and showing their goal in the game. Based on the observation in the usability testing, we found that most elderly participants were not aware of game-level increment in the gameplay because they lack the experiences in playing digital games, and sometimes games are not intuitive enough for them to understand what will happen next or what to do next. As a result, most elderly participants have lost themselves in the game. Therefore, we recommend that it is important to provide simple and intuitive information for elderly people to understand what is happening in the game and what will happen next.

Elderly people do not know what will happen next in the game. Most elderly participants in our usability testing do not realize what to do next after they have played the game. For instance, if they have to choose "Play Again" or "Menu" options in the game, they may not be aware of selecting a particular option to move forward. Therefore, they always need help from a researcher or caregiver to help them to continue the play. Therefore, we recommend that the intuitive design is important in designing digital game-based exercises for elderly people to understand what to do next in the game.

Long-term effects of physical activity games for elderly people is important to investigate. Although the literature shows that digital games are promising to improve elderly people's physical fitness and their engagement in exercises, it is still questionable how physical activity games can have positive effects on elderly people's physical well-being. Generally, most of the usability testing takes only a few weeks or months and there are only a few studies that conduct the longitudinal study to investigate the effectiveness of physical activity games on elderly people's physical health. Furthermore, it is still unclear how elderly people can know their improvements in doing regular digital game-based exercises.

The existing digital game-based exercises cannot support the auto-assessment system that can report the progress and health information of elderly people. To date, most of the commercial and existing digital game-based exercises rely on physiotherapists to assess elderly people's performance through traditional methods being used in physiotherapy. In the usability testing of the GSH project, we conducted a short-term study to investigate the usability of the games and the elderly participants' feedback towards the game. Moreover, currently, the games cannot perform auto-assessment to the elderly participants' physical improvements in terms of their balance, mobility, and motor skills. Therefore, when we design physical activity game for the elderly, it is important to investigate the long-term effectiveness of the games on elderly people. More importantly, we suggest that digital games should provide the auto-assessment to elderly people's improvements.

Digital game-based physical exercises cannot be easily operated by elderly people alone. In the usability testing in the GSH project, all the game devices and consoles for digital games for elderly people's physical exercises were operated by the researchers. We observe

that it is not simple and easy for the elderly participants to operate and play the game alone. For instance, to play the Skiing game in our study, they need to switch on the computer, TV, webcam, and game software. After that, they need to select games through the game menu. They also need to calibrate and configure game setting before they play the game. All these steps are not easy for the elderly participants to operate alone. It can be achievable only with the support from someone who can help the elderly participants. Therefore, it is an important usability issue how we can design a simple and intuitive device or console that can be easily operated by elderly people by themselves.

We do not know whether elderly people will play the game again. It is the most important question in our study. Most of the usability testing took place for a week or more. After that, the elderly participants do not continue to play although most of them showed their interests to continue to play the game. There are many factors to be considered to create such game-based activity sessions for elderly people. For instance, there must have someone who can operate the game and monitor elderly people's gameplay. Furthermore, most of the digital game-based exercises are not ready for elderly people to play at home individually. Thus, it is a good question to ask how to design and develop the game for elderly people to play for long-term and home-based activity.

5. Conclusions and Future Work

In this paper, we report the usability lessons that should be taken into consideration when we design digital game-based physical exercises for elderly people. The discussion about the usability lessons in this paper is based on the experiences, findings, and observations from our usability testing of digital game-based physical exercises for elderly people in the GSH project. These findings are insightful and helpful for us to consider for further game design and development. Furthermore, we aim at sharing our knowledge to game designers, developers, and practitioners who are working in the same area of digital game-based physical exercises for elderly people.

In our future work, we will address the usability issues that we have identified in the usability testing of the games in the GSH project. Then, we will design and develop a physical activity game system, which is comprehensive, intuitive, easy, user-friendly, and effective for elderly people's physical activity. Furthermore, we will evaluate our games with elderly participants in different countries, including Finland, Japan, Singapore, and other partners in Asia.

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