# Pre-studies on Using Digital Games for the Elderly's Physical Activities

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**Abstract.** In this paper, we report the findings from the pre-studies of Gamified Solutions in Healthcare (GSH) project, which include a literature review, a review of commercial games, and a pilot usability testing of Kinect and existing physical activity games for the elderly. We conduct a literature review of motivational factors for the elderly in physical rehabilitation. We also review commercial games in the market. Then, we conduct a pilot usability testing of Kinect for Xbox One with eight elderly participants. From the findings from the literature review, we learn game design guidelines to motivate the elderly. The findings from the pilot usability testing of Kinect show that some of the built-in gestures in Kinect are hard for the elderly at the first time. However, it seems that it can improve through adequate training and support. Pre-defined simple and user-friendly gestures may help the elderly to be more effective and efficient in their interaction experiences with Kinect. Regarding the pilot usability testing of existing games, we evaluate Puuha's SportWall game and two commercial games (Xbox's Climbing game and PlayStation's Tennis game) with five elderly participants. From the findings from this usability testing, we learn insightful usability and game design guidelines for our future game development. In general, the findings from these pre-studies help us to understand the potentiality, usability, and usefulness of digital games for the elderly's physical well-being.

**Keywords:** Usability, exergames, gamification, human-computer interaction.

## 1 Introduction

Digital games today are no longer seen as just a form of entertainment. They have been using in various areas such as edutainment (education and entertainment), gamification for business (game-based business activities), healthcare, social media, and even military training. Digital games seem a promising tool to improve the elderly's social, physical, and mental well-being. Researchers in related areas (e.g., digital media and serious gaming) are continuously investigating the impact of digital games on the ageing society in terms of quality of life, safety, physical wellness and

rehabilitation, and social connection. Not only game developers and researchers but also healthcare professionals –doctors, nurses, and therapists – are increasingly interested in using digital games in the context of healthcare such as rehabilitation, physical training, recreation, and cognitive training.

There are several major areas where researchers are currently paying large attention to understand the effects of digital games on the ageing society. For instance, they are trying to use digital games to improve the social connectivity of the elderly such as intergenerational games, multiplayer games, and networked games. Furthermore, they try to use digital games as an engaging platform for the elderly where they can do their physical exercises and rehabilitative training. Digital games are also used as a recreational tool for the elderly to create positive emotions and motivation. For example, chess, bingo, yoga-based exercises games, and card games are used for the elderly as recreational activities.

In our current project Gamified Solutions in Healthcare (GSH), we emphasize the areas of socialization, rehabilitation, entertainment, and digital counseling services for the elderly. In this paper, we report the background of GSH project, present a literature review followed by a review of existing commercial games and technologies, and a pilot usability testing of Kinect for Xbox One and existing games. The main objectives of this study are as follow:

- To understand motivational factors for the elderly in designing games for physical rehabilitation,
- To investigate the potentiality of existing commercial games and technologies for the elderly's physical rehabilitation,
- To find out the usability of Kinect for Xbox One for the elderly, and
- To investigate the usability of Puuha's game and existing commercial games.

## 2 Background

Digital games can be regarded as a form of socialization for the elderly when they play games with peers, friends, and family members. Playing games can help them to improve the quality of life, especially for the elderly who have often engaged in the leisure time and activities [1]. In recent years, there is an emerging trend of "intergenerational games" which involves a gameplay between the elderly (e.g., parents and grandparents) and younger generation (e.g., children and grandchildren) [1]. The purpose of intergenerational games is to improve social connectedness between older and younger people as it can bridge the social gap between two age groups. One of the promising positive effects of the use of intergenerational games is that young people can have positive attitudes towards older adults when they have a tight social tie with seniors [2]. Moreover, it can prevent segregation between older and younger groups [3] and they can exchange strong social and emotional support each other [4]. There are other types of social games for the elderly such as online social games for the elderly [5], Nintendo Wii as an entertaining and socializing tool

[6], and social exergames for the elderly [7].

Digital games can be used to improve the physical fitness of the elderly. In stroke rehabilitation, therapists use digital games to improve patient's physical strength to regain mobility and to overcome functional deficits of upper and lower limbs. It can be used as an alternative tool to motivate the elderly to be more engaged in the regular exercise routines which are generally monotonous. Pyae et al. [8] designed and developed an augmented reality based rehabilitation games that include Activities of Daily Living (ADLs) games for the elderly stroke patients to train them to regain functional ability. They tested the game system with the elderly patients and report that elderly patients were more motivated and engaged in the therapeutic training after playing two-week game-based sessions. Marinelli and Rogers [9] advocate that exergames can help the elderly to improve their levels of physical activities that lead to positive health benefits. Kahlbaugha et al. [10] investigated the effects of compensatory strategies that were offered by Nintendo Wii on the physical activity, loneliness, and mood of elderly. They report that the elderly group who played Wii during the ten-week study had lower loneliness and a greater positive mood. There are other types of game applications that are targeted for the elderly's physical activities such as Nintendo Wii for the elderly [6], Dance Dance Revolution (DDR) system [11], and robot games for the elderly [12].

Regarding digital games as recreational activities for the elderly, Pyae et al. [13] point out that leisure activities such as playing board games, physical-based digital games (e.g., Wii Bowling), singing songs, participation in social events and activities, and shopping, are regarded as motivational factors for the elderly in their older life. By using latest technologies, people design digital games that can enhance the elderly's experiences in doing leisure activities. For example, in some senior homes, caregivers use Nintendo Wii Sport games (e.g., Wii Tennis). Moreover, they use computer-based board games, card games, and cognitive games (e.g., mobile based puzzle games) for leisure activities.

In Gamified Solutions in Healthcare (GSH) project, the core concept is "Virtual Nursing Home", which consists of four services: Socialization, Rehabilitation, Entertainment, and Counseling respectively. In this study, we focus on "Rehabilitation" service, which aims at promoting the elderly's physical well-being by utilizing game-based exercises. To design and develop effective and efficient game-based exercises for the elderly, we formed our research agenda as follow:

- To conduct a literature review on digital games for the elderly,
- To review existing commercial games,
- To conduct usability testing of existing and commercial games,
- To design and develop game-based exercises for the elderly based on the findings from pre-studies, and
- To conduct usability testing of game-based exercises for the elderly in both Finland and foreign countries.

According to our proposed research agenda, we firstly conducted the pre-studies

that includes a literature review, a review of commercial games, and a usability testing of Kinect and existing games. In the following sections, we report the pre-studies and the findings from each study.

## 3 Pre-study 1: A Literature Review

Motivation plays a key role in rehabilitation and physical exercises. It is also regarded as a driving force for the elderly to be more engaged in physical exercises and rehabilitative training. Based on the findings from the literature review, we investigated the important factors that can influence on the motivation level of the elderly. Social functioning (e.g., social connection and social engagement) is regarded as one of the most important factors for the elderly's motivation [14, 15, 16, and 17]. When we design games for the elderly, we can create multiplayer games, intergenerational games, and networked games to improve their socialization. The relationship between therapist and the elderly is vital. It can have a great influence on patient's level of motivation [14, 18]. In designing games, we can create a virtual therapist or virtual caregiver in the game to communicate with the elderly. Having a personal goal in older life is one of the motivational factors [19]. We can create game that has a goal-oriented level design to attract players from novice to professional levels.

Rehabilitative environment and setting are an important factor for the elderly's motivation [20]. Thus, when we design digital games for physical rehabilitation, we can design elderly-friendly game context or environment (e.g., household environment, park, and shopping mall). In physical rehabilitation, individual motoric level can be different from one player to another. That is why, the customization or calibration system is important in rehabilitation [21]. When we create digital games for the elderly's rehabilitation, we need to take into account that customization or calibration is necessary so that they can meet their individual needs in playing games. There are other important motivational factors for the elderly and their rehabilitative activities such as meaningful rehabilitative tasks [22], information from healthcare professional [22], positive feedback and encouragement from therapist [23], music for rehabilitation [24], and recreational and leisure activities [25]. All the motivational factors are useful and insightful for game design and development. Moreover, these findings can be useful when we design services in VNH concept. The detailed discussion of this section is mentioned in our previous study [13]. Table 1 shows the motivational factors for the elderly and proposed game design in developing motivation-driven games for the elderly.

**Table 1.** Motivational factors and game design.

| Motivational Factors | Game Design Consideration |
|---|---|
| Social Functioning | - Multiplayer game<br>- Intergenerational game<br>- Virtual friend<br>- Video chat in game<br>- Social-networking game |
| Patient-Therapist Relationship | - Virtual therapist<br>- Virtual nurse<br>- Virtual Coach |
| Goal Setting | - Level design<br>- Perceivable and achievable goals |
| Rehabilitative Setting and Environment | - Game theme and scenery<br>- Difficulty of the game<br>- Complexity of the game |
| Information from Healthcare Professionals | - Game tutorials<br>- Game introduction<br>- Help system<br>- Computer-controlled assistant |

## 4 Pre-study 2: A Review of Commerical Games

In this study, we review existing games available in the market and research. First of all, we can find a number of digital games in the market that support multiplayer gameplay. For instance, Nintendo Wii Tennis supports multiplayer gameplay in which two players can play the game together. In this way, they can not only play the game but also socialize through the gameplay. Moreover, the Wii Sports games are promising for intergenerational game and it is suitable for the elderly to play. Theng et al. [6] study the effects of Nintendo Wii games as an entertaining and socializing tool for improving mental and social well-being of the elderly. They conducted a pilot study with 14 pairs of elderly-teenager participants and the results from their study reported that in general, Wii games can bridge the inter-generational gap between older and young people, and it can promote positive mental and social wellness of elderly players. Moreover, the authors point out the fact that designing games that fulfill the needs and ability of both the elderly and young people could possibility be the key that opens up a new trend and market of older game players. With respect to the elderly's socialization, they advocate that computer games are promising to create a virtual social space and environment for both older and younger generation and they could come together to interact positively.

The idea of virtual coach for physical exercises can be seen in the Nintendo Wii's My Fitness Coach game. In this game, the virtual personal fitness coach will guide the player through dynamic workouts for physical exercises and player can customize the workout plan, goals, environment, and music. Another type of virtual trainer game can

be seen in Microsoft Xbox Fitness games, where virtual trainers are the real persons so that the player can socially connect to the trainer in the game itself. Although the concept of virtual coach or trainer is applied in this game, it is not targeted for rehabilitation and elderly users.

With respect to setting relevant rehabilitative goal, this concept can be also seen in Nintendo Wii's My Fitness Coach game and player can set his or her workout goal, calendar, type of exercises, and level of difficulty. There are a few goal-oriented digital games in the market. For instance, in Nintendo Wii's Dance Dance Revolution provides goal-based challenges and allows players to earn game scores or points that can unlock new costumes and songs in the game itself. Nevertheless, it seems that there is a very limited number of goal-based digital games for the elderly and their rehabilitative exercises. The familiarity with the rehabilitative setting and environment is one of the most important factors for the elderly's motivation. In the digital games market, there are a number of physical game-based exercises or exergames that support elderly friendly and real-world environment to players such as Nintendo Wii's My Fitness Coach game, Wii Sports game, Dance Dance Revolution game, Microsoft Xbox Fitness Game, Nike + Kinect Training, and VirtualRehab games.

Regarding information from healthcare professionals, there are also a number of digital games that support relevant information or feedback to players. For example, in PlayStation's EyeToy: Kinetic Fitness games the virtual coach or instructor gives the relevant information or instruction to players. In addition, there are other games that provide relevant information or instruction from virtual instructor such as Nintendo's Wii Sports, Microsoft Xbox Fitness game, and VirtualRehab games.

In designing games, real-world activity games are likely to enhance players' motivation and engagement in the game itself. There are many games in the market and research that base on the real-world activities such as physical sports (soccer, tennis, and boxing), household activities (cooking and cleaning), recreational activities (shopping and playing cards), and cognitive activities (chess and puzzles). For example, Nintendo Wii' Sports games, Microsoft Xbox Fitness games, and PlayStation's EyeToy support game-based sport activities games are quite successful in the market and among younger players. For household activities, there is a few numbers of games available in the market such as Cooking MaMa and VirtualRehab's Window Cleaning Game.

Recreational activities games (e.g.,Virtual Shopping Games for Rehabilitation, Microsoft Solitaire Collection, Microsoft Xbox Karaoke Revolution) and cognitive games (e.g.,Candy Crush and Microsoft Chess Titans) can be seen in the market. Moreover, there are similar games available in research projects by different institutions and organizations. The game customization or pre-setting is one of the most important game principles and many digital games apply this principle in their games. The leading games in the market such as Nintendo Wii, Microsoft Xbox, PlayStation EyeToy, and research-based VirtualRehab games, follow this principle. Apart from VirtualRehab games, most of the games available in the market are targeted for healthy and young players. Thus, the customization of these games is not elderly-friendly.

With regard to the positive feedback for the elderly, it is one of the important

factors to be taken into consideration in designing games for them. However, most of the digital games available in the market support normal feedback to players such as scores, rewards, incentives, player's lifespan, and virtual cash. There is no or limited games that have encouraging and positive feedback to players no matter what their performance is. Thus, it will be an interesting topic to investigate if players are more motivated to play game if they receive positive feedback regardless of their achievement in the game.

Most of the games in the market use appealing background music and audio feedback to players to be more motivated and engaged in the game itself. However, not many games support personalized music for player. Some of the musical games are quite successful in the market such as Microsoft Xbox Karaoke Revolution, Nintendo Wii's Music, and PlayStation Guitar Hero. With regard to recreational activities, as mentioned earlier in this section, there are a few numbers of digital games that support recreational activities for player such as Wii Sports, Xbox Fitness games, Dance Dance Revolution, Microsoft Card games, and Karaoke Revolution game.

Based on this review, we found out that most of the games available in the market are not designed for elderly and their physical rehabilitation. Although there are a few game designs that can be suitable for the elderly's physical rehabilitation, they still lack proper game elements for players with special needs in rehabilitation. For example, Nintendo Wii's Sports games have potential to train the elderly to improve their movements in rehabilitation but these games are not well-designed in customization or personalization that can be adjusted according to the elderly's ability in movements, range-of-motions, and strength. In addition, most games lack conveying encouraging or positive feedback to players regardless of their performance. The virtual coach or trainer in these games is mostly aimed for healthy players and therefore, the instructions and guidance from these virtual characters are not user friendly for the elderly.

A few motivational game designs for the elderly can be seen in digital games available in the market, but they still lack other important motivational game elements. The major problem is that these games do not address the problems and needs of the elderly such as personalization for individual ability to play the game, therapeutic game tasks, elderly friendly help system, and the game environment that reflects the elderly's social and cultural background. In this study, we conducted a literature review study and investigation on the games that have potential to be used in the context of the elderly's physical rehabilitation. However, it does not cover all the games in the market or in the research area. The findings from this literature review study may help not only game designers in designing games for the elderly's rehabilitation but also other healthcare professionals in the conventional way of rehabiliation.

## 5 Pre-study 3: A Pilot Usability Testing of Kinect

### 5.1 Kinect for Healthcare Games

Multimodal input devices to play digital games are as important as game design and gameplay for the elderly. There are various types of multimodal input devices in the market and research such as gesture-based input device (e.g., Microsoft's Kinect, ASUS's Xtion), controller-based input device (e.g., Wii Remote, PS3's PlayMove), traditional controller (e.g., Xbox 360 controller), touch-based interaction (e.g., Touch-based monitor, touch-based mobile, and tablet), and robot-based interactive equipment (e.g., assistive technology for rehabilitation). Among them, Microsoft's Kinect draws a large attention from developers, researchers, and healthcare professionals because of its controller-free interaction. Kinect seems to be an effective way of interacting with system especially for elderly because the user does not need to hold a particular device or controller and it can reduce the cognitive load of the user.

Recently, Microsoft has released a new version of Kinect for Xbox One, which claims more powerful features are integrated (e.g., voice and gesture). According to Microsoft's Xbox [26], the new Kinect includes the new features such as giving a command Xbox and TV with the voice and gestures, playing games where the player is the controller, calling friends and family with integrated Skype in HD, broadcasting gameplay live with pictures, being recognized and signed-in automatically, and dancing central spotlight downloadable token. Since the first generation of Kinect was introduced, the researchers and developers are trying to utilize Kinect in many applications (e.g., games) to help the ageing society in terms of their socialization, rehabilitation, safety, communication, and recreation. By using Kinect's features, elderly can play physical games to improve their mobility and movement and communicate with friends and family members through Skype feature. Furthermore, Kinect is used as a monitoring system to detect elderly's movements at home or senior homes (e.g., fall prevention and alert system). Kinect is also used as a recreational platform for the elderly to do their recreational activities (e.g., dance games).

According to Pyae at al. [13], they designed and developed an augmented reality based rehabilitation system for stroke patients. They used Kinect for motion tracking and augmented reality feature. They reported that Kinect is an efficient and effective way of interaction for elderly to play the rehabilitative games. Pisan et al. [27] advocate that physical exercises can reduce the risk of falling of the elderly by 40% if they comply with the recommended exercise routine. They designed and implemented Kinect-based step exercise for elderly and conducted a usability testing with 57 elderly participants. They reported that gamified exercises using Kinect to track player's lower limbs can encourage the elderly to be more engaged in the exercise regimes [27]. Webster and Celik [28] points out that Kinect is the front-runner in the market because of three reasons: a) it provides the natural movements of human body; b) it is the most feasible technology for exergaming; and c) it provides the freedom of controller-free data acquisition.

The utilization of Kinect can be categorized into different groups: Fall detection, Fall risk reduction, Evaluation of Kinect's accuracy, Kinect-based rehabilitative methods, and Kinect for serious games. The authors also reveal that Kinect is financially affordable and medically beneficial to the ageing society [28]. According

to Ganesan and Anthony [29], they developed Kinect-based physical exercise program to improve elderly's level of motivation in doing exercises. They conducted a usability testing with elderly participants and reported that the results were promising. Pompeu et al. [30] reported that Kinect-based training for people with Parkinson's disease was safe and feasible for the patients and they have improved in balance and gait activities after going fourteen 60-minutes sessions.

In this study, we chose new Microsoft's Kinect for Xbox as a potential technology to be used in our study for GSH. Although there are some findings regarding Kinect for healthcare games, the reason why we would like to conduct a pilot usability testing of Kinect is that most of the previous usability testing used the older version of Kinect and there was no related usability findings found for new version of Kinect for Xbox one. Therefore, we decided to investigate whether the new Kinect and its features are suitable and user-friendly for the elderly.

### 5.2 A Pilot Usability Testing of Kinect

We conducted a pilot usability testing with eight elderly participants who reside at the service homes in Finland. The main objective of this usability testing is to investigate the usability and usefulness of Kinect for Xbox as well as to understand the elderly's user experiences. Firstly, we recruited elderly participants through the advertisement at the center. The age range of the elderly participants is between 64 and 78 year old. Most of them are currently residing at the service home, whereas the rest are the regular comers to do their physical and social activities. There were equal numbers of male and female participants. Generally, elderly participants are physically and mentally sound and stable. They do physical exercises regularly and often involve in the social activities at the center.

According to the pre-survey, half of them spend at least 3 hours per week for doing physical exercises while the other half spend more than 6 hours per week. In this study, the elderly participants need to use their hand movements to control the computer system based on the different actions (e.g., wave to Kinect and swipe). Based on the pre-survey, all of them are right-handed. They have prior experiences in using TV remote control, whereas 2 out of 8 participants are familiar with computer tablets and smart phone. The only four participants use personal computers. None of them have used digital game consoles or smart TV.

In the usability testing, it included one Kinect-based tutorial that contained ten gesture-based tasks. Every participant needed to perform every task in the tutorial by using their hand. For example, the participants wave to the Kinect sensor and find the target by moving their hands. Before they performed each gesture-based task, the researcher demonstrated them how to perform the task. After a participant has finished a particular task, the researcher evaluated their performance by giving the different level of success. It includes "Independently and easily (4)", "Independently after a little training (3)", "With a tester's additional help (2)", and "The mission did not succeed (1)". If the elderly participant cannot perform a particular task, we skipped to the next task. The complete tutorial and description are shown in the table 2.

**Table 2.** Kinect-based Tasks.

| Task | Description |
|---|---|
| Wave to Kinect | Get started with gestures by moving your forearm left and right. |
| Find a target | Point the palm of your hand toward the screen, and move your palm so the hand-cursor on a screen moves over the image of a white horse (x 3). |
| Make a selection | Engage Kinect by raising your hand with an open palm facing the sensor.<br>Move your hand over a specific item or tile.<br>Push forward (away from your body) and then pull back to make the selection. |
| Scroll through a screen | Engage Kinect by raising your hand with an open palm facing the sensor.<br>When the hand icon appears on the screen, close your hand anywhere over the area you want to scroll.<br>Move your hand to the left or right to pull the screen in that direction.<br>Find the horse (x2) |
| Return to Home | Hold out both of your hands towards the edge of the screen.<br>Close your hands and move them toward each other in front of your chest. |
| Return back to tutorial | Hold your closed hands toward each other in front of your chest.<br>Move your closed hands towards the edge of the screen and in the end open your hands. |
| Zoom in | Engage Kinect by raising your hand, with an open palm facing the sensor.<br>When the hand icon appears on the screen, close your hand over the area you want to zoom.<br>Pull your hand toward you to zoom the screen in. |
| Zoom out | Engage Kinect by raising your hand, with an open palm facing the sensor.<br>When the hand icon appears on the screen, close your hand over the area you want to zoom.<br>Push your hand away from your body to zoom the screen out. |
| Open the system menu -Skype | Engage Kinect by raising your hand with an open palm facing the sensor.<br>Move the hand cursor over the Skype button.<br>Extend your arm forward toward the Kinect and hold until a |

| | |
|---|---|
| | circle timer appears.<br>After the ring has filled, you'll see the system menu. Select Pin to Home from the menu like you selected the application. |
| Open the system menu -Explorer | Engage Kinect by raising your hand with an open palm facing the sensor.<br>Move the hand cursor over the Skype button.<br>Extend your arm forward toward the Kinect and hold until a circle timer appears.<br>After the ring has filled, you'll see the system menu. Select Snap from the menu like you selected the application. |

After each participant has done the Kinect tutorial, we conducted a post-tutorial survey that contains the usability questionnaires to get the feedback from the elderly participants. Basically, the usability questionnaires are divided into two parts: usability of Kinect sensor and the participant's self-efficacy in using this device. The questionnaires use 5-point Likert scale from "Strongly disagree (1)" to "Strongly agree (5)". The feedback given by the elderly participants were recorded by the researcher. Then, we have conducted a follow-up interview session with all participants to understand their user experiences during the tutorial session. Table 3 shows the detailed procedures of the Kinect tutorial session.

**Table 3.** The design and procedure of Kinect tutorial.

| Activity | Duration |
|---|---|
| Introduction and pre-study interview | 10 min |
| Kinect tutorial tasks 1-10 | 20 min |
| Post-study usability and self-efficacy questionnaires | 10 min |
| Post-study interview | 5 min |
| Total | 45 min |
| Introduction and pre-study interview | 10 min |

### 5.3 Findings and Discussion

After we have conducted the usability testing with the elderly participants, we consolidated the data that we have gathered from the testing. We combined the participants' level of success in each task given in the Kinect tutorial session. Firstly, the maximum number of participants who have succeeded a particular task without support from the researcher is five. For example, there are only five participants who can independently and easily perform the task "Wave to Kinect". According to Table 4, we can see that there are only three tasks succeeded by five elderly participants ("Wave to Kinect", "Return to Home", and "Return back to tutorial"). In contrast, the task called "Open the system menu-Explorer" has only one participant who has succeeded followed by the task called "Open the system menu –Skype" that was succeeded by two participants. The tasks that have the maximum number of participants (four participants in total) who have failed the mission are "Make a selection", "Zoom out", "Open the system menu -Skype", and "Open the system menu

-Explorer" respectively. Table 4 shows the participants' level of success in the tutorial. We used the numbers to reveal the different levels of success by the elderly participants and the description of each number is shown below Table 4.

**Table 4.** The participants' level of success.

| Task | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | Mean |
|---|---|---|---|---|---|---|---|---|---|
| Wave to Kinect | 4 | 4 | 2 | 3 | 4 | 4 | 4 | 3 | 3.5 |
| Find a target | 4 | 4 | 3 | 2 | 4 | 4 | 1 | 1 | 2.8 |
| Make a selection | 4 | 4 | 1 | 1 | 4 | 4 | 1 | 1 | 2.5 |
| Scroll through a screen | 2 | 2 | 2 | 2 | 4 | 4 | 1 | 1 | 2.2 |
| Return to Home | 4 | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 3.1 |
| Return back to tutorial | 4 | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 3.1 |
| Zoom in | 4 | 4 | 2 | 1 | 4 | 3 | 1 | 1 | 2.5 |
| Zoom out | 4 | 4 | 1 | 1 | 4 | 3 | 1 | 1 | 2.3 |
| Open the system menu -Skype | 3 | 4 | 1 | 1 | 4 | 3 | 1 | 1 | 2.2 |
| Open the system menu -Explorer | 3 | 4 | 1 | 1 | 3 | 3 | 1 | 1 | 2.1 |

1- Mission did not succeed 2- With a tester's additional help
3- Independently after a little training 4- Independently and easily

According to the data shown in Table 5, "Wave to Kinect" is the easiest among other tasks in this tutorial (M = 3.5, SD = 0.7). The second easiest task for the participants are "Return to home" and "Return back to tutorial" (M = 3.1, SD = 1.3) respectively. In this tutorial, only "Wave to Kinect" is the one which was succeeded by all elderly participants, whereas the other tasks have the failed attempts by at least two up to four elderly participants. The scrolling task (M = 2.2, SD = 1.1) and opening the system menu tasks (M = 2.2, SD = 1.3 for Skype and M= 2.1, SD = 1.2 for Explorer) are the hardest tasks for the elderly participants. The tasks "Make a selection" (M = 2.5), Zoom in (M= 2.5), and Zoom out (M = 2.3, SD = 1.6) have the average success rate. With regard to the individual participants, it can be seen that Participant 5 (P5) has the highest level of success in most of the tasks. The participant 2 (P2) also has the second highest level of success, which is slightly lesser than the participant 5 (P5). The participant (P3) has the second highest score in the seven tasks out of ten. The participants (P5, P2, P3, and P6) have no failed attempts in this tutorial. The participant (P3) has the least number of failed attempts, whereas the participants (P6 and P7) have the highest number of failed attempts. In other words, P6 and P7 could succeed a single task "Wave to Kinect". Table 5 shows the average score and standard deviation of each task in this tutorial.

**Table 5.** Average score.

| Kinect task | Mean | SD |
|---|---|---|
| Wave to Kinect | 3.5 | 0.7 |
| Find a target | 2.8 | 1.3 |
| Make a selection | 2.5 | 1.6 |
| Scroll through a screen | 2.2 | 1.1 |
| Return to Home | 3.1 | 1.3 |
| Return back to tutorial | 3.1 | 1.3 |
| Zoom in | 2.5 | 1.4 |
| Zoom out | 2.3 | 1.5 |
| Open the system menu -Skype | 2.2 | 1.3 |
| Open the system menu -Explorer | 2.1 | 1.2 |

In general, in this tutorial, only half of the participants could succeed all the given tasks. By looking at the pre-interview data, it can be seen that the participants (P1, P2, P5, and P6) who succeeded all tasks have the prior experiences in using personal computers, tablets, and smart phones. However, there is no evidence seen in the findings whether their prior experiences can influence on this performance in this tutorial.

**Table 6.** Usability of Kinect.

| No | Questionnaire | Mean | SD |
|---|---|---|---|
| 1 | I believe that I would use this kind of interactive device regularly. | 3.25 | 1.16 |
| 2 | In my opinion, this interactive device was overly complicated. | 2.87 | 0.99 |
| 3 | In my opinion, using the device was easy. | 2.75 | 1.16 |
| 4 | I suppose that I might need help with using the device from a person who knows well technical devices. | 3.0 | 1.51 |
| 5 | In my opinion, many features of the device were well integrated. | 3.0 | 0 |
| 6 | In my opinion, there were too many inconsistencies in this interactive device. | 3.0 | 1.06 |
| 7 | I believe that most of the users would learn to use this kind of device very quickly. | 3.62 | 0.91 |
| 8 | In my opinion, this device is difficult to use. | 3.25 | 1.16 |
| 9 | I am confident to use this device. | 3.50 | 0.75 |
| 10 | I should learn a lot of things until I could use this kind of interactive device. | 3.12 | 1.12 |

Regarding the usability of Kinect sensor, we consolidated the data and calculated the mean score and standard deviation (See Table 6). The overall results show that the usability of Kinect is just an average for the elderly participants. The questionnaire (Q7) has the highest mean score (M= 3.62, SD = 0.91), whereas the questionnaire (Q3) has the lowest (M=2.75, SD = 1.16) followed by the questionnaire 2 (M = 2.87, SD = 0.99). The rest of the questionnaires have achieved equal or greater than 3 score. In general, most of the elderly participants think that the usability of Kinect is a challenge for them. However, they mention that they are confident to use it and they will be able to learn it quickly. They reveal their interests in using this sensor in interacting with computers. Table 6 shows the average scores of the usability of Kinect.

With regard to their self-efficacy in using this device, it can be seen that most of the elderly participants were confident to use it. The questionnaires regarding self-efficacy have achieved the mean score greater than 3 and the highest score is (M =3.87, SD = 0.99) in questionnaire (Q4 and Q5), whereas the lowest score can be seen in the questionnaire 3 (M = 3.0, SD = 1.51). Table 7 shows the average scores of elderly's self-efficacy towards using Kinect.

**Table 7.** Elderly's self-efficacy.

| No | Questionnaire | Mean | SD |
|---|---|---|---|
| 1 | I am sure that I accomplished the assignments effectively. | 3.12 | 1.35 |
| 2 | Although the assignments were challenging, I did pretty well. | 3.5 | 0.75 |
| 3 | I succeeded in winning many challenges during performing the assignments. | 3 | 1.51 |
| 4 | I believed that I could perform the given assignments also when I face difficulties. | 3.87 | 0.99 |
| 5 | Generally speaking I believe that I can achieve great and important results. | 3.87 | 0.99 |

According to the post-tutorial interview session, half of the elderly participants mentioned that they encountered difficulties in using Kinect sensor, whereas the other half had no significant issues to use it. The elderly participants who succeeded all the given tasks in this tutorial mentioned that they enjoyed using the device and would like to use regularly in playing games and interacting with the computer. The two participants (P6 and P7) mentioned that they were frustrated to use it. The participants (P4 and P5) revealed that they are interested in learning how to use it although they had some failures in the tutorial.

Based on the findings from this Kinect usability testing session with the elderly participants, we can highlight the findings. Firstly, we can see that the elderly participants who have prior experiences in using computer, tablets, and smart phones can efficiently use the Kinect sensor. However, there is no evidence of relationship between their prior experiences and their user experiences in using Kinect. Secondly, the majority of the elderly participants had succeeded the tutorial to a certain extent. They have also mentioned their interests towards the use of Kinect in future play. Thirdly, the majority of the elderly participants have mentioned their confidence towards using Kinect sensor in interacting with computer. More importantly, they mention that they would be able to learn quickly how to use it through adequate learning. Moreover, we have learned that some built-in hand gestures of Kinect for Xbox in this tutorial are difficult for the elderly participants, whereas some gestures are easy for them. The other finding in our usability testing is that the software system that we have used in this tutorial is not well-designed for the elderly. Hence, there might have some usability issues for them to control the Kinect sensor. Therefore, it will be an interesting idea if we can design an elderly friendly system and let the

elderly interact the system by using Kinect sensor. The limitation of our study is that the sample size we used in this study is relatively small.

# 6 Pre-study 4: A Pilot Usability Testing of Existing Games

## 6.1 A Pilot Usability Testing

In this study, we conduct a pilot usability testing of existing games, which include Puuha's SportWall game and two commercial games: Xbox's Climbing game and PlayStation's Tennis game. The main objective of this study is to understand the elderly's feedback and user experiences in playing SportWall game and commercial games. SportWall game is designed and developed by Puuha Group Finland, and it is targeted for the elderly's physical exercise by using game-based physical activity. In this game, player needs to ride a skateboard and avoid obstacles. Player can control the movement of skateboard by moving body from side to side. To avoid obstacles, player needs to sit or jump according to the types of obstacles. This game is simply designed based on therapeutic actions such as side-swaying, sit-to-stand, and light jump. This game is implemented using Unity3D game engine, and it uses simple webcam, which uses Xtreme Reality technology to detect player's movements. Regarding commercial games, we select Microsoft Xbox's Climbing game and PlayStation's Tennis game because Xbox's Kinect-based Fitness games and PlayStation's controller-based PlayMove Fitness games provide variety of exercise games. However, these games are not designed for the elderly. Thus, in this study, we would like to investigate if commercially available exercise games are suitable for the elderly and their physical activities. Figure 1 shows a screenshot of Puuha's SportWall game.

**Fig. 1.** Puuha's Game

The usability testing took place at one of the elderly service homes in Finland. We recruited five elderly participants for this pilot study. Basically, elderly participants in our study are 60 years old and above, and they are physically and mentally stable. They are the regular visitors to the elderly service home. Furthermore, they need to tolerate for 10 minutes in standing position to play the games. Before the elderly played the games, researcher asked pre-interview questions that contain demographic and physical activities of the elderly. After that, the elderly needs to go through a game tutorial session to play a particular game. There were three game stations for three games: SportWall, Climbing, and Tennis games respectively. Elderly participants were randomly assigned to each game station. After the elderly has gone through a game tutorial session, he or she played a particular game for five minutes followed by a questionnaire session in which researcher asked the elderly's user experiences in the gameplay and the usability of the game. The elderly had to go through the same procedure for next two games. After finishing all three games, researcher asked post-game general interview questions that include the elderly's overall experiences in playing three different games. The whole session would require an hour for individual elderly participant. Figure 2 shows a photo from the usability testing of existing games.

**Fig. 2.** Usability Testing

### 6.1 Findings and Discussion

According to the findings from the pilot study of existing games, we found out that commercial games are not user friendly for the elderly. First of all, we investigated that the user interfaces, game contexts and contents, and gameplay in the commercial games are not suitable for elderly. In Xbox's Climbing game, elderly were distracted by the game contents such as user interface, icons, feedback, and game audios. Due to the complex game interthe face, it affectedthe elderly's gameplay and sometimes,

they did not know how to proceed their gameplay. In PlayStation's Tennis game, the elderly found out that it was the hardest to play because of the PlayMove game controller. Furthermore, the elderly faced some challenges in playing game because of cluttered interface, contexts, and contents. Among three physical activity games, SportWall game was well-accepted by the elderly participants because of its simple, uncluttered, and clear game interface, contexts, and contents. Moreover, the gameplay in SportWall game is simple enough for the elderly to pay attention to their gameplay. According to the elderly's feedback towards the games, we found out that SportWall game is the most effective game for the elderly followed by Xbox's Climbing game in the second place and PlayStation's Tennis game in the third place respectively.

Regarding the interactive input devices, in this study, we used three different multimodal input devices: Microsoft Kinect sensor, PlayStation's PlayMove controller, and traditional webcam. Among them, based on the feedback from the elderly participants, Microsoft Kinect sensor is the most effective device to play the game followed by traditional webcam. The elderly participants gave negative feedback towards PlayStation's PlayMove controller that it is too complicated for them to control the game. Basically, the elderly needs to press particular buttons on the controller and sometimes, they forgot to press the buttons and as a result, they could not proceed the gameplay. Based on the findings from the post-game interview sessions, the elderly participants mentioned that they had fun in playing three games except the fact that they encountered some difficulties in some games. Moreover, they are interested in playing these games again, and advocated that they can improve their ability in playing games through adequate training and guidance from trainer. In general, they advocated that digital games seem to be an effective way of exercising for their physical well-being. Table 8 shows the selected quotes from the post-game interview session.

**Table 8.** Post-Game Interview.

| Subject | Quotes |
|---|---|
| S1 | "I like Climbing game and SportWall game"<br>"It's hard to handle the second controller (PlayMove"<br>"Overall, I enjoyed playing but I have no confident to play again by my own" |
| S2 | "I like all three games. Just that the second controller is difficult to use"<br>"I want to play more games in the future"<br>"It's quite good. I want to try again" |
| S4 | "It's enjoyable and comfortable playing it. I want to try more"<br>"It will be a good idea if I can play these games at the center or home" |
| S5 | "It's good to learn new things. I will try again if I can".<br>"It's fun" |

Based on the findings from this pilot study, we summarize the following usability and game design guidelines for our future game development. In designing games for elderly's physical rehabilitation, it is important to take into account that game user interface should be simple and uncluttered. It should provide effective visual cues for elderly so that they can pay more attention to their gameplay. It should design less

text-based feedback to elderly. Instead, it should use effective audio and visual feedback to elderly. Gameplay should be simple but effective enough for the elderly to improve their ability in doing exercises. Furthermore, their progress in game itself should be simple and meaningful for the elderly rather than using points and scores. We also learn that some physical actions are not suitable for the elderly for their safety in playing games (e.g., jump). The controller-free natural movements are suitable for the elderly because its simplicity and ease-of-use.

## 7 Conclusion

In this study, we conducted the pre-studies of GSH project. First of all, we found out the motivational factors for the elderly in their physical rehabilitation through a literature research. Then, we propose a number of game design guidelines for designing and developing game-based exercises for elderly's physical rehabilitation. Then, we reviewed commercial games if they follow motivational game designs for the elderly and their physical rehabilitation. Furthermore, we reviewed if their game contexts, contents, and gameplay are suitable for the elderly. Based on the findings from the literature review on Kinect for healthcare games and the usability of Kinect, we found out that Kinect has potential to be used as an interactive device for the elderly to play game-based exercises. Furthermore, we learned that Kinect's built-in gestures are not user friendly for the elderly. Thus, it is important to design specific elderly-friendly gestures when we design and develop game-based exercises for the elderly. According to the findings from the pilot usability study of Puuha's SportWall game and two commercial games: Xbox' Climbing game and PlayStation's Tennis game, we found out a few usability and game design guidelines for our future game development. All the findings from these pre-studies help us to understand more about the elderly's requirements in doing their physical exercises. Moreover, we found out the usability of existing commercial games and technologies for the elderly. The usability guidelines from these studies provide us insightful game design ideas for future game development. Based on these findings, as a future work, we will design and develop a game system for the elderly's physical rehabilitation, which is simple, easy, effective, and efficient for the elderly and their physical rehabilitation.

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